Unit 2 · The Cell

STUDY NOTES

WHAT NEB'S GRADE 11 EXAM ASKS

- **CDC's grid (2077):** Biomolecules and Cell Biology (Units 1–3 together): 9 of 75 marks; with Biology, Microbiology, Biota and Environment and Conservation a combined 21, at least 3 MCQs, 2 short and 1 long from them
- **The paper:** 11 MCQs × 1 · 8 short × 5 · 3 long × 8; 3 hours; 1 mark per expected point
- **MCQ (1 mark)**
  - not a prokaryote feature; not membrane-bound (ribosome)
  - selectively permeable; plasmodesmata; exocytosis
  - integral proteins; ATP synthase; metacentric
  - mesosomes; 80S; SER (lipids); lysosome's non-function
  - chlorophyll; chloroplast
- **Short and long (in parts)**
  - prokaryotic vs eukaryotic, with labeled sketches
  - fluid mosaic model; sandwich vs fluid mosaic
  - mitochondrion: structure and functions; why "powerhouse"; semi-autonomous
  - plastids: kinds, structure, functions; leucoplasts vs chromoplasts; pyrenoids
  - ER: structure; SER vs RER; Golgi and primary lysosomes
  - lysosome: "suicidal bag", autophagy; nucleus and nucleolus
  - parts of a nucleotide from a drawing; labeled nucleus and ER drawings

Key terms

Cell: smallest unit that can carry out all the activities of life on its own; enclosed by a membrane.

Cytology (*kytos*, cell): study of cells; now **cell biology**; made a subject by **Oscar Hertwig** (*Die Zelle und die Gewebe*, 1893–1898).

Protoplast: plant cell without its wall: plasma membrane + contents (wall digested by cellulase, pectinase).

Protoplasm: living matter of a cell; "physical basis of life" (Huxley, 1868); named by **Purkinje**; = cytoplasm + nucleus.

Cyclosis: streaming of cytoplasm round a plant cell (myosin on actin); *Hydrilla*, *Chara*.

Biomembranes: plasma membrane + all organelle membranes; same basic structure.

Cell inclusions (ergastic, deutoplasmic): non-living products of metabolism in the cytoplasm; no membrane of their own.

Prokaryotic and eukaryotic cells

- **prokaryotic**: no organized nucleus, no membrane-bound organelles; **eukaryotic**: true nucleus in an envelope, membrane-bound organelles
- words: *pro* before, *eu* true, *karyon* nucleus; **Chatton** 1925; Dougherty 1957

Feature	Prokaryotic	Eukaryotic
nucleus	no membrane; DNA in **nucleoid**	true nucleus, double envelope, nucleolus
DNA	one circular, **naked** (no histones); plasmids	several linear chromosomes, **histones**
organelles	none membrane-bound	mitochondria, ER, Golgi, lysosomes, plastids
ribosomes	**70S** (50S + 30S)	**80S** (60S + 40S); 70S in mitochondria, chloroplasts
wall	**peptidoglycan** (murein)	cellulose (plants), chitin (fungi); none (animals)
flagella	simple **flagellin** thread	**9 + 2** microtubules
respiration	on plasma membrane	mitochondria
photosynthesis	on lamellae (thylakoids) in cytoplasm	chloroplasts
division	binary fission, no spindle	mitosis, meiosis, with spindle
size	0.2–5 μm	10–100 μm
examples	bacteria, cyanobacteria (*Nostoc*, *Anabaena*, *Lyngbya*)	plants, animals, fungi, protists

- **mesosomes**: folds of a bacterium's membrane, once said to be the site of respiration (and DNA attachment in division); now known to be **artifacts** of preparation

Shapes and sizes

- shape set by **function**, age, wall, pressure of neighbors, position, tension and viscosity of contents

- most eukaryotic cells **10–100 μm**
  - smallest: **mycoplasmas**, 0.2–0.3 μm
  - largest: **ostrich egg**, ~15 cm
  - longest: nerve cells (a meter in a person)
- small: surface grows slower than volume; everything enters and leaves by the surface

Cell wall

- non-living; rigidity, support; plants, bacteria, fungi, many algae; **never in animals**
- none: naked gametes, zoospores; 0.1–10 μm thick
- **Robert Hooke** 1665: walls of dead cork cells, "cells"

