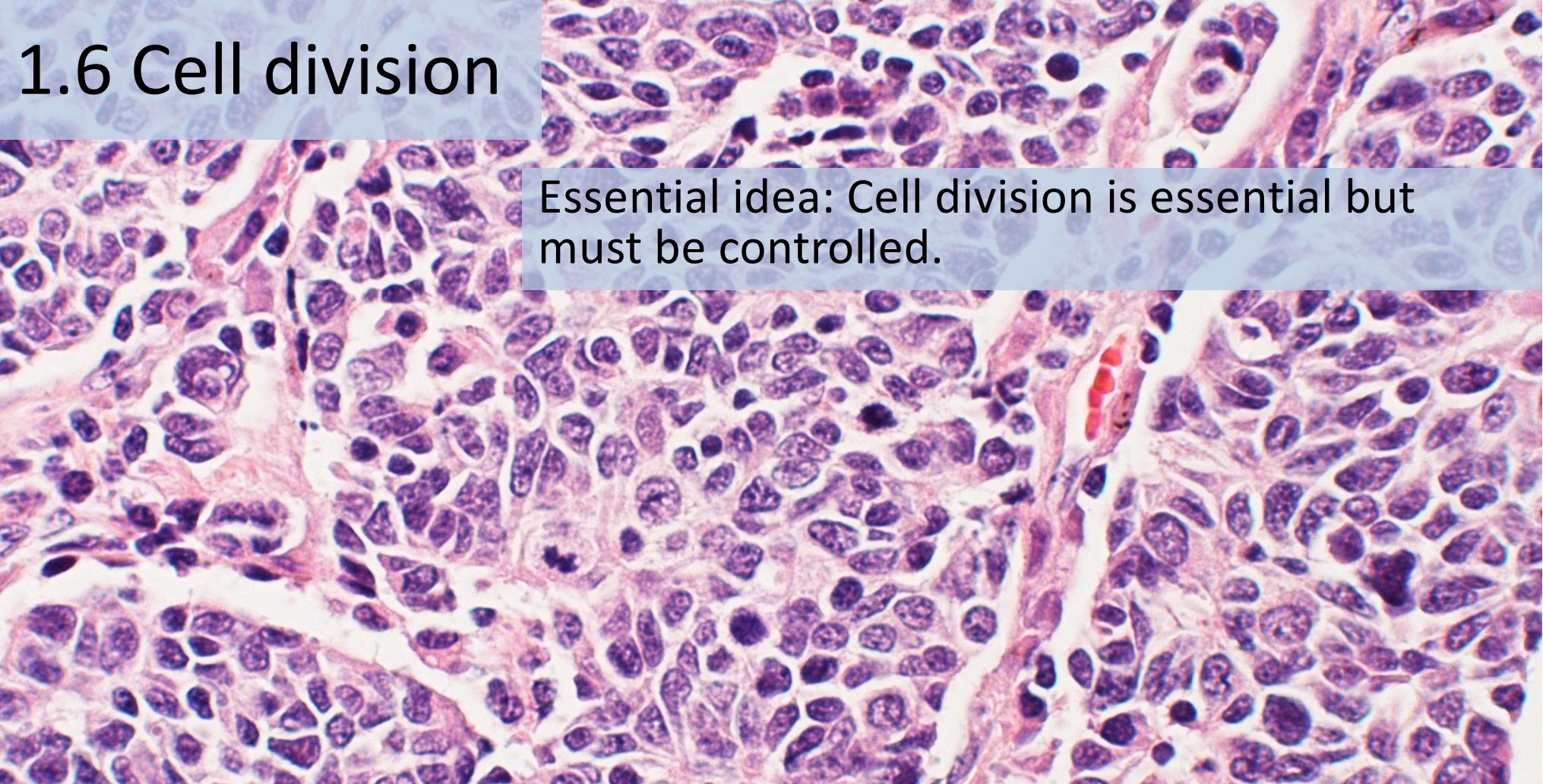


1.6 Cell division



Essential idea: Cell division is essential but must be controlled.

The background image shows a cancerous tumor in the lungs. Tumors are caused by uncontrolled cell division.

Understandings

Statement	Guidance
1.6.U1 Mitosis is division of the nucleus into two genetically identical daughter nuclei.	The sequence of events in the four phases of mitosis should be known. To avoid confusion in terminology, teachers are encouraged to refer to the two parts of a chromosome as sister chromatids, while they are attached to each other by a centromere in the early stages of mitosis. From anaphase onwards, when sister chromatids have separated to form individual structures, they should be referred to as chromosomes.
1.6.U2 Chromosomes condense by supercoiling during mitosis.	
1.6.U3 Cytokinesis occurs after mitosis and is different in plant and animal cells.	
1.6.U4 Interphase is a very active phase of the cell cycle with many processes occurring in the nucleus and cytoplasm.	
1.6.U5 Cyclins are involved in the control of the cell cycle.	
1.6.U6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumours.	

Why do cells divide?

Remember that **large cells have a reduced SA:VOL ratio** and are therefore much less efficient than smaller cells.

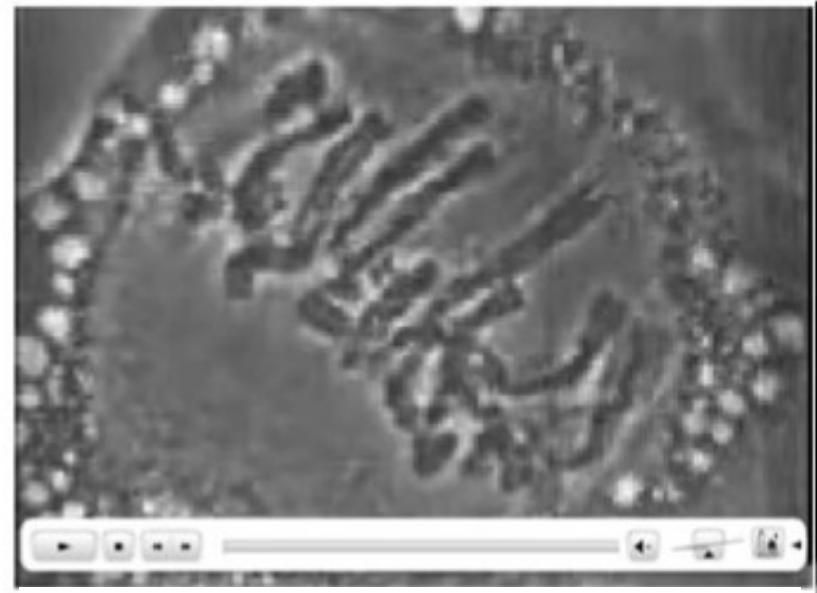
If an organism is to grow larger, it needs to produce more cells - and each of those cells needs a copy of the organism's DNA.

Cell division allows for **growth of the organism** by producing more copies of cells - and also allows for more **cell differentiation** to occur.



Cell division (specifically through mitosis) is also used in **asexual reproduction** (essentially self-replication).

Cell division footage:



<http://youtu.be/s1yIUTbXyWU>

Mitosis is happening most frequently in **developing embryos**.

New cells are also needed on a regular basis to replace dead, damaged or infected cells.

sea anemones reproduce asexually



<http://www.valdosta.edu/~jlgoble/Sea%20Anemone%20Diadumene%20Dia%2030cm%201.JPG>



In summary any time new cells are required, mitosis is required:

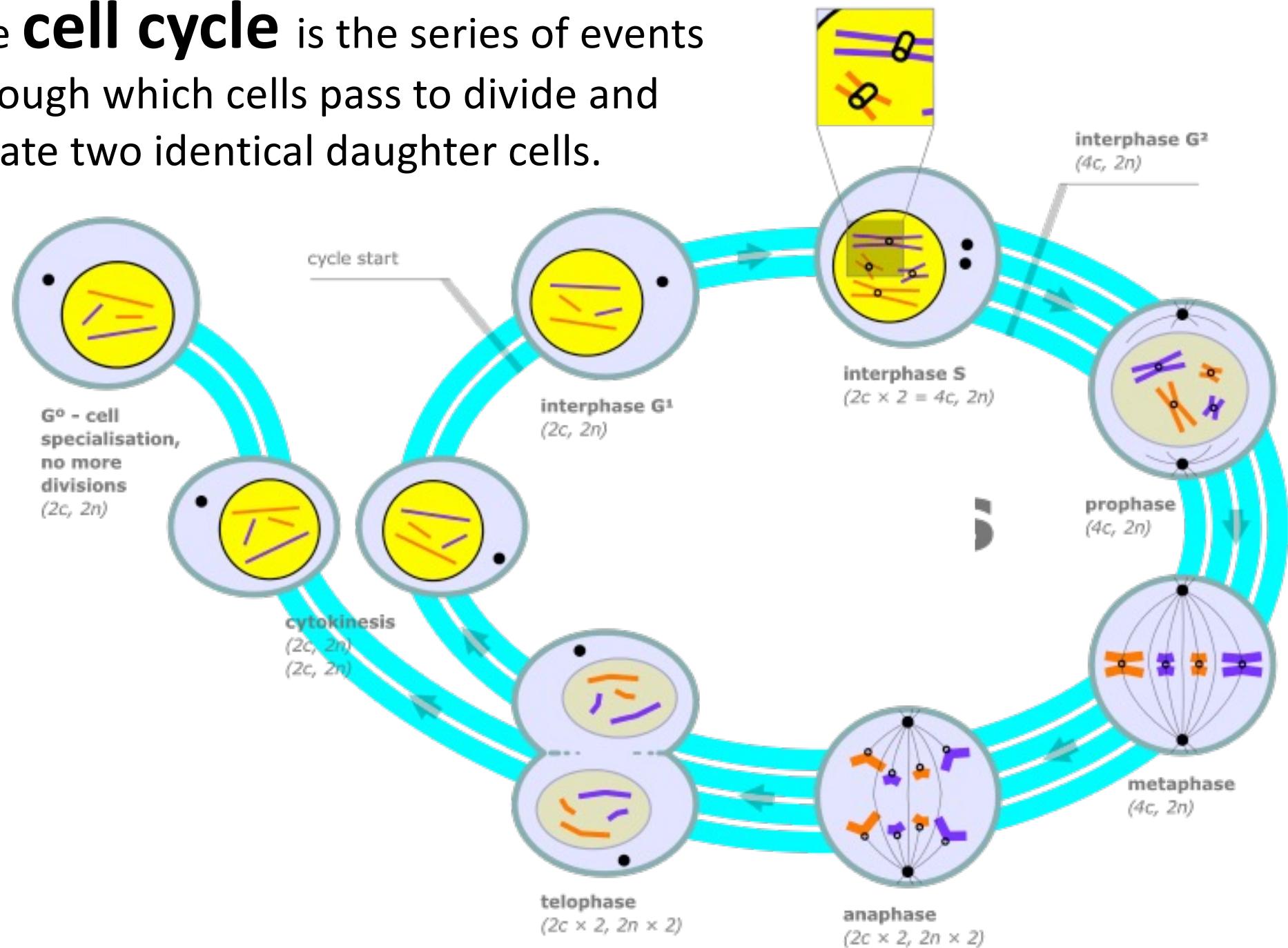
Growth: Multicellular organisms increase their size by increasing their number of cells through mitosis

Asexual reproduction: Certain eukaryotic organisms may reproduce asexually by mitosis (e.g. vegetative reproduction)

Tissue Repair: Damaged tissue can recover by replacing dead or damaged cells

Embryonic development: A fertilised egg (zygote) will undergo mitosis and differentiation in order to develop into an embryo

The **cell cycle** is the series of events through which cells pass to divide and create two identical daughter cells.



A Chromosome Story

Every eukaryote has genes on chromosomes - storage units in the nucleus.

