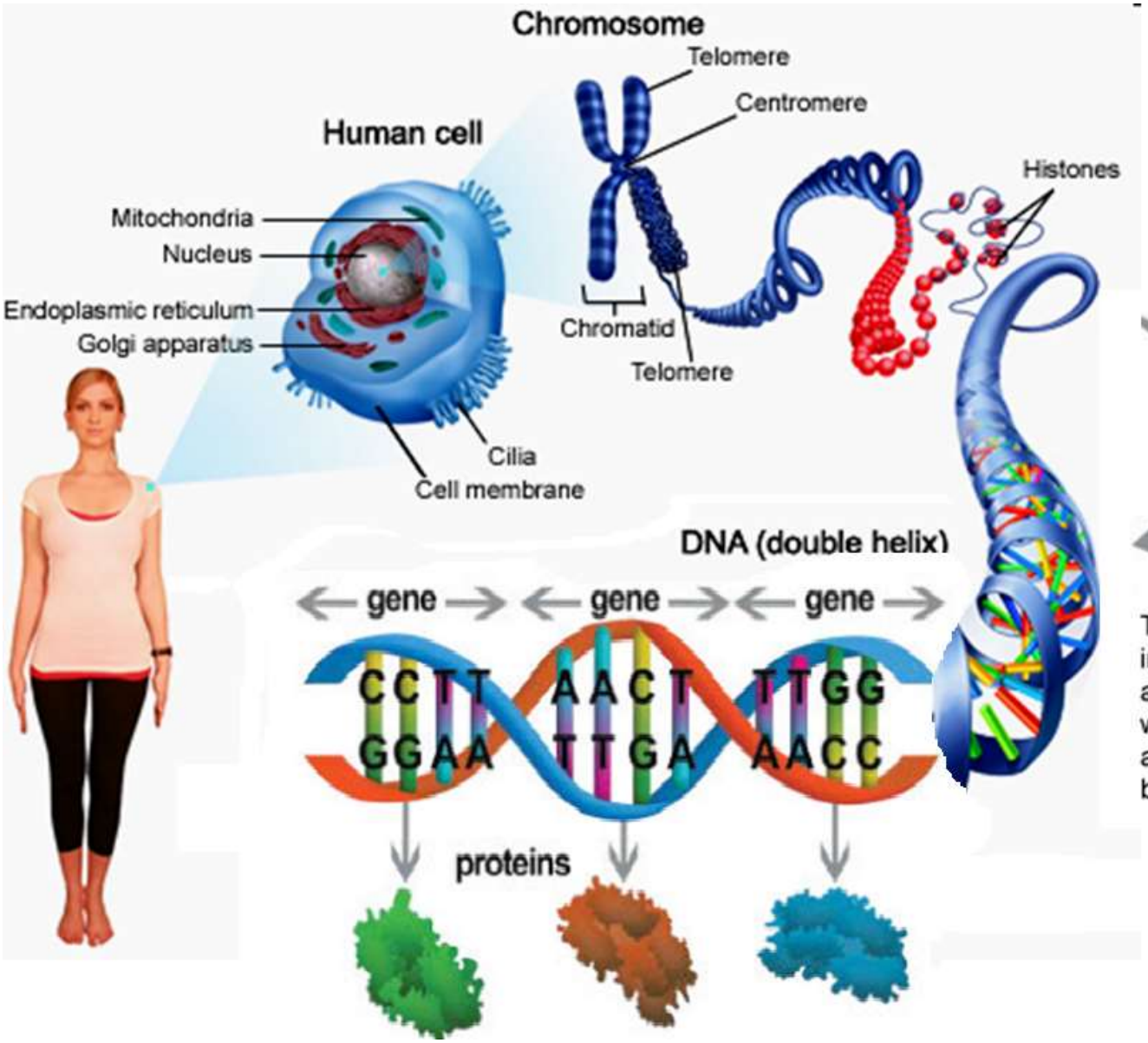
Meiosis and genetic variation



Each chromosome is made up of many genes, with about 20,000 genes in the whole genome

These genes provide the information or blueprint to make all the proteins in the body, which promote development and growth, and carry out all body functions.

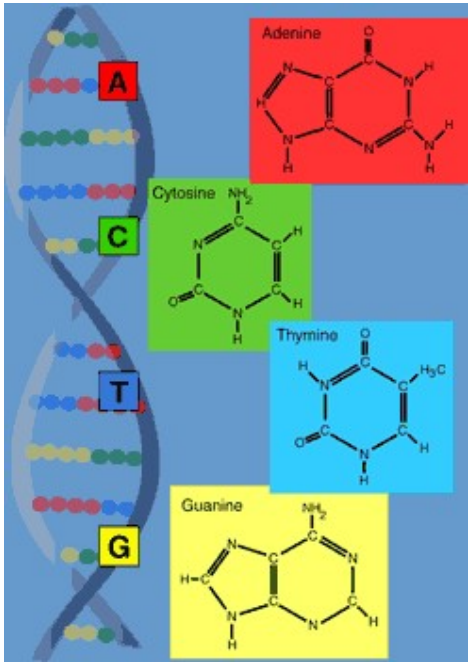
Meiosis and genetic variation

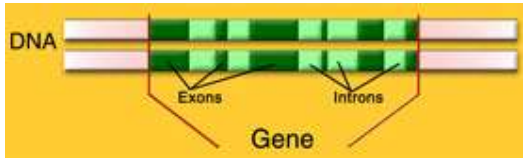
Genome: Complete sequence of an organism's DNA.

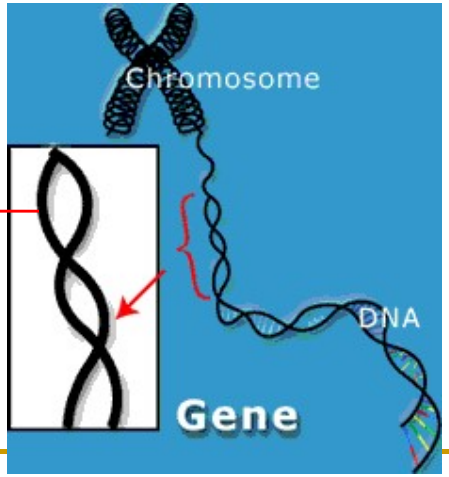
Includes **genes** (control traits) and non-coding DNA organized in **chromosomes**.

Genes

- Eukaryotic DNA is organized in chromosomes.
  - DNA sequence that produces a particular proteins
  - Genes have specific places on chromosomes.





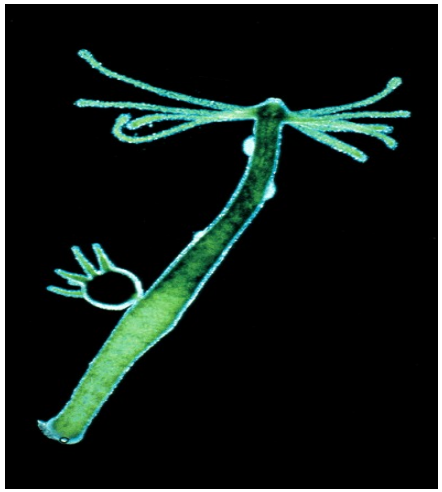


Heredity

- Heredity – **way of transferring genetic information to offspring**
- Chromosome theory of heredity: **chromosomes carry genes.**
- Gene – **"unit of heredity".**

Reproduction

- Asexual
  - Many single-celled organisms reproduce by splitting, budding, parthenogenesis.
  - Some multicellular organisms can reproduce asexually, produce **clones** (*offspring genetically identical to parent*).



