

CUET · BIOLOGY · CLASS XI · CODE 304

Cell Cycle and Cell Division

CUET unit: Cell Structure and Function → Cell Cycle and Cell Division

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Snapshot

- Defines the **cell cycle** — the ordered sequence of events ($G1 \rightarrow S \rightarrow G2 \rightarrow M$) by which one cell duplicates its genome and divides into two daughter cells.
- Maps **mitosis** (equational, somatic, $2n \rightarrow 2n$) and **meiosis** (reductional + equational, gametic, $2n \rightarrow n$) stage by stage.
- High-yield for CUET: stage-event matching (e.g., "centromere splits in?"), DNA-vs-chromosome arithmetic across G1/S/G2/M, and the five sub-stages of prophase I (leptotene–zygotene–pachytene–diplotene–diakinesis).
- NTA loves pairing **kinetochore / synaptonemal complex / bivalent / chiasmata / cell-plate** with the precise stage they appear in.

Detailed Notes

2.1 Core concepts

- **Cell cycle defined.** The sequence of events by which a cell duplicates its genome, synthesises the other constituents of the cell and eventually divides into two daughter cells is termed the **cell cycle**. Cell growth (cytoplasmic increase) is continuous, but **DNA synthesis occurs only during one specific stage** of the cell cycle; the replicated chromosomes are then distributed to daughter nuclei by a complex series of events that are under **genetic control** (NCERT §10.1, p. 120).
- **Cycle duration.** A typical eukaryotic cell cycle is illustrated by human cells in culture — they divide once approximately every **24 hours**. Duration varies between organisms and cell types — **yeast** can progress through the cell cycle in only about **90 minutes** (NCERT §10.1.1, p. 121).
- **Two basic phases.** The cell cycle is divided into **Interphase** and **M Phase (Mitosis phase)**. M phase represents actual cell division (mitosis); interphase is between two successive M phases. In a 24-hour human cell cycle, **cell division proper lasts only about an hour** and the **interphase lasts more than 95 per cent** of the duration (NCERT §10.1.1, p. 121).
- **M phase = karyokinesis + cytokinesis.** M phase starts with **nuclear division (karyokinesis)** corresponding to separation of daughter chromosomes, and usually ends with **division of cytoplasm (cytokinesis)**. Interphase, also called the "resting" phase, is when the cell prepares for division through cell growth and DNA replication (NCERT §10.1.1, p. 121).

- **Sub-phases of interphase — G1, S, G2. G1 (Gap 1)** corresponds to the interval between mitosis and initiation of DNA replication; the cell is metabolically active and continuously grows but does NOT replicate DNA. **S phase (Synthesis)** marks the period of DNA synthesis/replication — the DNA per cell **doubles** from **2C to 4C**. However, **there is no increase in chromosome number** — if the cell had $2n$ chromosomes at G1, after S phase the number stays $2n$ (each chromosome now has two sister chromatids). **G2 (Gap 2)** — proteins are synthesised in preparation for mitosis while cell growth continues (NCERT §10.1.1, pp. 121–122).
- **S-phase animal cell specifics.** In animal cells, during the S phase, **DNA replication begins in the nucleus and the centriole duplicates in the cytoplasm** (NCERT §10.1.1, p. 121).
- **Quiescent G0 stage.** Some cells in the adult animals (e.g., **heart cells**) do not appear to exhibit division; many other cells divide only occasionally to replace cells lost by injury or cell death. Cells that do not divide further exit G1 to enter an inactive **quiescent stage (G0)** of the cell cycle — they remain **metabolically active** but no longer proliferate unless called on to do so depending on the requirement of the organism (NCERT §10.1.1, p. 122).
- **Where mitosis happens.** In animals mitotic cell division is only seen in **diploid somatic cells**. There are few exceptions to this where **haploid cells divide by mitosis — for example, male honey bees**. Plants can show mitotic divisions in **both haploid and diploid cells** (NCERT §10.1.1, p. 122).
- **M phase — most dramatic period.** Involves a major reorganisation of virtually all components of the cell; because chromosome number in parent and progeny is the same, it is also called **equational division**. Karyokinesis is divided for convenience into four stages: **Prophase, Metaphase, Anaphase, Telophase** (NCERT §10.2, p. 122).
- **Prophase (mitotic).** Follows S and G2 — the new DNA molecules are not distinct but intertwined. Prophase is marked by initiation of **condensation of chromosomal material** (chromatin untangles during condensation). Two characteristic events: (i) **chromosomal material condenses to form compact mitotic chromosomes** — each chromosome is seen to be composed of **two chromatids attached together at the centromere**; (ii) the **centrosome**, which underwent duplication during S phase, begins to move towards opposite poles; each centrosome radiates out microtubules called **asters**; the two asters together with the spindle fibres form the **mitotic apparatus**. Cells at the end of prophase, viewed under the microscope, **do not show golgi complexes, ER, nucleolus and the nuclear envelope** (NCERT §10.2.1, pp. 122–123).
- **Metaphase.** The **complete disintegration of the nuclear envelope marks the start of metaphase**. Chromosomes are spread through the cytoplasm; condensation is now complete and **chromosomes are best studied morphologically** at this stage. Each metaphase chromosome is made of two sister chromatids held together by the centromere. **Small disc-shaped structures at the**

