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Notebook



Glossary
D2. Continuity and change: Cells / D2.1 Cell and nuclear division



Reading
assistance



(https://intercom.help/kognity)



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The big picture

? Guiding question(s)

- How can large numbers of genetically identical cells be produced?
- How do eukaryotes produce genetically varied cells that can develop into gametes?

Keep the guiding questions in mind as you learn the science in this subtopic. You will be ready to answer them at the end of this subtopic. The guiding questions require you to pull together your knowledge and skills from different sections, to see the bigger picture and to build your conceptual understanding.

When you get a cut, a scab forms to seal the wound, preventing blood loss and microbial entry (**Figure 1**). But this scab is not permanent. Eventually the scab will fall off, revealing fresh, new skin where the cut once was. The new skin cells that replace the damaged ones are genetically identical to all other somatic (non-sex) cells in your body, but genetically unique in comparison with the DNA of every other person that lives today or has ever existed (unless you are an identical sibling).

How is your body able to produce new, genetically identical cells to replace those that are lost or damaged? And why is your DNA unique to you?

This subtopic will explore the mechanisms behind the two types of nuclear division that occur in our bodies: mitosis and meiosis, and the subsequent cell division that follows.



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Figure 1. After a cut, your body will produce genetically identical cells to form new, fresh skin.

Credit: fjanecic, Getty Images

☰ Prior learning

Before you study this subtopic make sure that you understand cell structure (see [subtopic A2.2 \(/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43253/\)](#)).

D2. Continuity and change: Cells / D2.1 Cell and nuclear division

Cytokinesis

D2.1.1: Generation of new cells by cell division D2.1.2: Cytokinesis D2.1.3: Equal and unequal cytokinesis

☰ Learning outcomes

By the end of this section you should be able to:

- Outline how new cells can be generated by cell division.
- Outline the process of cytokinesis in plant and animal cells.
- Explain that not all cells undergo equal cytoplasmic division.

Cells are the basic structural unit of all living organisms (see [section A2.2.1-2 \(/study/app/bio/sid-422-cid-755105/book/using-microscopes-id-43573/\)](#)). In all living organisms, a parent cell – sometimes referred to as a mother cell – divides to produce two daughter cells. Note that the terms ‘mother’ and ‘daughter’ are identifier names and there is no male or female involved in this process.

For example, prokaryotic cells, such as bacteria, divide by a process called binary fission, and eukaryotic cells undergo a type of nuclear division called mitosis. Most eukaryotic organisms are also capable of carrying out another type of nuclear division called meiosis, which creates gametes (sex cells), leading to sexual reproduction.



Student view

How does the cell physically separate once the nucleus has divided? And is separation of the cell always equal?

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Mechanisms of cytokinesis

For the two daughter cells to separate, the cytoplasm of the parent cell must be split between the daughter cells. This process is called cytokinesis (**Figure 1**).

Feedback

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43548/print/)

Assign

In animal cells, a network of actin and myosin proteins form a contractile ring that pinches the cell membrane together. This forms a cleavage furrow, which gradually deepens and eventually splits the cytoplasm to form the two separate daughter cells. The fluid nature of the double membrane facilitates this process (see [section B2.2.4–6](#) (/study/app/bio/sid-422-cid-755105/book/structure-and-function-of-double-membranes-hl-id-44251/)).

Actin and myosin are also important contractile proteins involved in muscle contraction (see [section B3.3.2–4](#) (/study/app/bio/sid-422-cid-755105/book/muscle-contraction-hl-id-44815/)).

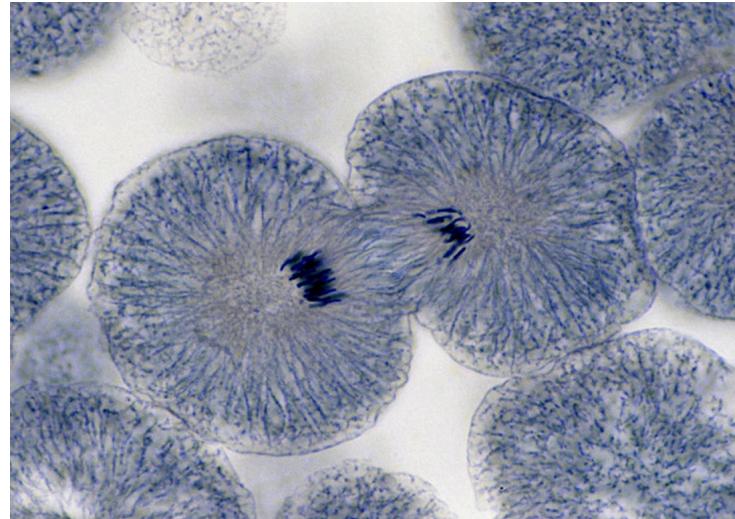


Figure 1. Cytokinesis in the embryo of white fish (genus *Coregonus*).

Credit: Ed Reschke, Getty Images

In plant cells, cytokinesis involves the assembly of a cell plate, formed from the fusion of vesicles containing cell wall materials (**Figure 2**). The cell plate grows outwards until it reaches the existing cell wall, which it fuses with, splitting the parent cell into the two daughter cells. See [section B2.2.1–3](#) (/study/app/bio/sid-422-cid-755105/book/compartmentalisation-and-organelles-id-44250/) and [section B2.1.11–13](#) (/study/app/bio/sid-422-cid-755105/book/membrane-fluidity-hl-id-44646/) for more information on the formation, structure and function of vesicles.



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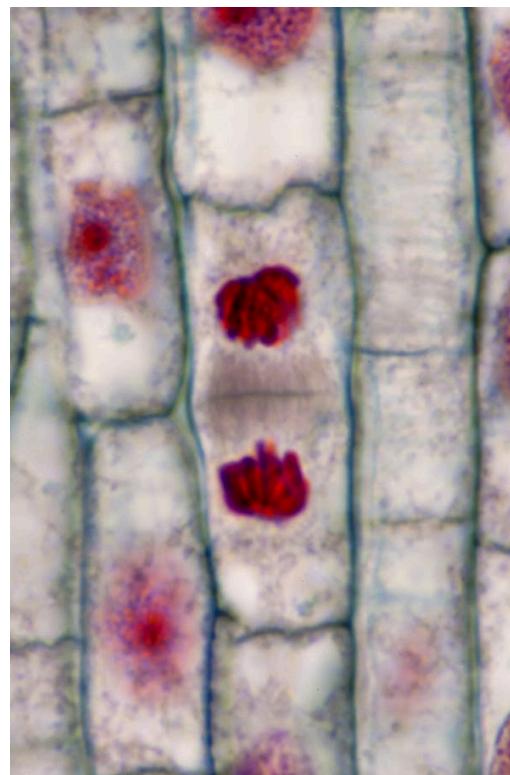


Figure 2. Cytokinesis in onion (genus *Allium*) root tip.

Credit: Ed Reschke, Getty Images

More information for figure 2

Figure 3 shows the differences between cytokinesis in plant and animal cells.

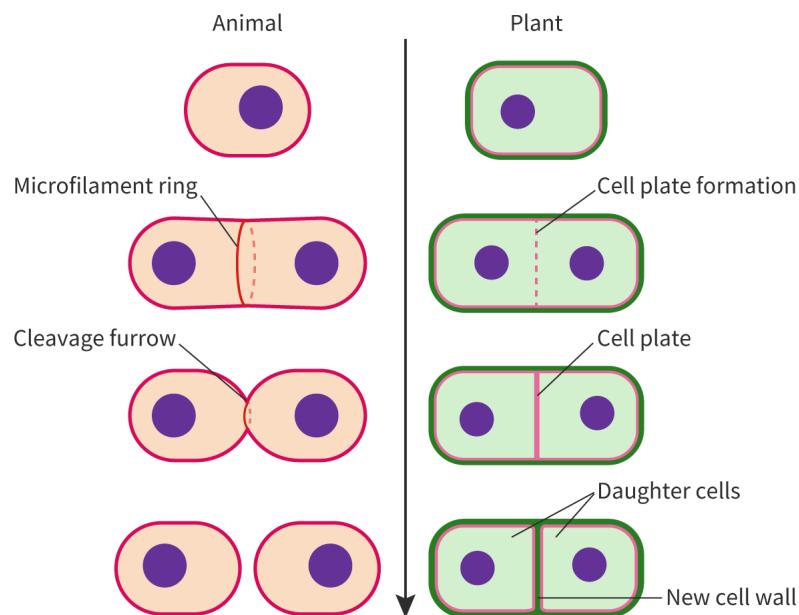


Figure 3. Cytokinesis in plant and animal cells.

More information for figure 3

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In cytokinesis, the division of cytoplasm is usually, but not in all cases, equal. Both daughter cells must receive at least one mitochondrion, essential for aerobic cellular respiration to produce ATP, and any other organelle that can only be made by dividing a pre-existing structure, such as peroxisomes. Equal cytoplasmic division results in both daughter cells being the same size, which is important to ensure they have the same structure and function.

Unequal division of cytoplasm

Oogenesis

Oogenesis is the process of producing mature egg cells or ova in humans (see [section D3.1.14 \(/study/app/bio/sid-422-cid-755105/book/puberty-and-gametogenesis-hl-id-45735/\)](#)). Oogenesis involves an unequal distribution of cytoplasmic contents through a series of cell divisions. During oogenesis, the primary oocyte undergoes two rounds of cell division, resulting in the production of a secondary oocyte and the first polar body during the first round (**Figure 4**). The secondary oocyte is larger than the first polar body and receives most of the cytoplasmic contents, including organelles, ribosomes and energy stores.

If fertilisation occurs, the secondary oocyte undergoes a second round of cell division, producing a mature ovum (egg cell) and a second polar body. The mature ovum contains the majority of the cytoplasmic contents and organelles required for early embryonic development. The first polar body usually does not divide unless there is sufficient cytoplasm, and will instead disintegrate and be re-absorbed by the body.

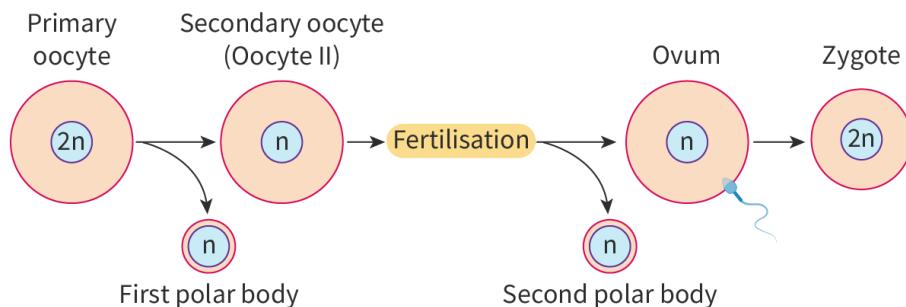


Figure 4. Oogenesis involves unequal cytoplasmic division.

[More information for figure 4](#)

This unequal distribution of cytoplasmic contents is essential for the development of a healthy and functional embryo. The larger size and greater cytoplasmic content of the mature egg cell ensures that it can provide the necessary nutrients and cellular machinery required for fertilisation and early embryonic development. The smaller size of the polar bodies helps to ensure that the developing embryo has sufficient nutrients and energy to support its growth and development until it can establish its own source of nutrients. It is also necessary to ensure the proper chromosome count (haploid).