1. **middle lamella**: first formed (from cell plate); **calcium and magnesium pectates**; cement; dissolves as fruit ripens
2. **primary wall**: thin, **elastic**, permeable; **cellulose** microfibrils in **hemicellulose** + **pectin**, some protein; growing cells; leaves, fruits, cortex, pith
3. **secondary wall**: thick, **rigid**, after growth stops; S_1, S_2, S_3, microfibrils in different directions (plywood); cellulose, hemicellulose, **lignin**; 1–10 μm; **tracheids, vessels, sclerenchyma**
   - also cutin, waxes (epidermis), suberin (cork), mucilage, silica (grasses)
4. **tertiary wall**: cellulose + **xylan**; gymnosperm tracheids
5. **plasmodesmata**: channels through walls, lined by membrane, **desmotubule** (ER) inside; join neighbors' cytoplasm; cross at **pits**

- collenchyma: thick corners are **primary** wall (no lignin), not secondary

Functions

- mechanical strength, support
- protects; keeps out germs
- permeable
- gives shape
- absorption (root hairs)
- suberin, cutin cut water loss
- stops bursting (wall pressure)
- holds enzymes

Plasma membrane

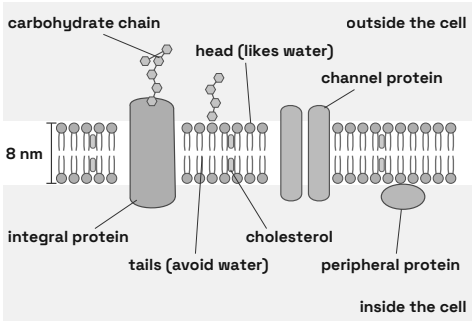
- thin, elastic, **selectively permeable**, self-repairing
- "cell membrane": **Cramer and Nägeli** (1855); "plasmalemma": **Plowe** (1931)
- **lipoproteinous**: lipids + proteins (~equal), a little carbohydrate outside
  - red blood cell: 43 % lipid, 49 % protein, 8 % carbohydrate
  - myelin ~80 % lipid; inner mitochondrial membrane ~25 % lipid
- proteins by work
  - **structural**
  - **enzymes**
  - **transport**: carriers, channels; **facilitated diffusion** (down gradient); **pumps** (against, ATP: active transport)

Sandwich model (Danielli and Davson, 1935)

- **phospholipid bilayer**: hydrophilic heads (glycerol + phosphate) out, hydrophobic tails (fatty acids) in, van der Waals forces
- continuous **globular protein** layer on each face
- protein-lined **pores** 7–10 Å
- **trilaminar**: protein–lipid–protein (dark–light–dark in EM)
- failed: different jobs of membranes, active transport

Fluid mosaic model (Singer and Nicolson, 1972)

- proteins scattered in a **fluid** phospholipid bilayer: "icebergs in a sea"
- lipids move: **lateral movement** (often), **flip-flop** (rare)
- **extrinsic (peripheral)** proteins on surfaces, loose; **intrinsic (integral)** in it, some right across (**transmembrane**): channels, carriers
- phospholipid **amphipathic**: heads out, tails in
- **glycoproteins**, **glycolipids** on outer face; **cholesterol** controls fluidity (animals)
- support: Frye and Edidin (1970): mouse + human cell fused, green and red proteins mixed in 40 min at 37 °C; not when cold



Fluid mosaic model: phospholipid bilayer, integral and peripheral proteins, sugar chains outside; ~8 nm thick.

Sandwich	Fluid mosaic
Danielli and Davson, 1935	Singer and Nicolson, 1972
continuous protein layers on both faces	proteins scattered, like icebergs
fixed, rigid	fluid; lipids, proteins move
proteins on surfaces only	peripheral + integral proteins
can't explain different jobs, active transport	explains channels, carriers, receptors

Functions

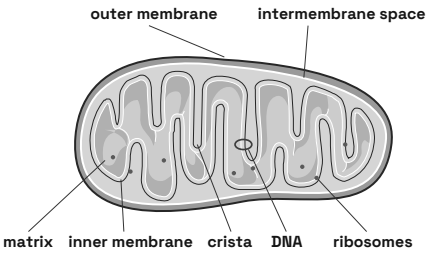
- shape (animal cells), protection
- controls entry and exit: diffusion, osmosis, facilitated diffusion, active transport
- **endocytosis**: **phagocytosis** (solids), **pinocytosis** (liquids); **exocytosis** (large molecules out)
- movement: pseudopodia (*Amoeba*, white blood cells)
- identity: **antigens**; ABO groups
- **microvilli** (intestine): more surface
- **receptors** for hormones, antigens

