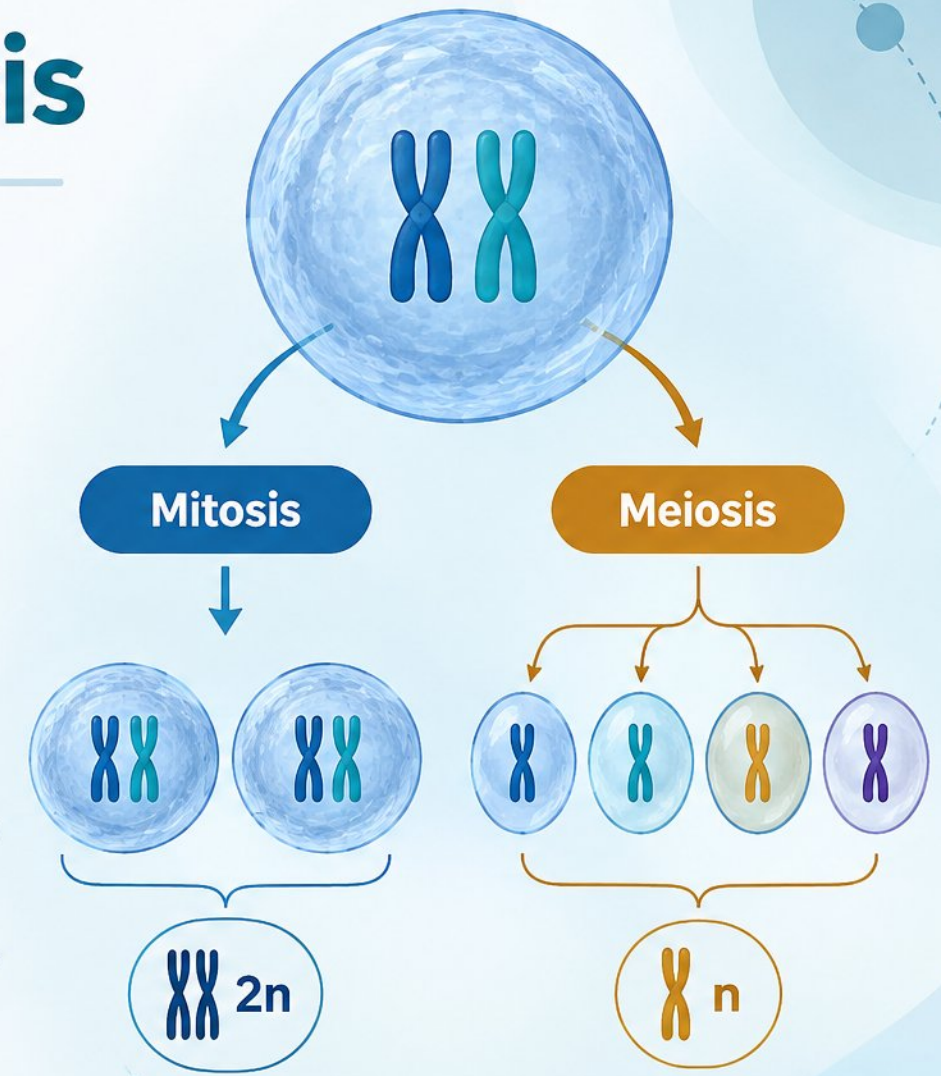
Cell Division:
Mitosis and Meiosis

Framing question: how does one cell become two — and why are the products sometimes genetically different?

Two core modes: mitosis (growth, repair, maintenance) versus meiosis (gamete formation and genetic variation)

Learning path: chromosome vocabulary → cell cycle → mitotic phases → meiotic phases → variation → comparison → classroom applications

Why it matters: exam essentials for students, big-picture outcomes for adult learners, teaching-ready models for educators



Learning Goals and How to Use This Deck

By the end, you can:

- Describe chromosome behavior in each phase
- Distinguish reductional from equational division
- Explain three sources of genetic variation

Audience pathways:

- Students: phase-order and chromosome counting drills
- Adult learners: big-picture outcomes
- Teachers: models, misconceptions, assessment items

Students
phase-order and chromosome counting drills

Adult learners
big-picture outcomes

Teachers
models, misconceptions, assessment items

Deck structure: five parts — foundations, mitosis, meiosis, variation and clinical links, teaching and review