Budding

Budding in yeast is also an example of unequal cytokinesis (**Figure 5**). Budding is a type of asexual reproduction (see [section D3.1.1 \(/study/app/bio/sid-422-cid-755105/book/asexual-and-sexual-reproduction-id-45736/\)](#)) that involves the outgrowth of a genetically identical daughter cell or 'bud' from the parent cell. The bud starts small and grows in size until it forms a fully developed cell that can function independently from the parent cell. The daughter cell is typically smaller than the parent cell and receives less than half of the cytoplasm and organelles from the parent cell.

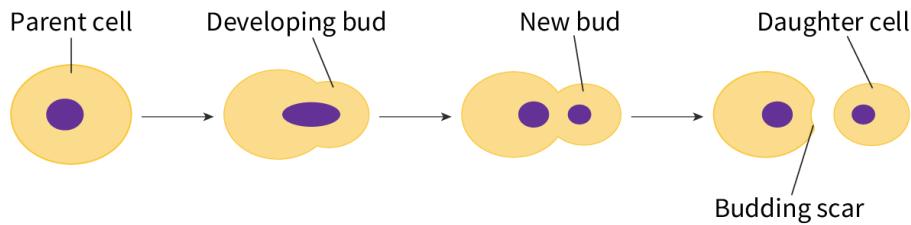


Figure 5. Yeast budding.

[More information for figure 5](#)

The parent cell will be left with a small round mark on its surface at the point where the daughter cell has been separated from it. These marks are called budding scars and can be used by scientists to determine how old a yeast cell is and how many times it has divided.

Hydra is a genus of small aquatic invertebrates. Like yeast, *Hydra* can bud, producing a small outgrowth which eventually detaches to become a genetically identical individual. This form of asexual reproduction allows *Hydra* to rapidly increase their population size.

Video 1 shows the process of budding in *Hydra*.

The Undying Hydra: A Freshwater Mini-Monster That Defies Aging | D...

▶

Video 1. Budding in *Hydra*.

Try the activity to model the process of cytokinesis in plant and animal cells.

Activity

- **IB learner profile attribute:** Reflective
- **Approaches to learning:** Thinking skills — Designing procedures and models
- **Time required to complete activity:** 15 minutes
- **Activity type:** Individual activity

Use modelling clay to make models to show the differences in cytokinesis in plant cells and cytokinesis in animal cells.



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D2. Continuity and change: Cells / D2.1 Cell and nuclear division

Shared features of mitosis and meiosis

D2.1.4: Roles of mitosis and meiosis in eukaryotes D2.1.5: DNA replication as a prerequisite for both mitosis and meiosis D2.1.6: Condensation and movement of chromosomes

Learning outcomes

By the end of this section you should be able to:

- Outline the roles of mitosis and meiosis in eukaryotic cells.
- Describe the shared features of mitosis and meiosis.

Prior to cell division (cytokinesis), nuclear division is needed. This avoids the production of anucleate cells, which would not be able to develop. Cells that are naturally anucleate, such as red blood cells or sieve tube elements (see [section A2.2.8–11 \(/study/app/bio/sid-422-cid-755105/book/animal-plant-and-fungal-cells-id-44719/\)](#)), lose the nucleus after differentiation in a process called enucleation.

Mitosis and meiosis are both types of nuclear division in eukaryotic cells (**Figure 1**). How are these processes similar? And how are they different?

Role of mitosis and meiosis in eukaryotic cells

Mitosis occurs in somatic cells and produces diploid daughter cells (cells with the normal chromosome number, represented as '2n') that are genetically identical to the parent cell. In eukaryotic cells, mitosis occurs to produce cells for growth, or to replace cells that are lost or damaged. Mitosis can also occur as a form of asexual reproduction (see [section D3.1.1 \(/study/app/bio/sid-422-cid-755105/book/asexual-and-sexual-reproduction-id-45736/\)](#) for the differences between sexual and asexual reproduction).

Meiosis is a type of nuclear division that produces four haploid genetically unique daughter nuclei, which will form gametes (sperm and ovum) for sexual reproduction. The cells produced by meiosis are genetically unique, because of crossing over and independent assortment. Like mitosis, meiosis begins with a diploid cell. Unlike mitosis, meiosis involves two rounds of nuclear division, producing four daughter cells. The daughter cells produced in meiosis are haploid, meaning they contain half the normal number of chromosomes (represented by 'n'). It is for that reason that meiosis is referred to as a reduction division.

Although there is diversity in the chromosome numbers of different species (see [section A3.1.5–7 \(/study/app/bio/sid-422-cid-755105/book/what-chromosomes-tell-us-id-43228/\)](#)), there is unity in the chromosome number of a single species (see [section A3.1.8–11 \(/study/app/bio/sid-422-cid-755105/book/comparing-genomes-id-43229/\)](#)); therefore, the diploid number and the haploid number for a single species will be consistent.



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Mitosis consists of four stages: prophase, metaphase, anaphase and telophase. Meiosis is a two-part process, consisting of meiosis I and meiosis II, which each have a prophase, metaphase, anaphase and telophase. After mitosis, meiosis I and meiosis II, cytokinesis occurs to physically separate the daughter cells.

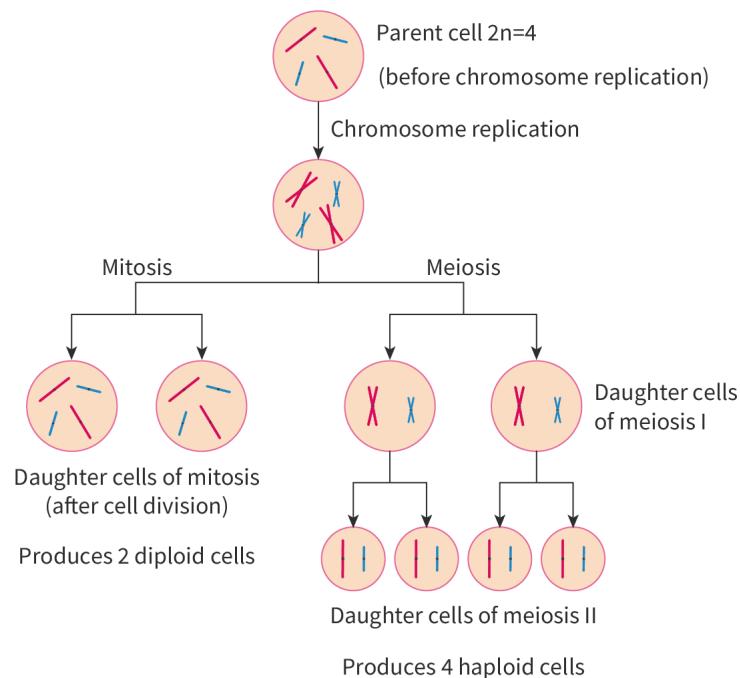


Figure 1. An overview of the processes of mitosis and meiosis.

More information for figure 1

Shared features of mitosis and meiosis

Before mitosis or meiosis, DNA replication must occur. DNA replication is the process by which a cell makes a copy of its DNA (see [subtopic D1.1 \(/study/app/bio/sid-422-cid-755105/book/big-picture-id-43546/\)](#)). DNA replication occurs during interphase, a period in the cell cycle where cells are growing and are metabolically active.

After each chromosome has been replicated, it will consist of two genetically identical elongated DNA molecules called sister chromatids, held together by a structure called a centromere (**Figure 2**).

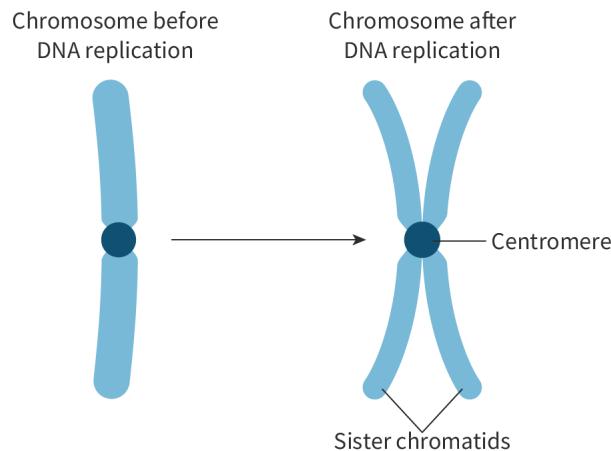


Figure 2. Sister chromatids are formed when a chromosome is replicated. Sister chromatids are held together at the centromere.

More information for figure 2

The DNA in eukaryotic cells is wrapped around proteins called histones, forming structures called nucleosomes (see [section A1.2.11–13 \(/study/app/bio/sid-422-cid-755105/book/dna-base-sequences-hl-id-46211/\)](#) for more information about nucleosomes and [section A2.2.4–6 \(/study/app/bio/sid-422-cid-755105/book/prokaryotic-and-eukaryotic-cells-id-43583/\)](#) for more information about eukaryotic cell structure) (**Figure 3**). Histone proteins have an overall positive charge, and so interact with negatively charged DNA. The nucleosome is composed of eight histone proteins arranged in a core, around which DNA is coiled in a repeating pattern. A ninth histone protein helps to stabilise the DNA. The nucleosome structure is the basic building block of chromatin, the complex of DNA and proteins that make up chromosomes in their relaxed form in eukaryotic cells.

When the cell is not undergoing nuclear division, the DNA is loosely packed around the histone proteins. At the beginning of nuclear division the chromatin is supercoiled and condensed by histone proteins. This results in tightly coiled shapes that we recognise as chromosomes. Supercoiling of DNA allows for efficient separation of replicated DNA during nuclear division.

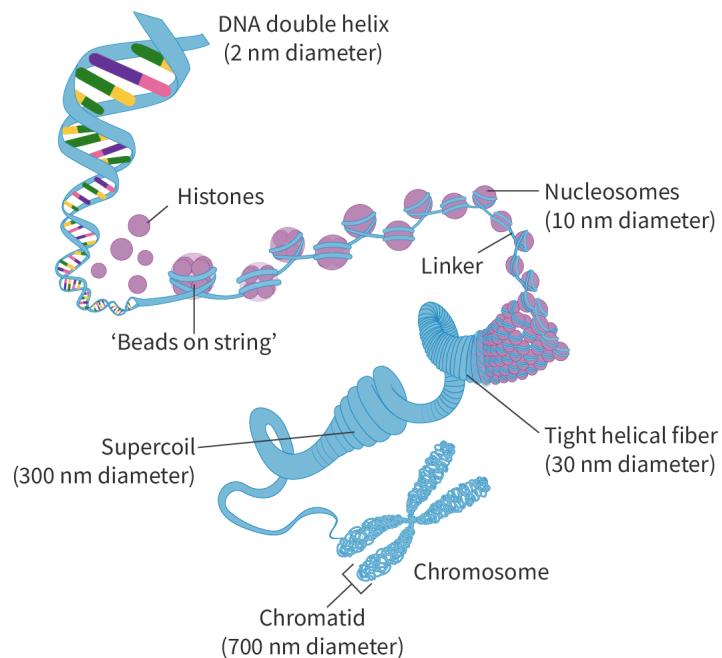


Figure 3. Eukaryotic DNA is wrapped around histone proteins to form nucleosomes. Loosely packed nucleosomes form chromatin, which condenses into chromosomes during nuclear division.