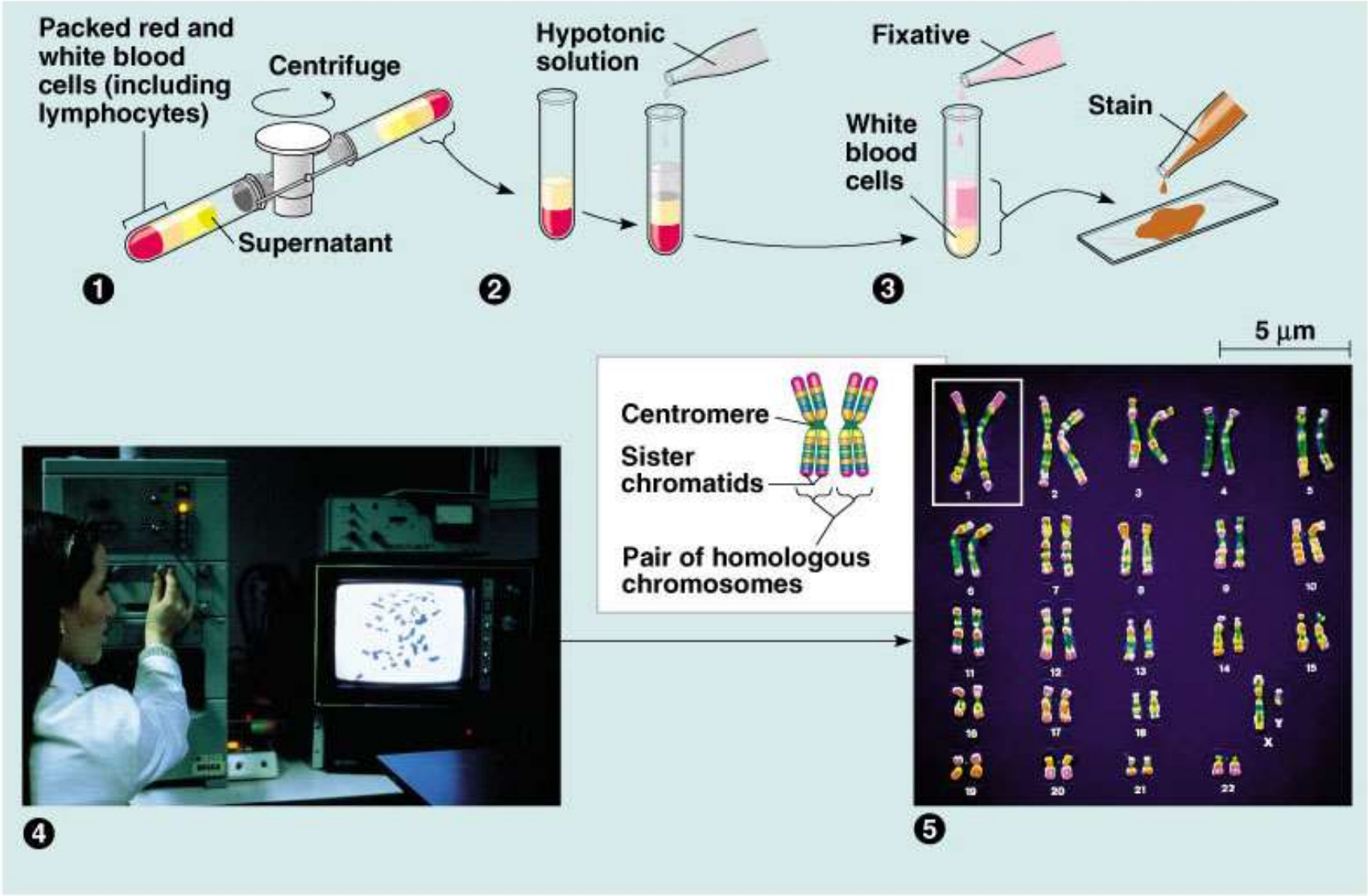
Sexual reproduction

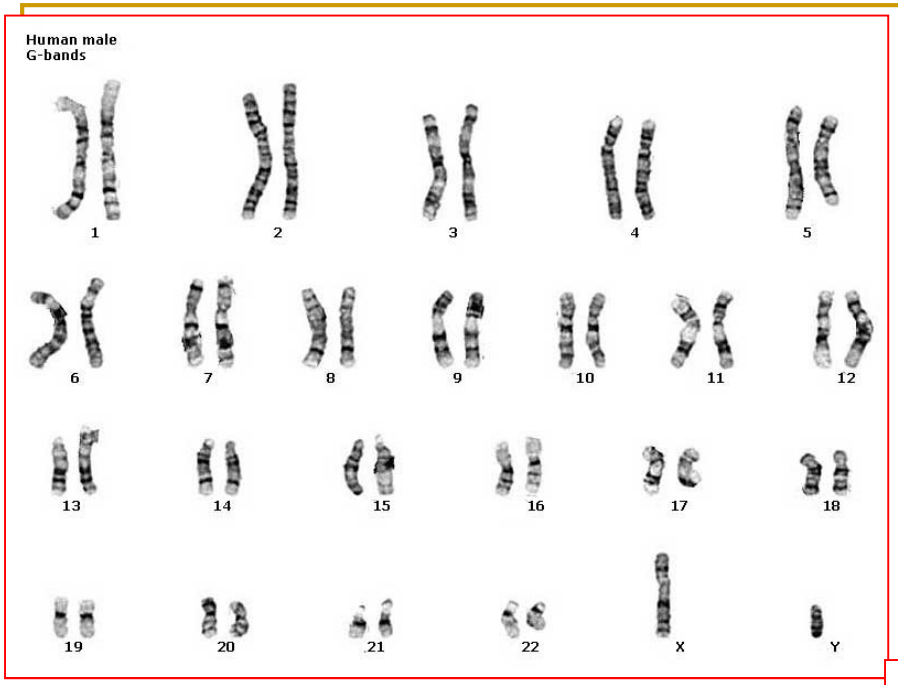
- Fusion of two gametes to produce a single zygote.
- Introduces greater genetic variation, allows genetic recombination.
- With exception of self-fertilizing organisms (e.g. some plants), zygote has gametes from two different parents.

Chromosomes

- Karyotype:
  - ordered display of an individual's chromosomes.
  - Collection of chromosomes from mitotic cells.
  - Staining can reveal visible band patterns, gross anomalies.