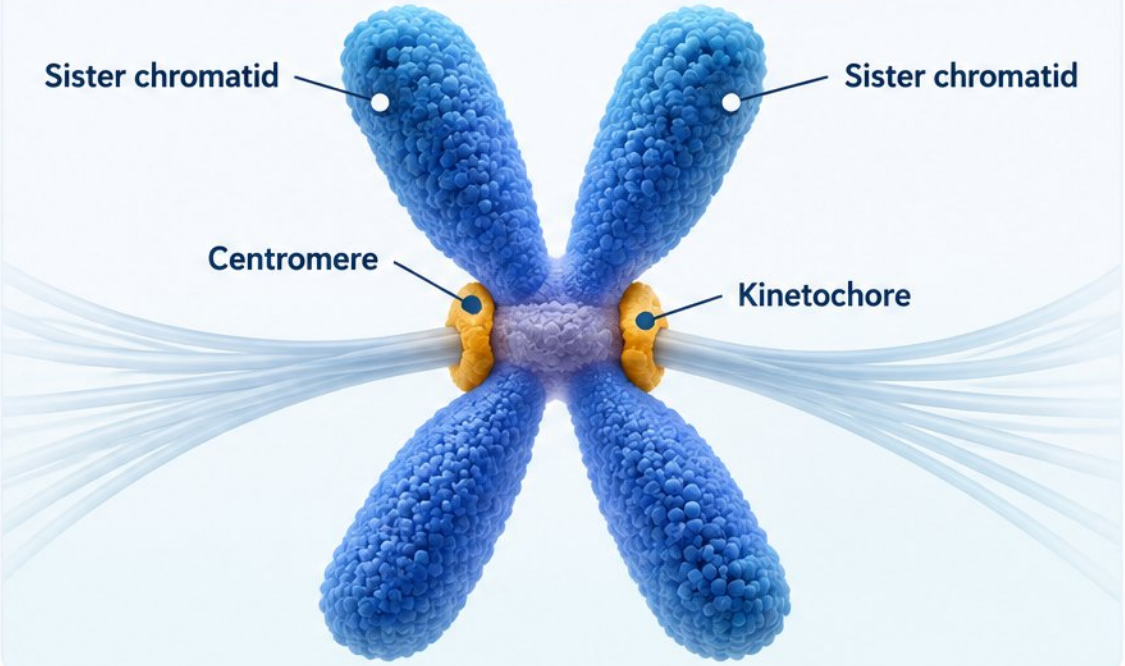


Terminology: standard 2n/n notation; human diploid number = 46 chromosomes (23 pairs)

Chromosome Basics: Chromatin, Chromatids, and Ploidy

- **Chromatin, chromosome, chromatid:** one replicated chromosome has two sister chromatids
- **Centromere** joins sister chromatids; **kinetochore** is the microtubule attachment site
- **Diploid (2n)** = two homologous sets; **haploid (n)** = one set
- **Homologs** carry the same genes at the same loci, but alleles can differ
- **Key correction:** DNA replicates in S phase — division does not double chromosomes