More information for figure 3

Both mitosis and meiosis involve the movement of chromosomes. This involves the use of microtubules and microtubule motors to move the chromosomes. Microtubules are long, thin, cylindrical fibrous proteins that form the spindle apparatus during cell division. The spindle is responsible for pulling chromosomes apart during nuclear division. Microtubule motors are specialised proteins that bind to microtubules and hydrolyse ATP to provide the energy to move chromosomes to either pole (end) of the cell.

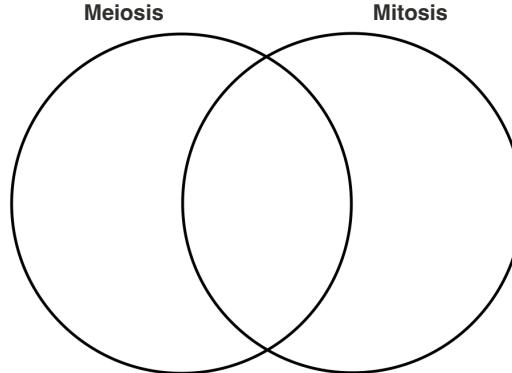
Try this drag and drop activity to check your understanding of cell division.

Activity

- **IB learner profile attribute:** Knowledgeable

- **Approaches to learning:** Thinking skills — Reflecting at all stages of the assessment and learning cycle
- **Time required to complete activity:** 10 minutes
- **Activity type:** Individual activity

Complete the Venn diagram in **Interactive 1** by dragging and dropping the statements to the correct location.



- 1 Before it can occur, DNA must be replicated
- 2 Can occur as a form of asexual reproduction
- 3 Daughter cells are genetically identical to each other and to the parent cell
- 4 Daughter cells are genetically unique
- 5 Followed by cytokinesis
- 6 Involves the movement of chromosomes using microtubules and microtubule motors
- 7 Nuclear division
- 8 Occurs in somatic cells
- 9 Produces cells for growth, and to replace cells that are lost or damaged
- 10 Produces diploid ($2n$) daughter cells
- 11 Produces four daughter cells
- 12 Produces gametes for sexual reproduction
- 13 Produces haploid (n) daughter cells
- 14 Produces two daughter cells
- 15 Reduction division

Check

Interactive 1. Cell Division.

More information for interactive 1

5 section questions ▾

D2. Continuity and change: Cells / D2.1 Cell and nuclear division

Mitosis

D2.1.7: Phases of mitosis D2.1.8: Identification of phases of mitosis

Learning outcomes

By the end of this section you should be able to:



- Describe the phases of mitosis.
- Identify the stages of mitosis from photomicrographs.

Mitosis is a type of nuclear division that produces two genetically identical diploid daughter nuclei for somatic cells.

Mitosis can be divided into four stages: prophase, metaphase, anaphase and telophase (**Figure 1**). What happens in these stages?

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Feedback



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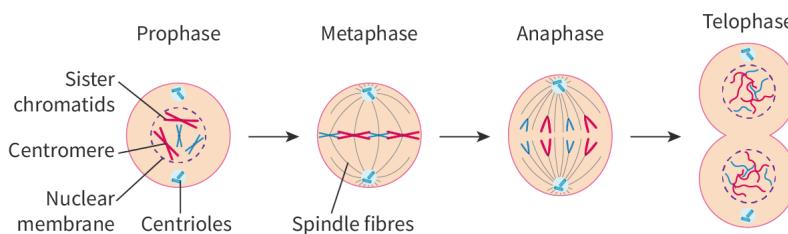


Figure 1. The stages of mitosis.

More information for figure 1

Prophase

In prophase, the chromatin condenses into chromosomes. Each chromosome has undergone replication prior to mitosis (see [section D1.1.1](#) (/study/app/bio/sid-422-cid-755105/book/dna-replication-basics-id-45740/)) and consists of two genetically identical sister chromatids held together at the centromere. The nuclear membrane breaks down and spindle fibres form. Plant cells use microtubule organising centres (MTOCs) to organise spindle fibres during cell division, anchoring them to either pole of the cell. Animal cells, however, use centrosomes, a type of MTOC that contains centrioles. MTOCs migrate to each pole (end) of the cell during prophase.

Metaphase

In metaphase, sister chromatids line up on the metaphase plate. Spindle fibres, which bind to the centromeres of sister chromatids, move them into position.

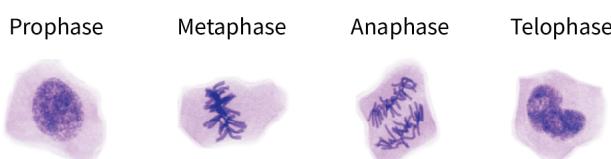
Anaphase

In anaphase the spindle fibres shorten, splitting the centromere and pulling sister chromatids apart to opposite poles of the cell.

Telophase

In telophase, the chromosomes decondense and the nuclear membrane reforms at each pole. The spindle fibres disintegrate and the cell elongates in preparation for cytokinesis.

You also need to be able to identify the stages of mitosis from photomicrographs (**Figure 2**) (see [section A2.2.1–2](#) (/study/app/bio/sid-422-cid-755105/book/using-microscopes-id-43573/)) for information on microscopy skills).





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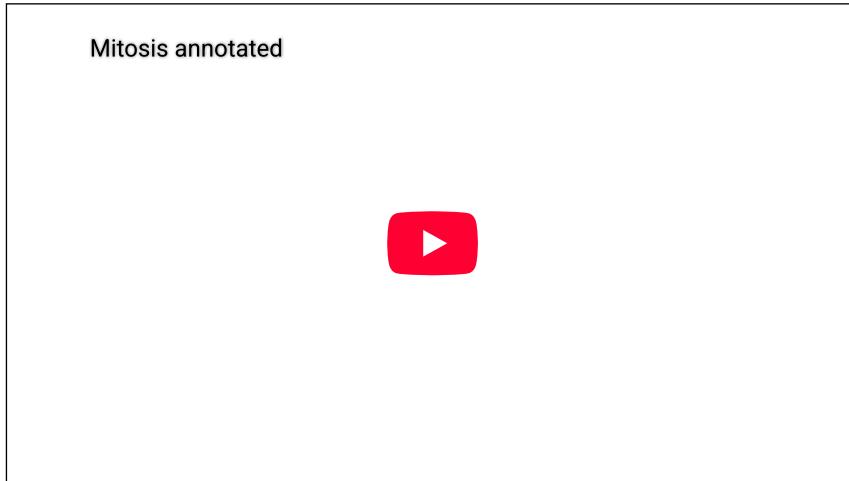
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Figure 2. The stages of mitosis in meristem cells in the roots of onions as seen under a light microscope.

Source: Doc. RNDr. Josef Reischig, CSc [↗](#)

[https://commons.wikimedia.org/w/index.php?title=File:Mitosis_in_onion_root_meristem_\(Reischig\).jpg&oldid=132826113](https://commons.wikimedia.org/w/index.php?title=File:Mitosis_in_onion_root_meristem_(Reischig).jpg&oldid=132826113)
CC BY-SA 3.0 [↗](https://creativecommons.org/licenses/by-sa/3.0/) (<https://creativecommons.org/licenses/by-sa/3.0/>). via Wikimedia Commons

Video 1 shows a time lapse of a dividing cell, with overlaid animation graphics so you can visualise the spindle and other structures involved in this process.



Video 1. The process of mitosis.

ⓘ More information for video 1

Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Reflecting at all stages of the assessment and learning cycle
- **Time required to complete activity:** 15 minutes
- **Activity type:** Individual activity

The micrographs in **Interactive 1** show the stages of mitosis in a random order.

For each micrograph:

- Identify the name of the stage.
- Write a description (on a piece of paper), explaining how you have identified each stage.



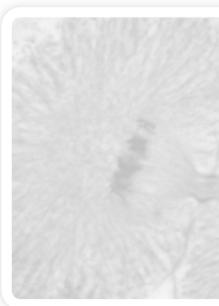
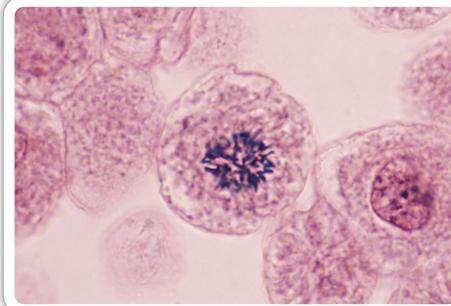
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Name the stages of mitosis

1 / 4



Your answer

Check

Your answer



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• **Interactive 1. Stages of mitosis.**

More information for interactive 1

5 section questions ▾

D2. Continuity and change: Cells / D2.1 Cell and nuclear division

Meiosis

D2.1.9: Meiosis as a reduction division D2.1.10: Down syndrome and non-disjunction

Learning outcomes

By the end of this section you should be able to:

- Explain why meiosis is a reduction division.
- Identify meiosis as a source of variation
- Describe the stages of meiosis.
- Describe the causes and consequences of non-disjunction.
- Explain how meiosis generates genetic diversity.



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Meiosis is a type of nuclear division that produces four haploid genetically unique daughter nuclei, which will form gametes for sexual reproduction. How does this process occur? And how does it produce genetically unique daughter cells?

Meiosis as a reduction division

Meiosis begins with diploid cells and produces haploid cells. Whereas diploid cells contain the normal number of chromosomes ($2n$), haploid cells contain half the normal number of chromosomes (n). Because meiosis halves the chromosome number and is then followed by cytokinesis, dividing the cell in two, it is known as a reduction division.

During fertilisation, male and female gametes fuse, joining their nuclei to produce a zygote (see [section D3.1.6](#) (/study/app/bio/sid-422-cid-755105/book/sexual-reproduction-in-flowering-plants-id-45746/) and [section D3.2.1](#) (/study/app/bio/sid-422-cid-755105/book/from-haploid-to-diploid-id-45747/)). It is important that the gametes are haploid so that the zygote and the cells that form from the zygote by mitosis are diploid.

Assign

As in mitosis, DNA replication must occur prior to meiosis, and so at the start of meiosis, each chromosome will consist of two sister chromatids, joined together at a centromere. Meiosis consists of two rounds of division: meiosis I and meiosis II. Each round of division consists of a prophase, metaphase, anaphase and telophase, and will end with cytokinesis.