Cytoplasm

- between plasma membrane and nuclear envelope: **cytosol** (salts, sugars, amino acids, enzymes; **glycolysis**) + **organelles** + **inclusions**
- organelles: double membrane (mitochondria, chloroplasts, nucleus); single (ER, Golgi, lysosomes, vacuoles); none (ribosomes, centrioles)

Mitochondria

- *mitos* thread + *chondrion* granule; **Kölliker** 1857 (insect muscle); named by **Benda** 1898
- **powerhouses**: ATP from **aerobic respiration**
- absent: prokaryotes, **mature mammalian red blood cells**
- 0.5–1 μm wide, 1–10 μm long; one (some algae) to thousands (liver 1,000–2,000); many in muscle, liver, kidney, sperm
- composition: 65–70 % protein, 25–30 % lipid, ~0.5 % RNA, a little DNA



Mitochondrion: outer and inner membranes, cristae, intermembrane space, matrix with DNA and 70S ribosomes.

- **outer membrane**: smooth
- **inner membrane**: folded into **cristae** (more surface)
- **intermembrane space** (outer chamber) → intercristal space
- **matrix** (inner chamber): **Krebs cycle** enzymes, 70S ribosomes, circular DNA
- **F_1 particles** (oxysomes, elementary particles) on the matrix side of the cristae: **head** (F_1), **stalk**, **base** (F_0) = **ATP synthase** (ATPase); H^+ flows back → ATP (**oxidative phosphorylation**); functional units

Semi-autonomous

- own **DNA** (human: 16,569 base pairs, 37 genes, **13 for proteins**), **70S ribosomes**, divides by fission
- most proteins (more than 1,000) coded by the nucleus, imported
- **endosymbiotic theory** (Margulis, 1967): mitochondria from oxygen-using bacteria, chloroplasts from cyanobacteria; double membranes, fission, circular DNA, 70S

Functions

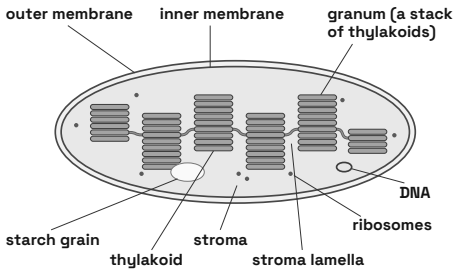
- ATP: Krebs cycle (matrix), electron transport, ATP synthesis (inner membrane)
- intermediates → **steroids**, **cytochromes**, heme, chlorophyll's porphyrin
- some **amino acids**
- **calcium ion** control
- **yolk** formation in eggs
- **middle piece** of sperm

Plastids

- double membrane; plants and some protists (*Euglena*); named by **Haeckel** 1866
- absent: fungi, animals, prokaryotes (pigments on **chromatophores**); sperm of many flowering plants
- three kinds by color: **chloroplasts**, **chromoplasts**, **leucoplasts**

Chloroplasts

- **chlorophyll** + carotenoids (carotene, xanthophyll); von Mohl (1830s); named by **Schimper** 1883; none in roots
- **lens-shaped**, **5–10 μm** across, **2–3 μm** thick; 20–100 a leaf cell
- algae: **cup** (*Chlamydomonas*), **girdle** (*Ulothrix*), **spiral** (*Spirogyra*), **star** (*Zygnema*), **net** (*Oedogonium*)



Chloroplast: envelope, stroma, thylakoids in grana, stroma lamellae.