One replicated chromosome

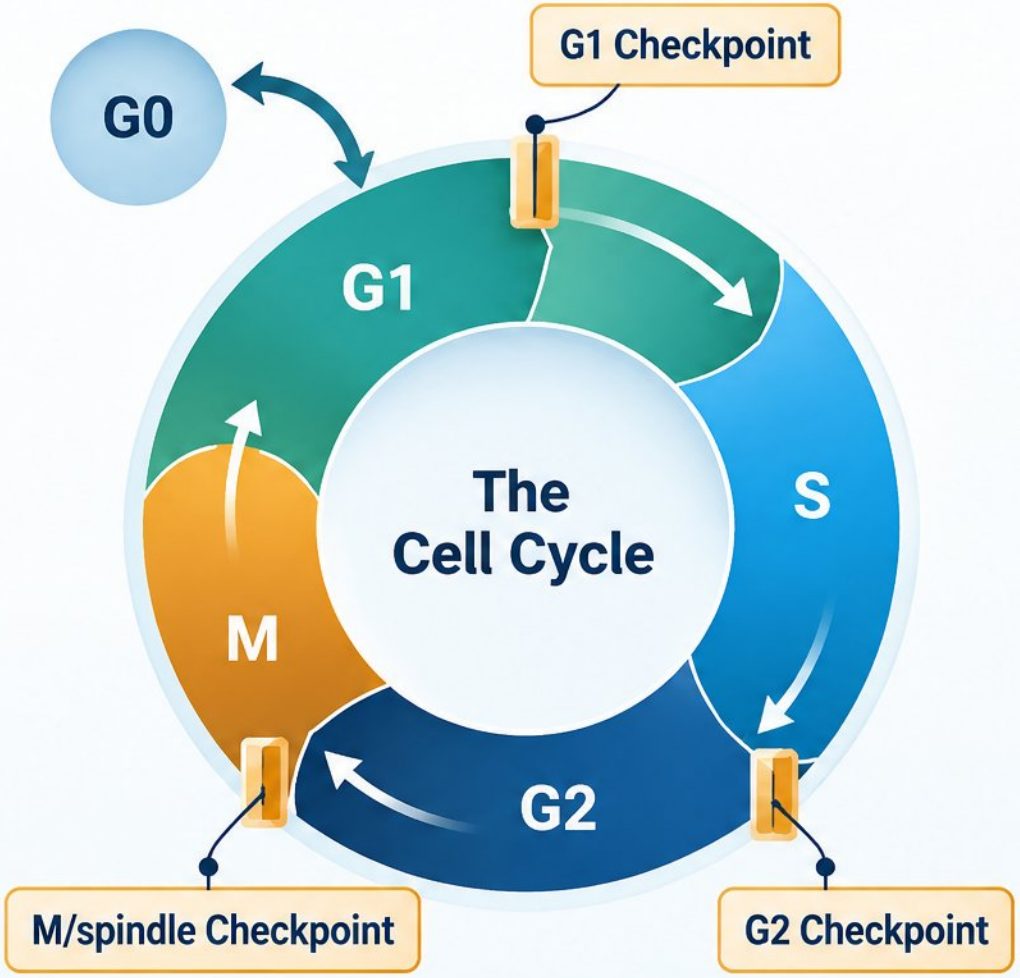


Ploidy and homologs



Homologs carry the same genes at the same loci, but alleles can differ.

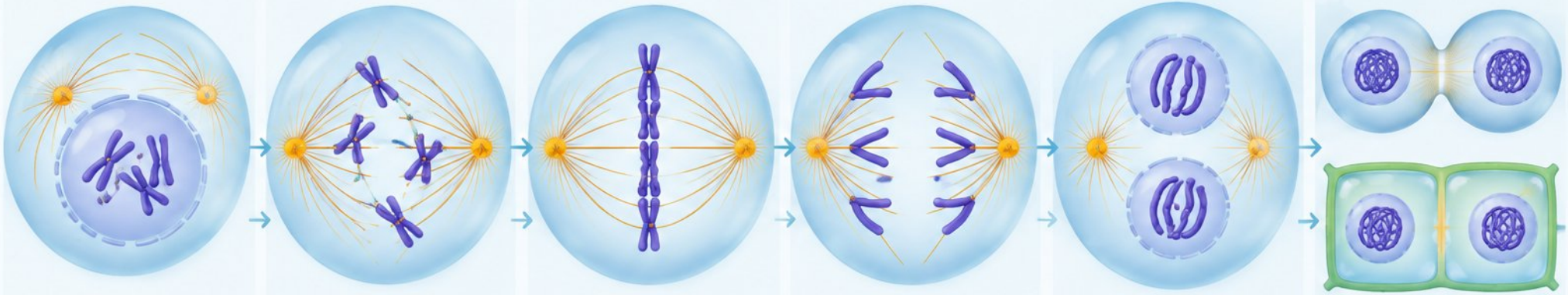
The Cell Cycle and Its Checkpoints



- **Interphase:** G1 growth, S-phase DNA replication, G2 preparation; G0 = non-dividing
- **S phase:** one chromosome becomes two sister chromatids
- **M phase:** mitosis then cytokinesis — typically 1–2 hours total
- **Three checkpoints:** G1 (size, energy, DNA damage), G2 (replication complete, undamaged), M/spindle (every kinetochore attached to both poles)
- Checkpoint failure links directly to cancer
- **Correct the myth:** interphase is not a resting phase

Interphase is an **active and highly regulated** part of the cell cycle.

Mitosis, Step by Step: Prophase to Cytokinesis



Prophase

- Prophase: chromatin condenses, centrosomes move apart, spindle forms, nuclear envelope breaks down

Prometaphase

- Prometaphase: kinetochores appear and attach to spindle microtubules; nuclear envelope fully disperses

Metaphase

- Metaphase: chromosomes align at the metaphase plate; sister chromatids attach to opposite poles

Anaphase

- Anaphase: cohesin is cleaved; sister chromatids separate and are pulled to opposite poles

Telophase

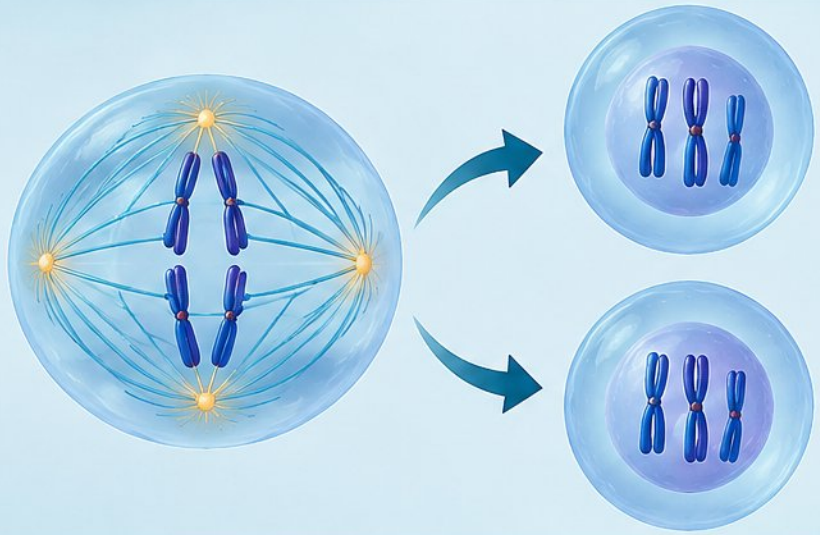
- Telophase: nuclear envelopes re-form, chromosomes decondense, spindle disassembles

