

Mitosis v. Meiosis

CHROMOSOME STRUCTURE

1. During nuclear division, the DNA (as **chromatin**) in a Eukaryotic cell's nucleus is coiled into very tight compact structures called **chromosomes**. These are rod-shaped structures made of protein and DNA, **which are visible (when stained) only during nuclear division**.

2. The DNA in Eukaryotic cells is coiled tightly around proteins called **histones**, which help in the tight packing of DNA. During interphase, the DNA is not tightly coiled into chromosomes, but exists as **chromatin**.

3. When preparing for nuclear division, during the S phase of interphase, the chromosomes copy themselves (i.e. DNA replication occurs). Each half of the chromosome is now called a **chromatid**. **Note that there is still only one chromosome**; it consists of **two chromatids** but has only **one centromere**. The function of this is to hold the two chromatids together until they separate during anaphase.

4. Chromosomes are simpler in Prokaryotes. Their DNA is in a single chromosome, and exists as a loop (ccc DNA).

CHROMOSOME NUMBERS

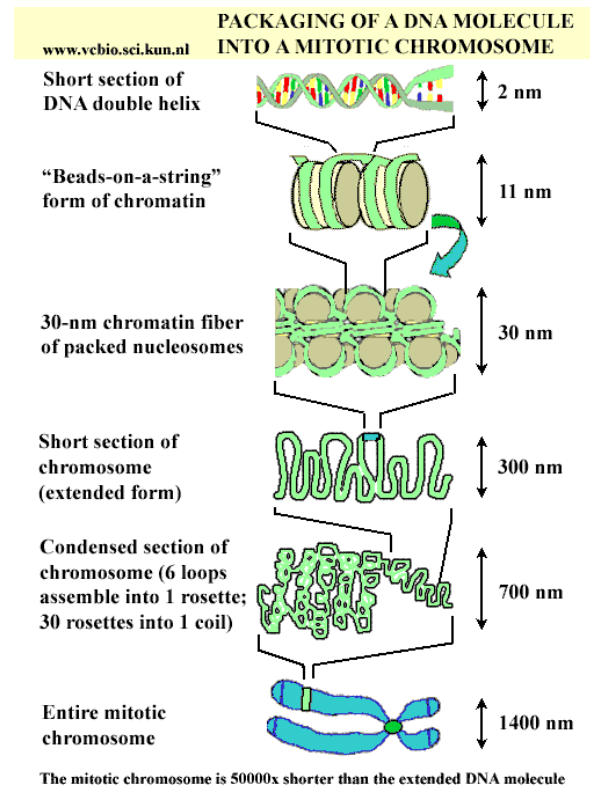
1. Each human **somatic** (or body) cell contains **two** complete sets of chromosomes (one from each parent). This is the normal for Eukaryotes and is known as **diploid (2n)**. For humans (**only**) this means our cells have **46 chromosomes**. **For other species, this number can be very different** – e.g. Lettuce 14, Goldfish 94. Such cells are formed by **mitosis**.

2. Sex cells (**gametes** – **eggs** and **sperm**) have only **one** set of chromosomes (in humans, 23) and such cells are known as **haploid (n)**. **Each cell is unique**, as it is produced by **meiosis** (*though the 'mother cells' for the gametes are produced by mitosis, the final division is always meiotic*).

3. Meiosis is necessary because most organisms reproduce sexually, and during **fertilisation**, the gametes fuse and the number of chromosomes therefore doubles (sperm (n) + egg (n) = 2n), to produce the first cell of the next generation – the **zygote (2n)**.

4. Chromosomes can be divided into two types. In humans, we have **22 pairs of autosomes**, which are the same in every individual, and **one pair of sex chromosomes** (**XX** = female, **XY** = male). This means that females are the **homozygous sex** and males the **heterozygous sex**. The effect of this is that **females can be carriers for sex-linked characteristics** (e.g. colour-blindness), but it is (almost) always males that are **afflicted** (Exception: if a **female carrier marries an afflicted male; half their female children will be afflicted**.) *Note that, in birds, the opposite applies; males are XX (carriers) and females are XO (and thus have the condition)*.