Stages of meiosis

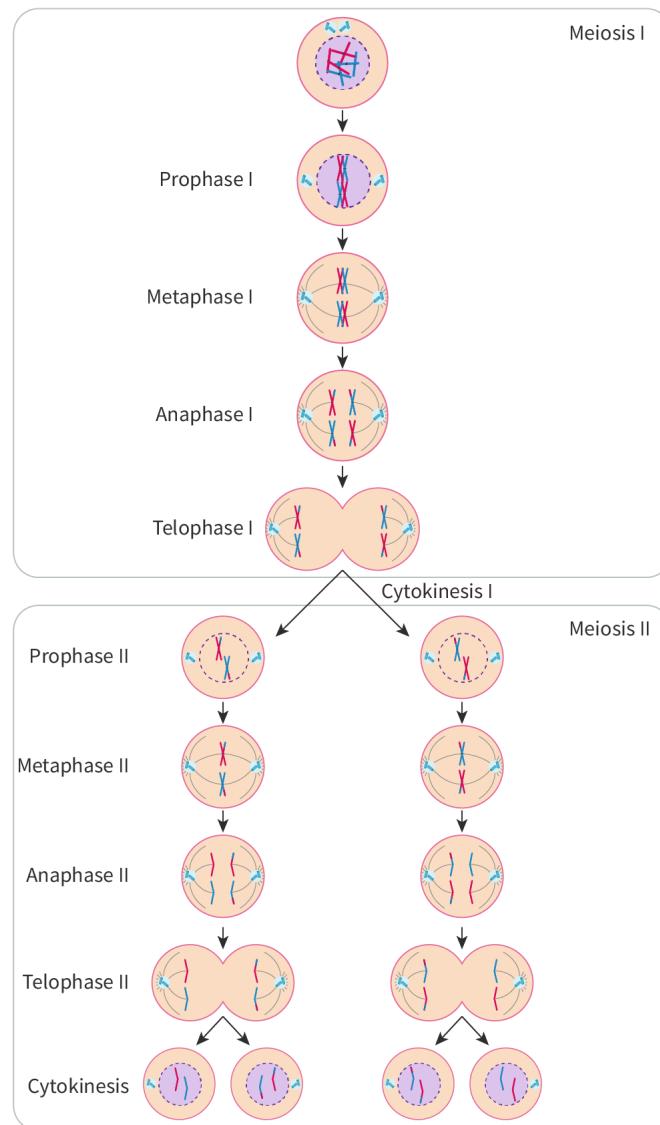


Figure 1. The stages of meiosis.[More information for figure 1](#)

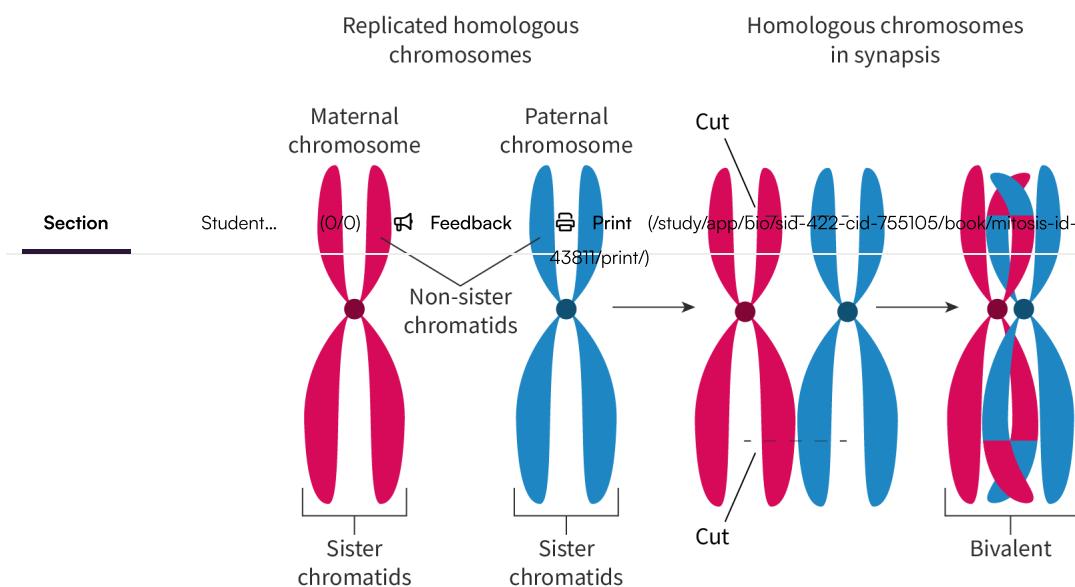
When discussing the stages of meiosis, it is essential to use Roman numerals 'I' and 'II' to accurately refer to the first and second divisions (**Figure 1**). For example, prophase I occurs in the first division of meiosis, and prophase II occurs in the second division of meiosis.

Meiosis I

Prophase I: During prophase I the nuclear membrane disintegrates. MTOCs will migrate to opposite poles and the spindle fibres start to form. Chromatin condenses into chromosomes, with each set of parental chromosomes forming sister chromatids. The sets of sister chromatids join together to form a bivalent (also known as a tetrad). The two pair of joined chromatids is called a homologous pair (**Figure 2**).

Diploid cells contain two copies of each chromosome, one copy inherited from the female parent (the maternal chromosome) and one copy inherited from the male parent (the paternal chromosome). Homologous chromosomes are similar in size and shape, and contain the same genes at the same locations (loci), although they may have different alleles for a gene.

Once a bivalent has formed, crossing over may occur. Crossing over is the exchange of equivalent segments of DNA between non-sister chromatids. The DNA molecule of one of the chromatids is cut, then a second cut is made at exactly the same point on the non-sister chromatid. The DNA of each chromatid is joined up to the DNA of the non-sister chromatid with the effect of swapping sections of DNA between chromatids. This results in sister chromatids that are no longer genetically identical. Crossing over will be discussed later in this section.

**Figure 2.** Homologous chromosomes pair up during prophase I.[More information for figure 2](#)

Metaphase I: In metaphase I, spindle fibres attach to the centromeres of homologous chromosomes and pull the bivalents to the centre of the cell. Maternal and paternal homologues show random orientation towards the poles, meaning that the orientation of any one maternal chromosome (i.e. which pole it is closer to and will move towards in

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the next phase) is independent of the other maternal chromosome. Random orientation and independent assortment will be discussed later on in this section.

Anaphase I: In anaphase I, spindle fibres shorten, separating the bivalent and pulling homologous chromosomes apart and towards opposite poles. Unlike mitosis, sister chromatids remain connected at the centromere and move to the same pole.

Telophase I: In telophase I the homologous chromosomes reach the poles of the cell and decondense. A nuclear membrane forms around each nucleus and the spindle fibres (microtubules) break down.

Following meiosis I, cytokinesis will occur, resulting in the production of two non-identical haploid daughter cells. There will then be a period of rest called interkinesis. DNA replication does not occur during this time.

Meiosis II

Prophase II: During prophase II the DNA recondenses, the nuclear membrane disintegrates, MTOCs migrate to opposite poles and the spindle fibres start to form.

Metaphase II: In metaphase II spindle fibres attach to the centromeres, lining up sister chromatids in the centre of the cell. Sister chromatids show random orientation towards the poles.

Anaphase II: In anaphase II, spindle fibres shorten, splitting the centromere and pulling sister chromatids apart towards opposite poles. Once sister chromatids are separated, they are called chromosomes.

Telophase II: In telophase II the chromosomes reach the opposite poles of the cell and decondense. A nuclear membrane forms around each nuclei.

Following meiosis II, cytokinesis will occur to create four haploid daughter cells.

Photomicrographs of the different stages of meiosis in lily anthers are shown in **Figure 3**.

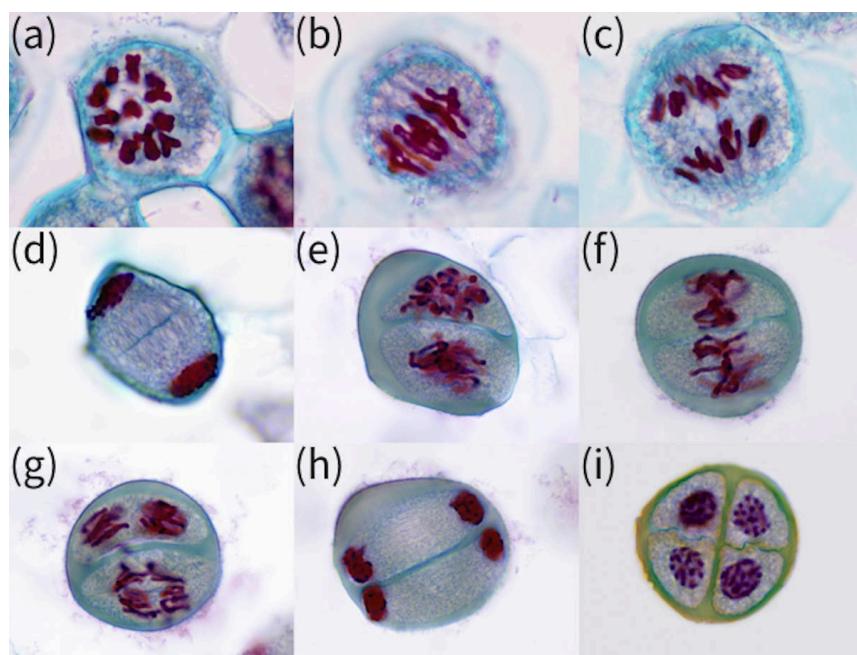


Figure 3. Photomicrographs of some of the different stages of meiosis. (a) prophase I, (b) metaphase I, (c) anaphase I, (d) telophase I, (e) prophase II, (f) metaphase II, (g) anaphase II, (h) telophase II (i) cytokinesis II.



Overview
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Nature of Science

Aspect: Observations

Advancements in light microscopes in the late 19th century enabled the observation of chromosomes during mitosis and meiosis. However, an additional challenge of observing meiosis is that it only occurs in male and female sexual organs, the tissues of which can be difficult to interpret under the microscope.

The exact behaviour of the chromosomes during meiosis was determined using many ingenious protocols on invertebrate gonads and careful interpretation of data leading to the understanding of the sequence of events.

Down syndrome and non-disjunction

Non-disjunction is a genetic error that can occur during meiosis. Non-disjunction can be either the failure of pairs of homologous chromosomes to separate (failure to 'disjoin') during anaphase I, or the failure of sister chromatids to separate during anaphase II (**Figure 4**). This leads to gametes with one extra or one missing chromosome.

Non-disjunction can also occur during anaphase of mitosis, but it usually only impacts a few cells, and therefore the effects are rarely noticeable.