surface of the centromeres are called kinetochores, which serve as sites of attachment of spindle fibres. **Metaphase plate** is the plane of alignment of chromosomes at the equator — one chromatid of each chromosome is connected by its kinetochore to spindle fibres from one pole, its sister chromatid to fibres from the opposite pole. Key features: spindle fibres attach to kinetochores; chromosomes are aligned at the equatorial plate (NCERT §10.2.2, p. 123).

- **Anaphase.** At its onset, **each chromosome arranged at the metaphase plate is split simultaneously** and the two **daughter chromatids — now referred to as daughter chromosomes** — begin migration towards opposite poles. As each chromosome moves away from the equator, the **centromere of each chromosome remains directed towards the pole and hence at the leading edge**, with the **arms of the chromosome trailing behind**. Key events: centromeres split and chromatids separate; chromatids move to opposite poles (NCERT §10.2.3, pp. 123–124).
- **Telophase.** Chromosomes that reach their respective poles **decondense and lose their individuality**; individual chromosomes can no longer be seen. Each set of chromatin material collects at each pole. Key events: chromosomes cluster at opposite spindle poles and lose identity as discrete elements; **nuclear envelope develops around the chromosome clusters at each pole, forming two daughter nuclei; nucleolus, golgi complex and ER reform** (NCERT §10.2.4, p. 124).
- **Cytokinesis.** Mitosis accomplishes not only segregation of duplicated chromosomes into daughter nuclei (karyokinesis) but also division of the cell itself by separation of cytoplasm — **cytokinesis** — at the end of which cell division is complete. In an **animal cell**, a **furrow appears in the plasma membrane** which gradually deepens and ultimately joins in the centre dividing the cell cytoplasm into two. **Plant cells** are enclosed by a relatively inextensible cell wall, so cytokinesis uses a different mechanism — **wall formation starts in the centre of the cell and grows outward** to meet the existing lateral walls. The new wall begins with a simple precursor called the **cell-plate** that represents the **middle lamella** between the walls of two adjacent cells. Organelles (mitochondria, plastids) get distributed between the two daughter cells. In some organisms, **karyokinesis is not followed by cytokinesis**, producing a multinucleate condition — **syncytium** (e.g., **liquid endosperm of coconut**) (NCERT §10.2.5, p. 124).
- **Significance of mitosis.** Mitosis (equational division) is usually restricted to diploid cells, although in some lower plants and in some social insects haploid cells also divide by mitosis. **Mitosis usually results in production of diploid daughter cells with identical genetic complement.** Growth of multicellular organisms is due to mitosis. Cell growth disturbs the **nucleo-cytoplasmic ratio**, so the cell divides to restore it. A very significant contribution of mitosis is **cell repair** — cells of the upper layer of the epidermis, cells of the lining of the gut, and blood cells are constantly replaced. Mitotic divisions in meristematic tissues — the **apical and the**

lateral cambium — result in continuous growth of plants throughout their life (NCERT §10.3, p. 125).