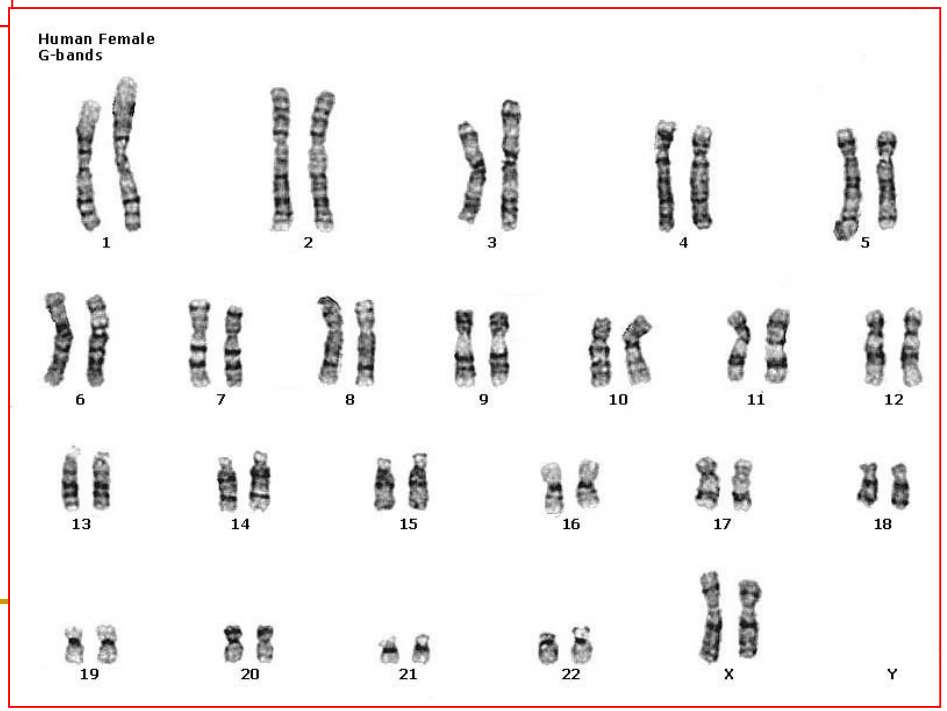
Karyotyping




Human male
G-bands
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
X
Y

Male

Female


Human Female
G-bands
1
2
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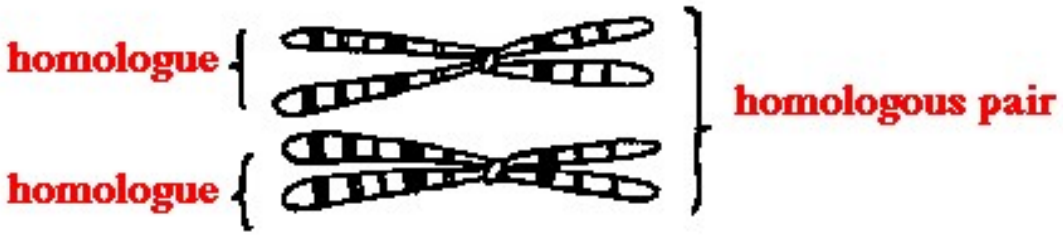
19
20
21
22
X
Y

Homologues

- Chromosomes exist in homologous pairs in diploid cells.



Exception: **Sex chromosomes** (X, Y).

Other chromosomes are known as **autosomes**, they have homologues.

In humans …

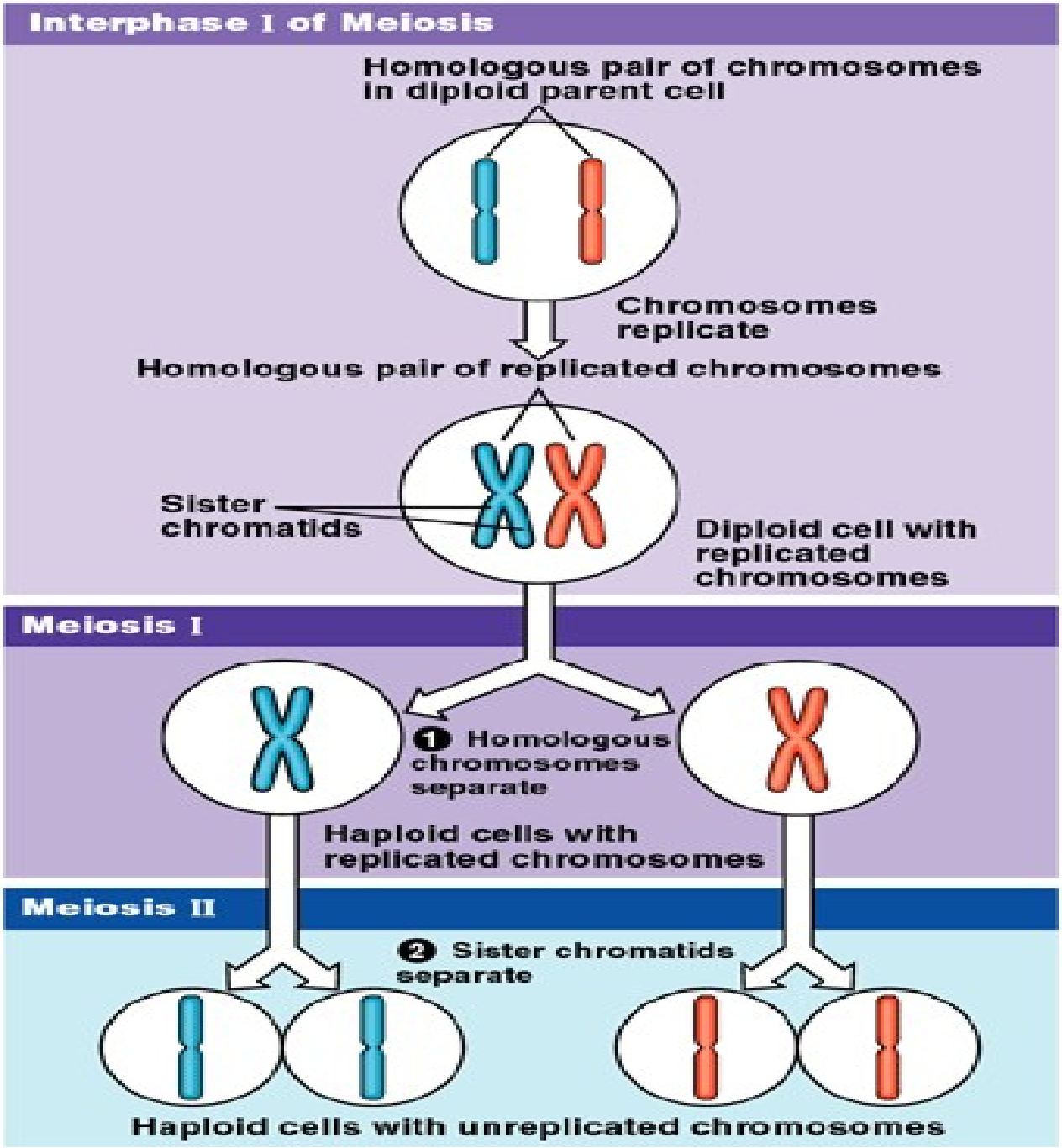
- 23 chromosomes donated by each parent (total = 46 or 23 pairs).
- Gametes (sperm/ova):
  - Contain 22 autosomes and 1 sex chromosome.
  - Are haploid (haploid number *"n" = 23 in humans*).
- Fertilization/syngamy results in zygote with 2 haploid sets of chromosomes - now **diploid**.
  - Diploid cell; *2n = 46.* (*n=23 in humans*)
- Most cells in the body produced by **mitosis**.
- *Only gametes are produced by **meiosis.***

