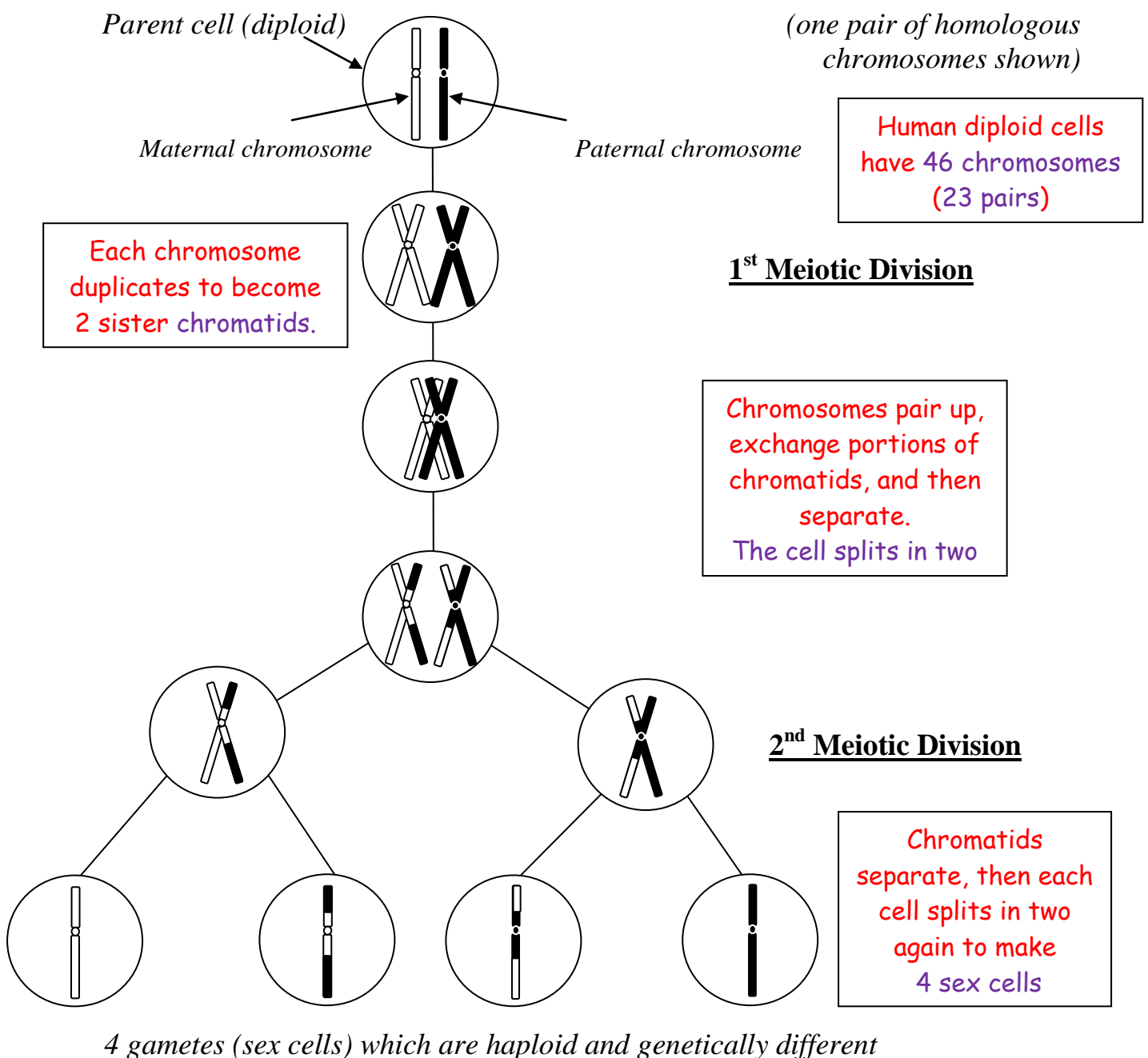# Meiosis (Outline)

1. Meiosis involves **two divisions** of the cell & nucleus

2. **Homologous chromosomes pair up** during 1st division and swap portions of chromatids (**crossing-over**)

3. **Homologous chromosomes separate** during the 1st division.

4. **Chromatids separate** during the 2nd division.

5. One diploid parent cell forms **four haploid gametes** (sex cells)

Parent cell (diploid)

(one pair of homologous chromosomes shown)

Maternal chromosome   *Paternal chromosome*

Human diploid cells have 46 chromosomes (23 pairs)

Each chromosome duplicates to become 2 sister chromatids.