Cytokinesis

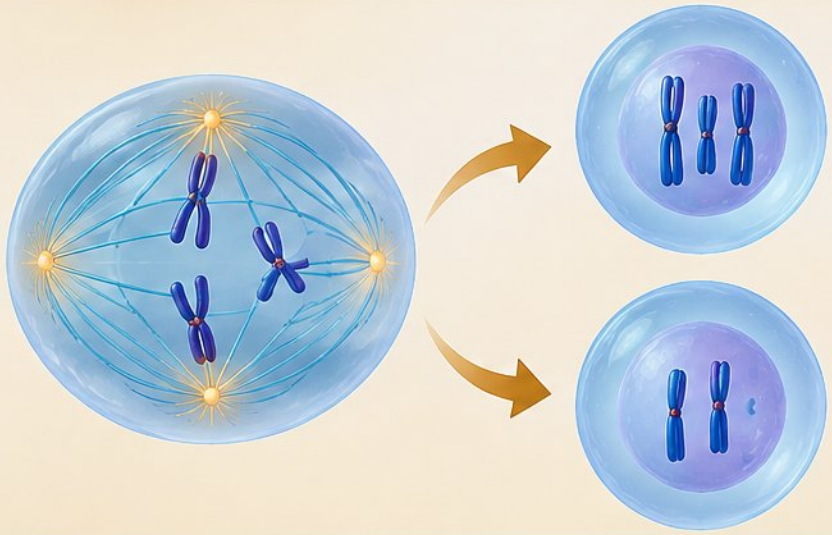
- Cytokinesis: cleavage furrow in animal cells (actin ring) versus cell plate in plant cells

Mitosis Outcomes and What Happens When It Fails

Normal Mitosis

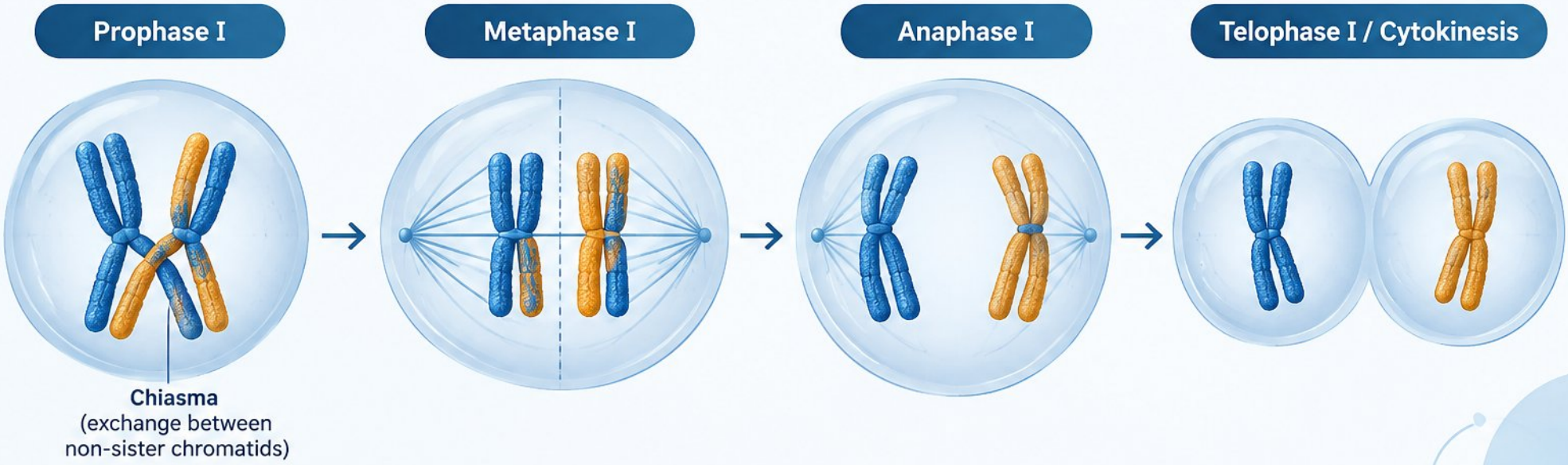


Spindle Error and Aneuploidy



- Outcome: two genetically identical daughter cells, same ploidy as parent
- Basis of growth, wound healing, and cell replacement
- Underlies asexual reproduction in many organisms
- Spindle errors → aneuploid cells; unregulated mitosis → tumorigenesis
- Fidelity matters: ~2 trillion cell divisions daily in the human body
- **Quick check:** 2n = 10 cell in anaphase — how many chromatids separate? (20)