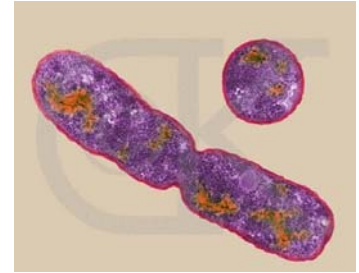
5. The two matching sets of autosomes are known as **homologous pairs**, and both will code for the same features (have the same **genes**, e.g. for eye colour), but they **may** well have different **alleles** (e.g. blue or brown).



CELL DIVISION

PROKARYOTES

1. Prokaryotic cells divide by **binary fission**, in which the DNA replicates and then the cell divides in two. That's all – no mitosis, no spindle, no nothing!



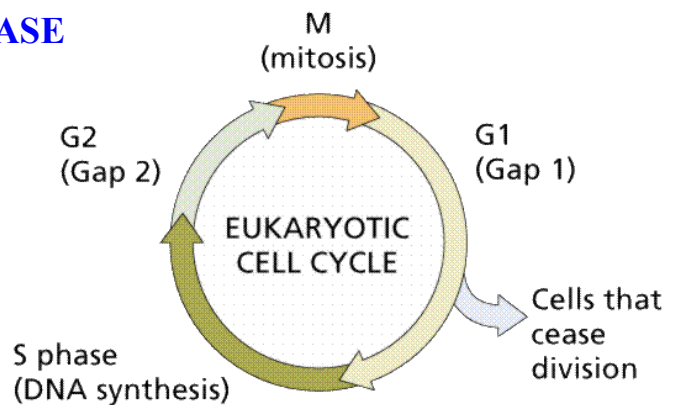
EUKARYOTES

1. A cell typically goes through **three** phases during its life, beginning with growth before it can divide. This is known as the **cell cycle** and consists of three phases:

- A. **Interphase**
- B. **Mitosis** (nuclear division, producing **2 identical nuclei**)
- C. **Cytokinesis** (cell division, producing **2 roughly equal cells**)

A. INTERPHASE

1. This is the longest phase of the cell cycle and can last from a few hours to many years. It used to be known as the '**resting phase**', which is **completely misleading**, as it is during this time of normal metabolic activity that the cell performs **all** its normal functions, beginning with **growth** and **development**.



2. Interphase can be divided into 3 stages:

- I. **G1 Phase** - A period of **normal metabolic activity** – the number of cell organelles increases to normal levels and the volume of cytoplasm increases too, eventually reaching mature size. A cell can remain in this phase indefinitely.
- II. **S Phase** - The **DNA and chromosomes replicate**. The cell is now committed to division.
- III. **G2 Phase** - **Structures directly involved with mitosis are formed**. The new DNA is checked for errors and the substances that will be needed during mitosis are synthesised.

B. MITOSIS

1. **Mitosis is only the division of the nucleus into two identical nuclei**. It is a continuous process, but has been artificially divided into 4 steps. These can be remembered as **I Pee MAT**:

- I. **Prophase**
- II. **Metaphase**
- III. **Anaphase**
- IV. **Telophase**

I. Prophase

1. The chromatin condenses into **chromosomes** by **dehydrating and coiling**. The chromosomes consist of two **identical sister chromatids**, joined together by a **centromere**. For the first time, they can be seen with a light microscope.

2. The nucleolus and nuclear envelope disappear, and the **centriole** (animal cells only) divides into two **centrosomes**, which move apart, creating the **spindle**. This eventually fills the whole of the cell and is made of the protein **tubulin** which forms **spindle fibres** – a form of **microtubule**.

II. Metaphase

The chromosomes are moved to the equator of the cell, and the centromeres are attached to the spindle fibres, so that the sister chromatids line up in the centre of the cell.

III. Anaphase

The centromeres of each chromosome divide and are pulled apart by the contraction of the spindle fibres, thus moving the **chromosomes** (as they must now be called) to opposite poles of the cell.