Student
view

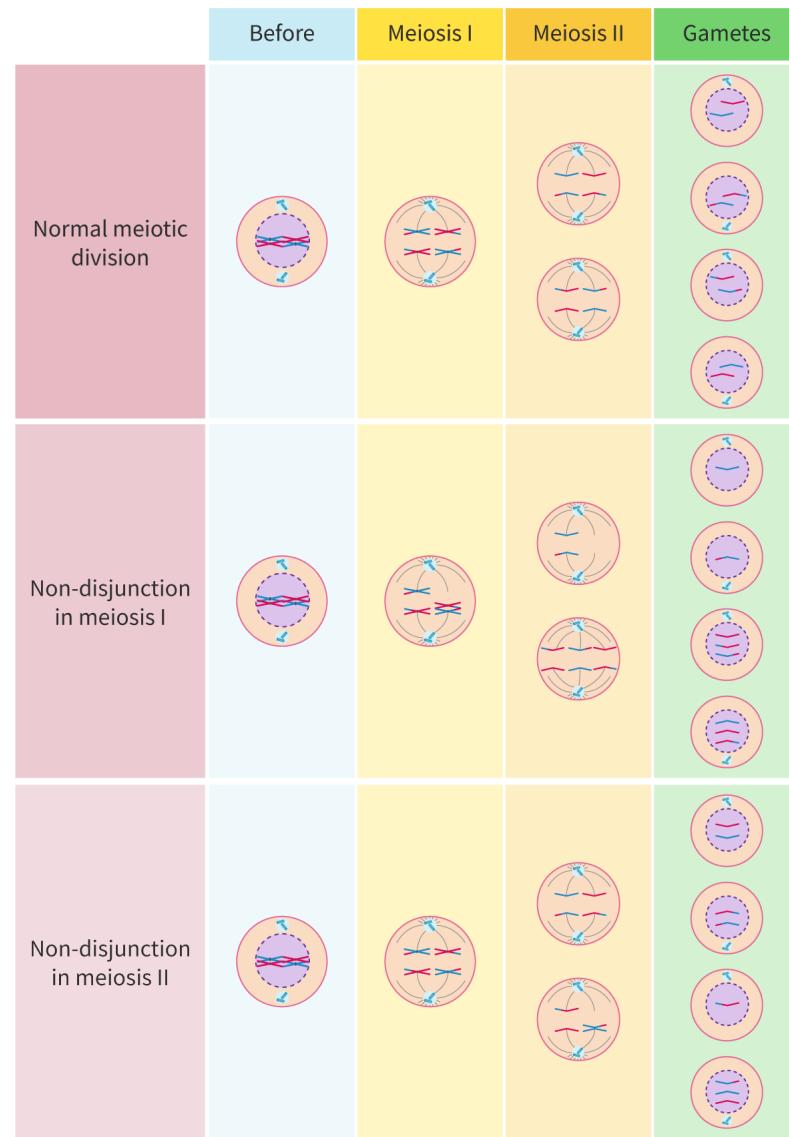


Figure 4. Non-disjunction during meiosis.

More information for figure 4

When a gamete with a chromosomal abnormality is involved in sexual reproduction, all of the somatic cells in the offspring will inherit the abnormality. Inheriting one extra chromosome results in trisomy (three chromosomes instead of the normal pair), and inheriting one fewer chromosome results in monosomy (one chromosome instead of the normal pair).

Non-disjunction can occur at any of the 23 chromosome pairs in humans, and the severity of the symptoms, or whether the offspring is able to survive with the abnormality depends on the specific chromosomes affected by non-disjunction.

Trisomy 21, also known as Down syndrome, is a condition that results from an extra copy of chromosome 21. Down syndrome occurs in approximately 1 in every 700 live births worldwide and results in individuals with a range of intellectual and physical disabilities. This includes poor muscle tone, heart defects and delayed development.

While individuals with Down syndrome exhibit a spectrum of symptoms, other trisomies can be so severe that the organism cannot survive.

Monosomy is rare as most monosomies result in severe developmental issues. The only known monosomy in humans is monosomy X, also known as Turner's syndrome. Normally, females inherit two copies of the X chromosome, one maternal and one paternal, and males inherit one X chromosome from their mother and one Y chromosome from their father (see [section D3.2.11 \(/study/app/bio/sid-422-cid-755105/book/unlinked-genes-hl-id-45749/\)](#)). Turner's syndrome can arise when non-disjunction in either the father or the mother results in the sex chromosomes not segregating properly in anaphase I. As a result, a gamete is produced without an X chromosome, and therefore the individual inherits only a single X chromosome from the other parent, rather than inheriting one from each. Monosomy X is a relatively common chromosomal abnormality, occurring in approximately 1 in 2500 female births. It results in a range of physical and developmental abnormalities, including short stature, infertility and heart defects.

Karyotyping (see [section A3.1.5–7 \(/study/app/bio/sid-422-cid-755105/book/what-chromosomes-tell-us-id-43228/\)](#)) is a genetic testing technique that analyses the number and structure of chromosomes and is commonly used to detect chromosomal abnormalities such as trisomy 21 in foetal cells. Karyotypes use images of sister chromatids. The sister chromatids are often so close together that they appear to be singular, but a close look can often show the structure of a pair of sister chromatids. Foetal cells for karyotyping can be gathered through techniques such as amniocentesis (the collection of amniotic fluid) and chorionic villus sampling (the collection of placental tissue).

Meiosis and genetic diversity

Genetically unique gametes are created in meiosis through the processes of crossing over in prophase I, and random orientation and independent assortment of homologous chromosomes in metaphase I, and of sister chromatids in metaphase II. The random fusion of genetically unique gametes during sexual reproduction results in genetically diverse offspring (see [section D3.1.2 \(/study/app/bio/sid-422-cid-755105/book/male-and-female-reproductive-systems-id-45750/\)](#)).

Crossing over

In prophase I, homologous chromosomes pair up to form bivalents and exchange equivalent sections of DNA between non-sister chromatids. Crossing over can occur multiple times in the same bivalent. The points at which crossing over occurs between two non-sister chromatids are called chiasmata (singular: chiasma) (**Figure 5**). Although there are some areas where chiasma formation and crossing over are more frequent, crossing over occurs at different places each time meiosis occurs, and can occur almost anywhere along the chromosome.

Chromatids not involved in crossing over are called non-recombinant chromatids, and chromatids that have undergone crossing over are called recombinant chromatids. As sister chromatids are no longer genetically identical, each gamete will inherit different combinations of alleles from the maternal and paternal chromosome.

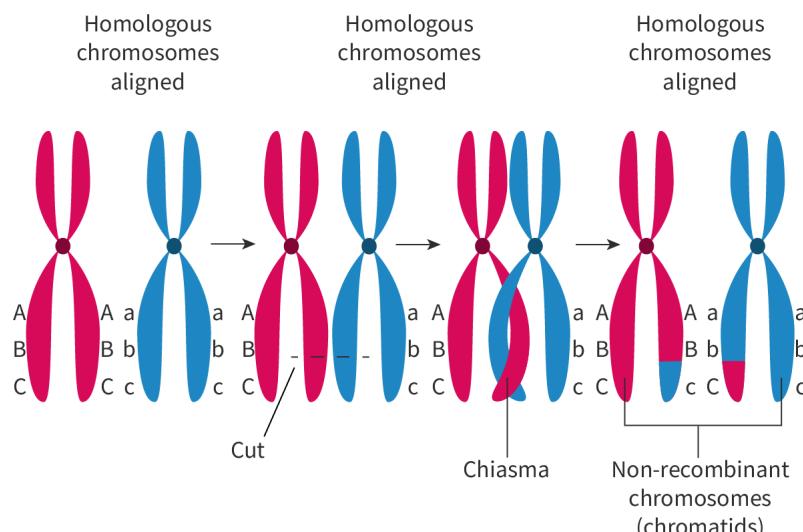


Figure 5. Chiasmata formation and crossing over between homologous chromosomes.

[More information for figure 5](#)

Random orientation

During metaphase I, homologous chromosomes line up on the equator. Chromosomes are oriented randomly, which means that there is no relationship between the position of one maternal chromosome and the position of another. The same is true for the position of one paternal chromosome and the position of another – it is equally likely that they will be closer to one pole, or closer to opposite poles.

Consider a cell with two pairs of chromosomes ($2n = 4$) undergoing meiosis. **Figure 6** shows the possible outcomes after random orientation in metaphase I.

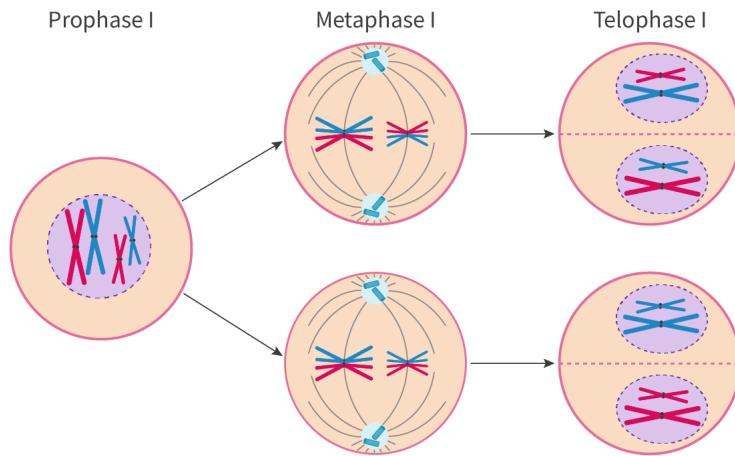


Figure 6. Random orientation of homologous chromosomes in meiosis I.

[More information for figure 6](#)

The formula 2^n can be used to calculate the number of possible combinations produced at the end of meiosis I, where 'n' is the haploid number. In the example shown in **Figure 6**, the diploid number is 4, and therefore the haploid number (n) is 2. Using the formula, 2^2 tells us that there are four possible combinations.

Human cells have a diploid number of 46, and therefore a haploid number of 23. The number of possible outcomes after meiosis I is $2^{23} = 8\,388\,608$.

Random orientation also occurs in metaphase II, further increasing the number of possible outcomes.

Because random orientation is more likely to separate genes that are on different chromosomes (unlinked genes), they are less likely to be inherited together. Find out more about segregation and independent assortment of unlinked genes in meiosis in [section \(/study/app/bio/sid-422-cid-755105/book/linked-genes-hl-id-45752/D3.2.16-17 \(/study/app/bio/sid-422-cid-755105/book/unlinked-genes-hl-id-45749\)\)](#).

Random fertilisation

When two gametes fuse during fertilisation, the resulting offspring inherit a combination of alleles from both parents that have never previously been combined. Additionally, as it is random which sperm and egg are involved in fertilisation, this further increases the possible genetic combinations.

Increased genetic diversity results in populations that are more adaptable and resilient to environmental changes and challenges, reduces risks of inbreeding and susceptibility to diseases, and provides a basis for evolution and natural selection.

Try the activity to analyse some data about the incidence of non-disjunctions in relation to maternal age.

Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Reflecting at all stages of the assessment and learning cycle
- **Time required to complete activity:** 15 minutes
- **Activity type:** Individual activity

Non-disjunction in meiosis occurs more often in older parents, especially mothers. The graph in Figure 7 shows the relationship between maternal age and the number of offspring per 10 000 with Down syndrome.

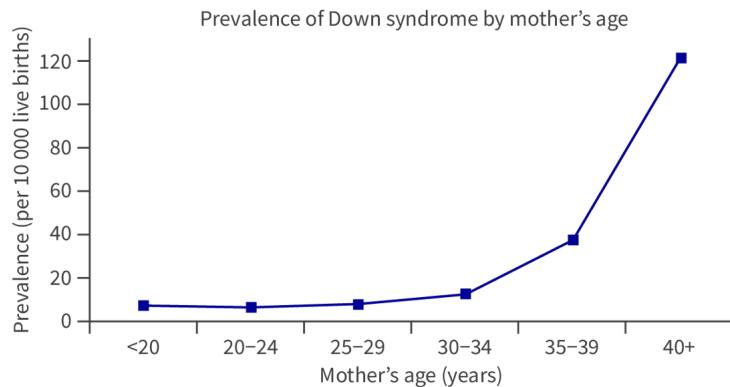


Figure 7. Maternal age and the prevalence of Down syndrome.