Each chromosome has a partner - one from each parent. **Both copies are required for the cell to function.**

Different species have different chromosome numbers:

Humans = 23 pairs ($n=23$)
 \therefore **diploid number** ($2n$) = 46

Frogs = 13 pairs ($n=13$)

Corn = 10 pairs ($n=10$)

Dogs = 39 pairs ($n=39$)

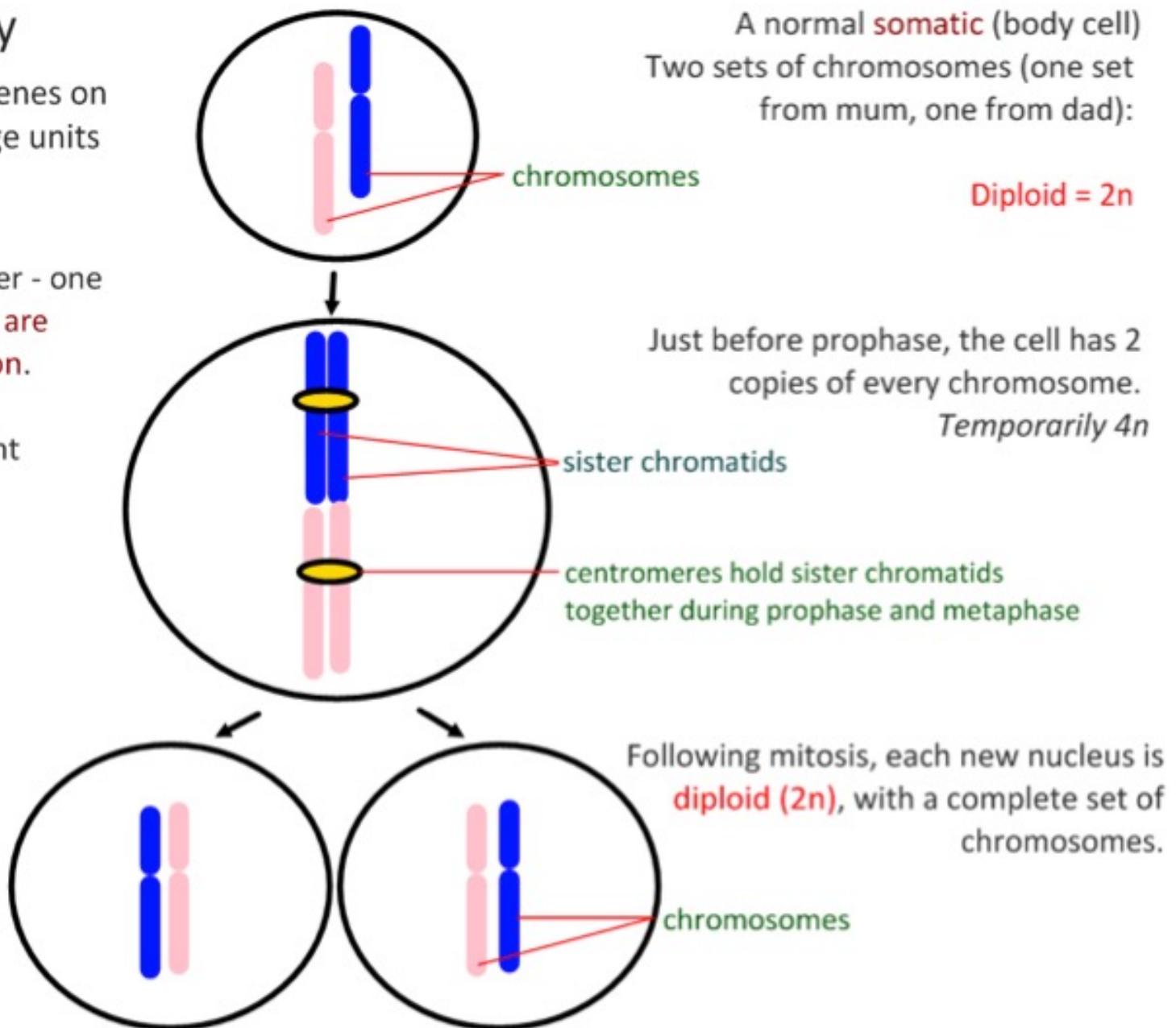
Gametes (sex cells - sperm and eggs) are **haploid** (n). They have a **half set**, as they will **pair up** with the other **half** in fertilisation.

A normal **somatic** (body cell)
Two sets of chromosomes (one set from mum, one from dad):

Diploid = $2n$

Just before prophase, the cell has 2 copies of every chromosome.

Temporarily $4n$



Following mitosis, each new nucleus is **diploid** ($2n$), with a complete set of chromosomes.

1.6.U4 Interphase is a very active phase of the cell cycle with many processes occurring in the nucleus and cytoplasm.

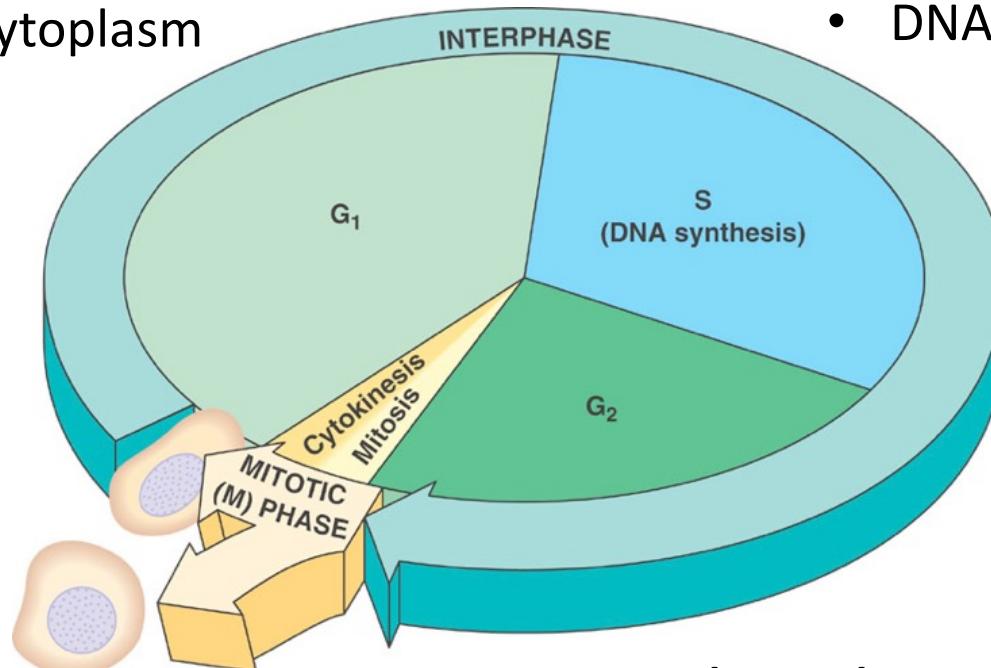
Interphase consists of the parts of the cell cycle that don't involve cell division.

G1 (Gap 1)

- Increase the volume of cytoplasm
- Organelles produced
- Proteins synthesised

S (Synthesis)

- DNA replicated



n.b. cells can also be said to be in **G0 (Gap 0)**. This is a 'resting' phase where the cell has **left the cycle and has stopped dividing**. Cells in G0 still carry out all their normal functions.

G2 (Gap 2)

- Increase the volume of cytoplasm
- Organelles produced
- Proteins synthesised

1.6.U4 Interphase is a very active phase of the cell cycle with many processes occurring in the nucleus and cytoplasm.

Interphase

Cells spend the majority of their time in interphase. It is a very active phase of the cycle.

This is when the cell carries out its normal functions

M
r

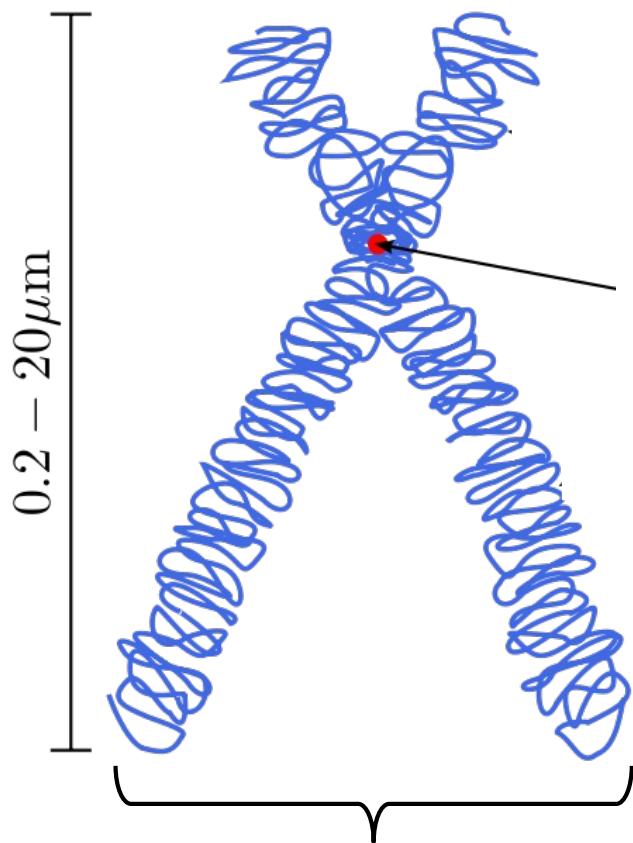
P
O

D

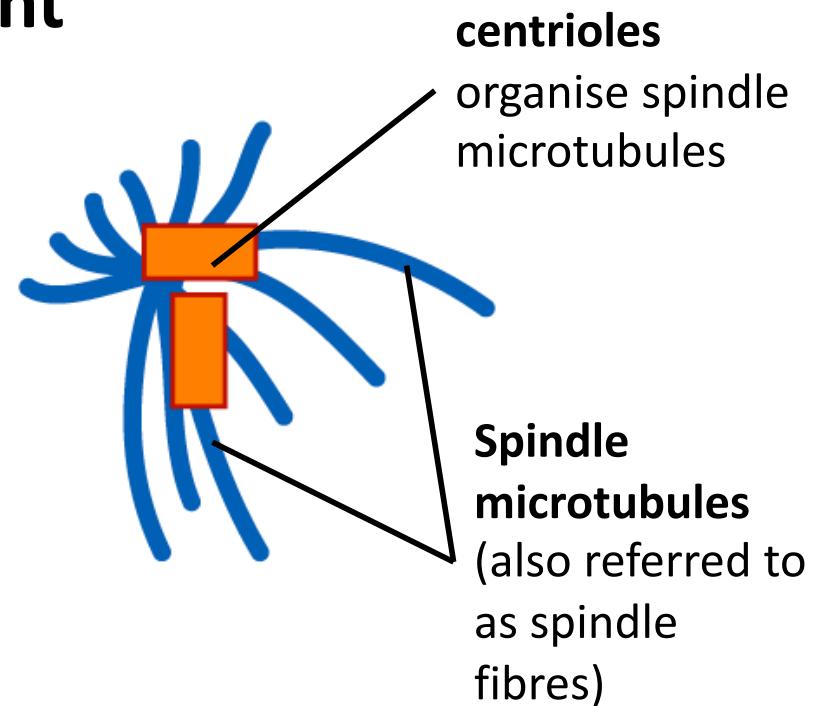
Metabolic reactions (e.g. respiration to produce ATP) are necessary for the life of the cell
Protein synthesis - proteins and enzymes are necessary to allow cell growth
Organelles numbers are increased to first support the enlarged cell
DNA is replicated to ensure a second copy is available to enable mitosis

1.6.U1 Mitosis is division of the nucleus into two genetically identical daughter nuclei.

Get the terminology right



centromere is the part of a chromosome that links sister chromatids



centrioles
organise spindle microtubules

Spindle microtubules
(also referred to as spindle fibres)

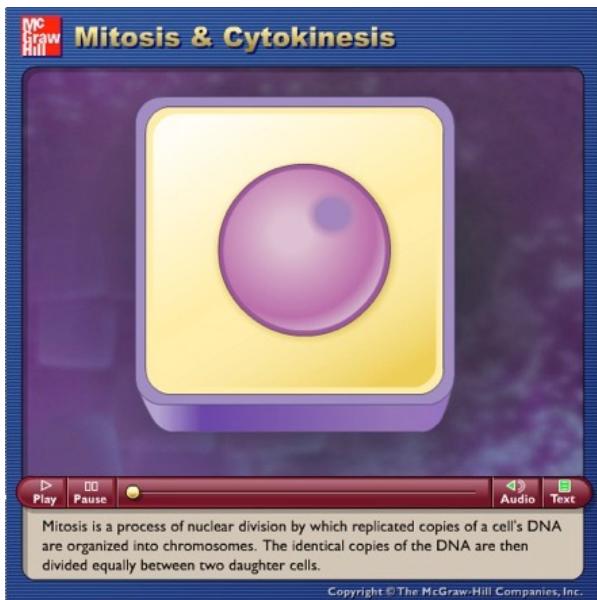
*In animal cells two centrioles are held by a protein mass referred to as a **centrosome***

Sister chromatids are duplicated chromosomes attached by a centromere

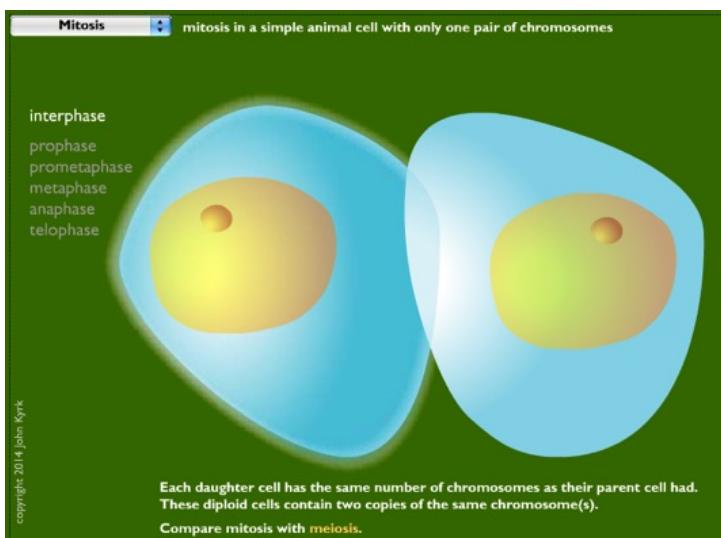
*After anaphase when the sister chromatids separate they should then be referred to as **chromosomes***

It is easy to misuse the terms chromatid and chromosome. It is even easier to confuse the terms centromere, centriole and centrosome due to their similar spelling. Keep the terms clear in your mind to avoid losing marks.