1. **envelope**: outer + inner membrane, intermembrane space
2. **stroma**: Rubisco, **70S ribosomes**, circular DNA, mRNA, tRNA; **dark reaction** (Calvin cycle); starch, oil
3. **thylakoids**: stacked into **grana**, joined by **stroma lamellae**; chlorophyll; **light reaction**

- semi-autonomous, like mitochondria
- functions
  - **photosynthesis**: the cell's kitchen
  - give out **oxygen**
  - O_2 / CO_2 balance
  - take in CO_2: slow **global warming**
  - **pyrenoids** (algae): protein bodies packed with Rubisco, concentrate CO_2; starch stored round them
  - green color

Chromoplasts

- yellow, orange, red **carotenoids**; petals, ripe fruits, some roots; no grana
- from chloroplasts (green tomato, chilli → red) or leucoplasts (carrot)
- color → **pollination**, **seed dispersal**
- **anthocyanins**: in the vacuole's cell sap, not plastids
- listed with them:
  - **phaeoplasts**: **fucoxanthin**; brown algae, diatoms, dinoflagellates
  - **rhodoplasts**: R-phycoerythrin, R-phycocyanin; red algae
  - chromatophores of blue-green algae: **C-phycocyanin**, C-phycoerythrin, chlorophyll *a*
  - chromatophores of purple bacteria: bacteriochlorophyll, carotenoids
- phaeoplasts, rhodoplasts **do photosynthesize** (chloroplasts of brown and red algae)

Leucoplasts

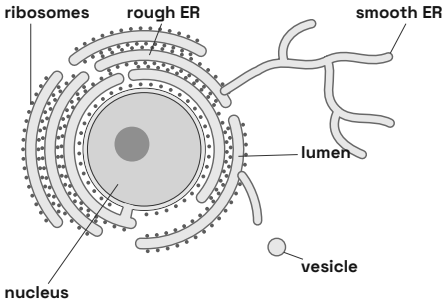
- colorless; roots, tubers, seeds; few or no thylakoids; turn green in light (potato)
- **amyloplasts**: **starch** (potato, wheat, rice, maize)
- **elaioplasts**: **oils** (mustard, castor, groundnut, sunflower, cotton)
- **proteinoplasts** (aleuroplasts): **proteins** (aleurone layer)

Leucoplast	Chromoplast
colorless	yellow, orange, red (carotenoids)
storage organs, out of light	petals, fruits
stores starch, oil, protein	attracts pollinators, seed dispersers

- **interconversion** (Schimper): all from **proplastids**; leucoplast ⇄ chloroplast (light) → chromoplast (ripening); carrot top turns green

Endoplasmic reticulum

- network of **cisternae, tubules, vesicles** in the endoplasm; only eukaryotes; absent in mammalian red blood cells
- poor in eggs, embryonic cells; rich in pancreas, liver
- **Garnier** 1897 (ergastoplasm); EM: **Porter, Claude, Fullam** 1945; named by **Porter** 1953



ER round a nucleus: rough ER joined to the nuclear envelope, smooth ER tubules, vesicles, lumen.

1. **cisternae**: long, flat, unbranched sacs, parallel stacks near nucleus; **lumen**
2. **vesicles**: round or oval sacs (pancreas)
3. **tubules**: wider, branched, changing; join the network

SER (agranular)	RER (granular)
no ribosomes	**ribosomes** on outer surface
mostly **tubules**	mostly **cisternae**
near cell membrane; from RER	near nucleus; joined to outer nuclear membrane
makes **lipids, steroids**	makes **proteins** for export, membranes, lysosomes
fat cells, testis interstitial cells, corpus luteum, sebaceous glands, adrenal cortex, liver, muscle (sarcoplasmic reticulum)	pancreas acinar cells, goblet cells, plasma cells, **Nissl granules**

Functions

- SER: lipids (phospholipids, cholesterol, steroids); RER: proteins
- **intracellular transport** through lumen, to the Golgi
- compartments, mechanical support
- forms **nuclear envelope** after division; enzymes of first lysosomes made on RER
- **cell plate** (plants, with Golgi); runs through plasmodesmata
- enzymes: **glycogen** → glucose, sterols (liver)
- carries messages from nucleus
- stores glycogen, calcium
- SER **detoxifies** drugs, alcohol (xenobiotics) in liver

Golgi complex

- membrane-bound, cup-shaped, near nucleus; **processes, packs, sends on** proteins and lipids
- **Camillo Golgi** 1898 (silver stain; cat, barn owl nerve cells); "**traffic police**" (Darnell, 1986)
- absent: mammalian red blood cells, bryophyte and pteridophyte sperms, sieve tubes
- **pleomorphic**; large in secreting cells (nerve, pancreas, liver); plants: scattered stacks, **dictyosomes**