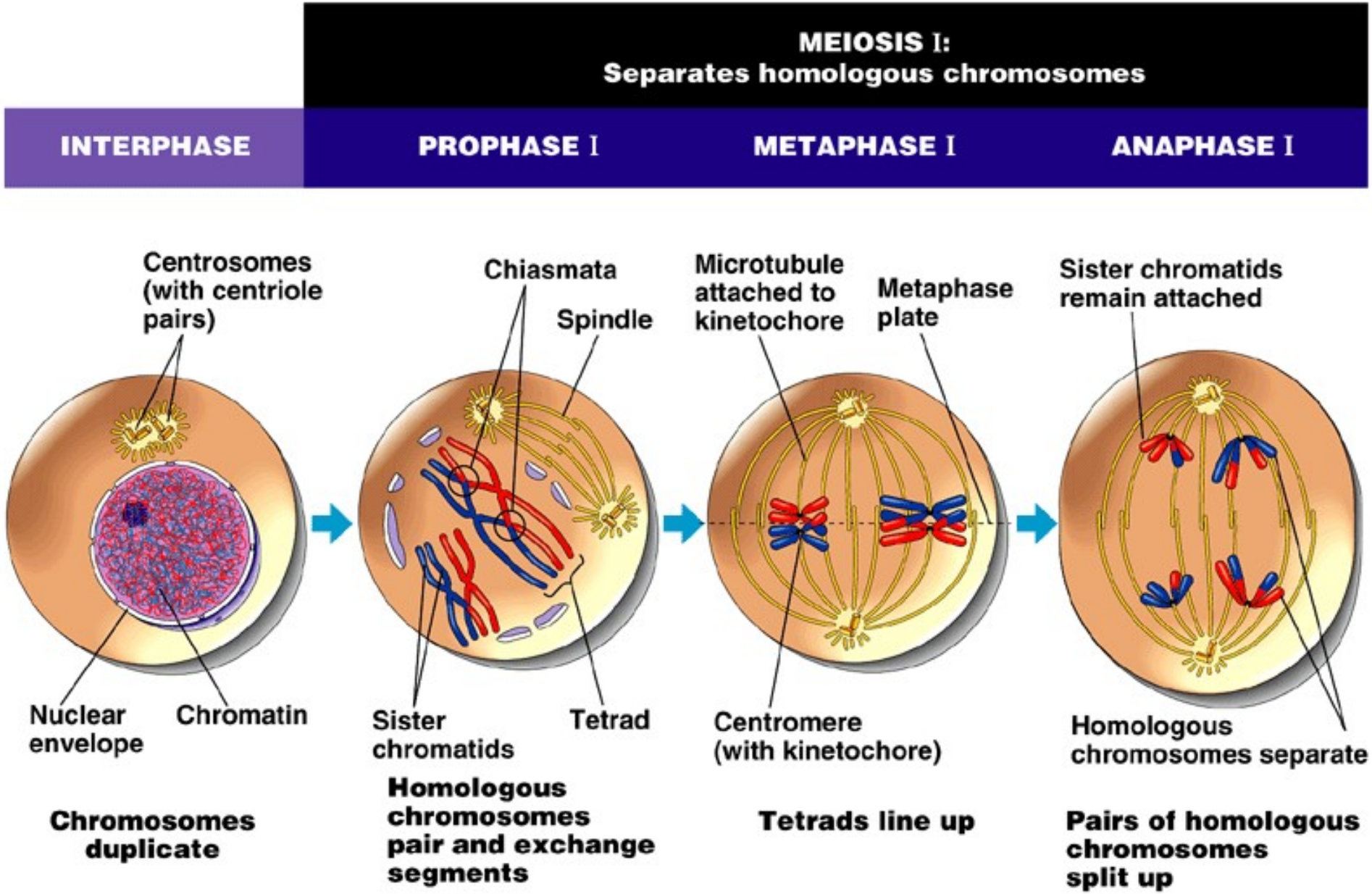
Chromosome numbers

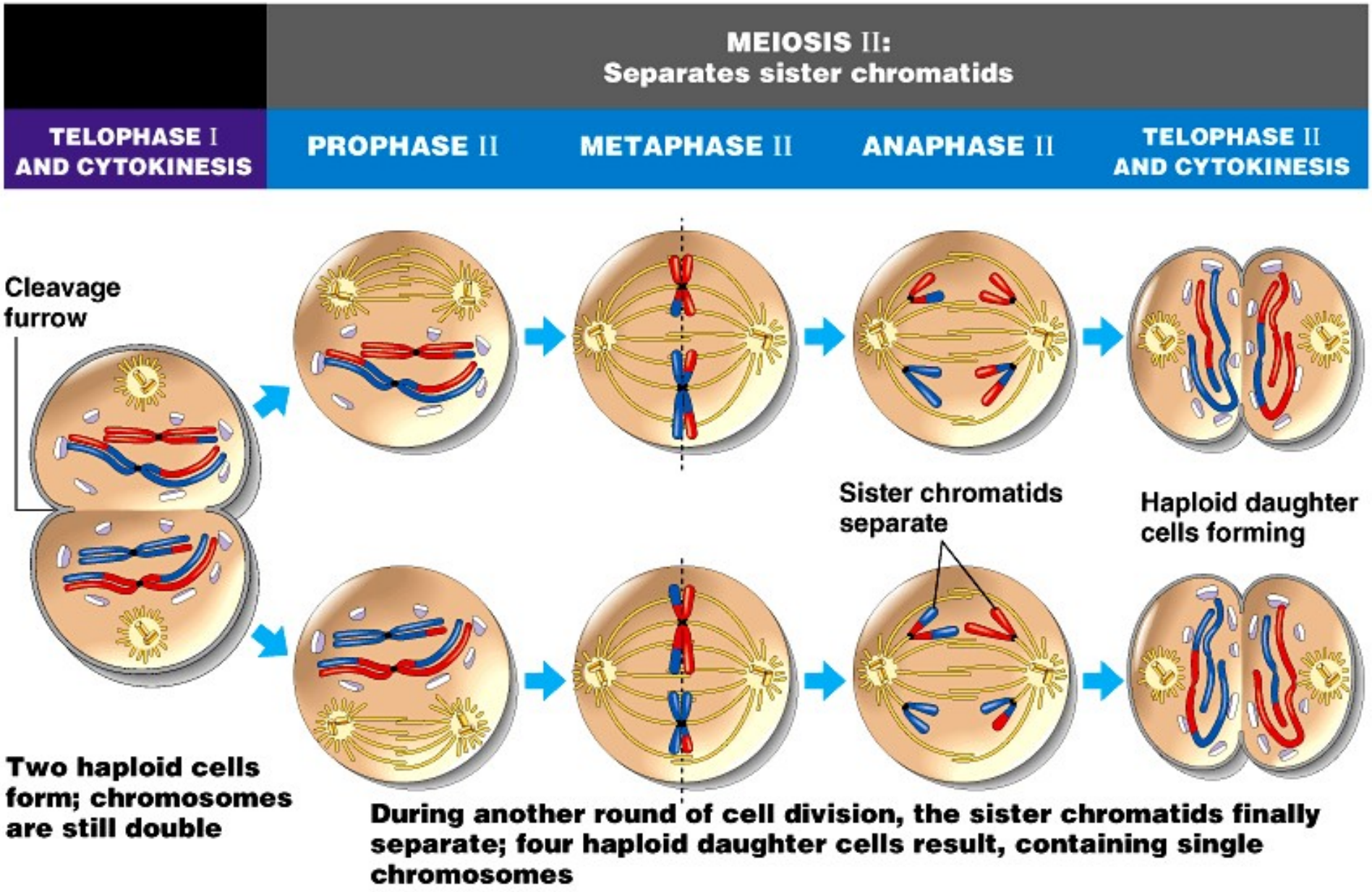
Organism	Number of chromosomes
pea plant	14
sun flower	34
cat	38
puffer fish	42
human	46
dog	78

