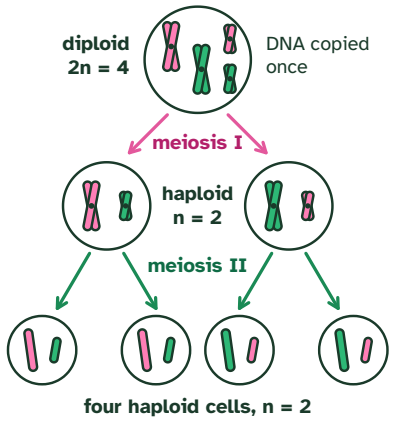
AP BIOLOGY | UNIT 5 | TOPICS 5.1 AND 5.2 | REVISION ON TWO PAGES

Meiosis halves and *shuffles*

What to know, what to draw and what to say. Nothing else.

THE ONE IDEA

Copy the DNA once, divide twice: one diploid cell gives four haploid cells, and crossing over and random assortment make each one different.



Draw it like this. Pink from one parent, green from the other. Count centromeres to count chromosomes.

5.1.A START HERE

Copy once, *divide twice*

- Before meiosis the cell copies its DNA **once**, in S phase. Each chromosome is then two **sister chromatids** joined at the centromere.
- **Meiosis I separates homologous chromosomes**: each cell gets one chromosome of every pair, so the number is halved here.
- **Meiosis II separates sister chromatids**, much as mitosis does. No DNA is copied between the two divisions.
- One diploid cell becomes **four haploid cells**, each genetically different. In animals this happens only in the cells of the ovaries and testes that make gametes.

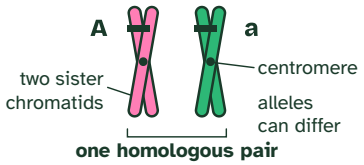
MEIOSIS I, IN ORDER — *Pairs Meet And Travel*

P Pairs: prophase I: homologs pair up	**M** Meet: metaphase I: pairs on the plate	**A** And: anaphase I: homologs separate	**T** Travel: telophase I: two haploid cells

5.1.A DIPLOID AND HAPLOID

Two sets in, *one set* out

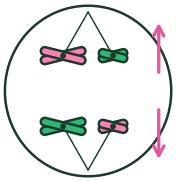
- A **diploid** cell (2n) has two sets of chromosomes, one from each parent. A **haploid** cell (n) has one set. In humans 2n = 46 and n = 23.
- The two chromosomes of a pair are **homologous**: the same length, the same genes at the same loci. Their alleles can differ.
- Gametes must be haploid so that **fertilization** gives a diploid zygote. If not, the number would double every generation.



5.1.A HOMOLOGS SEPARATE

Meiosis I: *pairs* part

- **Prophase I:** chromosomes condense and homologs pair along their length (**synapsis**); chiasmata may form. The spindle starts to form and the nuclear envelope breaks down.
- **Metaphase I:** spindle fibers line the **pairs** up on the metaphase plate.
- **Anaphase I: homologous chromosomes separate**.
- **Telophase I, cytokinesis:** two haploid cells.



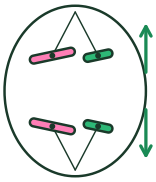
homologous chromosomes part

sister chromatids stay joined

5.1.A CHROMATIDS SEPARATE

Meiosis II: *chromatids* part

- **Prophase II:** no DNA is copied. A spindle forms in each cell and attaches at the centromeres.
- **Metaphase II:** chromosomes line up one by one, sister kinetochores held from opposite poles.
- **Anaphase II:** the proteins holding the centromere together break down and **sister chromatids separate**.
- **Telophase II, cytokinesis:** four haploid cells.



sister chromatids part

each is now a chromosome

5.1.A TRACKING THE NUMBERS

Count *centromeres*, not chromatids

- Chromosome number counts centromeres. Two joined sister chromatids are **one** chromosome; once they separate, each is a chromosome of its own.
- **Meiosis I halves the chromosome number** (2n to n). Meiosis II halves the chromatids in each chromosome.
- A cell is already haploid after meiosis I: it holds one chromosome of each pair, though each is still two chromatids.