1. **cisternae**: flat curved sacs in stacks, **4–8** (animals), 20+ (some plants); fenestrated rims
   - **cis (forming) face**: **convex**, faces **nucleus**, ER; materials arrive
   - **trans (maturing) face**: **concave**, faces **cell membrane**; products leave
2. **tubules**: from fenestrated rims
3. **vesicles**: **smooth** and **coated** (clathrin)
4. **Golgian vacuoles**: swollen trans cisternae; secretions; some become lysosomes

Functions

- modifies materials from ER (adds sugars → **glycoproteins**), sends them on
- stores, **condenses**, packs
- **secretion** by exocytosis (enzymes, mucus, milk proteins, insulin)
- **cell plate** (pectin)
- forms **primary lysosomes** (packs RER-made enzymes into vesicles)
- **hormones**: sugars on thyroglobulin (thyroxine)
- membrane renewal, recycling
- glycoproteins, glycolipids, wall polysaccharides

Lysosomes

- *lysis* dissolving + *soma* body; single membrane; **hydrolytic enzymes** (proteases, lipases, nucleases), best at **pH 5**
- **Christian de Duve** 1955 (rat liver); Nobel 1974 with **Claude** and **Palade**
- most animal cells (not mammalian red blood cells), yeasts, *Euglena*, maize root tip; many in **phagocytes**, reticuloendothelial cells (bone marrow, liver, spleen)
- membrane breaks → **autolysis** → "**suicidal bag**"

1. **primary** (virgin): budded from **Golgi**; enzymes from RER, unused
2. **secondary** (digestive vacuoles):
   - **heterophagosome**: + food vacuole (phagosome, pinosome) from **outside**
   - **autophagosome**: digests **own** worn-out parts (mitochondria, ribosomes, peroxisomes, glycogen) = **autophagy**; in growth, repair, starvation
   - **residual body** (tertiary lysosome, telolysosome): undigested remains → exocytosis; in nerve and heart cells stays as **lipofuscin**

Functions

- digest food, **bacteria, viruses** (white blood cells)
- digest stored glycogen, proteins, lipids in starvation
- **autophagy**: recycle worn-out ER, mitochondria
- **acrosome** of sperm: path through egg coverings
- destroy unneeded cells (tadpole's tail)

- bone remodeling
- missing enzyme → **Tay–Sachs disease** (fat in brain nerve cells)

Ribosomes

- no membrane; **protein factories**; **Claude** 1943 (centrifuge); **Palade** 1955 (EM)
- all cells; not mature mammalian red blood cells
- eukaryotes: **free** (cytosol) and **bound** (RER, outer nuclear membrane); smaller ones in mitochondria, chloroplasts
- many in plasma, liver, meristem, cancer, gland cells; *E. coli* ~20,000
- **two subunits**, joined only while making protein; large one attaches to ER; mRNA in groove between
- **rRNA + protein**: ~⅔ rRNA (bacteria), a little over half (eukaryotes)
- **polysome**: several ribosomes on one mRNA
- **S** = svedberg unit (sedimentation coefficient)

	70S	80S
subunits	50S + 30S	60S + 40S
size	~20 nm	~25 nm
in	bacteria, cyanobacteria, mitochondria, chloroplasts	eukaryotic cytoplasm

- S values don't add: sinking speed depends on **shape** as well as mass

RNA of the cell

- **rRNA** ~80 % (50–80): 60S has 28S, 5.8S, 5S rRNA + ~47 proteins; 40S has 18S + ~33 proteins; joins amino acids: a **ribozyme**
- **mRNA** ~5 % (5–10): made by **transcription**; carries the code from nucleus to ribosomes; polysomes
- **tRNA** ~15 % (10–20): soluble RNA; 75–90 nucleotides, **clover leaf**; amino acid at 3′ end (CCA); **anticodon** pairs with codon; > 20 kinds

Functions

- sites of **protein synthesis**
- structural proteins, enzymes
- **free**: proteins for the cytosol (glycolysis enzymes); **bound** (RER): proteins **sent out** (digestive enzymes, hormones), membranes, lysosomes
- hold mRNA, tRNA, growing protein; subunits stored for reuse