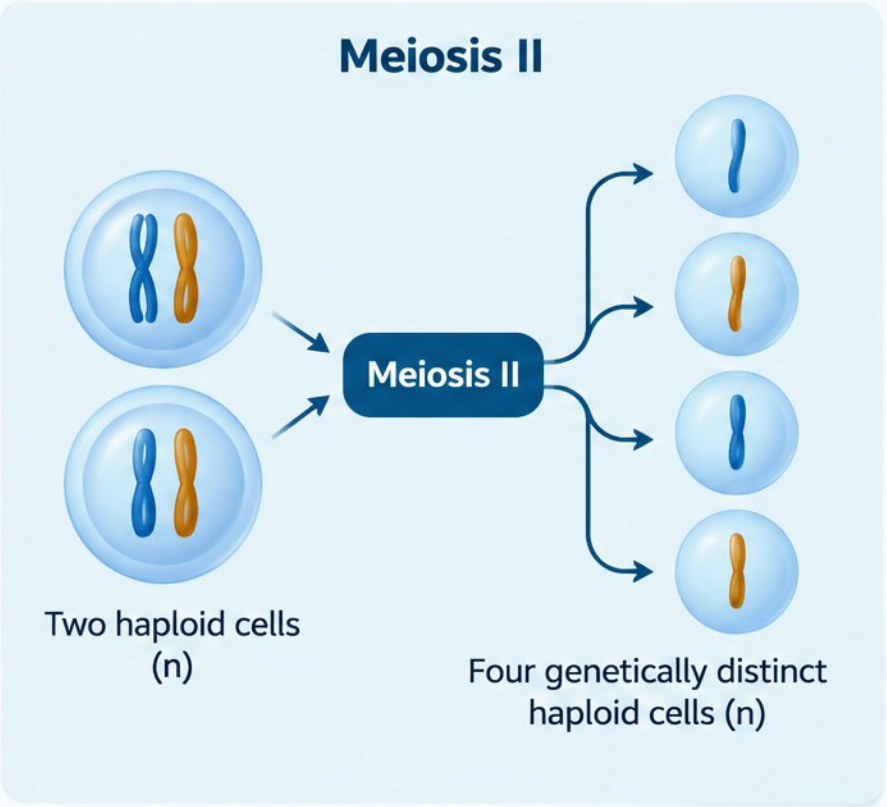
Meiosis I: Pairing, Crossing Over, and Separation of Homologs

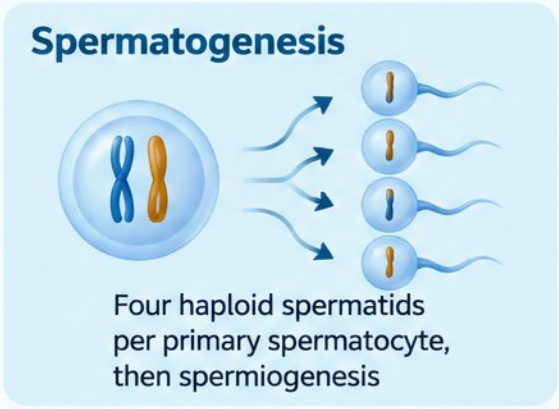


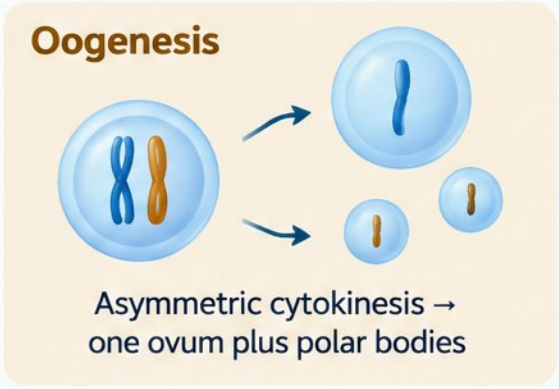
- **Prophase I:** synapsis via synaptonemal complex forms a tetrad
- Crossing over between non-sister chromatids creates chiasmata
- At least one chiasma per pair ensures correct segregation
- **Metaphase I:** homolog pairs line up in a double row
- **Anaphase I:** homologs separate; sister chromatids stay together
- **Reductional division:** 2n → n yields two haploid cells