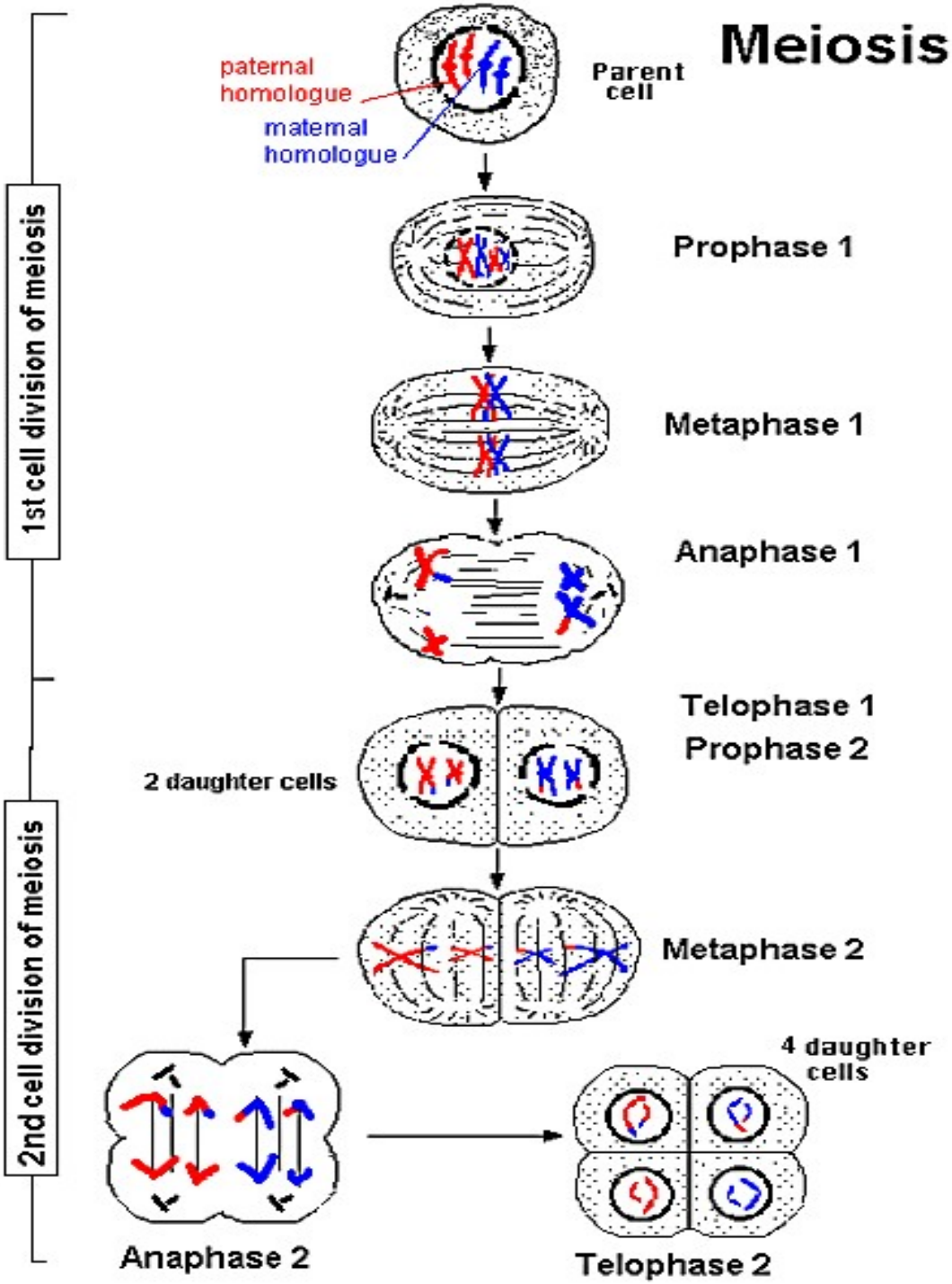
All are **even** numbers – diploid (2n) sets of homologous chromosomes!

Ploidy = number of copies of each chromosome.








Meiosis
paternal homologue
maternal homologue
Parent cell
Prophase 1
Metaphase 1
Anaphase 1
Telophase 1
Prophase 2
2 daughter cells
Metaphase 2
4 daughter cells
Anaphase 2
Telophase 2
1st cell division of meiosis
2nd cell division of meiosis

Meiosis 1

First division of meiosis

- **Prophase 1:** Each chromosome dupicates and remains closely associated. These are called sister chromatids. Crossing-over can occur during the latter part of this stage.
- **Metaphase 1**: Homologous chromosomes align at the equatorial plate.
- **Anaphase 1**: Homologous pairs separate with sister chromatids remaining together.
- **Telophase 1**: Two daughter cells are formed with each daughter containing only one chromosome of the homologous pair.

Meiosis II

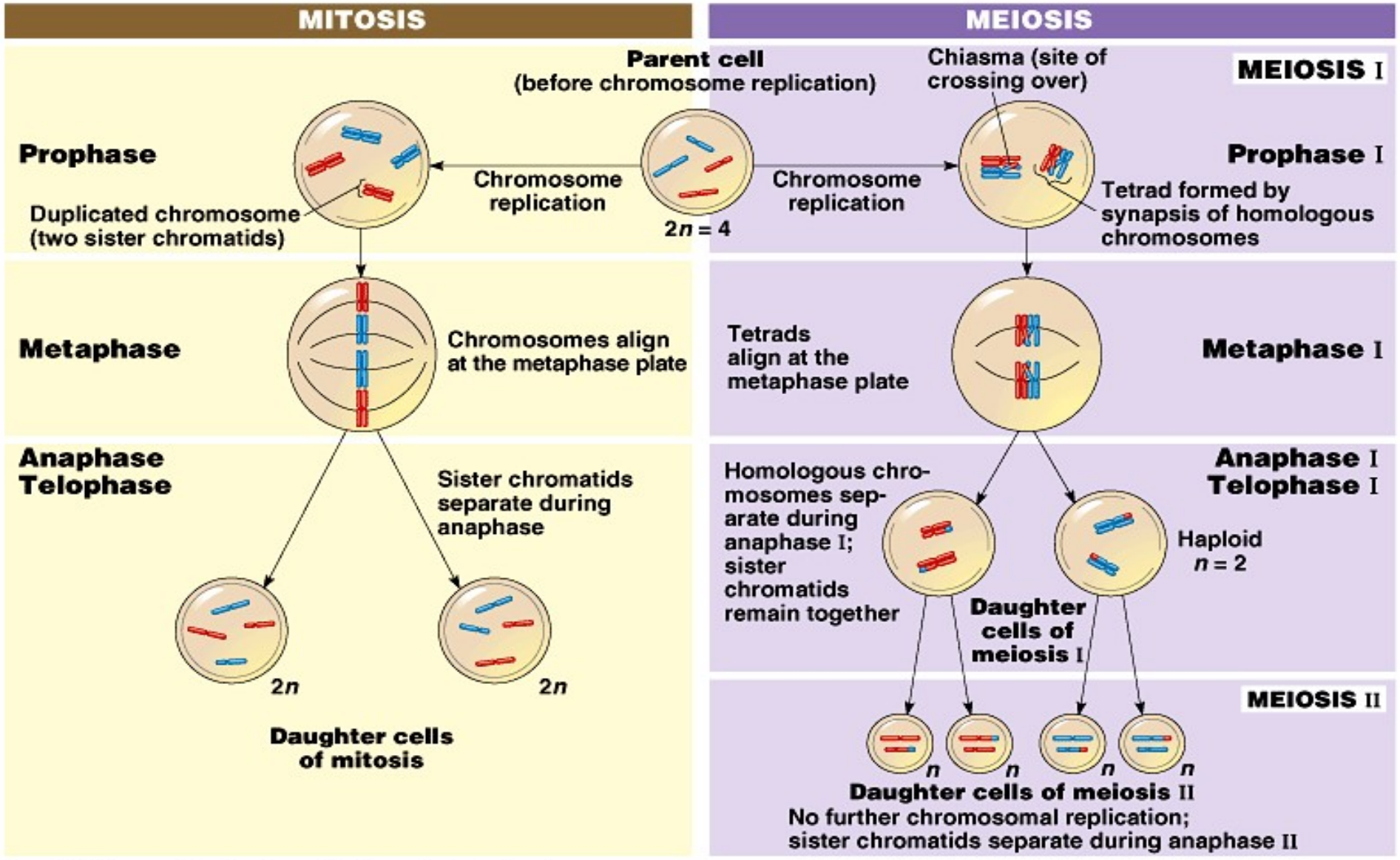
Second division of meiosis: Gamete formation