[More information for figure 7](#)

Study the graph and answer the questions:

1. What is the prevalence of Down syndrome in the offspring of mothers aged 35–39?
2. Outline the relationship between the prevalence of Down syndrome and maternal age in mothers aged between 20 and 29.
3. Outline the relationship between the prevalence of Down syndrome and maternal age in mothers aged between 30 and 40.
4. Explain how non-disjunction in meiosis can result in Down syndrome.
5. Although increased maternal age is a risk factor for non-disjunction, it should be noted that over 98% of children born to 40-year-old mothers will have typical chromosome numbers and 75% of children with Down syndrome are born to mothers under the age of 35. Suggest an explanation for this.
6. You might choose to watch **Video 1** for further information on Down syndrome and maternal age. This source reports slightly different numbers to the graph. Suggest why different sources might report slightly



different statistics regarding the prevalence of Down syndrome.

For further information on Down syndrome and maternal age, see **Video 1**.

The Maternal Age Effect: The Risks of Old Eggs



Video 1. Effect of maternal age.

5 section questions ▾

D2. Continuity and change: Cells / D2.1 Cell and nuclear division

The cell cycle (HL)

D2.1.12: Cell proliferation for growth, cell replacement and tissue repair (HL) D2.1.13: Phases of the cell cycle (HL) D2.1.14: Cell growth during interphase (HL)

Higher level (HL)

Learning outcomes

By the end of this section you should be able to:

- Outline the need for cell proliferation.
- Outline the phases of the cell cycle.
- Describe the changes that occur in a cell during interphase.

Most cells will only spend a very small proportion of their cell cycle proliferating. What is the function of cell proliferation? And what happens for the rest of the cell cycle?

Cell proliferation

Cell proliferation is the process of cellular division and replication. It is needed for growth, cell replacement and tissue repair.





Growth

Cell proliferation is responsible for the increase in cell number and/or organism size and complexity. In plants, growth is concentrated in regions called meristems, located in the tips of roots and shoots. Meristems are regions of undifferentiated cells that have the potential to become any cell type in the plant. Although meristem cells are stem cells, they are usually not called that so as to avoid confusion with cells in the stem of a plant. Stimulated by auxin (see [section C3.1.20–22 \(/study/app/bio/sid-422-cid-755105/book/more-on-auxins-and-cytokinins-hl-id-45755/\)](#)), cells in the meristem actively divide and differentiate, providing the cells needed for extension of the roots, stem and development of the leaves (see [section A2.2.12–14 \(/study/app/bio/sid-422-cid-755105/book/endosymbiosis-cell-differentiation-multicellular-organisms-id-44720/\)](#)).

During meristematic growth, cells at the apex, or tip, remain undifferentiated, allowing the cells behind them to specialise and differentiate into specific cell types. These regions are referred to as apical meristems (**Figure 1**), and they allow the plant to continually generate new cells while maintaining a population of undifferentiated cells that can divide and differentiate when needed.

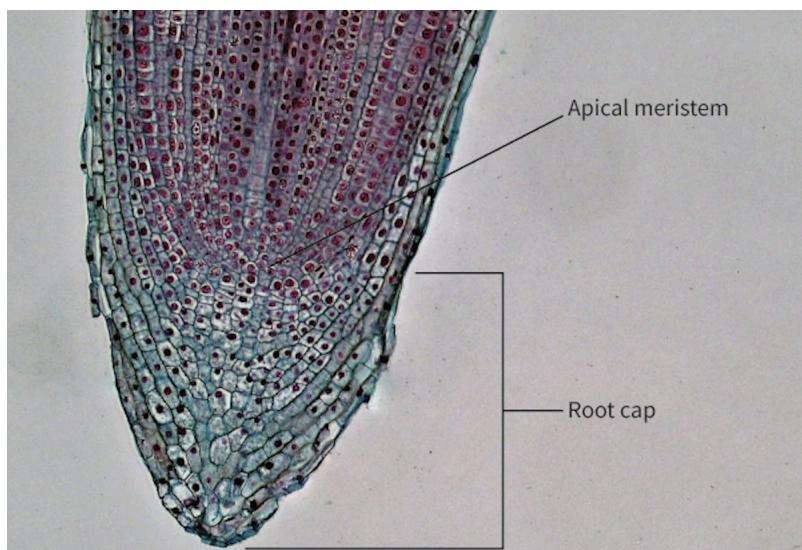


Figure 1. Apical meristem in onion root tip.

Source: Berkshire Community College Bioscience Image Library

(<https://www.flickr.com/photos/146824358@N03/34886438470/>), public domain

More information for figure 1

Similarly, during animal embryonic division, cells divide rapidly. During early human embryonic development, cell division occurs approximately once every 24 hours (**Figure 2**). This process is called cleavage and involves the division of the fertilised egg into multiple totipotent (see [section B2.3.1–4 \(/study/app/bio/sid-422-cid-755105/book/stem-cells-id-45383/\)](#)) cells, called blastomeres.

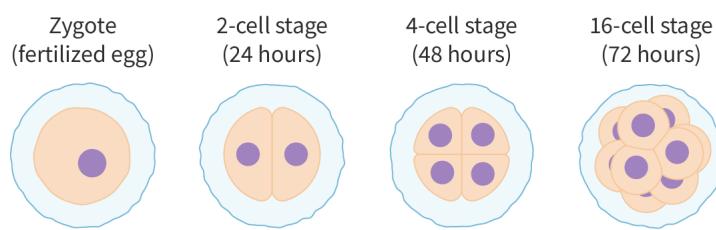


Figure 2. Cell division during early stage animal embryonic development.

More information for figure 2

As blastomeres continue to divide, they organise themselves into a structure called the blastula. The blastula then forms more complex layers that develop into specialised cells by differentiation, giving rise to the various tissues and organs of the body (see [section B2.3.1–4 \(/study/app/bio/sid-422-cid-755105/book/stem-cells-id-45383/\)](#)).

Cell replacement

Cell proliferation is necessary to replace cells, and occurs as routine in replacing the skin, which is constantly renewing itself in a process called skin turnover. In this process, new skin cells are formed from pools of stem cells in the epithelium. These stem cells divide asymmetrically to form one daughter cell that differentiates and matures, and another daughter cell that remains undifferentiated. The undifferentiated cell remains to produce more cells, and the mature cell moves upwards through the layers of the skin epidermis to replace the dead skin cells that are lost from the surface of the skin. This process helps to maintain healthy skin and ensure that this protective barrier is functioning properly (see [section C3.2.2 \(/study/app/bio/sid-422-cid-755105/book/innate-and-adaptive-immune-systems-id-45757/\)](#)).

On average, it is estimated that the skin completely renews itself approximately every 28 days. However, the rate can vary depending on factors including age, overall health and environmental factors such as sun exposure.

Tissue repair

Cell proliferation plays a critical role in wound healing, as it is responsible for the growth and repair of damaged tissues. When a tissue is damaged, cells in the surrounding area are stimulated to divide and migrate to the site of injury.

The rate at which cells proliferate to replace damaged tissues depends on the tissue type. Some tissues, such as the skin, have a high turnover rate and are constantly dividing, allowing them to quickly replace damaged cells. Other tissues, such as muscle and nerve cells, normally exist in a non-dividing state but may be stimulated to divide in response to certain stimuli, such as tissue injury or disease.

Stages of the cell cycle

Cell proliferation is achieved using the cell cycle. The cell cycle involves a sequence of events including interphase, which consists of Gap 1 (G₁), Synthesis (S) and Gap 2 (G₂), followed by mitosis and then cytokinesis (**Figure 3**).

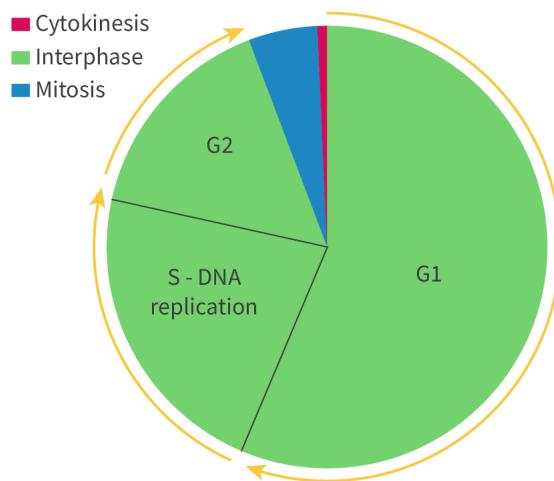


Figure 3. Phases of the cell cycle.

More information for figure 3

Interphase is the most active as well as the longest phase of the cell cycle. Cells will spend most of their life within this stage undergoing processes which are outlined in **Table 1**.

Table 1. Processes during interphase.

Phase	Location in cell	Processes
G1	Cytoplasm	<p>During G1, the cell grows in size and carries out normal metabolic functions including protein synthesis (see subtopic D1.2 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43547/)). Mitochondria and chloroplasts (in the case of plant cells) undergo replication through binary fission, a process that supports the endosymbiotic theory (see section A2.2.12–14 (/study/app/bio/sid-422-cid-755105/book/endosymbiosis-cell-differentiation-multicellular-organisms-id-44720/)).</p> <p>As a result of this growth, the cell approximately doubles in size.</p> <p>The G1 phase is also a checkpoint where the cell checks its internal environment to ensure that it is ready for DNA synthesis.</p>
S	Nucleus	<p>DNA replication occurs (see subtopic D1.1 (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43546/)), doubling the amount of DNA in preparation for nuclear and cell division.</p>
G2	Cytoplasm	<p>The cell continues to grow and prepares for mitosis by synthesising microtubules and other proteins required for nuclear and cellular division.</p> <p>The G2 phase also acts as a checkpoint, ensuring that DNA replication has been completed accurately and the cell is ready to enter mitosis.</p>

You can find an interactive summary of the cell cycle in this [interactive cell cycle](#) (<https://www.cpalms.org/Public/PreviewResourceStudentTutorial/Preview/123631>).

Try the activity to recreate the events of the cell cycle.

Activity

- **IB learner profile attribute:** Thinker
- **Approaches to learning:** Thinking skills — Designing procedures and models
- **Time required to complete activity:** 20 minutes
- **Activity type:** Individual activity

Make a stop motion animation using an application of your choice or draw a cartoon to show what happens in the different parts of the cell cycle. Alternatively, you could use modelling clay to model chromosomes and cells.

5 section questions ▾



Higher level (HL)

Learning outcomes

By the end of this section you should be able to:

- Describe how cyclins control the cell cycle.
- Explain the possible consequences of mutations in genes that control the cell cycle.
- Calculate mitotic index and explain the difference in mitotic index between cancerous and non-cancerous tissue.

The cell cycle is usually tightly regulated. What are the substances that control the cell cycle? And what happens when control of the cell cycle is compromised?

Control of the cell cycle using cyclins

Cyclins are a family of proteins that regulate the cell cycle. Cyclins bind to and activate cyclin-dependent kinases (CDKs), a group of enzymes that phosphorylate specific proteins to drive the cell cycle forward. Each cyclin is only active during specific stages of the cell cycle and must reach a certain concentration, known as a threshold, for the cell to progress to the next stage (**Figure 1**).