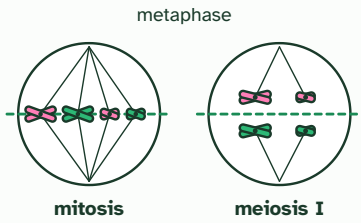
A HUMAN CELL	CELLS	CHROMOSOMES	CHROMATIDS
Before meiosis I DNA copied	1	46	92
After meiosis I	2	23	46
After meiosis II	4	23	23

Mitosis against meiosis, and where *variation* comes from

5.1.B MITOSIS AGAINST MEIOSIS

Same machinery, *different result*

	MITOSIS	MEIOSIS
Alike	DNA copied once. A spindle apparatus.	DNA copied once. A spindle apparatus.
Homologs	Do not pair.	**Pair, cross over and separate.**
Divisions	One: two cells, 2n to 2n.	Two: four cells, 2n to n.
Cells made	Identical to the parent.	Different from the parent and each other.
Role	Growth, repair, asexual reproduction.	Gametes for sexual reproduction.

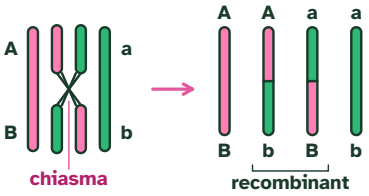


Meiosis II separates chromatids as mitosis does. Meiosis I is what sets meiosis apart.

5.2.A SHUFFLE 1: PROPHASE I

Crossing over

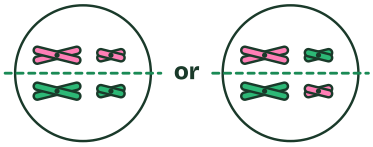
- In prophase I, **nonsister chromatids** of a homologous pair exchange matching segments at a **chiasma**: **crossing over**.
- No gene is lost or gained, but a **recombinant** chromatid carries a new combination of alleles.



5.2.A SHUFFLE 2: METAPHASE I

Random assortment

- At **metaphase I** each pair lines up **independently**, so a gamete gets one haploid set that mixes maternal and paternal chromosomes.
- With n pairs there are **2^n combinations**: 2^{23} is about 8.4 million in a human.



5.2.A SHUFFLE 3: AFTER MEIOSIS

Fertilization

- **Fertilization** fuses two haploid gametes into a diploid zygote, restoring 2n.
- Any sperm can meet any egg, so it multiplies the combinations. That is why siblings differ.
- Crossing over makes the true number far larger: each chromosome is itself a new mix.

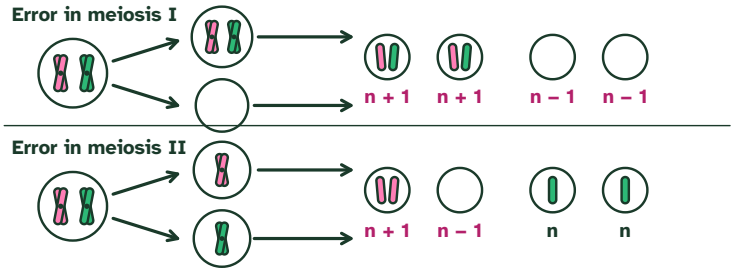
$2^{23} \times 2^{23}$
over 70 trillion possible zygotes from one couple, from assortment alone

The three shuffles: *Cats Avoid Fleas*

5.2.A INCORRECT SEPARATION

Nondisjunction: when a pair does not part

- **Nondisjunction**: homologous chromosomes (meiosis I) or sister chromatids (meiosis II) fail to separate, and both go to the same pole.
- The gametes are no longer haploid: one chromosome too many (**n + 1**) or one too few (**n – 1**).
- After fertilization by a normal gamete, the zygote has 2n + 1 or 2n – 1, copied into every cell by mitosis.



WATCH OUT

Five mistakes that *cost points*

- ✕ **Homologs are not identical.** Same genes, perhaps different alleles. Sister chromatids are the identical copies.
- ✕ **DNA is copied once, not twice.** Only before meiosis I.
- ✕ **The number halves in meiosis I, not II.** Count centromeres.
- ✕ **Crossing over is between nonsister chromatids of one pair.** Never sisters, never different pairs.
- ✕ **Meiosis makes no new alleles.** Mutation does. Meiosis makes new combinations of them.

COVER THE SHEET

Can you *answer these?*

1. Explain why gametes must be haploid.
2. Describe what separates in each division.
3. Calculate the chromatids at metaphase II if 2n = 8.
4. Identify two ways mitosis and meiosis are alike.
5. Explain how a recombinant chromatid forms.
6. Calculate the gamete combinations if 2n = 6.
7. Explain why siblings with the same parents differ.
8. Predict the zygote from an n + 1 gamete.

IN THE EXAM

Say what separates, and when: homologous chromosomes in anaphase I, sister chromatids in anaphase II. "The chromosomes split" earns nothing. In a count, give chromosomes and chromatids separately.

GO FURTHER

Animated figures, a dry lab and a marked Check are in the full guide online.