Unit 1 · Cell Biology

STUDY NOTES

Key terms

Karyokinesis / cytokinesis: division of the nucleus / of the cytoplasm.

Mitosis: 1 cell → 2 daughter cells, same number and kind of chromosomes (**equational**).

Meiosis: 1 diploid cell, 2 divisions → 4 haploid cells (**reduction division**).

Diploid (2n) / haploid (n): two sets / one set of chromosomes.

Homologous chromosomes: a pair, one from each parent; same length, shape, genes at the same places.

Sister chromatids: two copies of one chromosome, joined at the centromere; identical.

Kinetochores: protein discs on the centromere, one per chromatid; spindle fibers attach here.

Meiocyte: diploid cell that undergoes meiosis (primary spermatocyte, primary oocyte, pollen mother cell).

Synapsis: pairing of homologs, gene for gene (zygotene).

Bivalent (tetrad): a paired couple of homologs; four chromatids.

Crossing over: non-sister chromatids swap matching pieces (pachytene).

Chiasma: point where non-sister chromatids cross; seen in diplotene.

Interkinesis: pause between meiosis I and II; **no DNA copied**.

Clone: organisms from one parent by asexual reproduction, all with the same genes.

Non-disjunction: a pair (or two chromatids) fails to separate.

Formulas and numbers

- 1C = DNA of **one set**; $G_1 = 2C$; $G_2 = 4C$
- count chromosomes by **centromeres**
- kinds of gamete = 2^n (n pairs; independent assortment alone); two parents: $2^n \times 2^n$
- mitotic index = cells dividing ÷ total cells × 100%
- time in a stage = (cells in stage ÷ total) × cycle time; short stage: few cells
- cells after r rounds = 2^r; chromosomes per cell don't change
- human: 2n = 46, 2^{23} = 8,388,608 kinds of gamete; $2^{46} \approx$ 70 trillion combinations
- 2n:
  - onion 16
  - garden pea 14
  - rice 24
  - maize 20
  - dog 78
  - fruit fly 8
  - lily 24
- one spermatocyte → **4 sperm**; one oocyte → **1 egg** + 2 or 3 polar bodies

Human cell, stage by stage

Stage	Chromosomes	Chromatids	DNA
G_1	46	46	2C
G_2, prophase, metaphase	46	92	4C
Anaphase (mitosis)	92	92	4C
After mitosis, each cell	46	46	2C
Prophase I, metaphase I (23 bivalents)	46	92	4C
After meiosis I, each cell	23	46	2C
Anaphase II	46	46	2C
After meiosis II, each cell	23	23	1C

- DNA: doubles once in S; halves each time the **cytoplasm** divides

Cell cycle

- **Interphase** (about 23 of 24 h in a human cell in a dish) + **M phase** (about 1 h)
- **G_1**:
  - growth
  - proteins
  - organelles
  - a check
- **S**:
  - DNA copied, 2C → 4C
  - centrosome copied too
  - chromosome number unchanged
- **G_2**:
  - more growth
  - proteins for division (tubulin)
  - DNA checked
- **G_0**: left the cycle from G_1 (most nerve cells for life; liver cells can return)

- not a “resting stage”: nucleus looks inactive, but the cell grows and copies DNA

Mitosis

- Where:
  - somatic cells
  - plant meristems (root, shoot tips, cambium)
  - animals throughout, fastest in skin, bone marrow, gut lining
- **Prophase** (usually longest):
  - chromatin → visible double chromosomes
  - nucleolus goes
  - centrosomes to the poles, asters
  - spindle forms
  - nuclear envelope breaks up at the end
- **Metaphase**:
  - fibers on kinetochores from both poles
  - chromosomes on the **equator**
  - shortest and thickest (counted here)
  - spindle checkpoint
- **Anaphase** (shortest, a few minutes):
  - cohesin released, centromeres split
  - chromatids to opposite poles, centromere first, about 1 μm a minute
  - cell lengthens
- **Telophase**:
  - spindle breaks down
  - envelope and nucleolus re-form
  - chromosomes uncoil

Animal cell	Plant cell
centrioles; asters (astral)	no centrioles, no asters (anastral)
cleavage furrow, actin + myosin ring	cell plate, Golgi vesicles on phragmoplast
outside in	center out; becomes middle lamella
rounds up	keeps its shape

Meiosis

Where:

- testes
- ovaries
- anthers
- ovules

DNA copied once, two divisions.