- **Meiosis — key features.** Production of offspring by sexual reproduction includes fusion of two gametes, each with a complete haploid set of chromosomes. Gametes are formed from specialised diploid cells. This specialised division reduces the chromosome number by half — **meiosis**. Meiosis ensures the production of haploid phase in the life cycle of sexually reproducing organisms; fertilisation restores diploidy. Key features: (a) **two sequential cycles of nuclear and cell division — meiosis I and meiosis II — but only a single cycle of DNA replication**; (b) meiosis I is initiated after the parental chromosomes have replicated to produce identical sister chromatids at the S phase; (c) pairing of homologous chromosomes and recombination between non-sister chromatids of homologous chromosomes; (d) **four haploid cells** are formed at the end of meiosis II (NCERT §10.4, p. 125).
- **Prophase I.** Typically longer and more complex than mitotic prophase; further subdivided into five phases — **Leptotene, Zygotene, Pachytene, Diplotene, Diakinesis** — based on chromosomal behaviour. **Leptotene** — chromosomes become gradually visible under the light microscope; compaction continues throughout. **Zygotene** — chromosomes start pairing (**synapsis**); paired chromosomes are called **homologous chromosomes**; electron micrographs show that synapsis is accompanied by formation of a complex structure called the **synaptonemal complex**; the complex formed by a pair of synapsed homologous chromosomes is called a **bivalent or tetrad**. **Pachytene** — the **four chromatids of each bivalent become distinct and clearly appear as tetrads**; this stage is characterised by **recombination nodules** at which **crossing over** occurs between non-sister chromatids of homologous chromosomes. Crossing over is an **enzyme-mediated** process; the enzyme involved is called **recombinase**. Recombination between homologous chromosomes is completed by the end of pachytene, leaving the chromosomes linked at the sites of crossing over. **Diplotene** — recognised by the dissolution of the synaptonemal complex and tendency of recombined homologous chromosomes of the bivalents to separate from each other except at the sites of crossovers — these **X-shaped structures are called chiasmata**. In oocytes of some vertebrates, **diplotene can last for months or years**. **Diakinesis** — marked by **terminalisation of chiasmata**; chromosomes are fully condensed; the meiotic spindle is assembled; by the end of diakinesis the **nucleolus disappears and the nuclear envelope breaks down**; diakinesis represents transition to metaphase (NCERT §10.4.1, p. 126).
- **Metaphase I.** The **bivalent chromosomes align on the equatorial plate** (Figure 10.3). The microtubules from opposite poles of the spindle attach to the **kinetochores of homologous chromosomes** (NCERT §10.4.1, pp. 126–127).
- **Anaphase I.** The **homologous chromosomes separate**, while **sister chromatids remain associated at their centromeres** — this is the reductional step (NCERT §10.4.1, p. 127).

- **Telophase I.** The **nuclear membrane and nucleolus reappear**; cytokinesis follows — called a **dyad of cells**. Chromosomes may undergo some dispersion but do not reach the extremely extended state of the interphase nucleus. The stage between the two meiotic divisions is called **interkinesis**; it is generally short-lived; **there is no replication of DNA during interkinesis**. Interkinesis is followed by prophase II, a much simpler prophase (NCERT §10.4.1, p. 127).
- **Meiosis II — Prophase II.** Initiated immediately after cytokinesis, usually before the chromosomes have fully elongated. In contrast to meiosis I, **meiosis II resembles a normal mitosis**. The nuclear membrane disappears by the end of prophase II; chromosomes again become compact (NCERT §10.4.2, p. 127).
- **Metaphase II.** Chromosomes align at the equator and microtubules from opposite poles of the spindle get attached to the **kinetochores of sister chromatids** (NCERT §10.4.2, p. 127).
- **Anaphase II.** Begins with the **simultaneous splitting of the centromere** of each chromosome (which was holding the sister chromatids together), allowing them to move toward opposite poles by shortening of microtubules attached to kinetochores (NCERT §10.4.2, p. 127).
- **Telophase II.** Meiosis ends with telophase II — the two groups of chromosomes once again get enclosed by a nuclear envelope; cytokinesis follows, resulting in the formation of a **tetrad of cells, i.e., four haploid daughter cells** (NCERT §10.4.2, p. 128).
- **Significance of meiosis.** Meiosis is the mechanism by which **conservation of specific chromosome number of each species is achieved across generations** in sexually reproducing organisms — even though it paradoxically reduces the chromosome number by half. It also **increases genetic variability** in the population from one generation to the next; variations are very important for the process of evolution (NCERT §10.5, p. 128).

2.2 Definitions to memorise

Term	Definition	Page
Cell cycle	Sequence of events by which a cell duplicates its genome, synthesises other constituents, and divides into two daughter cells	120
Interphase	Period between two successive M phases when the cell prepares for division (cell growth + DNA replication)	121
M phase	The phase of actual cell division — karyokinesis + cytokinesis	121
Karyokinesis	Nuclear division — separation of daughter chromosomes	121
Cytokinesis	Division of the cytoplasm at the end of M phase	121
G1 phase	Interval between mitosis and initiation of DNA replication; cell grows, no DNA replication	121