IV. Telophase

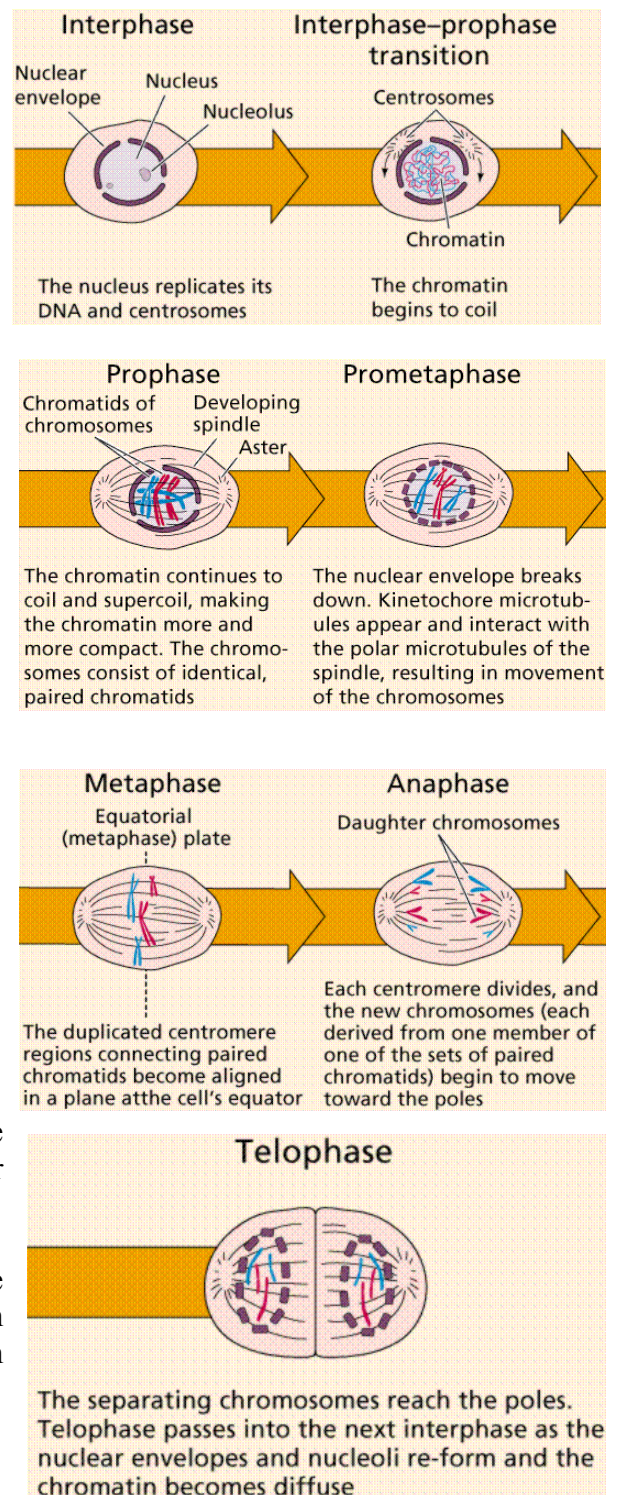
1. After the chromosomes reach the poles, the spindle disappears and the chromosomes return to their functional chromatin state by rehydrating and uncoiling.

2. A new **nuclear envelope** begins to form around the chromosomes at each end of the cell, each with its own nucleolus. With mitosis now over, **cytokinesis** can begin.