Cilia and flagella

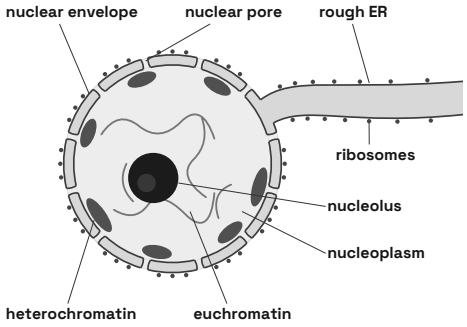
- hair- or whip-like, beat; arise from **basal bodies**; covered by plasma membrane; **Engelmann** 1860s
- **cilia**: Ciliata (*Paramecium*), flame cells, larvae (bipinnaria), **windpipe**, **fallopian tubes**; short (5–20 μm), many
- **flagella**: *Euglena*, collar cells of sponges, cnidarian gastrodermal cells, **sperms**, zoospores, gametes; long (100–200 μm), one or few
- parts: **basal body**, **rootlets**, **basal plate**, **shaft**
- shaft: **axoneme**, **9 + 2**; membrane ~90 Å
  - outer **doublets**: **A** tubule (complete, 13 protofilaments) + **B** (incomplete)
  - A carries inner and outer **dynein arms** (ATPase motor)
  - **two central** single tubules in a **central sheath**
  - **radial spokes** A → central sheath
- **basal body** = centriole: **9 triplets** (A, B, C), cartwheel hub, no central pair (**9 × 3 + 0**)
- **all** tubules **tubulin**; only the arms are dynein
- beat: dynein walks on next doublet; links stop sliding → **bending**; ATP from mitochondria at base
  - cilium: fast **power stroke**, slow **recovery stroke**; flagellum: waves base → tip

Functions

- **movement** (*Paramecium*, sperm)
- **water currents** for food, oxygen (*Paramecium* mouth, sponge collar cells)
- sweep mucus, dust, germs from **airways** (smoking slows, destroys them → cough)
- move fluid in kidney tubules
- move **egg** in oviducts
- larvae swim, spread

Nucleus

- double membrane; **genetic information**; controls the cell; largest organelle; **Robert Brown** 1831
- lost in mature mammalian **red blood cells**, **sieve tubes**, **tracheids and vessels**
- prokaryotes: **nucleoid** (prokaryon, genophore)
- size: chromosome number, **nucleo-cytoplasmic index** (¼ young cell, 1/10 mature)



Interphase nucleus: double envelope, pores, outer membrane → RER, heterochromatin, euchromatin, nucleolus.

1. **nuclear envelope** (karyotheca): **two membranes**, **perinuclear space** 10–50 nm; outer → **rough ER**, with ribosomes; **nuclear pores** (pore complex)
   - small molecules pass freely; large ones actively: **mRNA, tRNA, ribosomal subunits** out; histones, enzymes, ribosomal proteins in
2. **nucleoplasm** (nuclear sap, karyolymph): gel-like, slightly **acidophilic**; water, nucleotides, sugars, Mn, Mg, enzymes, RNA
3. **chromatin** (nuclear reticulum): DNA on **histones**; network only in **interphase**; coils into chromosomes in division
   - **heterochromatin**: tightly packed DNA, **dark**, against envelope, genes **inactive**, repeated sequences
   - **euchromatin**: loose, **light**, genes **active**
4. **nucleolus** (plasmosome): **no membrane**; forms at **nucleolar organizer region** (rRNA genes); RNA + non-histone proteins + DNA; **makes ribosomes**; vanishes in division

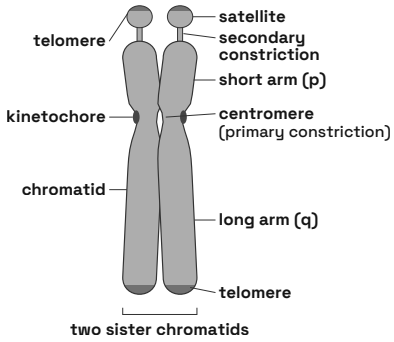
Functions

- controls all activities
- structural proteins
- enzymes

- genetic information; passed on at division
- makes ribosomes (nucleolus)
- mutations, recombination → **variation**
- **differentiation**

Chromosomes

- *chroma* color + *soma* body; seen by **Strasburger** 1875; named by **Waldeyer** 1888
- **DNA** + **histones** + a little RNA; carry **genes**
- number constant: human **46**, onion **16**, rice **24**, bread wheat **42**, *Drosophila* **8**
- **haploid (n)**: one set (gametes); **diploid (2n)**: **homologous pairs**, maternal + paternal
- human: **22 pairs autosomes** + **1 pair sex chromosomes** (XX female, XY male)



Metaphase chromosome: chromatids, centromere, kinetochore, arms, secondary constriction, satellite, telomeres.