- **Prophase 2**: DNA does not replicate.
- **Metaphase 2**: Chromosomes align at the equatorial plate.
- **Anaphase 2**: Centromeres divide and sister chromatids migrate separately to each pole.
- **Telophase 2**: Cell division is complete. Four haploid daughter cells are obtained.

Meiosis – key differences from mitosis

- Meiosis **reduces the number of chromosomes by half**.
- **Daughter cells differ from parent**, and each other.
- Meiosis involves **two divisions**, Mitosis only one.
- Meiosis I involves:
  - **Synapsis** – homologous chromosomes pair up. **Chiasmata** form (*crossing over* of non-sister chromatids).
  - In Metaphase I, **homologous pairs line up** at metaphase plate.
  - In Anaphase I, *sister chromatids do NOT separate.*
  - Overall, **separation of homologous pairs of chromosomes**, rather than sister chromatids of individual chromosome.

Mitosis vs. meiosis



SUMMARY

Event	Mitosis	Meiosis
DNA replication	Occurs during interphase before nuclear division begins	Occurs once, during the interphase before meiosis I begins
Number of divisions	One, including prophase, metaphase, anaphase, and telophase	Two, each including prophase, metaphase, anaphase, and telophase
Synapsis of homologous chromosomes	Does not occur	Synapsis is unique to meiosis: During prophase I, the homologous chromosomes join along their length, forming tetrads (groups of four chromatids); synapsis is associated with crossing over between nonsister chromatids
Number of daughter cells and genetic composition	Two, each diploid ($2n$) and genetically identical to the parent cell	Four, each haploid (n), containing half as many chromosomes as the parent cell; genetically nonidentical to the parent cell and to each other
Role in the animal body	Enables multicellular adult to arise from zygote; produces cells for growth and tissue repair	Produces gametes; reduces chromosome number by half and introduces genetic variability among the gametes

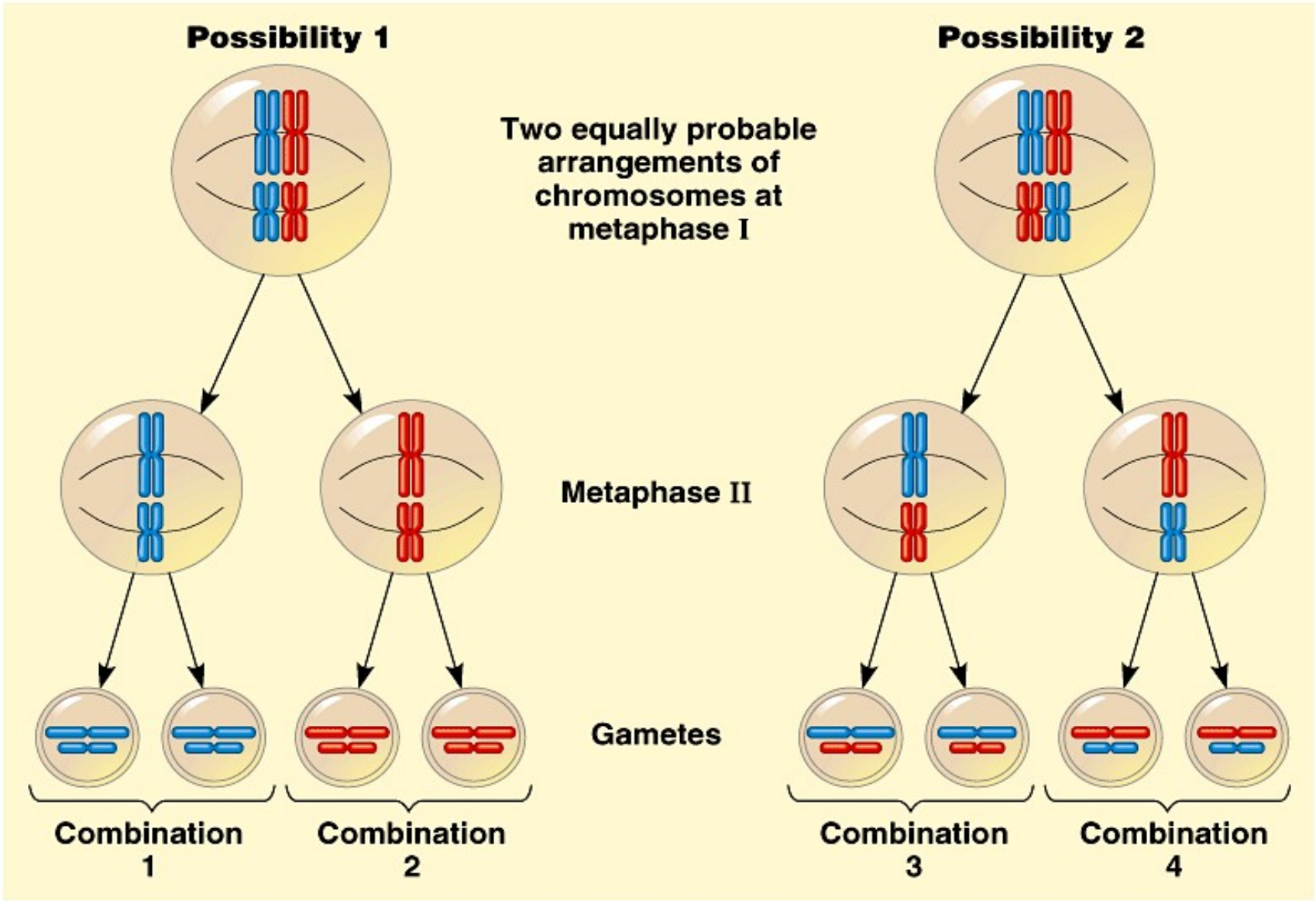
Meiosis creates genetic variation

- During normal cell growth, ***mitosis*** **produces daughter cells identical to parent cell** (2n to 2n)
- *Meiosis* results in **genetic variation** by **shuffling** of maternal and paternal chromosomes and **crossing over**.