1st Meiotic Division

Chromosomes pair up, exchange portions of chromatids, and then separate.
The cell splits in two

2nd Meiotic Division

Chromatids separate, then each cell splits in two again to make 4 sex cells

4 gametes (sex cells) which are haploid and genetically different

Meiosis (Key Facts)

Homologous chromosomes:

Pairs of chromosomes are called homologous chromosomes.
Homologous chromosomes are the same size & shape and carry the same genes.
Note that they may carry different versions of the genes (called alleles).

Where meiosis goes on:

Testes & ovaries of animals
Anthers & ovules of flowering plants

Diploid v. haploid

Diploid cells (2n) carry two copies of each chromosome (homologous pairs).
Haploid cells (n) carry one copy of each chromosome.
Human diploid cells have 46 chromosomes; haploid cells (gametes) have 23

Key features showing a cell is undergoing Meiosis
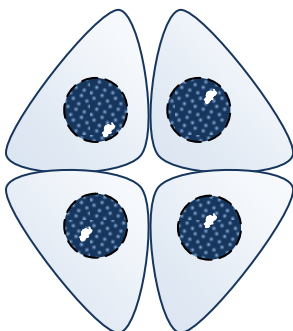
1st Meiotic Division
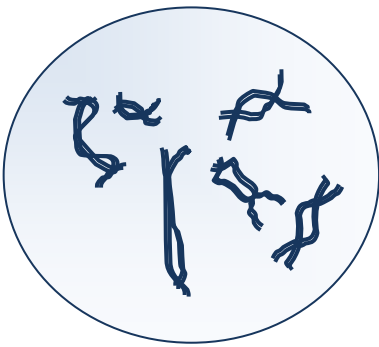
Homologous chromosomes pair up to form bivalents.

Homologous chromosomes swap portions of chromatid (cross-over) at exchange points called chiasmata.
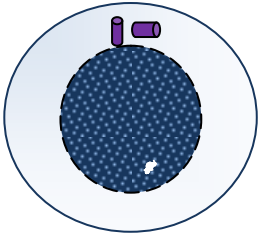
Homologous chromosomes separate during Anaphase I

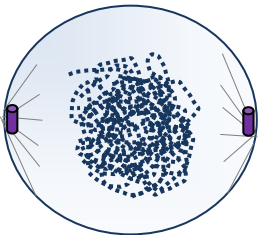2nd Meiotic Division

4 cells produced at the end of Telophase II (haploid gametes)

# Meiosis: 1st Division

Interphase

- DNA is replicated
- Each chromosome duplicates to become 2 sister chromatids, but they are loosely coiled, so not visible yet.
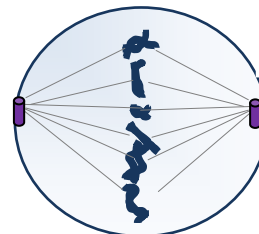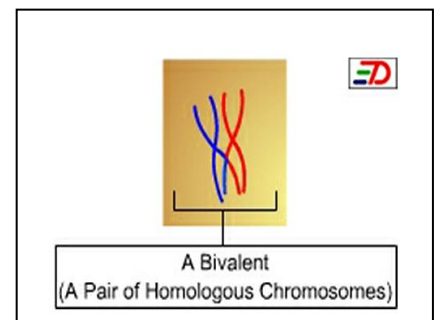
Prophase I

- Nuclear envelope disintegrates.
- Chromosome start to become visible because they coil, shorten & thicken (condense).
- Centrioles (in animal cells) begin to make spindle fibers to move the chromosomes around.
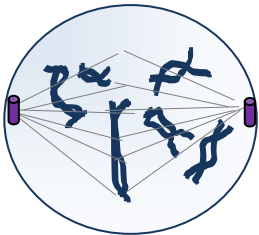
- Homologous chromosomes pair (synapsis) up to form bivalents. Bivalents are sometimes referred to as tetrads!
- They swap portions of chromatid at crossing-over points called chiasmata.
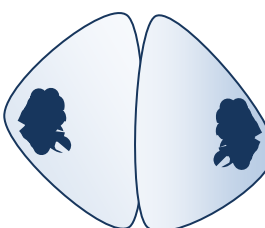
A Bivalent
(A Pair of Homologous Chromosomes)

Metaphase I

- Bivalents move to the centre of the cell along protein tubules called spindle fibres.
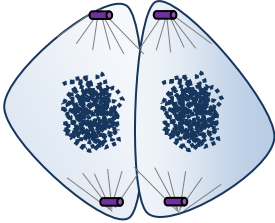- They line up on the equator of the spindle fibres.
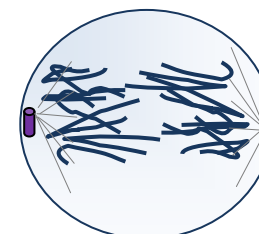
Anaphase I