For example, Cyclin E binds to a CDK just before the S phase of interphase, which triggers DNA replication.

Once the cyclin–CDK complex has completed its task, the cyclin is degraded and the CDK is deactivated. The cell cycle then continues to the next stage where a different cyclin takes over to activate a different CDK.

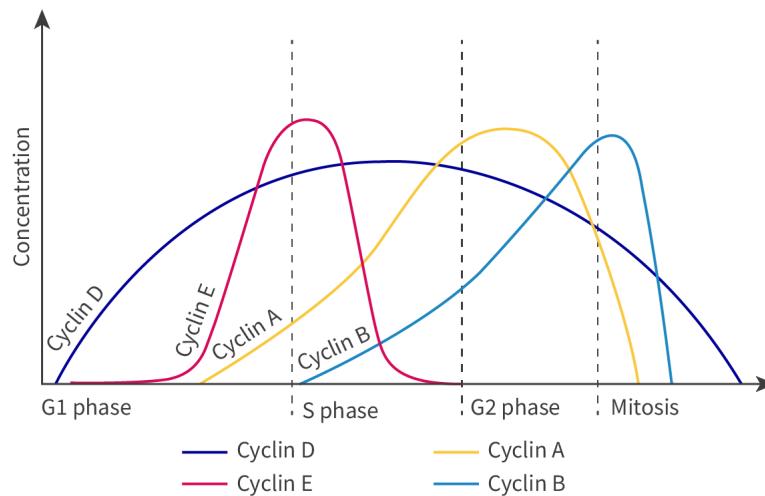


Figure 1. Fluctuating levels of different cyclins during the cell cycle.

More information for figure 1

Consequences of mutations in genes that control the cell cycle

Mutations are a change in the sequence of DNA, which can occur as part of normal DNA replication or due to external factors such as ionising radiation and exposure to mutagenic chemicals (see [section D1.3.4–7 \(/study/app/bio/sid-422-cid-755105/book/causes-and-consequences-of-gene-mutations-id-45759/\)](#)). When a

mutation occurs in a proto-oncogene or in tumour suppressor genes, this can result in uncontrolled cell division by causing the overproduction of certain cyclins.

Proto-oncogenes are genes that code for proteins that help promote cell growth and division. If a mutation in a proto-oncogene leads to these proteins becoming overexpressed, it can result in uncontrolled cell division. The mutated proto-oncogene is called an oncogene.

Tumour suppressor genes are genes that code for proteins that normally slow down or prevent cell division. They can also promote programmed cell death (apoptosis) to prevent the development of cancer. When these genes are mutated, the proteins they code for can no longer perform their protective function, leading to uncontrolled cell division.

Uncontrolled cell division can lead to the accumulation of an abnormal mass of cells, known as a tumour. Because tumour cells are derived from the body's own cells, the immune system may not recognise them as abnormal. Tumours can also secrete signalling molecules that stimulate the development of blood vessels, which supply nutrients and oxygen to the growing masses of cells.

Differences between tumours

Tumours can be classified as benign or malignant based on their characteristics and behaviours.

Benign tumours are growths of abnormal cells that are not cancerous. They tend to grow slowly and often do not cause harm unless they press into nearby tissues or organs, causing pain and other symptoms. Benign tumours have well-defined borders and do not spread to other parts of the body.

While benign tumours are usually not life-threatening, they may still require treatment if they are causing symptoms or affecting normal bodily functions. In many instances, benign tumours can be removed surgically with high success rates.

If left untreated, benign tumours can grow to become quite large, and in rare cases a benign tumour can transform into a malignant tumour.

Malignant tumours are cancerous, growing and dividing more rapidly than benign tumours. Malignant tumours often lack a well-defined border and are therefore difficult to remove completely, making them more likely to reoccur. They have the ability to spread to other parts of the body through the bloodstream or lymphatic system through a process called metastasis.

When a malignant tumour metastasises, the original tumour is called the primary tumour, and the tumour that has spread from the primary tumour is called the secondary tumour. Secondary tumours are often more difficult to treat than primary tumours because they have the ability to spread to other parts of the body and may therefore be more widespread and harder to locate and completely eliminate. The presence of secondary tumours indicates a more advanced stage of cancer, with a higher likelihood of affecting vital organs or functions, which further complicates treatment.

Malignant tumours are often targeted with a combination of treatments including surgery, radiotherapy and chemotherapy.

International Mindedness

Age-standardised rates are used in epidemiology to standardise rates of a disease in different populations that differ in age structure by adjusting for differences in age distributions. According to the World Cancer Research Fund's [↗ \(https://www.wcrf.org/cancer-trends/global-cancer-data-by-country/\)](https://www.wcrf.org/cancer-trends/global-cancer-data-by-country/) 2020 study, the country with the highest incidence of age-standardised cancer in men was Hungary, with an average of 371 men per 100 000. The country with the highest incidence of cancer in

women is Denmark at 328.3 women per 100 000. The highest rate of death from cancer in men was in Mongolia at 224.3 men per 100 000 and the highest rate of death from cancer in women was in Zimbabwe at 142.9 women per 100 000.

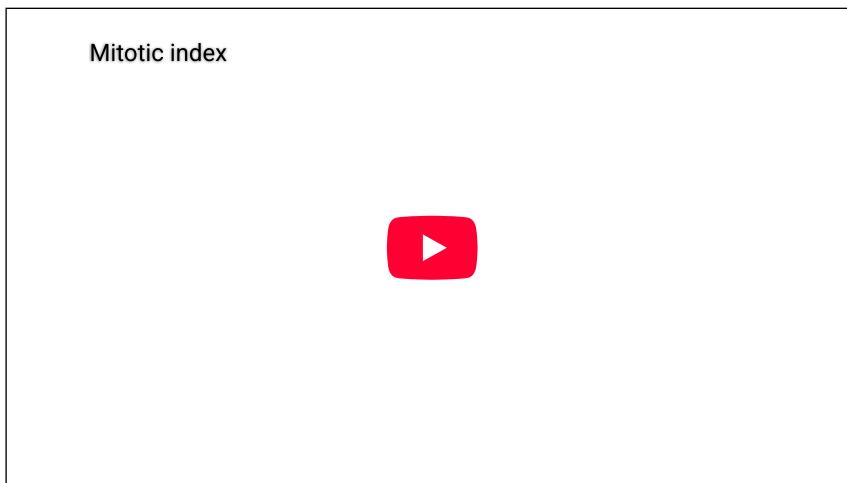
❖ Theory of Knowledge

To what extent can we attribute the variations in cancer incidence and mortality rates among different countries to factors such as genetics, lifestyle, environmental factors and access to healthcare?

Calculating mitotic index

The mitotic index is a measure of the proportion of actively dividing cells in a population, expressed as a value between 0 and 1, or as a percentage. This is calculated by dividing the number of actively dividing cells by the total number of cells. To convert this value to a percentage, multiply it by 100.

Video 1 explains how to calculate the mitotic index.



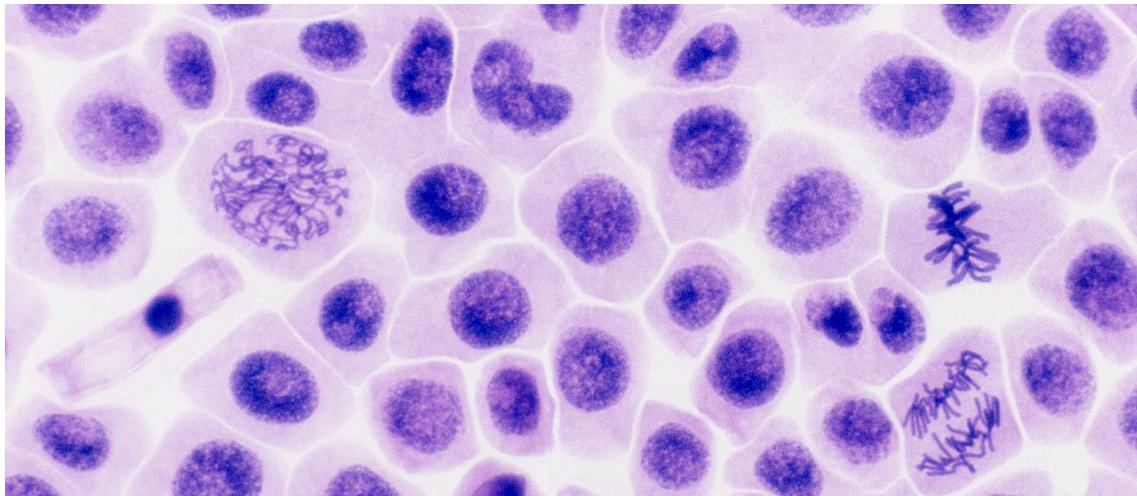
Video 1. Calculating mitotic index.

Worked example

Calculate the mitotic index of the population of cells in **Interactive 1**. Express your answer as a percentage.



Overview
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Interactive 1. Mitotic Index Calculation.

More information for interactive 1

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/the-cell-cycle-hl-id-43813/print/)

Assign

Tip: you can use the slider in Interactive 1 to show these cells.

The total number of cells in the population (only include cells that are fully inside the boundary of the image)
= 48

$$\begin{aligned} \text{mitotic index} &= \frac{\text{the number of cells undergoing mitosis}}{\text{the total number of cells in the population}} \\ &= \frac{7}{48} \\ &= 0.1458 \end{aligned}$$

To express this as a percentage, multiply by 100 = 14.58%

The mitotic index is used as a measure of cell proliferation and growth rate. Cells that rapidly proliferate, such as early stage embryonic cells, skin cells, meristem cells and epithelial cells in the intestines, will have higher mitotic indexes than cells that proliferate more slowly.

In a [study](https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2133.1968.tb11901.x) (<https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2133.1968.tb11901.x>) carried out on normal epidermis cells, it was found that, in epidermal cells from men, between 1 and 44 out of 1000 will undergo mitosis in a 5-hour period, and for women between 1 and 17 epidermal cells out of 1000 will undergo mitosis in a 5-hour period. It should be noted that these data are specific to epidermal cells and other cell types may have higher or lower mitotic indexes.

The mitotic index is usually elevated in tumorous tissue because cancerous cells proliferate more quickly than normal cells. It can be used as a diagnostic tool, as a high mitotic index can indicate that a tumour is rapidly growing and is more likely to spread. In contrast, a low mitotic index may suggest that a tumour is less aggressive and may be more responsive to treatments such as chemotherapy.

Try the activity to help with your understanding of the cell cycle.



Student
view



Activity

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Research skills — Comparing, contrasting and validating information
- **Time required to complete activity:** 10 minutes
- **Activity type:** Individual activity

Explore [this interactive activity](http://media.hhmi.org/biointeractive/click/cellcycle/) (http://media.hhmi.org/biointeractive/click/cellcycle/) to consolidate your knowledge, add to your notes and find out more about the cell cycle.