Term	Definition	Page
S phase	DNA synthesis/replication phase — $2C \rightarrow 4C$ without change in chromosome number	121
G ₂ phase	Period of cytoplasmic growth and protein synthesis preparing for mitosis	122
Quiescent stage (G ₀)	Inactive stage of cells that exit G ₁ and stop dividing while remaining metabolically active (e.g., heart cells)	122
Equational division	Division in which chromosome number of parent and progeny cells is the same (mitosis)	122
Centrosome	Microtubule-organising centre duplicated during S phase; moves to opposite poles in prophase	122
Asters	Microtubules radiating out from each centrosome	122
Mitotic apparatus	Two asters together with spindle fibres	122
Kinetochores	Disc-shaped structure on the surface of the centromere; site of spindle fibre attachment	123
Metaphase plate	Plane of alignment of chromosomes at the equator during metaphase	123
Cell-plate	Simple precursor of the new cell wall formed at the centre during plant cytokinesis; represents the middle lamella	124
Syncytium	Multinucleate condition arising when karyokinesis is not followed by cytokinesis (e.g., liquid endosperm of coconut)	124
Meiosis	Specialised division that reduces chromosome number by half, producing haploid daughter cells	125
Synapsis	Pairing of homologous chromosomes during zygotene	126
Synaptonemal complex	Complex structure formed at synapsis between paired homologues	126
Bivalent / Tetrad	Complex formed by a pair of synapsed homologous chromosomes (four chromatids)	126
Recombinase	Enzyme that mediates crossing over between non-sister chromatids	126
Chiasmata	X-shaped sites where recombined homologues remain linked during diplotene	126
Interkinesis	Short stage between meiosis I and meiosis II; no DNA replication	127
Dyad	Pair of cells produced at the end of telophase I	127
Tetrad of cells	Four haploid daughter cells produced at the end of meiosis II	128

2.3 Diagrams / processes to remember

- **Figure 10.1 (p. 121)** — circular diagram of the cell cycle showing **G1** → **S** → **G2** within interphase and **Prophase** → **Metaphase** → **Anaphase** → **Telophase** → **Cytokinesis** within M phase. M is a tiny wedge; interphase fills >95% of the cycle.
- **Figure 10.2 a-e (pp. 123–124)** — stages of mitosis: **Early Prophase** (untangled threads), **Late Prophase (a)** (compact chromosomes with two sister chromatids + asters), **Transition to Metaphase, Metaphase (b)** (chromosomes at equator with kinetochore-attached spindle fibres from both poles), **Anaphase (c)** (chromatids moving to poles with centromere leading and arms trailing), **Telophase (d)** (decondensation at poles, nuclear envelope reforms), **Interphase (e)** (after cytokinesis).
- **Figure 10.3 (p. 127)** — meiosis I: **Prophase I** (bivalents with chiasmata visible), **Metaphase I** (bivalents at equator), **Anaphase I** (homologues separating with sister chromatids still attached), **Telophase I** (dyad).
- **Figure 10.4 (p. 128)** — meiosis II: **Prophase II** → **Metaphase II** → **Anaphase II** (sister chromatids separating after centromere split) → **Telophase II** (tetrad of four haploid cells).
- **DNA/chromosome arithmetic** (from §10.1.1, p. 121): if **2C at G1**, then **4C after S = 4C at G2**, drops to **2C after M** in each daughter; chromosome number $2n$ stays $2n$ throughout interphase and after mitosis.
- **Onion root tip recall (p. 122 margin box)** — 16 chromosomes at G1, S, G2, after M; DNA goes $2C \rightarrow 4C \rightarrow 4C \rightarrow 2C$ if M phase content is $2C$.

2.4 Common confusions / NTA trap points

- **"Reductional vs equational"** — **Meiosis I is reductional** (homologues separate, $2n \rightarrow n$); **Meiosis II is equational** (sister chromatids separate, like mitosis). Don't say "meiosis = reductional" without qualifying which division.
- **"Centromere splits in anaphase"** — true for **mitotic anaphase** and **anaphase II**, **NOT for anaphase I** (where centromeres stay intact and only homologues separate).
- **"Crossing over happens in zygotene"** — WRONG. **Synapsis** is in zygotene; **crossing over** is in **pachytene**.
- **"Chiasmata appear in pachytene"** — WRONG; they appear in **diplotene** when the synaptonemal complex dissolves; they are **terminalised** in diakinesis.
- **"DNA doubles in S, so chromosome number doubles"** — WRONG. DNA goes $2C \rightarrow 4C$ but chromosome number remains $2n$ (each chromosome now has two sister chromatids).
- **"Cleavage furrow in plants"** — WRONG. Plants use a **cell-plate** built outward from the centre; the furrow is animal-only because plants have a rigid cell wall.