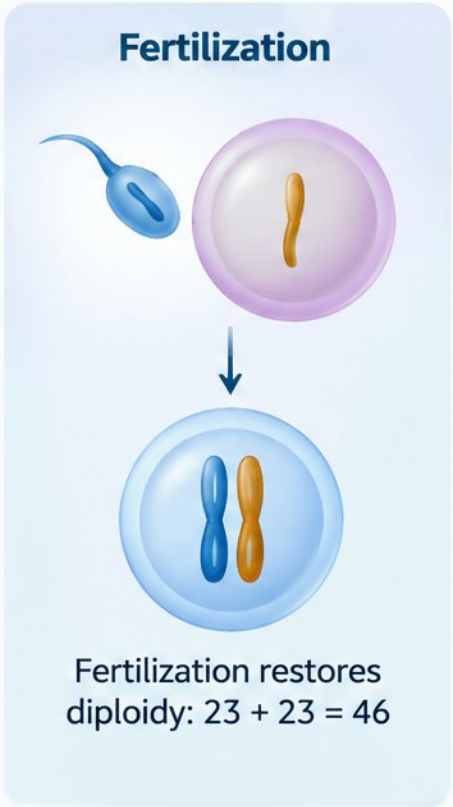
Meiosis II and Gamete Formation

- Meiosis II mirrors mitosis — but no DNA replication; brief interkinesis intervenes
- Anaphase II separates sister chromatids: four genetically distinct haploid cells
- Equational division: ploidy stays n; counterpart to reductional Meiosis I
- Spermatogenesis: four haploid spermatids per primary spermatocyte, then spermiogenesis
- Oogenesis: asymmetric cytokinesis → one ovum plus polar bodies
- Oocytes arrest at prophase I before birth, then metaphase II until fertilization
- Fertilization restores diploidy: 23 + 23 = 46







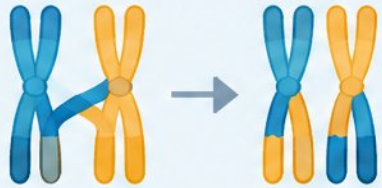


Sources of Genetic Variation

DIFFERENT PROCESSES. GREATER DIVERSITY.

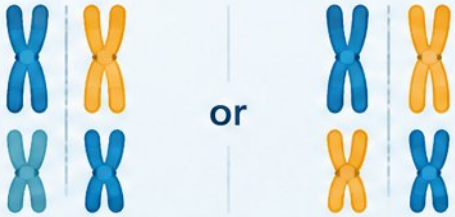


Crossing over



Crossing over in prophase I swaps segments between non-sister chromatids

Independent assortment



Independent assortment at metaphase I: random homolog orientation yields up to 2^n combinations

Random fertilization



Random fertilization multiplies these combinations further

More unique combinations

- Crossing over in prophase I swaps segments between non-sister chromatids
- Independent assortment at metaphase I: random homolog orientation yields up to 2^n combinations
- In humans, $2^{23} \approx 8.4$ million gamete combinations from assortment alone
- Random fertilization multiplies these combinations further
- Typical human chromosome pair averages 2–3 crossovers per meiosis
- Quick drill: for 2n = 8, assortment gives $2^{\wedge 4} = 16$ combinations

Nondisjunction and Human Aneuploidy

1. **Nondisjunction:**
homologs (Meiosis I) or sister chromatids (Meiosis II or mitosis) fail to separate

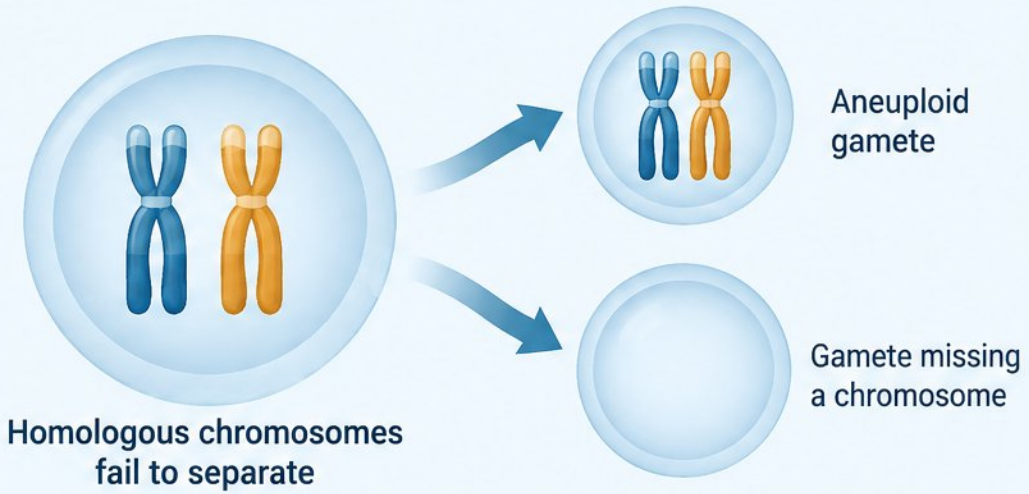
2. **Aneuploidy:**
~1 in 300 liveborn infants; trisomies 21, 13, 18; Turner 45,X; Klinefelter 47,XXY