Prophase I (Little Zebras Play Down Dale):

1. **Leptotene**: long, thin beaded threads (chromomeres)
2. **Zygotene**:
   - **synapsis**
   - synaptonemal complex
   - bivalents (n of them)
3. **Pachytene**:
   - thick
   - tetrads
   - **crossing over**, genetic recombination
4. **Diplotene**:
   - complex breaks down, homologs pull apart
   - **chiasmata seen**
   - human eggs wait here, 12–50 years
5. **Diakinesis**:
   - most coiled
   - terminalization
   - nucleolus and envelope go
   - spindle forms

Rest of meiosis I

- **Metaphase I**: **pairs** on the equator, each homolog facing one pole; orientation by chance = independent assortment
- **Anaphase I**:
  - **homologs** to opposite poles
  - centromeres **don't** split
  - **number halves here**
- **Telophase I**:
  - two haploid cells
  - n chromosomes, each double
  - 2C

Meiosis II (like mitosis, both cells):

1. prophase II
2. metaphase II (single chromosomes on the equator)
3. anaphase II (**centromeres split**)
4. telophase II
5. cytokinesis: 4 cells, n single chromosomes, 1C

- meiosis I: 2n → n; meiosis II: n stays, 2C → 1C

Mitosis	Meiosis
somatic cells	meiocytes
1 division, 2 cells	2 divisions, 4 cells
2n, identical	n, all different
no synapsis, no crossing over	synapsis, crossing over, chiasmata
single chromosomes at metaphase	pairs at metaphase I
growth, repair, asexual	gametes, spores, variation

Why they matter

Mitosis:

- growth
- repair and replacement (about 2 million red blood cells a second)
- asexual reproduction
- genetic stability
- right cell size (surface to volume)
- regeneration (starfish, planarian)
- uncontrolled → **cancer**, tumor (cycle-control genes damaged)
- normal cells stop after about 40–60 divisions (**Hayflick limit**); HeLa cells never stopped

Meiosis:

- gametes and spores
- **constant chromosome number** (without it 46, 92, 184…)
- variation
- DNA repair while paired
- non-disjunction: gametes n + 1 and n − 1
- egg with two copies of chromosome 21 → 47 chromosomes, **Down syndrome** (about 1 in 1,000–1,100 births); chance rises with the mother's age

Asexual and sexual reproduction

Asexual	Sexual
one parent; no gametes	usually two; gametes fuse
mitosis (or fission)	meiosis, fertilization, mitosis
clone, no variation	variation
fast, many, less energy	slower, fewer, more energy
good genes kept exactly	good combination broken up
disease can kill all	some likely to survive change
Amoeba, yeast, *Hydra*, potato tubers, banana suckers	humans, frogs, mustard, rice

Clones:

- potato
- sugarcane
- banana
- bamboo
- garlic
- grafted mango
- *Bryophyllum*
- identical twins (one zygote)

Danger of one clone: Irish Lumper potato, late blight, from 1845: about a million dead, another million left. Gros Michel banana lost to Panama disease; Cavendish now at risk.

Three sources of variation

1. **Crossing over** (prophase I): new mixture on each chromosome; about 27 per sperm, 42 per egg
2. **Independent assortment** (metaphase I): 2^n kinds of gamete
3. **Random fertilization**: any sperm, any egg

- breeders: cross to make the variety (sexual), then copy it (asexual)

COMMON MISTAKES

✗ Counting by arms or threads
✓ by **centromeres**: metaphase 46 chromosomes, 92 chromatids.

✗ Meiosis II halves the number
✓ meiosis **I** does; II halves only the DNA (2C → 1C).

✗ DNA copied in interkinesis
✓ once only, before meiosis I.

✗ Interphase is a resting stage
✓ cell grows and copies its DNA.

✗ Crossing over in diplotene
✓ in **pachytene**; chiasmata are *seen* in diplotene.

✗ Crossing over between sister chromatids
✓ **non-sister** chromatids of homologs.

✗ Centromeres split at anaphase I
✓ they split at anaphase of mitosis and anaphase II.