1.6.U1 Mitosis is division of the nucleus into two genetically identical daughter nuclei.

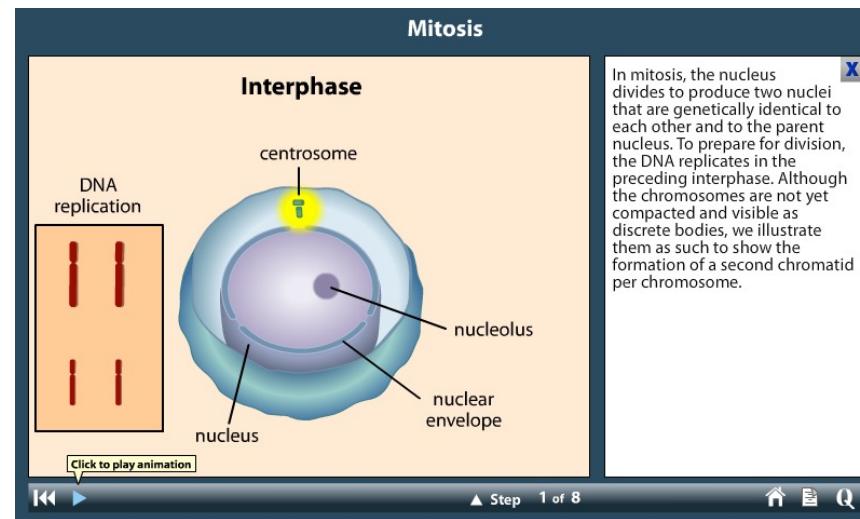


http://highered.mheducation.com/sites/0072495855/student_view0/chapter2/animation_mitosis_and_cytokinesis.html

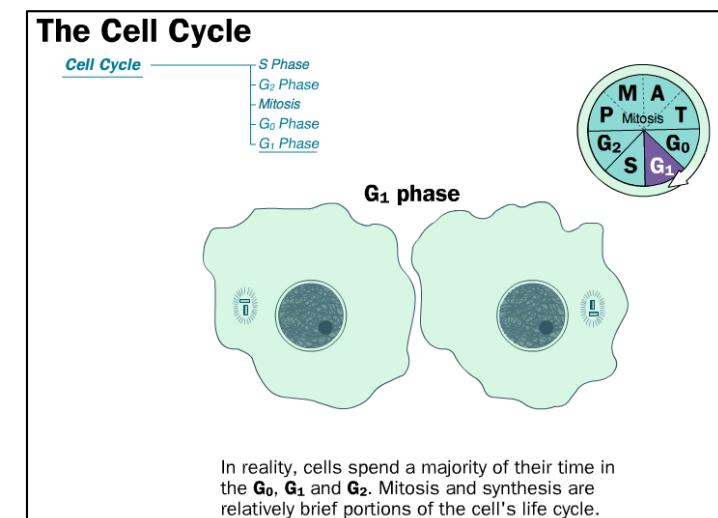


<http://www.johnkyrk.com/mitosis.html>

Use the animated tutorials to learn about mitosis

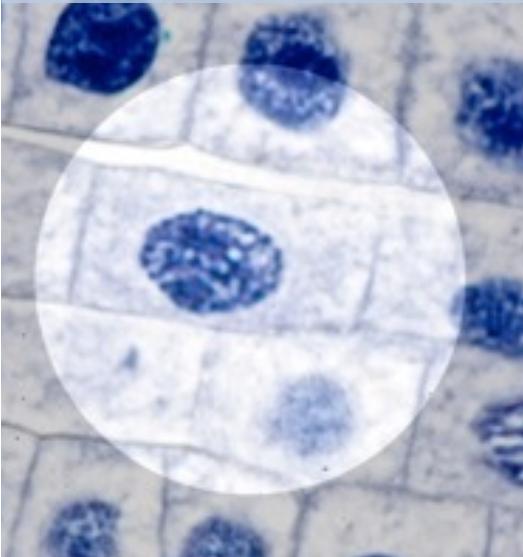


<http://www.sumanasinc.com/webcontent/animations/content/mitosis.html>



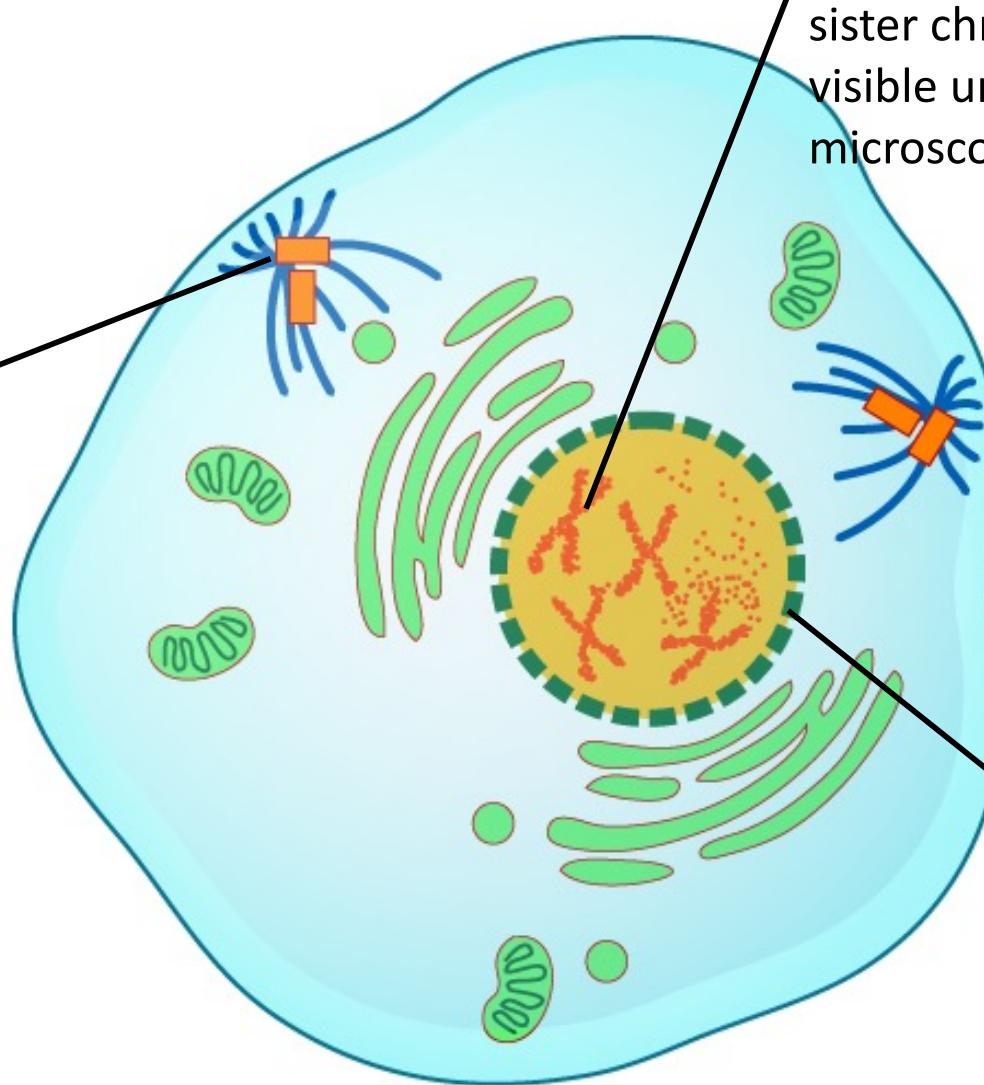
<http://outreach.mcb.harvard.edu/animations/cellcycle.swf>

1.6.U1 Mitosis is division of the nucleus into two genetically identical daughter nuclei.



Prophase

The centrosomes move to opposite poles of the cell and spindle fibres begin to form between them



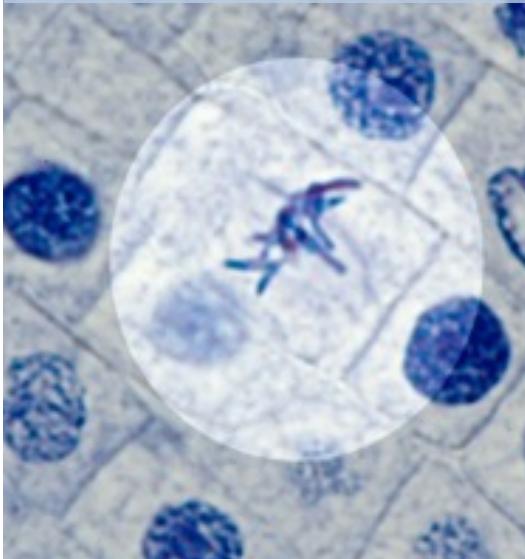
DNA supercoils* chromatin condenses and becomes sister chromatids, which are visible under a light microscope

The nuclear membrane is broken down and disappears

*supercoiling is dealt with in more detail by 1.6.U2

<http://www.microscopy-uk.org.uk/mag/artnov04macro/jironionroot.html>
http://commons.wikimedia.org/wiki/Mitosis#/mediaviewer/File:Mitosis_cells_sequence.svg

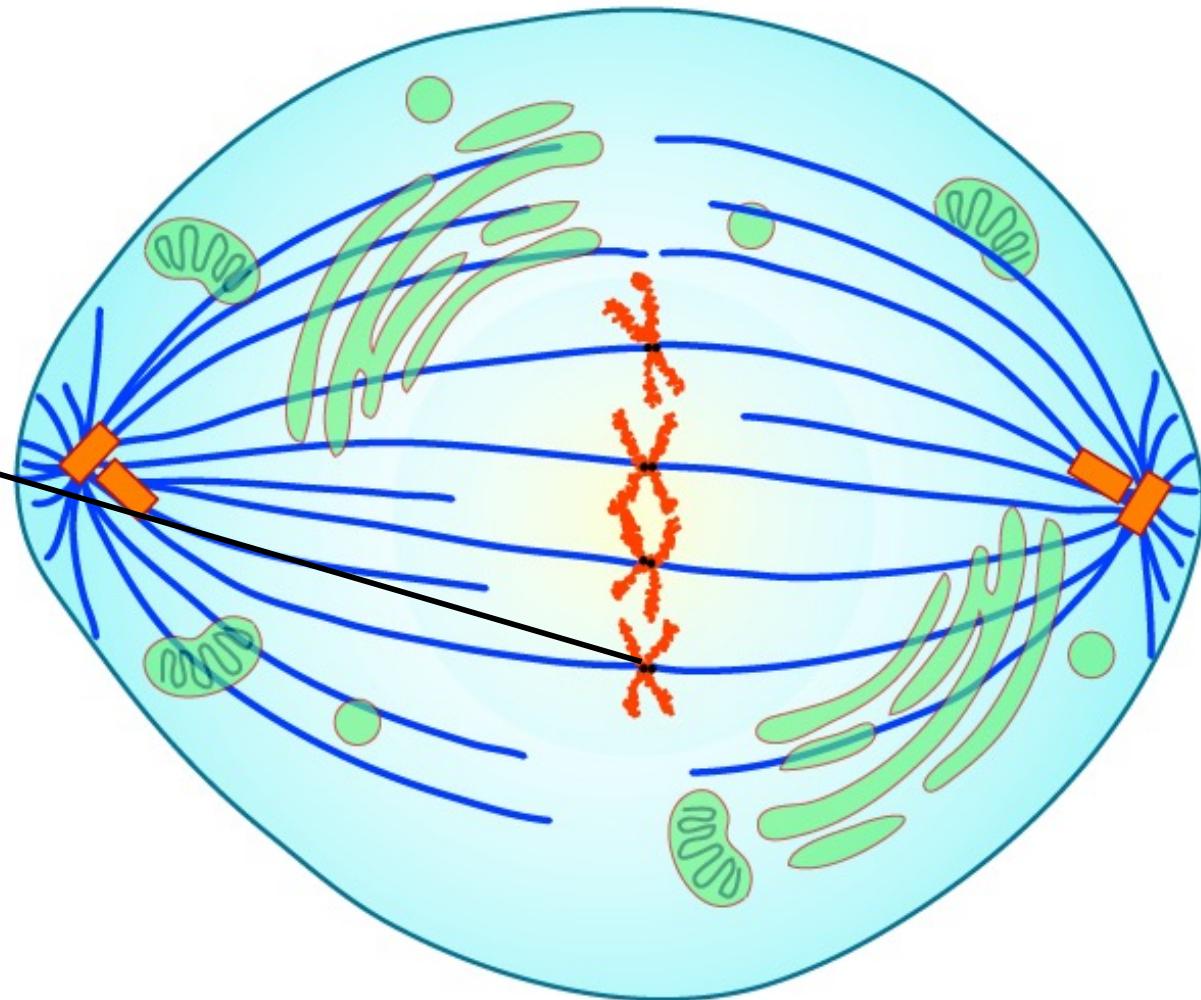
1.6.U1 Mitosis is division of the nucleus into two genetically identical daughter nuclei.