- **"Interkinesis has DNA replication"** — WRONG. **No DNA replication** occurs between meiosis I and meiosis II.
- **"G0 cells are dead/inactive"** — WRONG. They are **metabolically active**; they just no longer proliferate.
- **"Mitosis = only diploid cells everywhere"** — WRONG. Honey bee males show haploid mitosis; plants show both haploid and diploid mitosis.
- **"Nuclear envelope breaks down in prophase"** — WRONG; it disintegrates at the **start of metaphase** per NCERT (golgi/ER/nucleolus/nuclear envelope are "not visible" at the end of prophase, but disintegration "marks the start of metaphase").
- **"All recombination occurs at chiasmata in diakinesis"** — WRONG; **recombination is complete by the end of pachytene**; diplotene's chiasmata are merely visible evidence.
- **"Syncytium needs failure of karyokinesis"** — WRONG. Syncytium arises when **karyokinesis is NOT followed by cytokinesis** (many nuclei + one cytoplasm).

2.5 Key processes / classifications

#	Stage	Major event	Chromosome state	DNA state	Page
1	G1	Cell growth, no DNA replication	2n	2C	121
2	S	DNA replication; centriole duplicates in animals	2n (each with two chromatids)	2C → 4C	121
3	G2	Protein synthesis, prep for mitosis	2n	4C	122
4	G0	Quiescent — metabolically active, not dividing	2n	2C	122
5	Prophase (mitosis)	Chromatin condenses; centrosome moves; asters appear	2n	4C	122–123
6	Metaphase	Nuclear envelope disintegrates; chromosomes align at equator; kinetochores attach	2n	4C	123
7	Anaphase (mitosis)	Centromeres split; chromatids move to poles	4n (transiently)	4C	123–124
8	Telophase	Chromosomes decondense; nuclear envelope reforms	2n	2C per daughter	124
9	Cytokinesis — animal	Cleavage furrow forms	—	—	124

#	Stage	Major event	Chromosome state	DNA state	Page
10	Cytokinesis — plant	Cell-plate forms centre-out	—	—	124
11	Leptotene	Chromosomes gradually visible	2n	4C	126
12	Zygotene	Synapsis; synaptonemal complex forms; bivalent forms	2n (paired)	4C	126
13	Pachytene	Tetrads visible; crossing over (recombinase)	2n (bivalents)	4C	126
14	Diplotene	Synaptonemal complex dissolves; chiasmata visible	2n (bivalents)	4C	126
15	Diakinesis	Terminalisation of chiasmata; spindle assembled; nuclear envelope breaks	2n	4C	126
16	Metaphase I	Bivalents at equator; spindle attaches to homologue kinetochores	2n	4C	126–127
17	Anaphase I	Homologues separate; sister chromatids stay together	2n → n (per pole)	4C → 2C per pole	127
18	Telophase I	Dyad of cells; nuclear envelope reappears	n	2C per cell	127
19	Interkinesis	Short gap; NO DNA replication	n	2C	127
20	Prophase II	Resembles mitosis; nuclear membrane disappears	n	2C	127
21	Metaphase II	Chromosomes at equator; kinetochores of sister chromatids	n	2C	127
22	Anaphase II	Centromeres split; sister chromatids separate	n	2C → C per pole	127
23	Telophase II	Four haploid daughter cells (tetrad)	n	C	128
24	Mitosis significance	Growth, repair, nucleocytoplasmic ratio restoration	—	—	125
25	Meiosis significance	Chromosome conservation across generations + genetic variability	—	—	128

Practice MCQs

Q1. What is the approximate duration of the cell cycle in a typical human cell in culture and in yeast, respectively?

- A. 90 minutes and 24 hours
- B. 24 hours and 90 minutes
- C. 12 hours and 60 minutes
- D. 24 hours and 24 minutes

Q2. In a 24-hour human cell cycle, the M phase (actual cell division) lasts for approximately:

- A. 95% of the cycle
- B. 12 hours
- C. 1 hour
- D. 9 hours

Q3. During the S phase of interphase in an animal cell, which of the following events occur together?

- A. DNA replication in the nucleus and centriole duplication in the cytoplasm
- B. DNA replication in the nucleus and chromosome decondensation
- C. Centriole duplication and spindle assembly
- D. Cell growth and nuclear envelope breakdown

 **12 more MCQs + answer key**

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PYQ Alignment

Cell Cycle and Cell Division is a near-certain CUET appearance (typically 2–4 MCQs per shift across 2023–25), with NTA favouring stage-event matching (which stage shows chiasmata / kinetochore attachment / centromere splitting), DNA-vs-chromosome



arithmetic across G1/S/G2/M, and exact terminology from the five sub-stages of prophase I (leptotene–zygotene–pachytene–diplotene–diakinesis). Plant-vs-animal cytokinesis and the G0 definition are also recurring direct-recall traps.