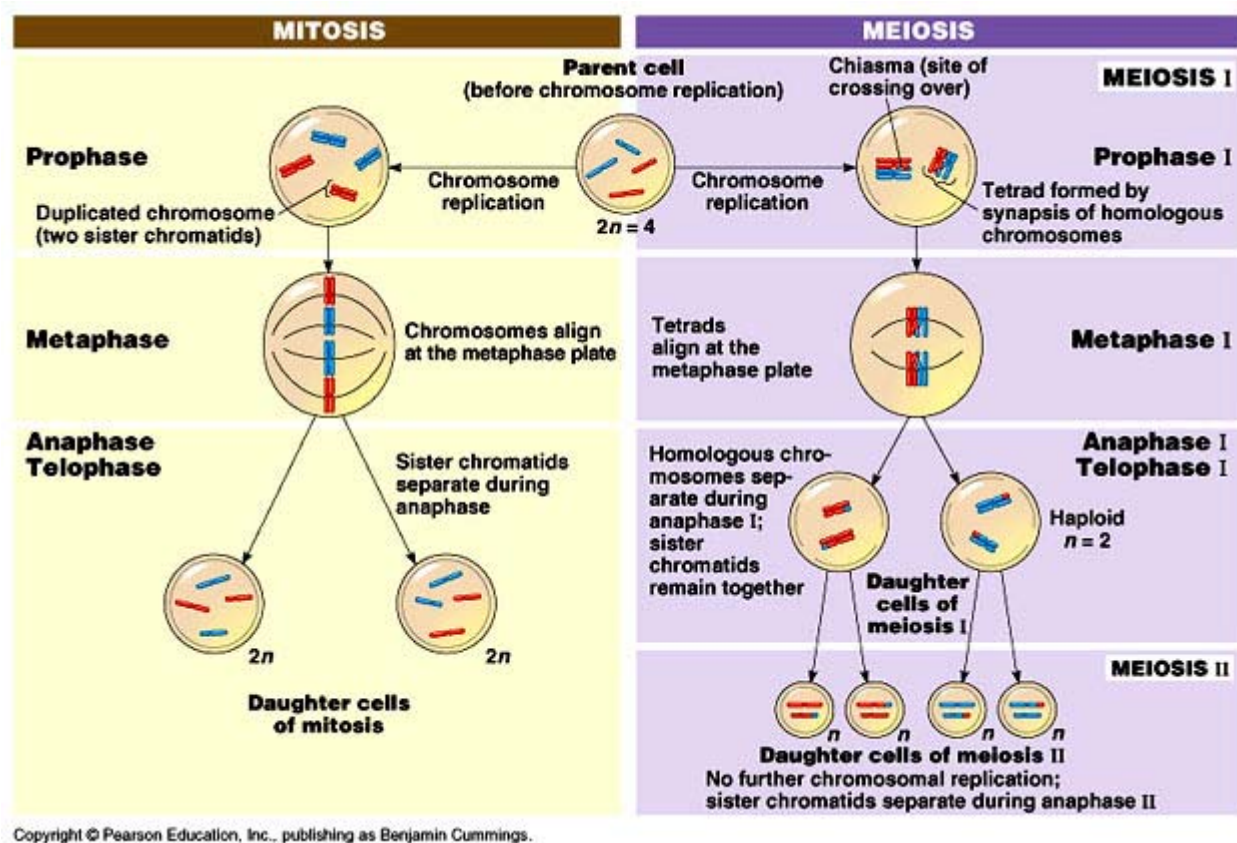
C. CYTOKINESIS

1. Following mitosis, cytokinesis completes the process of cell division. The two cells formed are roughly equal in size. It is rather different in animal and plant cells:

- I. **Animal cells.** The cytoplasm divides by the pinching of the cell in the middle.
- II. **Plant cells.** In a plant cell, a new cell wall begins to form across the centre of the cell, along the line of the **cell plate (or middle lamella)**, which is made of pectin. A new cellulose cell wall is then laid down on **both** side of this, and new cell membranes form inside that, leaving gaps through which the cytoplasm of one cell links to that of its sister. These gaps are known as **plasmodesma** (pl. **plasmodesmata**).



MEIOSIS



Meiosis is a nuclear division that reduces the number of chromosomes in new cells to half the original number (diploid, $2N \rightarrow$ haploid, N). This counteracts the fusion of cells in fertilisation (haploid, $N \rightarrow$ diploid, $2N$). Crucially, it also **produces unique gametes**, which means that **sexual reproduction results in variation**, the raw material for evolution. Whilst mitosis can occur anywhere in an animal, meiosis is confined to the **gonads** (sex organs).