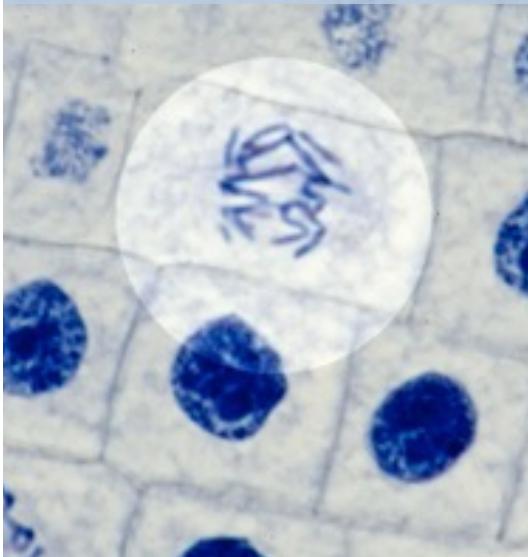
Metaphase

Spindle fibers from each of the two centrosomes attach to the centromere of each pair of sister chromatids

Contraction of the microtubule spindle fibres cause the sister chromatids to line up along the centre of the cell.



1.6.U1 Mitosis is division of the nucleus into two genetically identical daughter nuclei.

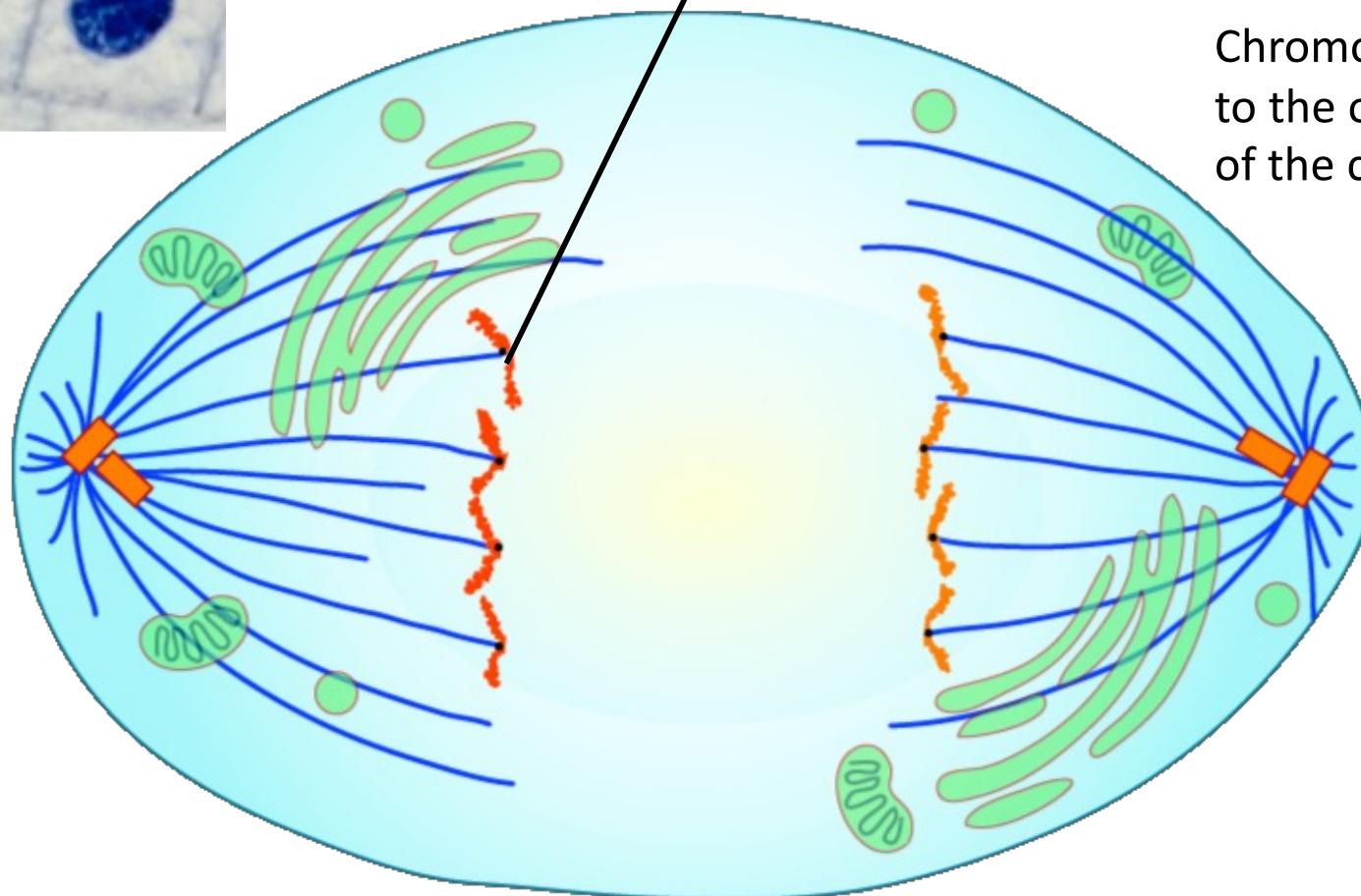


Anaphase

Continued contraction of the microtubule spindle fibres cause the separation of the sister chromatids

The chromatids are now referred to as chromosomes

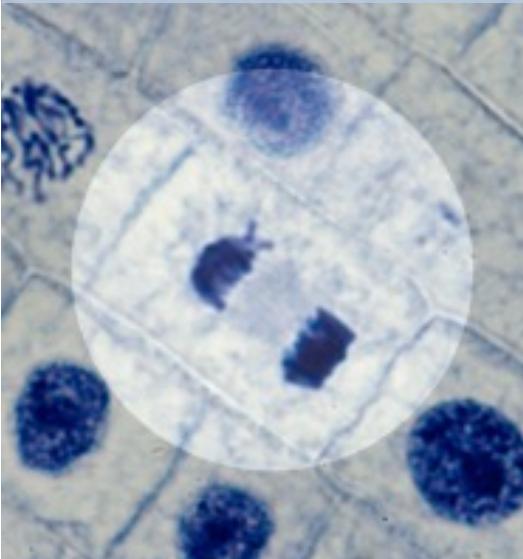
Chromosomes move to the opposite poles of the cell



<http://www.microscopy-uk.org.uk/mag/artnov04macro/jironionroot.html>

http://commons.wikimedia.org/wiki/Mitosis#/mediaviewer/File:Mitosis_cells_sequence.svg

1.6.U1 Mitosis is division of the nucleus into two genetically identical daughter nuclei.



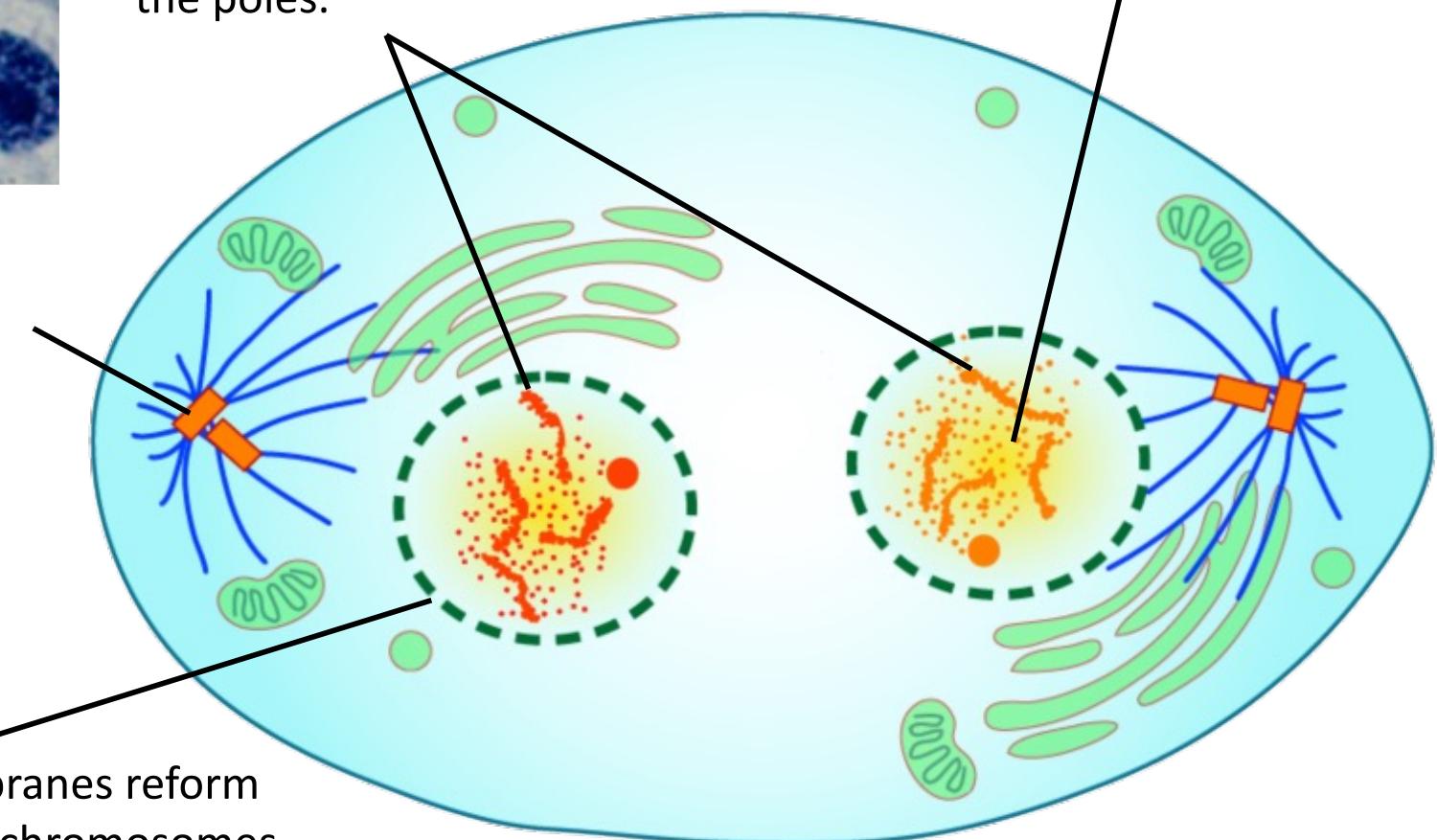
Telophase

Chromosomes arrive at the poles.

The chromosomes uncoil de-condense to chromatin (and are no longer visible under a light microscope).

Microtubule spindle fibers disappear

New nuclear membranes reform around each set of chromosomes



Now cytokinesis begins!