5 section questions ▾

D2. Continuity and change: Cells / D2.1 Cell and nuclear division

Summary and key terms

- Cytokinesis is the physical separation of the cytoplasm of the parent cell into two daughter cells. Animal cells use a contractile ring which pinches the cell membrane inwards, creating a cleavage furrow, while plant cells create a cell plate from fused vesicles, which grows outwards and merges with the existing cell wall. Although cytokinesis is typically equal, both oogenesis and budding in yeast involve unequal division.
- Mitosis and meiosis are both types of nuclear division. Before either can occur, DNA replication is necessary. At the start of both types of nuclear division, DNA will condense into chromosomes in the form of two sister chromatids joined together at a centromere. Condensation allows the efficient separation of DNA, a process which also occurs in both types of nuclear division and is achieved using microtubules and microtubule motors.
- Mitosis results in the formation of two genetically identical daughter nuclei through four distinct stages: prophase, metaphase, anaphase and telophase. During prophase, DNA condenses, the nuclear membrane breaks down and spindles fibres form. In metaphase, spindle fibres attach to centromeres, putting the sister chromatids to the metaphase plate (middle of the cell). During anaphase sister chromatids are separated, pulled to either pole by the spindle fibres. In telophase, sister chromatids reach their respective poles and decondense. The spindle fibres break down and the nuclear membrane reforms.
- Meiosis is a reduction division that generates four genetically unique haploid daughter nuclei from a diploid cell. It involves two rounds of division (meiosis I and meiosis II), each encompassing prophase, metaphase, anaphase and telophase. Crossing over in prophase I and random orientation/independent assortment in metaphase I and II lead to daughter nuclei with diverse combinations of alleles. Non-disjunction refers to the improper separation of homologous chromosomes during anaphase I or sister chromatids during anaphase II.

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Assign ▾

Higher level (HL)

- The cell cycle comprises interphase, mitosis and cytokinesis. Interphase, the longest stage, encompasses G1, S and G2. G1 involves cell growth, protein synthesis and organelle duplication. S phase involves DNA replication, while G2 phase supports further growth and synthesis of essential substances for nuclear and cellular division.
- The cell cycle is controlled by proteins called cyclins, which bind to and activate enzymes called cyclin-dependent kinases (CDKs), enabling them to modify target proteins to progress the cell through the cell cycle.
- Mutations in proto-oncogenes and tumour suppressor genes can lead to uncontrolled cell proliferation, which can lead to the formation of a tumour. Tumours can be classified as benign or malignant. Benign tumours grow slowly, are non-cancerous and usually do not cause harm unless they press into other structures or transform into malignant tumours. Malignant tumours grow quickly, are cancerous and have the potential to break off to form metastases.

secondary tumours in different parts of the body. The mitotic index can be used to quantify the proportion of cells that are actively dividing in a population, and is a useful measure when identifying whether a tissue sample is cancerous.

↓ Key terms

Review these key terms. Do you know them all? Fill in as many gaps as you can using the terms in this list.

1. In order to produce new cells and organisms nuclear and cell division is necessary. Eukaryotic cells have two types of nuclear division: mitosis and .
2. Mitosis produces two genetically diploid daughter nuclei and is necessary for growth, cell replacement, tissue repair and asexual reproduction.
3. Meiosis produces four genetically haploid daughter nuclei, which will form gametes for reproduction.
4. Following mitosis and meiosis, will occur, the physical separation of the cell cytoplasm into two daughter cells. In plant cells, this involves the formation of a cell plate, which grows outwards until it reaches the existing cell wall, whereas in animal cells, a ring pinches the cell membrane inwards.
5. [HL] Most of the cell cycle will be spent in , which consists of three phases, G1, S and G2. The cell cycle is controlled by proteins called , which can bind to and activate enzymes called cyclin-dependent kinases, which then phosphorylate other proteins in the cell to move the cell to the next stage of the cell cycle.
6. [HL] in proto-oncogenes or tumour suppressor genes can lead to the formation of tumours, which can be benign or malignant.
7. [HL] index can be used to quantify the proportion of cells in a population that are actively dividing.

Check

Interactive 1. Key Processes in Mitosis and Meiosis.

D2. Continuity and change: Cells / D2.1 Cell and nuclear division

Checklist

Section

Student...

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What you should know

After studying this subtopic you should be able to:

- Outline how new cells can be generated by cell division.
- Outline the process of cytokinesis in plant and animal cells.
- Explain that not all cells undergo equal cytoplasmic division.
- Outline the roles of mitosis and meiosis in eukaryotic cells.
- Describe the shared features of mitosis and meiosis.
- Describe the phases of mitosis.
- Identify the stages of mitosis from photomicrographs.
- Explain why meiosis is a reduction division.
- Describe the stages of meiosis.
- Describe the causes and consequences of non-disjunction.
- Explain how meiosis generates genetic diversity.

Higher level (HL)

- Outline the need for cell proliferation.
- Outline the phases of the cell cycle.
- Describe the changes that occur in a cell during interphase.
- Describe how cyclins control the cell cycle.
- Explain the possible consequences of mutations in genes that control the cell cycle.
- Calculate mitotic index and explain the difference in mitotic index between cancerous and non-cancerous tissue.

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Investigation

Section

Student...

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Feedback



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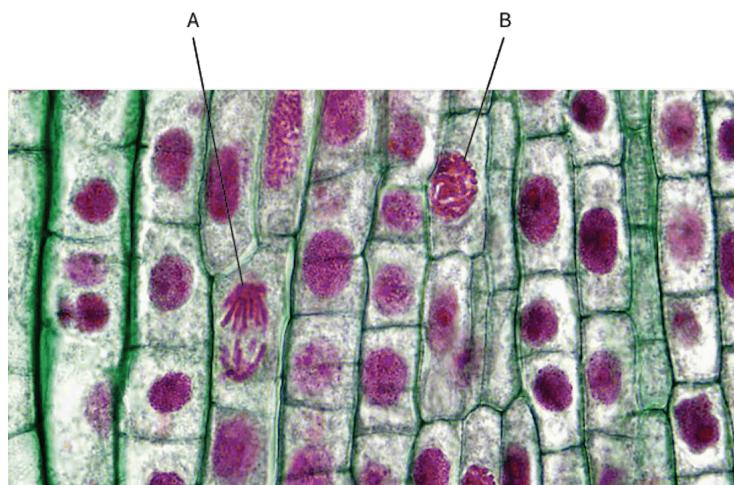
Assign

- **IB learner profile attribute:** Inquirer
- **Approaches to learning:** Thinking skills – Applying key ideas and facts in new contexts
- **Time required to complete activity:** 25 minutes
- **Activity type:** Individual activity

Your task

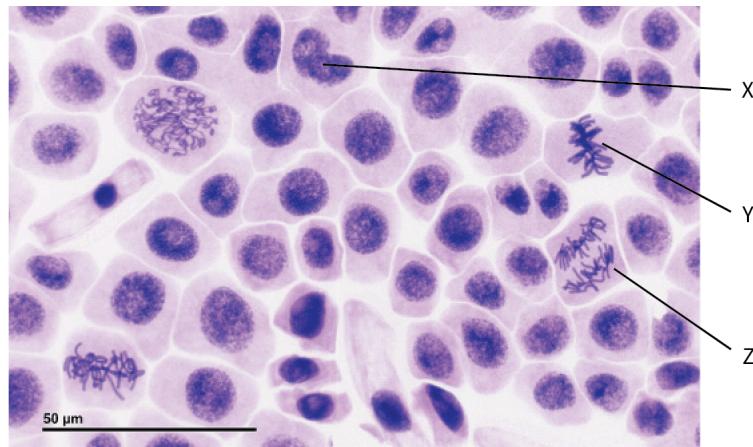
1. Identify, with a reason, whether the micrograph in **Figure 1** shows a population of plant or animal cells.

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**Figure 1.** Micrograph 1.

Source: removed to preserve challenge

2. Identify the stages of mitosis of cells A and B in **Figure 1**. Justify your answers.
3. Calculate the mitotic index of the population of cells in **Figure 1**.
4. Identify, with a reason, whether the micrograph in **Figure 2** shows a population of plant or animal cells.

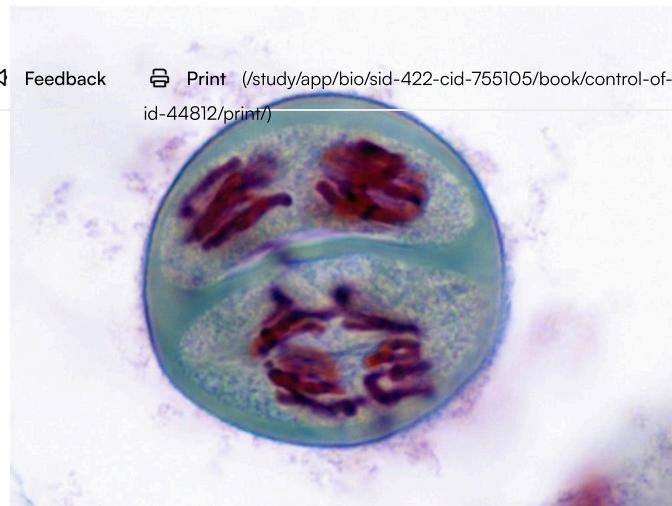
**Figure 2.** Micrograph 2.

Source: removed to preserve challenge

5. Identify the stages of mitosis of cells X, Y and Z in **Figure 2**. Justify your answers.
6. Calculate the mitotic index of the population of cells in **Figure 2**.
7. Compare the mitotic indexes of the two populations of cells in **Figures 1 and 2**.
8. Suggest reasons for differences in the mitotic indexes of these two populations.
9. Explain why it is necessary to calculate the mitotic index to compare how rapidly two different populations are undergoing mitosis.
10. The cell shown in **Figure 3** is undergoing meiosis. Identify which stage of meiosis is shown.

Assign

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**Figure 3. Micrograph 3.**

Credit: alanphillips, Getty Images

11. How do the cells produced by mitosis compare with those produced by meiosis?

D2. Continuity and change: Cells / D2.1 Cell and nuclear division

Reflection

Teacher instructions

The goal of this section is to encourage students to reflect on their learning and conceptual understanding of the subject at the end of this subtopic. It asks them to go back to the guiding questions posed at the start of the subtopic and assess how confident they now are in answering them. What have they learned, and what outstanding questions do they have? Are they able to see the bigger picture and the connections between the different topics?

Students can submit their reflections to you by clicking on 'Submit'. You will then see their answers in the 'Insights' part of the Kognity platform.

Reflection

Now that you've completed this subtopic, let's come back to the guiding question introduced in [The big picture](#) (/study/app/bio/sid-422-cid-755105/book/big-picture-id-43548/).

- How can large numbers of genetically identical cells be produced?
- How do eukaryotes produce genetically varied cells that can develop into gametes?

With these questions in mind, take a moment to reflect on your learning so far and type your reflections into the space provided.

You can use the following questions to guide you:

- What main points have you learned from this subtopic?
- Is anything unclear? What questions do you still have?
- How confident do you feel in answering the guiding questions?



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- What connections do you see between this subtopic and other parts of the course?

⚠ Once you submit your response, you won't be able to edit it.

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Submit

Rate subtopic D2.1 Cell and nuclear division

Help us improve the content and user experience.



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