3. **Trisomy 21:**
~95% from an extra chromosome 21, mostly maternal; about two-thirds are Meiosis I errors

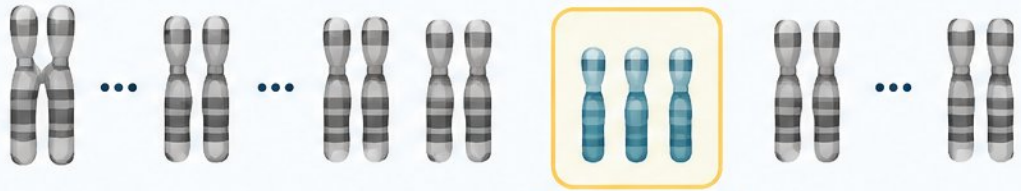
4. **Risk factors:**
altered crossover number/position and loss of sister-chromatid cohesion with maternal age

5. **Clinical link:**
karyotyping and prenatal screening detect chromosome-number changes

Nondisjunction in Meiosis I

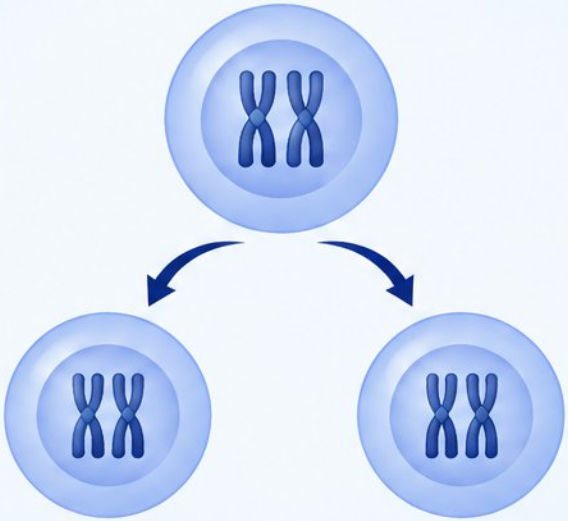


Karyotype Example: Trisomy 21



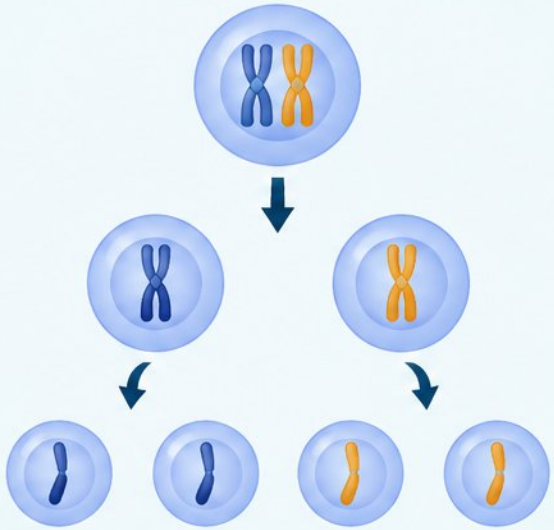
Mitosis vs. Meiosis: One Comparison Table That Settles It

Mitosis



One division, 2 identical diploid cells

Meiosis



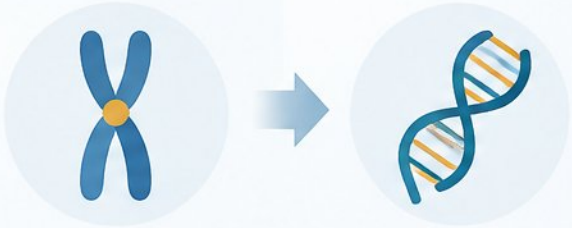
Two divisions, 4 distinct haploid cells

- **Compare:** divisions, ploidy change, daughter cells, location, life-cycle role
- **Key distinction:** Meiosis I separates homologs (reductional); Meiosis II separates chromatids (equational)
- **Only meiosis has** synapsis, chiasmata, and crossing over
- **Mitosis:** one division, 2 identical diploid cells
- **Meiosis:** two divisions, 4 distinct haploid cells
- **Self-test:** culture daughters match parent = mitosis; four half-number cells = meiosis

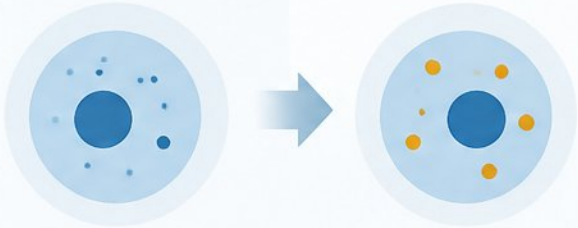
Misconceptions That Persist — and How to Correct Them

CLEARER IDEAS. STRONGER UNDERSTANDING.