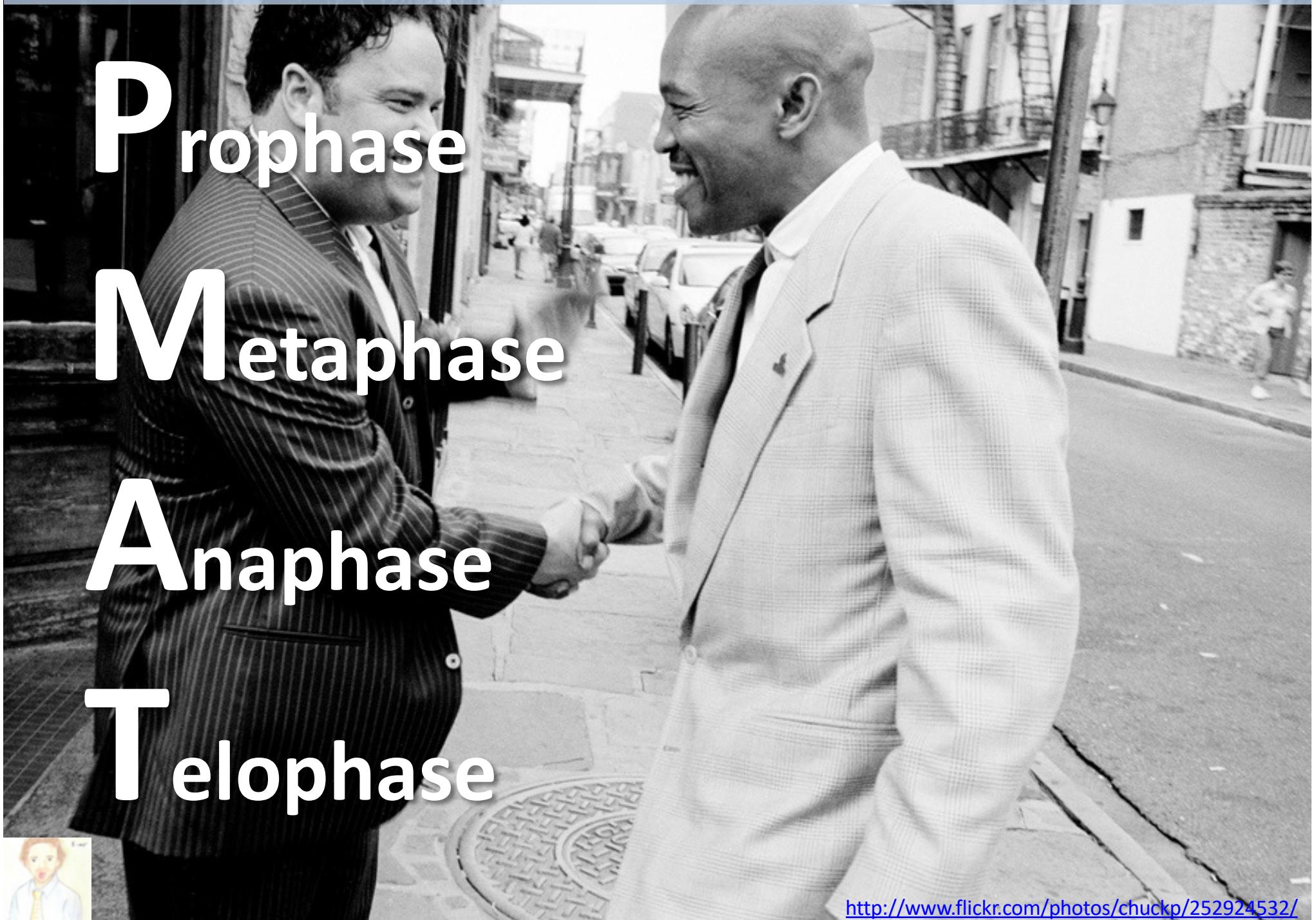
1.6.U1 Mitosis is division of the nucleus into two genetically identical daughter nuclei.

Prophase

Metaphase

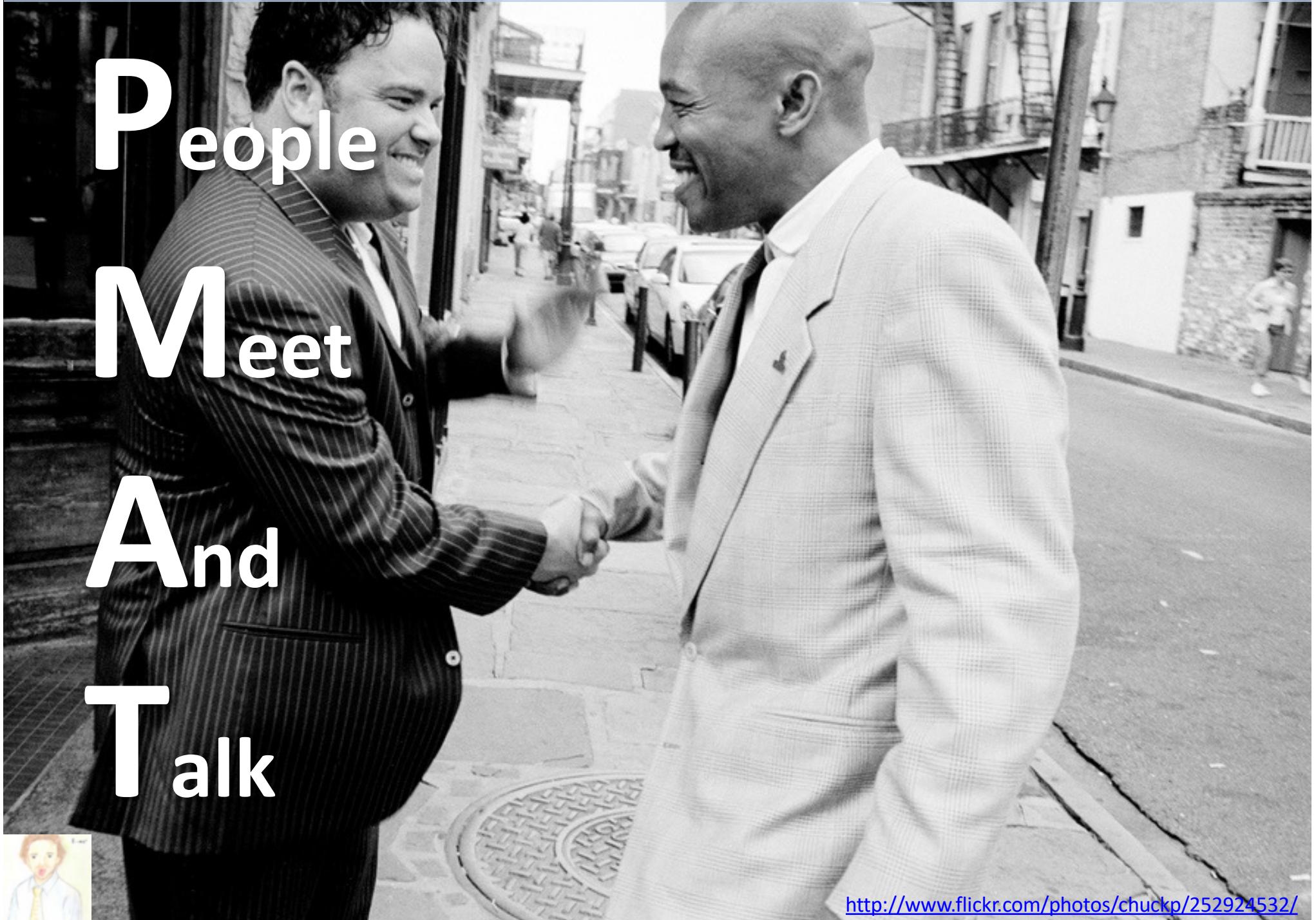
Anaphase

Telophase



1.6.U1 Mitosis is division of the nucleus into two genetically identical daughter nuclei.

P
eople
Meet
And
Talk



<http://www.flickr.com/photos/chuckp/252924532/>

1.6.U3 Cytokinesis occurs after mitosis and is different in plant and animal cells.

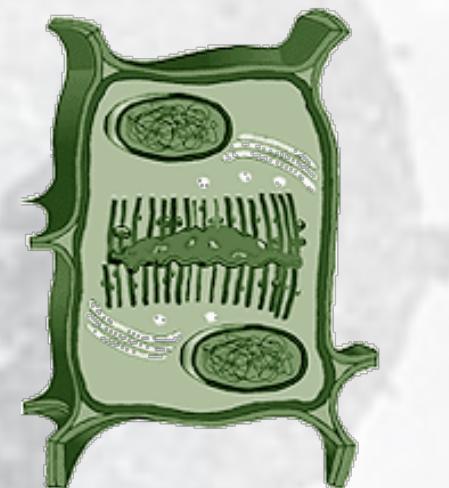
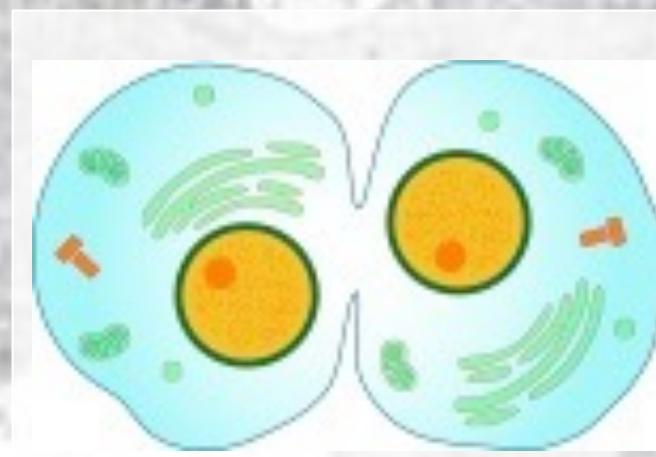
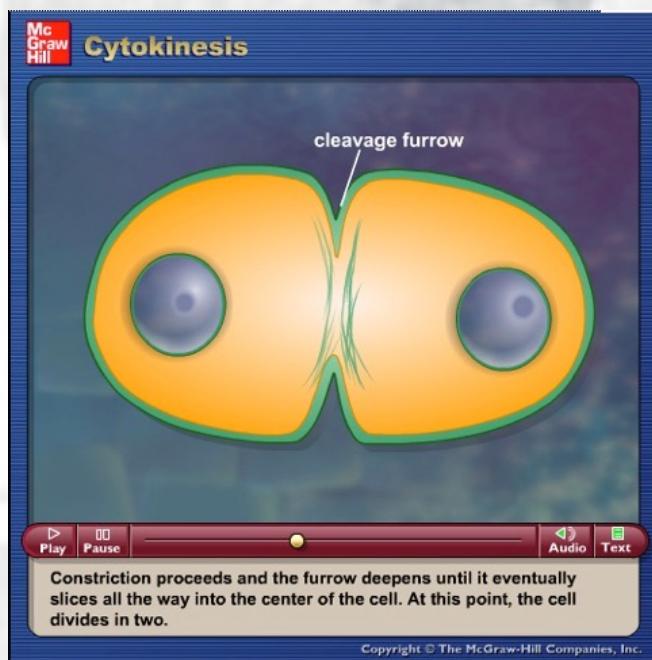


Urrrmm, we have only divided the nucleus ... what about the rest of the cell?

1.6.U3 Cytokinesis occurs after mitosis and is different in plant and animal cells.

mitosis is the division of the nucleus whereas
cytokinesis is the division of the cytoplasm
and hence the cell

The division of the cell into two daughter cells (cytokinesis) occurs concurrently with telophase.

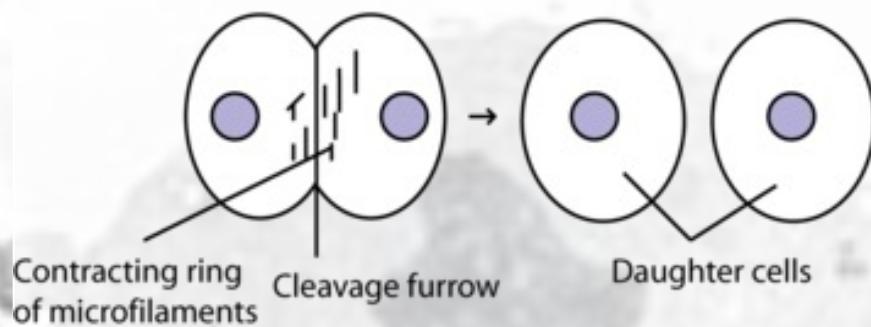


Though mitosis is similar for animal and plant cells cytokinesis is very different.

http://glencoe.mheducation.com/sites/9834092339/student_view0/chapter10/animation_cytokinesis.html

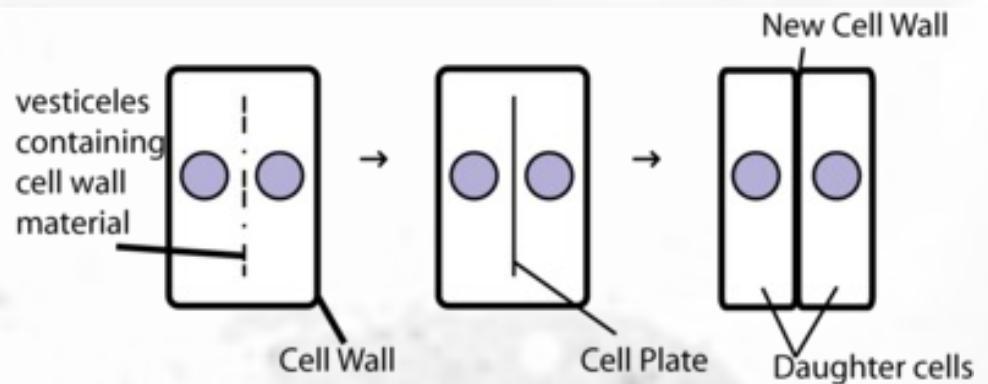
http://www.haroldsmithlab.com/images/pg_HeLa_cell_division.jpg
http://wwwprod.biochem.wisc.edu/biochem/faculty/bednarek/images/figure_color.gif
http://commons.wikimedia.org/wiki/Mitosis#/mediaviewer/File:Mitosis_cells_sequence.svg

1.6.U3 Cytokinesis occurs after mitosis and is different in plant and animal cells.