1. Most organisms reproduce sexually, by the fusion of separate male (= **sperm**) and female (= **egg** or **ovum**) gametes. Eggs are much larger and non-motile; sperm are the smallest human cell and swim by means of a flagellum. Reproduction therefore depends on water.

2. Meiosis is the second type of nuclear division, but in this case the number of chromosomes is halved. As in mitosis, meiosis is followed by cytokinesis. It is otherwise very different:

- I. Meiosis produces daughter cells with half the number of chromosomes of the parent cell, i.e. the cell goes from diploid to haploid.
- II. **Meiosis consists of two nuclear divisions**, resulting in **four haploid daughter cells**.
- III. The cells produced by meiosis are not all alike. Each cell is unique and this variation is produced by two processes – **independent segregation** of the chromosomes and by **crossing-over**. Both take place during Meiosis I.

STAGES OF MEIOSIS

Meiosis consists of two divisions:

- A. During **meiosis I** homologous pairs of chromosomes are separated **and cells become haploid**.
- B. During **meiosis II** the sister chromatids of each chromosome are separated (as in mitosis).

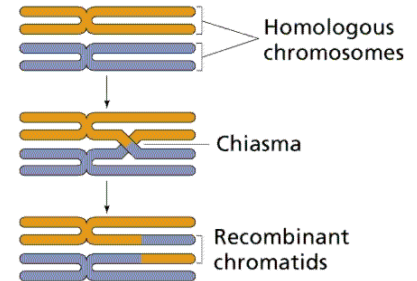
Meiosis I

1. At the start of meiosis, each chromosome consists of **two sister chromatids**, connected at the centromere. However, meiosis differs from mitosis, in that homologous pairs of chromosomes come together at the start of the meiosis, in a process called **synapsis**, forming a **tetrad**.

Prophase I.

1. Just as in mitosis, the nucleolus and nuclear membrane disappear, and the centriole divides and forms the spindle. As in mitosis, the chromosomes dehydrate and become thick and visible, **but** with the chromosomes of each homologous pair tangled together. There are thus **four chromatids in each pair of chromosomes (N.B. and so only half as many 'sets' visible in diagrams)**.

2. Portions of each chromatid may break off and reattach to an adjacent chromatid on the homologous chromosome. The places where this happens are called **chiasma** (pl. **chiasmata**). The whole process is called **crossing-over** and it results in unique combination of alleles on each chromatid. **Crossing-over can only take place between genes**. This is an **essential part** of the **genetic recombination** that takes place in meiosis.



Metaphase I. Homologous pairs are still together and arranged on the equator of the cell.

Anaphase I. The homologous pairs of chromosomes separate from each other, as the spindle fibres pull one of each pair to opposite ends of the cell. The random separation of the homologous chromosomes that this produces is called **independent assortment**, and results in 2^{23} different gametes being possible from any one human being – a couple could have 2^{46} different children!

Telophase I. Cytokinesis takes place; and **each new cell is haploid**, containing one chromosome from each pair.

MEIOSIS II

1. In males, this follows immediately. In females, meiosis I takes place before birth, but meiosis II takes place only **after** the sperm has fused with the egg (i.e. immediately before fertilisation). The chromosomes **do not replicate** before this, second, division, **so the gametes formed will have only half the DNA of a normal cell**.

2. The **second division of meiosis is essentially the same as mitosis**. Often Telophase I is omitted and, after cell division, both daughter cells are already at the end of prophase II.

N.B. When answering questions about the stage of meiosis (in a diagram) or when a particular event occurs (in words), you **MUST** state if it is the **first or second division**. So 'Prophase I' is **usually** the correct answer, but 'Prophase' is **ALWAYS WRONG!** Suggestion: when in doubt, the answer is **NORMALLY Prophase I, but ALWAYS in division I, as division II looks the same as mitosis**.