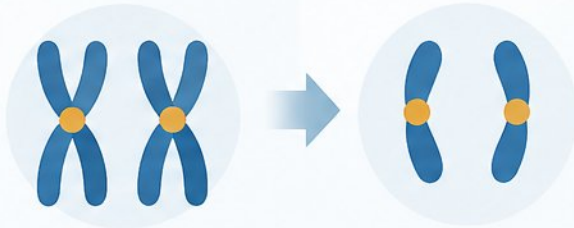
Myth	Reality
"DNA replication happens in prophase"	It occurs in S phase, before division begins



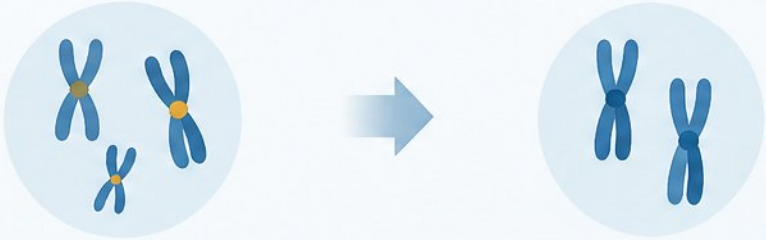
Myth	Reality
"Interphase is a resting phase"	It is metabolically the busiest stage



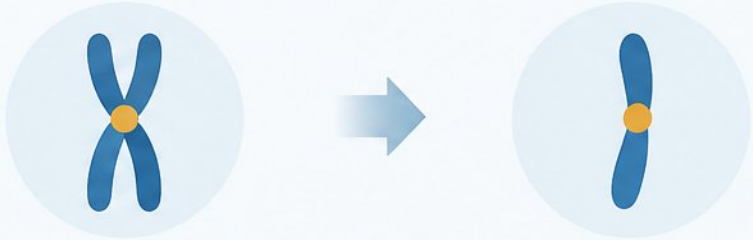
Myth	Reality
"Chromosome number doubles in prophase, halves in anaphase"	Count chromatids, not centromeres



Myth	Reality
"Ploidy halves in Meiosis II"	Reduction happens in Meiosis I

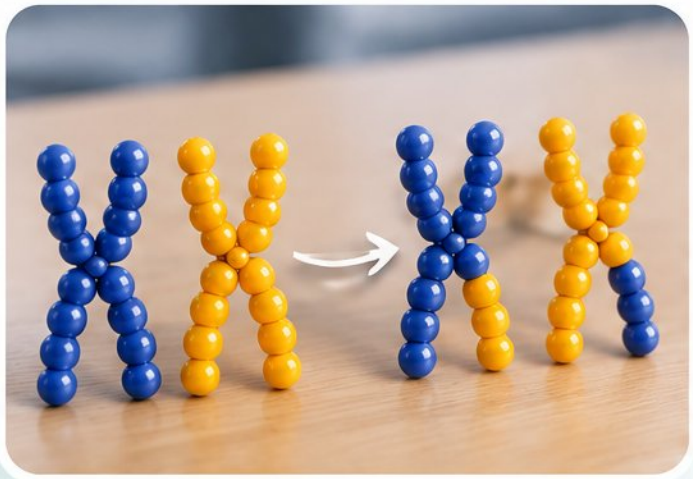


Myth	Reality
"A chromosome always has two chromatids"	After anaphase, each has one



Research: students know chromosome structure but fail to apply it to behavior

Teaching Strategies and Classroom-Ready Activities







- Model-based inquiry: bead, card, or foam chromosome kits for crossing over and counting
- Kinesthetic option: 'human mitosis' group performances embody each phase
- Microscopy lab: onion root tip squash; compare with prepared meiosis slides
- Formative menu: phase ordering, diagram labeling, calculation drills, nondisjunction predictions
- Evidence: pre/post studies show strong gains in ploidy, homology, segregation understanding
- Model-based crossing-over activities outperform nonparticipants on later genetics assessments

Teacher Tip:

Key Takeaways, Glossary, and Review Questions

Mitosis

- Recap: mitosis = 1 division, 2 identical diploid cells

Meiosis

- Recap: meiosis = 2 divisions, 4 distinct haploid gametes

Terms: chromatid, centromere, kinetochore, synapsis, chiasma, interkinesis

Formula: 2^n gamete combinations; track chromosome counts through Meiosis I–II

Review:

1. homolog separation
2. sister chromatid separation
3. crossing over
5. 2n = 24 after Meiosis I

Next: Mendelian genetics, cancer cell-cycle dysregulation, classroom or study plan

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