Animal cells

- A ring of **contractile protein** (microfilaments) immediately inside the plasma membrane at the equator pulls the plasma membrane inward.
- The inward pull on the plasma membrane produces the characteristic **cleavage furrow**.
- When the cleavage furrow reaches the centre of the cells it is pinched apart to form two daughter cells.



Plant cells

- During telophase, membrane-enclosed **vesicles** derived from the Golgi apparatus migrate to the centre of the cell.
- Vesicles fuse to form tubular structures.
- The tubular structures merge (with the addition of more vesicles) to form two layers of plasma membrane (i.e. the cell plate)
- The **cell plate** continues to develop until it connects with the existing cell's plasma membrane.
- This completes the division of the cytoplasm and the formation of two daughter cells.
- Vesicles deposit, by exocytosis, pectins and other substances in the lumen between the daughter cells to form the middle lamella ('gluing' the cells together)
- Both daughter cell secrete cellulose to form their new adjoining cell walls.

http://www.haroldsmithlab.com/images/pg_HeLa_cell_division.jpg

<http://upload.wikimedia.org/wikibooks/en/thumb/9/98/Cyto.png/800px-Cyto.png>

1.6.S1 Identification of phases of mitosis in cells viewed with a microscope or in a micrograph.

1.6.S2 Determination of a mitotic index from a micrograph.



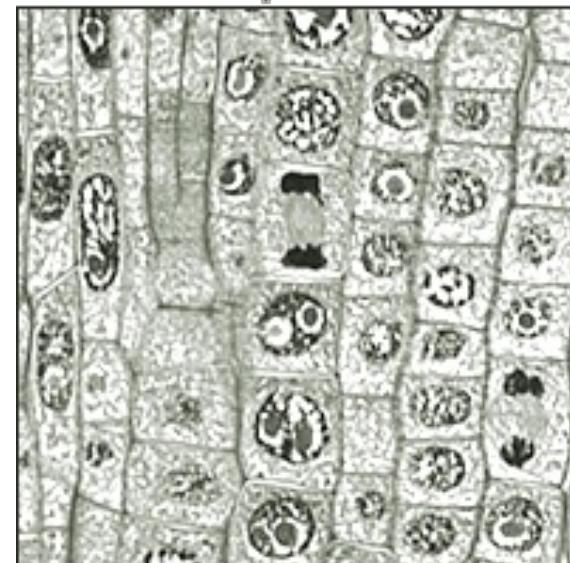
Investigating mitosis in allium root tip squash

<http://www.nuffieldfoundation.org/practical-biology/investigating-mitosis-allium-root-tip-squash>

A very good, well explained lab outline for creating slides and calculating the mitotic index.

THE BIOLOGY PROJECT • CELL BIOLOGY

Cells in the tip of an onion root

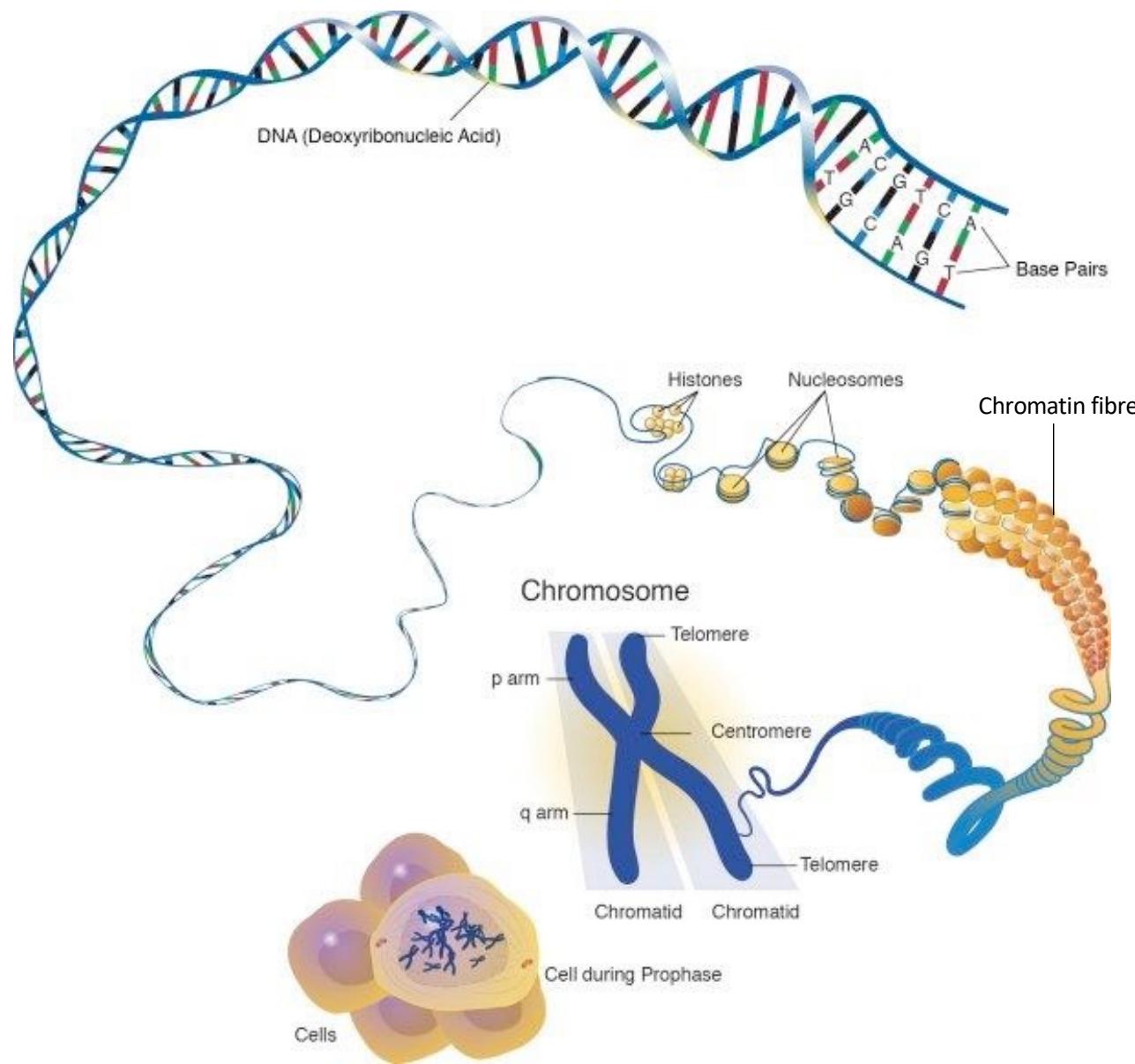


An excellent online alternative if resources don't permit students to create and view their own slides

http://www.biology.arizona.edu/cell_bio/activities/cell_cycle/cell_cycle.html

1.6.U2 Chromosomes condense by supercoiling during mitosis.

Why supercoil chromosomes?



Human cells are on average $10\mu\text{m}$ in diameter and the nucleus within each is less than $5 \mu\text{m}$ in diameter.

Human chromosomes are 15mm to 85mm ($15,000\mu\text{m}$ to $85,000 \mu\text{m}$) in length.

Chromosomes need to be stored compactly to fit within the nuclei of cells.

This problem becomes more acute during mitosis when chromosomes need to be short and compact enough that they can be separated and moved to each end of the cell.

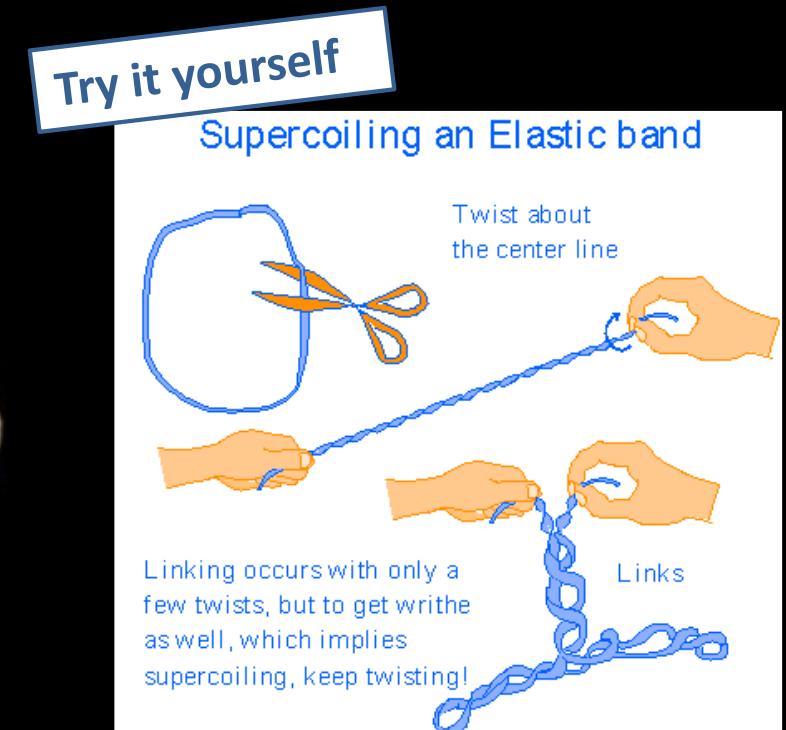
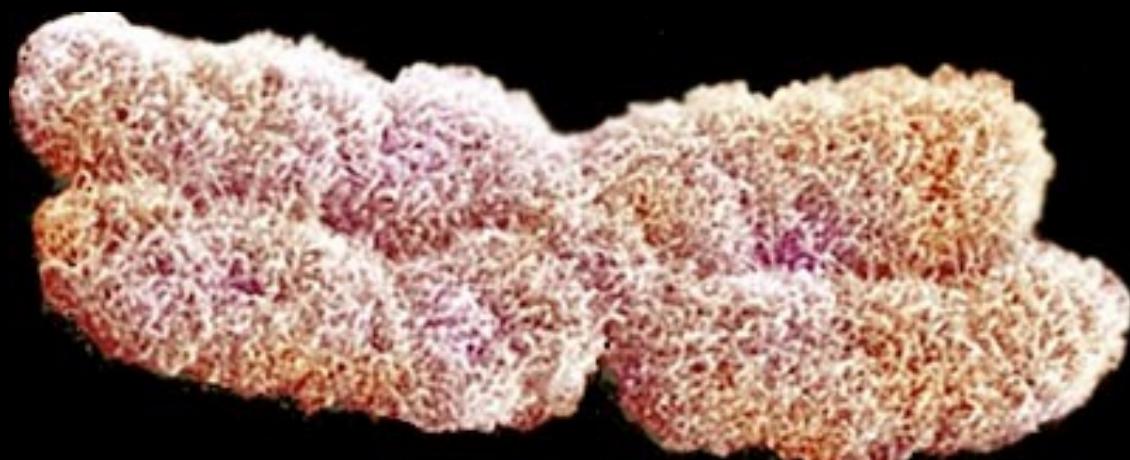
1.6.U2 Chromosomes condense by supercoiling during mitosis.

How are chromosomes supercoiled?

Strain is placed on a DNA helix by overwinding or underwinding of the helix

This causes the DNA molecule to coil back on itself becoming shorter and wider

n.b. in eukaryotes proteins called histones aid the process



1.6.U5 Cyclins are involved in the control of the cell cycle.

Cyclins are a family of proteins that control the progression of cells through the cell cycle

1

Cells cannot progress to the next stage of the cell cycle unless the specific cyclin reaches its threshold.