  No daughter cells formed during meiosis are genetically identical to either mother or father

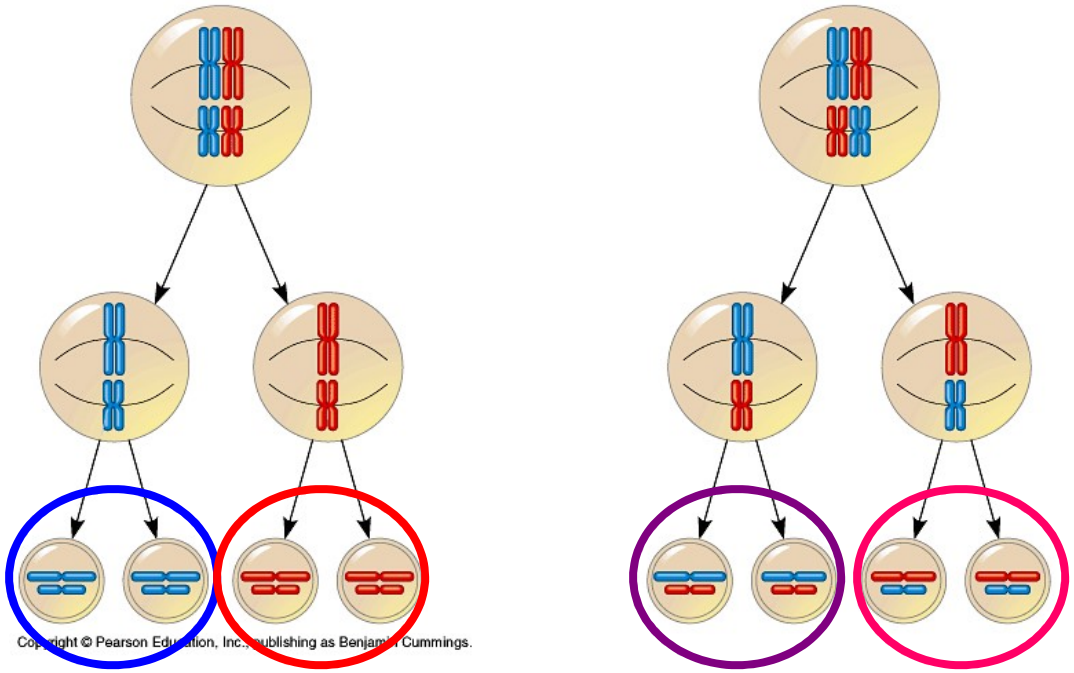
  During sexual reproduction, fusion of the unique haploid gametes produces truly unique offspring.