- **chromatid**: two **sister chromatids**, one DNA each (copied in S phase); separate at anaphase
- **chromonema**: early thread stage of a chromatid (named by **Vejdovsky**, 1912)
- **chromomeres**: bead-like tighter folds; clear in **polytene** chromosomes (fly salivary glands); unseen at metaphase
- **centromere** (primary constriction): joins sister chromatids; **kinetochore** (three-layered protein plate) holds spindle fibers
- **nucleolar organizer** (secondary constriction I): rRNA genes; nucleolus forms there
- **secondary constriction II**: other narrow places; break and rejoin; identify a chromosome
- **satellite**: knob beyond the nucleolar organizer; **SAT chromosomes** ("*sine acido thymonucleinico*", but it has DNA)
- **telomeres**: ends; repeated DNA (TTAGGG in humans); stop ends sticking; shorten each division

Type	Centromere	Arms	Anaphase shape
telocentric	at one end	one	I
acrocentric	very near one end	very short + long	J
submetacentric	a little off middle	unequal	L
metacentric	middle	equal	V

Functions

- DNA: genetic material, cell to cell, parent to offspring
- control structural and enzyme proteins → characters
- changes = **mutations** → variation
- exact sharing in mitosis; halving in meiosis keeps number constant

Cell inclusions

1. **reserve materials**
   - **nitrogenous**: proteins (aleurone grains), amino acids
   - **non-nitrogenous** (C, H, O; H : O = 2 : 1): starch, sugars (sugarcane, beet), **inulin** (dahlia), **glycogen** (fungi, animals); oils, fats
2. **secretory materials**
   - **pigments**: chlorophylls *a*, *b*, *c*, carotene, lutein, fucoxanthin, phycocyanin, phycoerythrin
   - **enzymes**
   - **nectar** (nectaries)
3. **excretory materials** (plants have no excretory organs)
   - **alkaloids**: quinine (*Cinchona*), nicotine (tobacco), morphine (opium poppy), atropine (belladonna), daturine (*Datura*)
   - **organic acids**: citric (lemon), tartaric (tamarind, grape), oxalic, malic (apple)
   - **gums**: gum arabic (*Acacia*)
   - **resins**: conifers (turpentine, rosin)
   - **tannins**: unripe fruits, bark, tea
   - **essential oils**: lemon, *Eucalyptus*, mint, *tulsi*
   - **latex**: fig, papaya, rubber tree
   - **crystals**: **calcium oxalate** raphides (*Colocasia*, *pindalu*: itchy throat), calcium carbonate **cystoliths** (fig), **silica** (grasses)

Nucleotide (exercise drawing)

- **phosphate** on carbon 5′ of the sugar
- **deoxyribose**: ring of 4 carbons (1′–4′) + O; 5′ CH_2 outside; no OH on 2′; OH on 3′ joins next phosphate → chain
- **base** on carbon 1′: purine (A, G) or pyrimidine (C, T)

COMMON MISTAKES

✗ Mesosomes are the bacterium's mitochondria
✓ once thought so; now known to be **artifacts**; respiration is on the plasma membrane.

✗ Collenchyma has a secondary wall
✓ its thick corners are **primary** wall; secondary walls: tracheids, vessels, sclerenchyma.

✗ Central tubules of a cilium are dynein
✓ all tubules are **tubulin**; dynein is the **arms**.

✗ 50S + 30S = 80S
✓ **70S**; S values don't add.

✗ Heterochromatin has little DNA, much RNA
✓ it is DNA **packed tightly**, genes inactive.

✗ Lysosomes start cell division, cause leukemia
✓ not accepted; cyclins and kinases control division.

✗ Phaeoplasts and rhodoplasts don't photosynthesize
✓ they are the **chloroplasts** of brown and red algae.

✗ Anthocyanins are in chromoplasts
✓ in the **vacuole's** cell sap.

✗ Basal body is 9 + 2
✓ **9 triplets**, no central pair (9 × 3 + 0).