2

Cyclins bind to enzymes called cyclin-dependent kinases

3

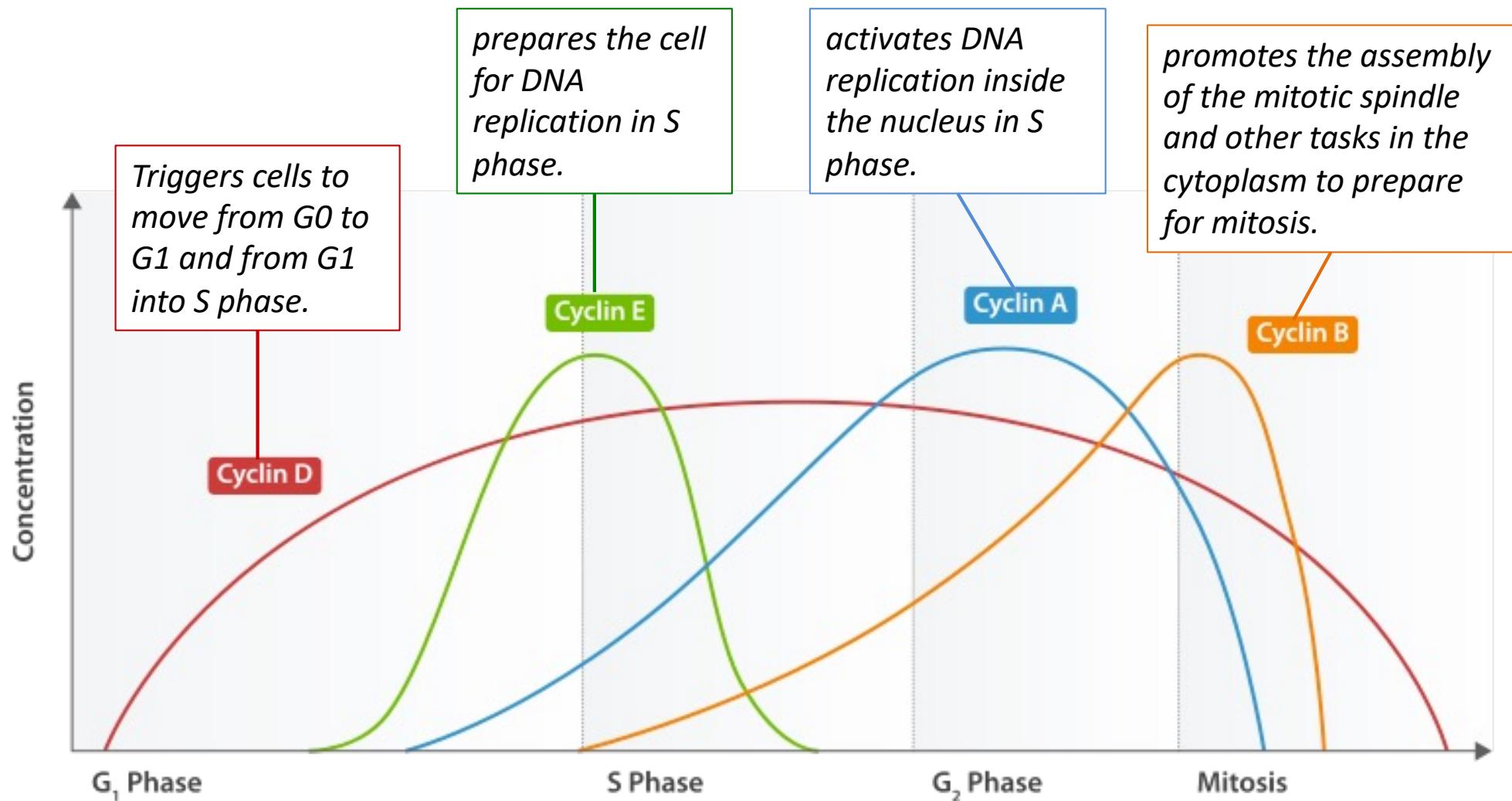
These kinases then become active and attach phosphate groups to other proteins in the cell.

4

The attachment of phosphate triggers the other proteins to become active and carry out tasks (specific to one of the phases of the cell cycle).

1.6.U5 Cyclins are involved in the control of the cell cycle.

Progression through parts of the cell cycle are affected in various ways by **specific cyclins**



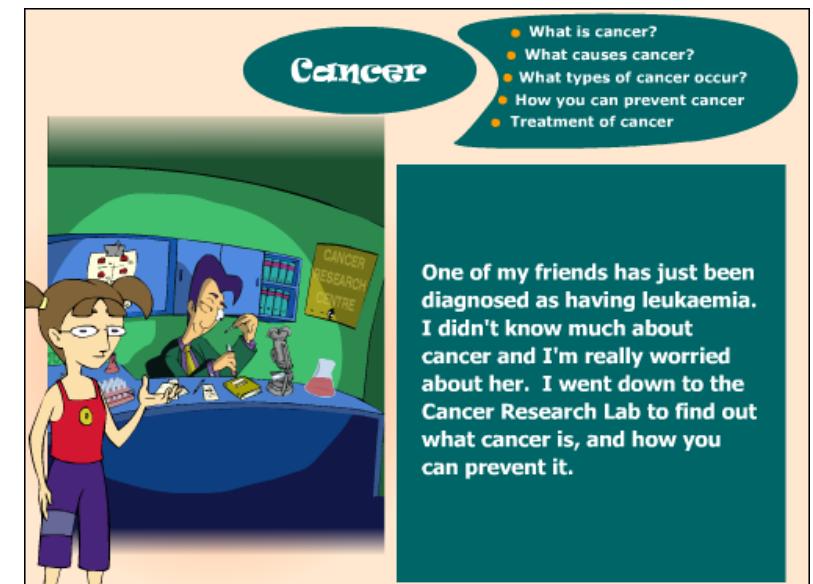
1.6.U6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumours.

Tumours are abnormal growth of tissue that develop at any stage of life in any part of the body. A **cancer** is a malignant tumour and is named after the part of the body where the cancer (primary tumour) first develops. Use the links to find out:

- most common types of cancer
- what causes cancer and associated risk factors
- how cancer can be treated

The image shows a video player interface. At the top left is the Cancer Research UK logo, which consists of a stylized 'C' made of colored dots (blue, pink, grey). To the right of the logo, the text 'CANCER RESEARCH UK' is written in a serif font. Below this, there is a video frame showing a cartoon illustration of a woman with glasses and a red tank top standing in front of a laboratory counter. On the counter, there is a computer monitor displaying a presentation slide with the word 'Cancer' in a large blue circle. To the right of the counter, a scientist with purple hair is working with a microscope. In the background, there are shelves with books and a sign that reads 'CANCER RESEARCH CENTRE'. The video player has a black control bar at the bottom with icons for play, volume, and progress. The progress bar shows '0:04 / 1:49'. The URL http://youtu.be/8BJ8_5Gyhg8 is displayed below the video frame.

The image shows a web page from Cancer Research UK. At the top left is the Cancer Research UK logo. To the right of the logo, the text 'What causes cancer?' is displayed in a large, bold, purple font. Below this, there is a link in blue text: <http://www.cancerresearchuk.org/cancer-info/cancerandresearch/all-about-cancer/what-is-cancer/>.



<http://www.e-learningforkids.org/health/lesson/cancer/>

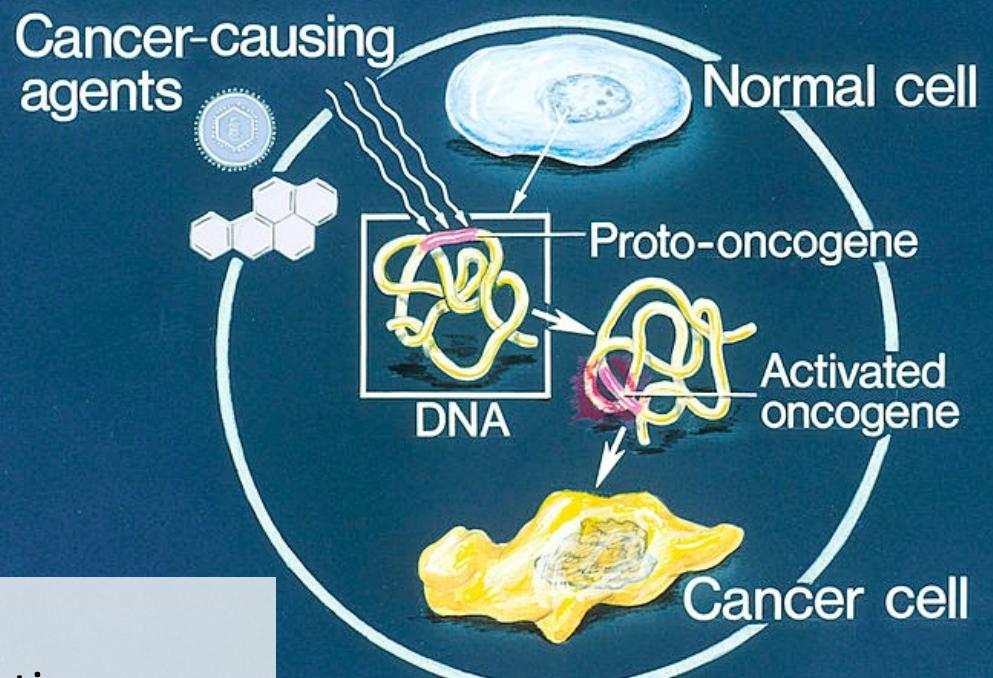
The image shows the homepage of the National Cancer Institute. The title 'National Cancer Institute' is prominently displayed in large red letters at the top. Below it, the text 'at the National Institutes of Health' is written in smaller red letters. At the bottom of the page, there is a link in blue text: <http://www.cancer.gov/cancertopics/types/commoncancers>.

1.6.U6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumours.

A **mutation** is a change in an organisms genetic code. A mutation/change in the base sequence of a certain genes can result in cancer.

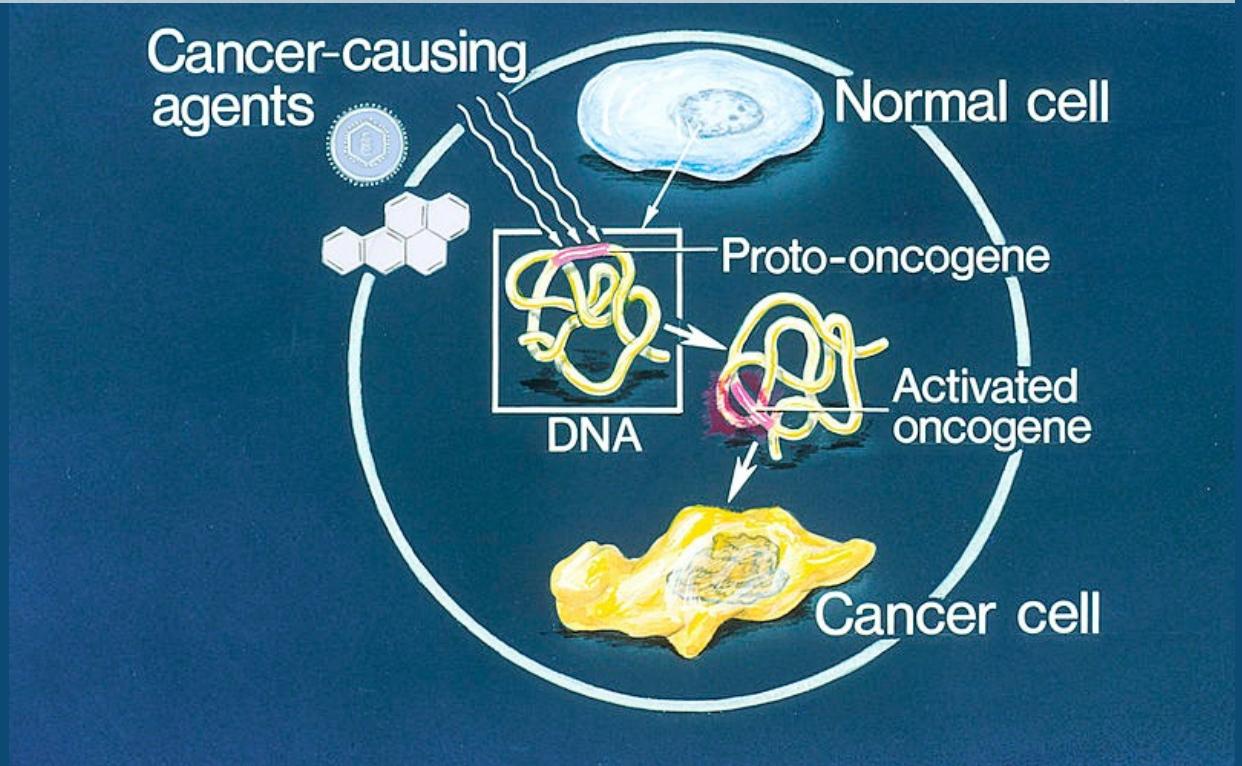
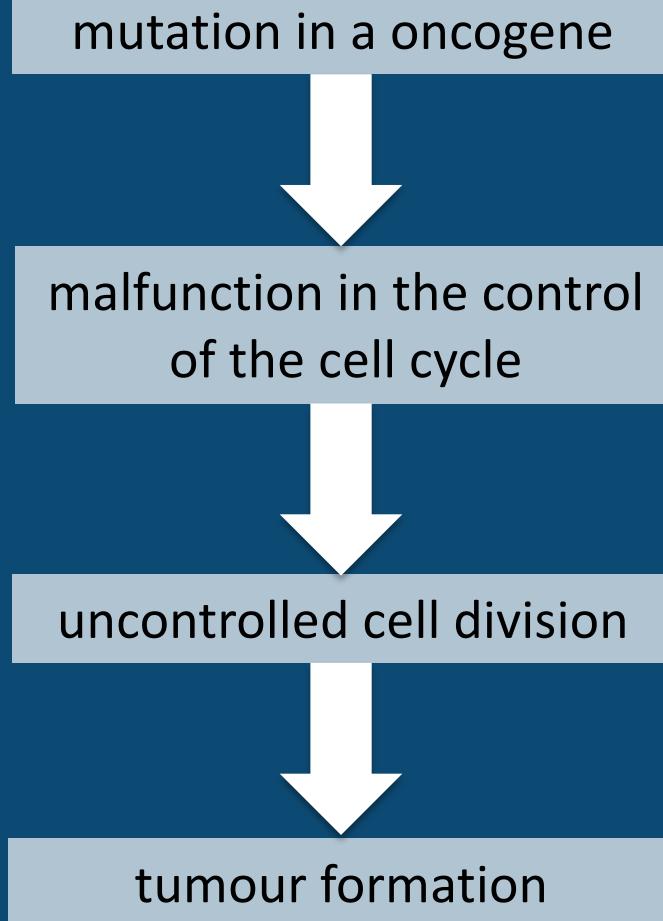
Mutagens are agents that cause gene mutations. Not all mutations result in cancers, but anything that causes a mutation has the potential to cause a cancer.