Independent assortment



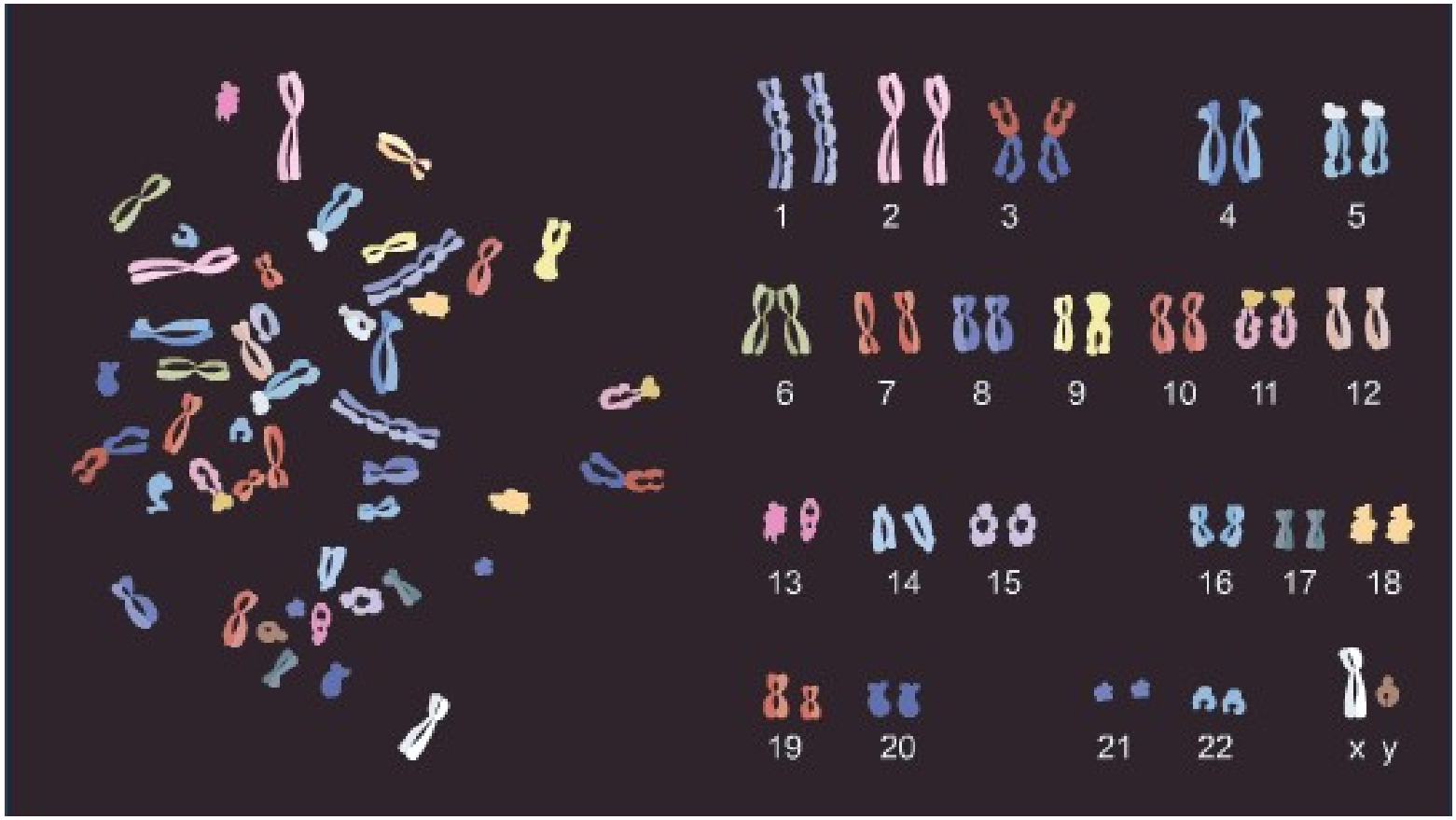
Independent assortment

Number of combinations: 2^n



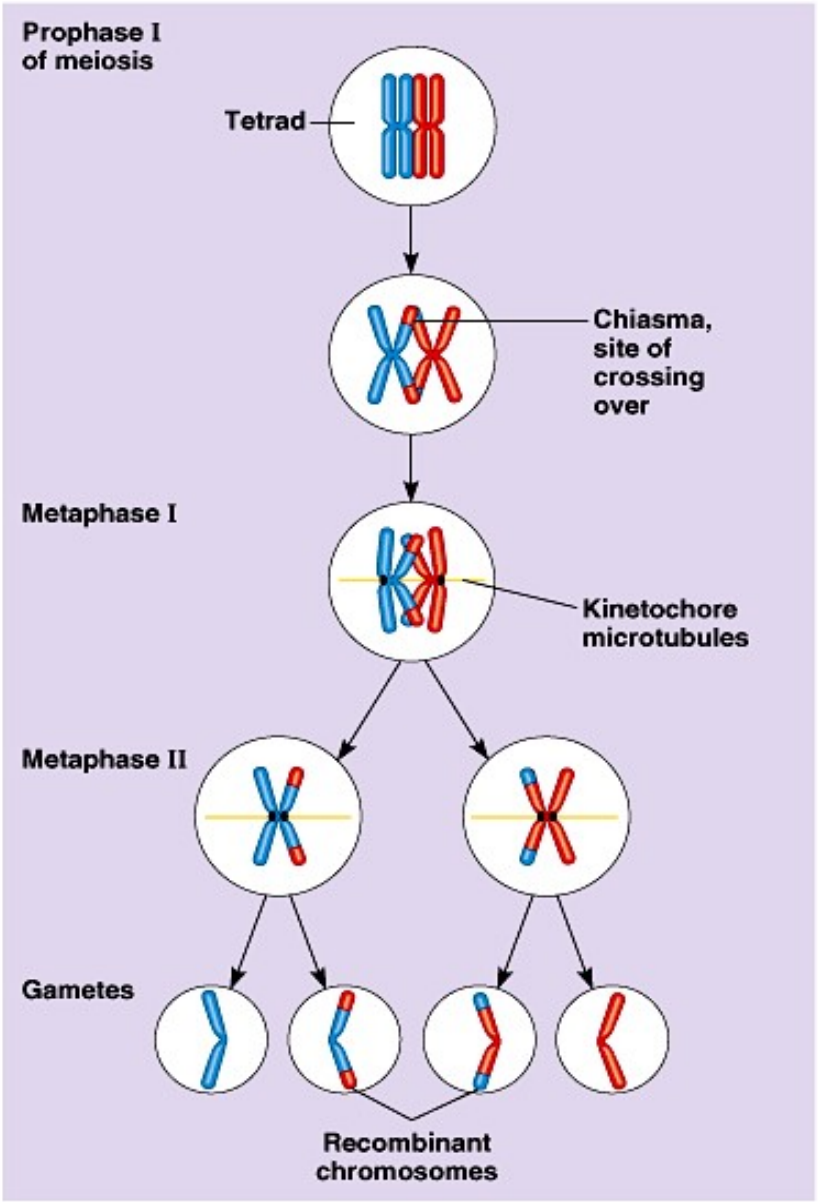
e.g. 2 chromosomes in haploid
2n = 4; n = 2
$2^n = 2^2 = 4$ possible combinations

In humans



e.g. 23 chromosomes in haploid
2n = 46; n = 23
$2^n = 2^{23}$ = ~ 8 million possible combinations!

Crossing over



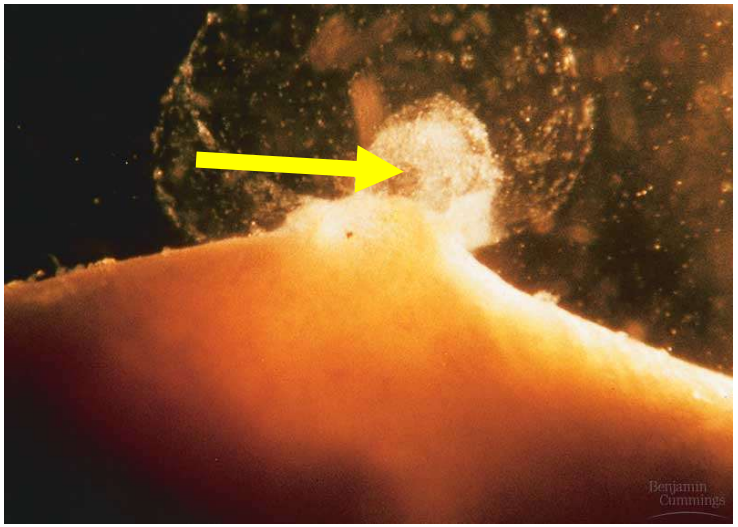
Chiasmata – sites of crossing over, occur in **synapsis**. Exchange of genetic material between non-sister chromatids.

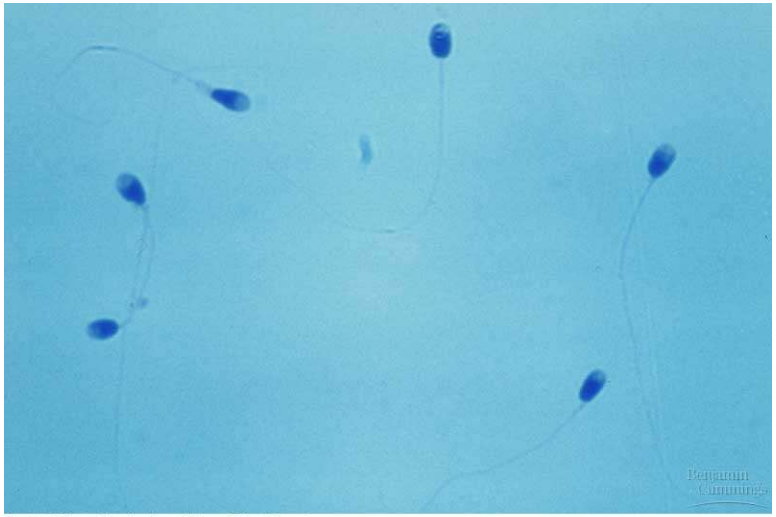
Crossing over produces **recombinant chromosomes**.

Random fertilization

At least 8 million combinations from Mom, and another 8 million from Dad …

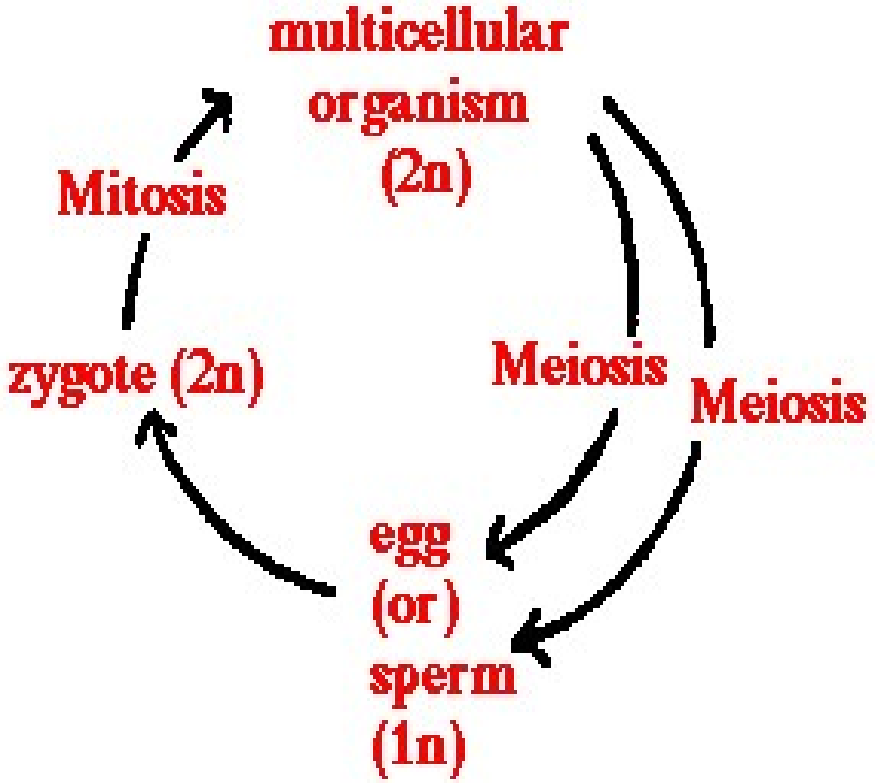
>64 trillion combinations for a diploid zygote!!!





Meiosis & sexual life cycles

- **Life cycle** = sequence of stages in organisms reproductive history; conception to reproduction.
- **Somatic** cells = any cell other than gametes, most of the cells in the body.
- **Gametes** produced by meiosis.



Generalized animal life cycle