- Spindle fibres contract and pull the chromosome pairs apart.
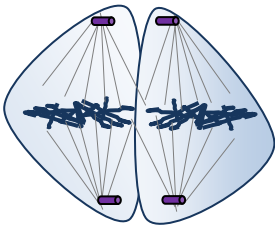
Telophase I

- Chromosomes arrive at the poles of the cell
- The cell divides into two
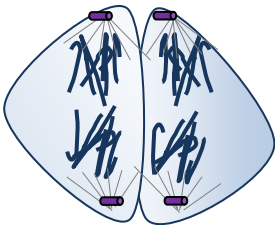
Meiosis: 2nd Division

Prophase II

- Chromosomes relax, then condense again
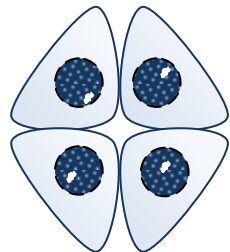- A second set of spindle fibers forms at right angles to the spindle fibers in the first division.

Metaphase II

- Chromosomes line up on equator of the spindle fibres.
- Note spindle fibres form at right angles to 1st division

Anaphase II

- Spindle fibres contract, centromeres split, & chromatids are pulled apart
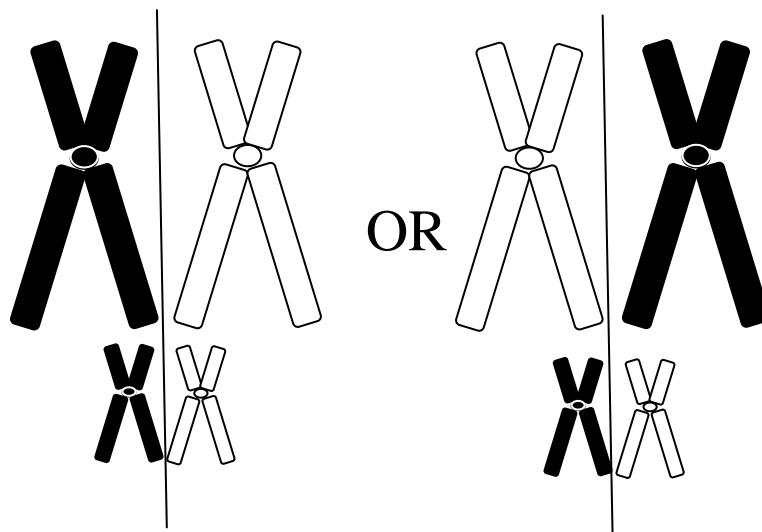- Once pulled apart they are called chromosomes

Telophase II

- Chromosomes arrive at the poles of each cell
- Each cell divides into two
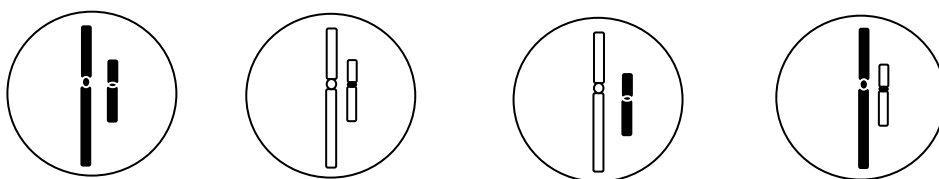- Four sex cells (gametes) are made

Meiosis & Genetic Variation

Independent assortment of chromosomes
(Metaphase I)

2 pairs of homologous chromosomes can arrange themselves in 2 ways
across the spindle equator during metaphase I:

OR

This produces 4 possible different combinations ("assortments")
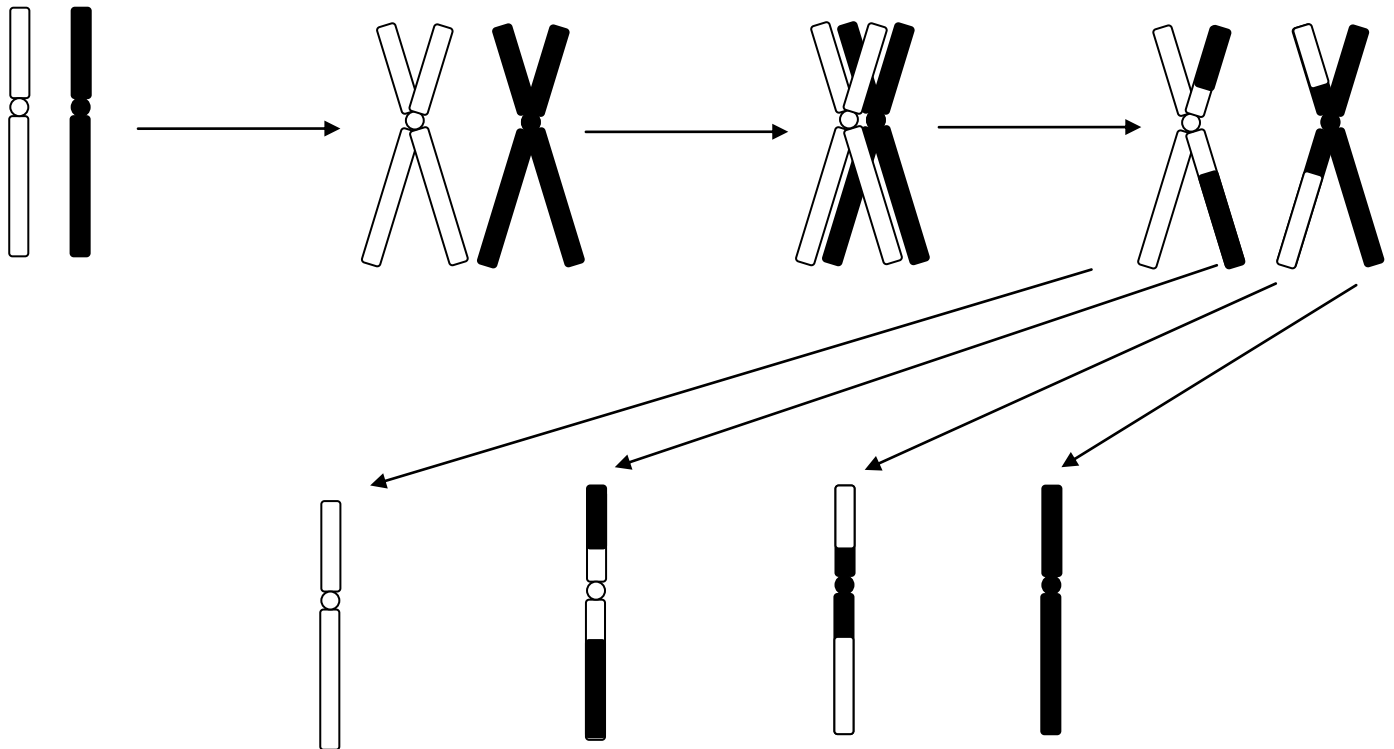of these chromosomes in the gametes:

Time & Chance Govern All
(Ecclesiastes IX ii)

- How the chromosomes arrange themselves (above or below the equator of the spindle fibres) is a random event.
- 2 pairs of homologous chromosomes can arrange themselves in 2^2 ways (giving 4 possible different chromosome combinations in the gametes).
- 23 pairs of homologous chromosomes can arrange themselves in 23^2 ways (giving 8.4 million possible different chromosome combinations in the gametes).

Meiosis & Genetic Variation

Crossing-over
(Prophase I)

- One crossing over event between one set of chromatids in one bivalent will produce four chromosomes which carry different sets of alleles!

- Given that multiple crossing-over can occur between any chromatids in any bivalent, and add in independent assortment, meiosis can gametes with produce gametes with billions of different genetic combinations!

We're all mixed up kids!

- How the chromosomes arrange themselves (above or below the equator of the spindle fibres) is a random event.
- 2 pairs of homologous chromosomes can arrange themselves in 2^2 ways (giving 4 possible different chromosome combinations in the gametes).
- 23 pairs of homologous chromosomes can arrange themselves in 23^2 ways (giving 8.3 million possible different chromosome combinations in the gametes).

Meiosis & Genetic Variation

Production of haploid gametes
(Telophase II)
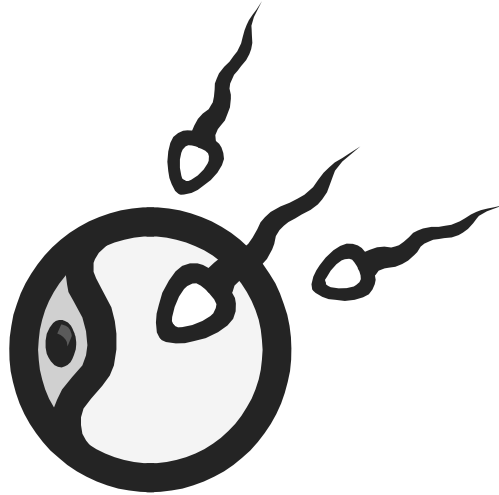
You're one in a zillion!

- The gametes produced by meiosis are haploid and must combine with the gametes of another individual to restore diploid number.

- Given that meiosis is a random event (a man's ejaculate on average contains 350 million different sperm!) then you will appreciate why meiosis leads to tremendous genetic variation!