- Mutagens can be:
- chemicals that cause mutations are referred to as **carcinogens**
 - **high energy radiation** such as X-rays
 - **short-wave ultraviolet light**
 - Some **viruses**



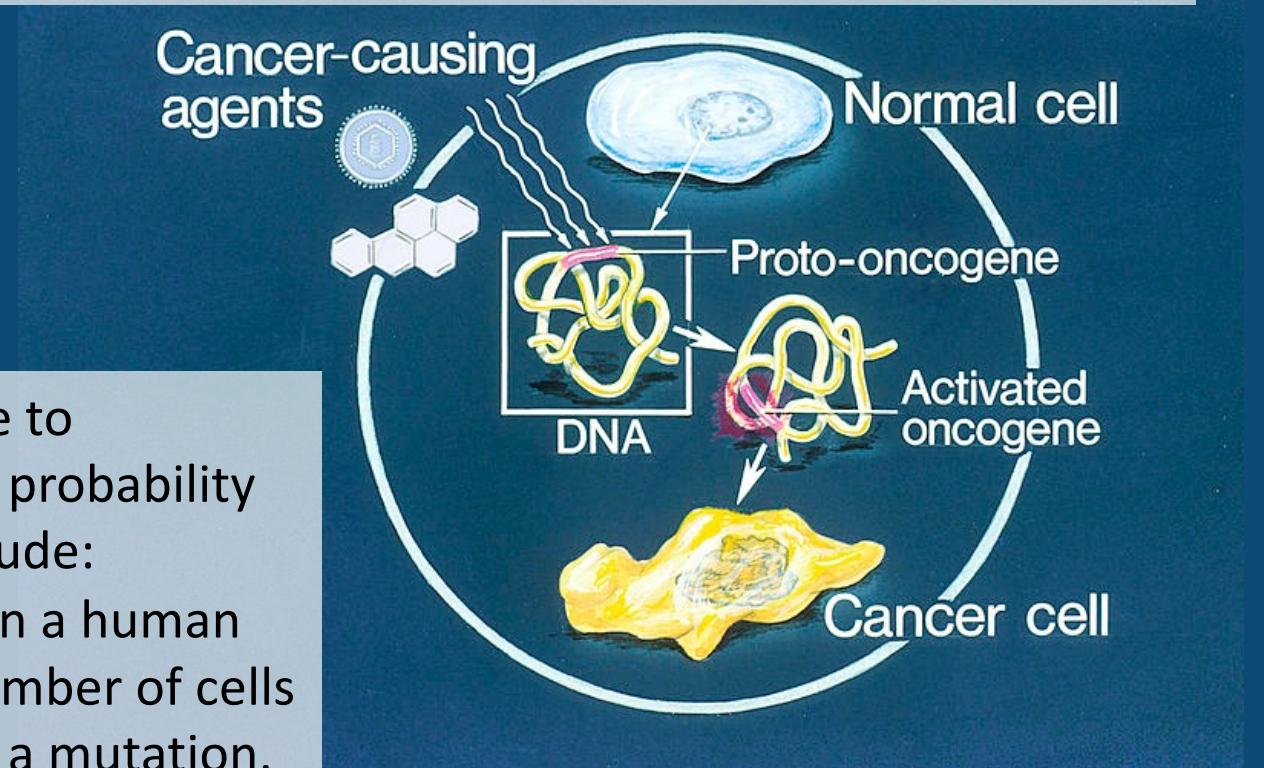
1.6.U6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumours.

If a mutation occurs in an **oncogenes** it can become cancerous. In normal cells oncogenes control of the cell cycle and cell division.



1.6.U6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumours.

Several mutations must occur in the same cell for it to become a tumour causing cell. The probability of this happening in a single cell is extremely small.



Factors (other than exposure to mutagens) that increase the probability of tumour development include:

- The vast number of cells in a human body – the greater the number of cells the greater the chance of a mutation.
- The longer a life span the greater the chance of a mutation.

1.6.U6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumours.

The development of a primary tumours (cancers) have been outlined. Below is how a primary tumor can become a secondary tumour.

A **primary tumor** is a malignant tumor growing at the site where the abnormal growth first occurred.

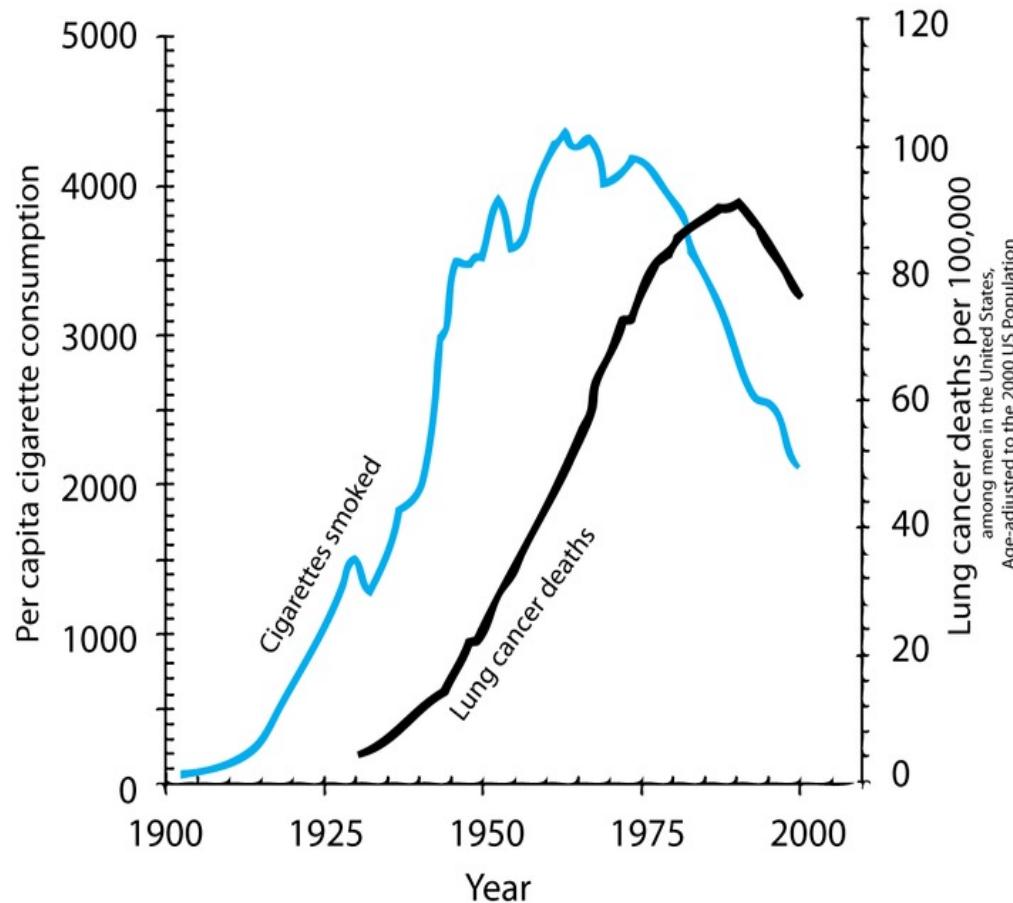
Metastasis is the movement of cells from a primary tumour to set up secondary tumours in other parts of the body.

The circulating cancerous cells invade tissues at a different locations and develop, by uncontrolled cell division, into a **secondary tumours**.

Cancerous cells can detach from the primary tumour.

Some cancerous cells gain the ability to penetrate the walls of lymph or blood vessels and hence circulate around the body

1.6.A1 The correlation between smoking and incidence of cancers.

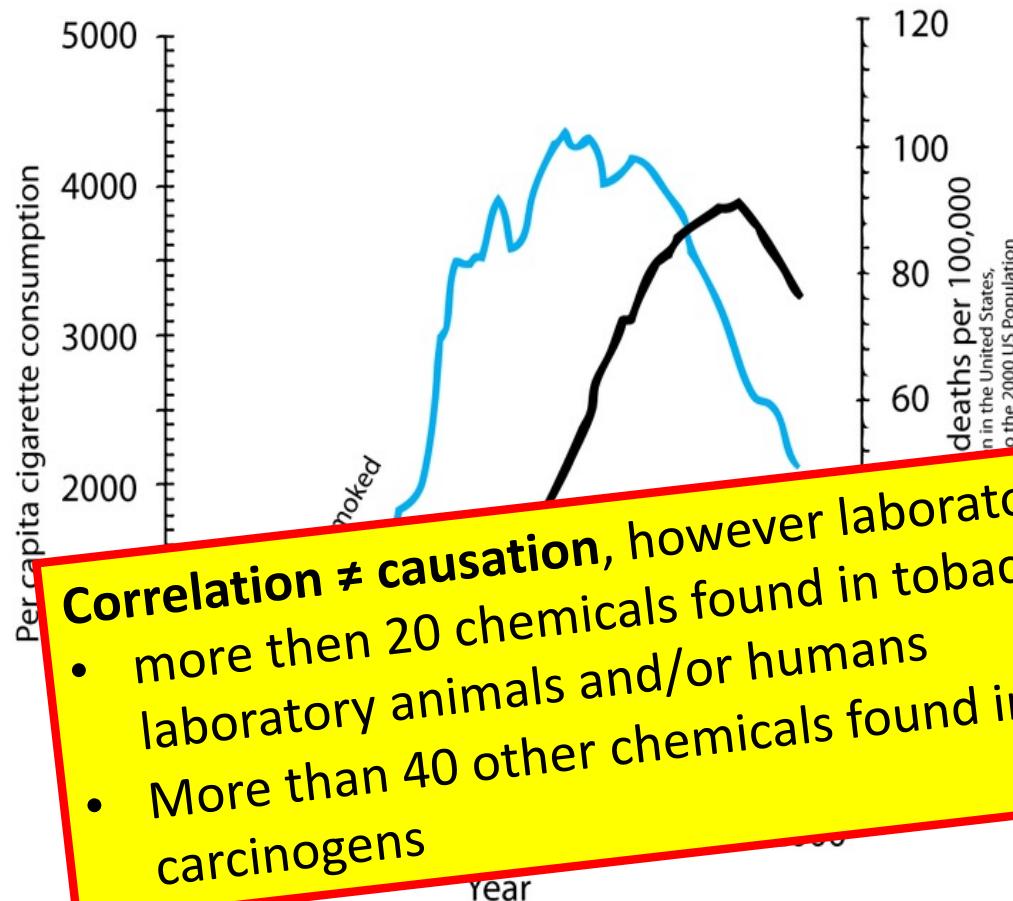


There are many other similar surveys in different countries, with different demographics that show similar results. Along with **lung** cancer, cancers of **mouth** and **throat** are very common as these areas are in direct contact with the smoke too. It might surprise you that the following cancers are also more common in smokers:

- Head and neck
- Bladder
- Kidneys
- Breast
- Pancreas
- Colon

- a. Describe the relationship shown.
- b. What type of correlation is shown
- c. How strong is the correlation? Justify your answer by discussing the evidence.
- d. The correlation shown here is lagged. A lag is a time gap between the factors. Estimate the size of the lag between cigarette consumption and lung cancer death.

1.6.A1 The correlation between smoking and incidence of cancers.



Correlation ≠ causation, however laboratory investigations have found:

- more than 20 chemicals found in tobacco have caused cancers in laboratory animals and/or humans
- More than 40 other chemicals found in tobacco have been identified as carcinogens

- a. Describe the relationship shown.
- b. What type of correlation is shown
- c. How strong is the correlation? Justify your answer by discussing the evidence.
- d. The correlation shown here is lagged. A lag is a time gap between the factors. Estimate the size of the lag between cigarette consumption and lung cancer death.

There are many other similar surveys in different countries, with different demographics that show similar results. Along with **lung** cancer, cancers of **mouth** and **throat** are very common as these areas are in direct contact.

Bibliography / Acknowledgments

