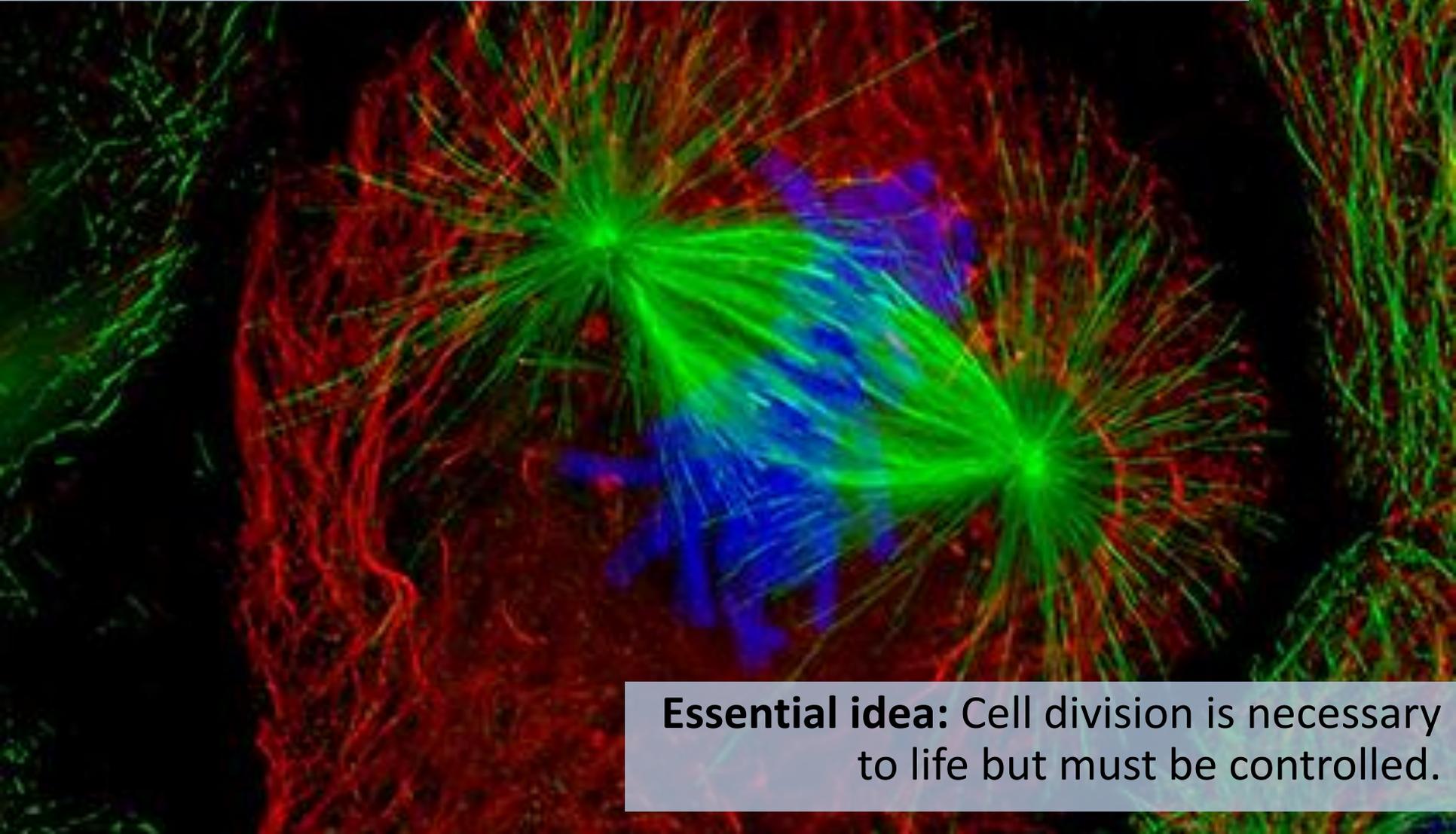


# Cell Division (1.6) & Stem Cells (1.1)

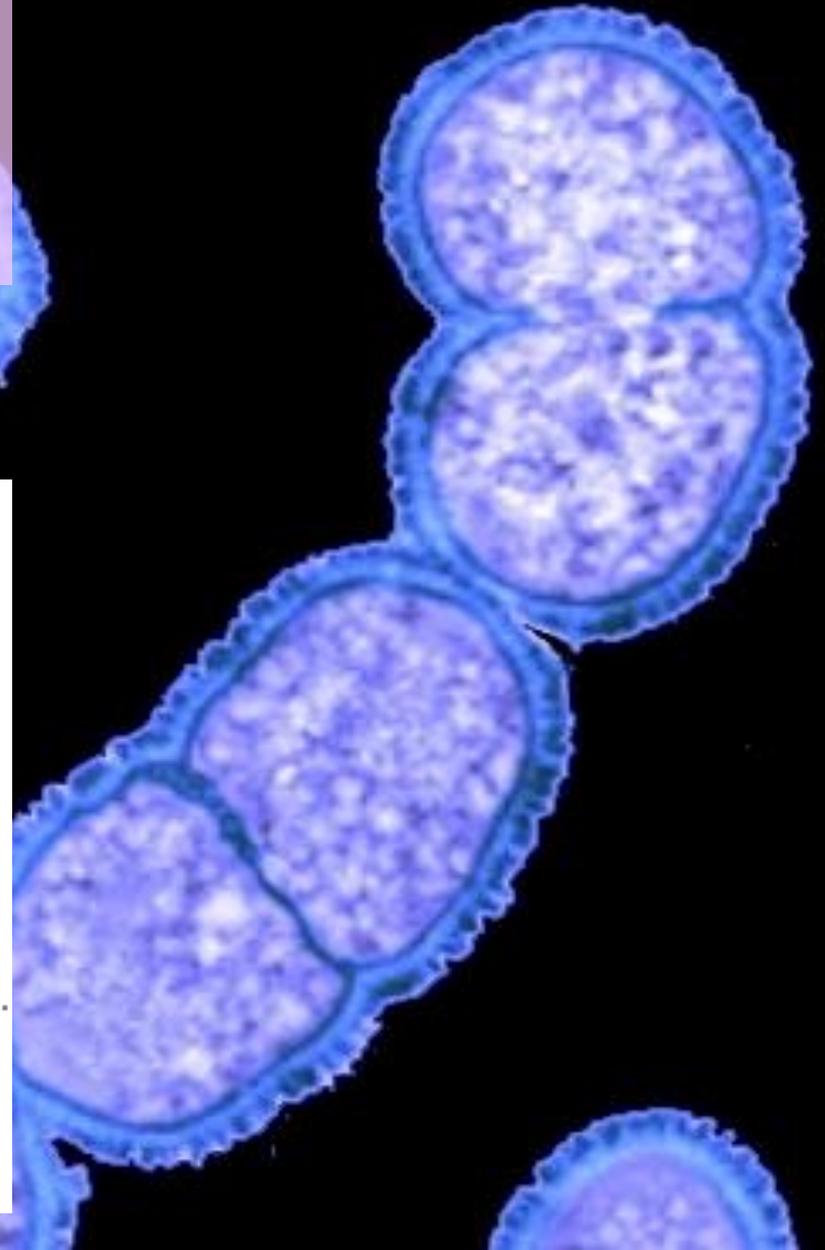
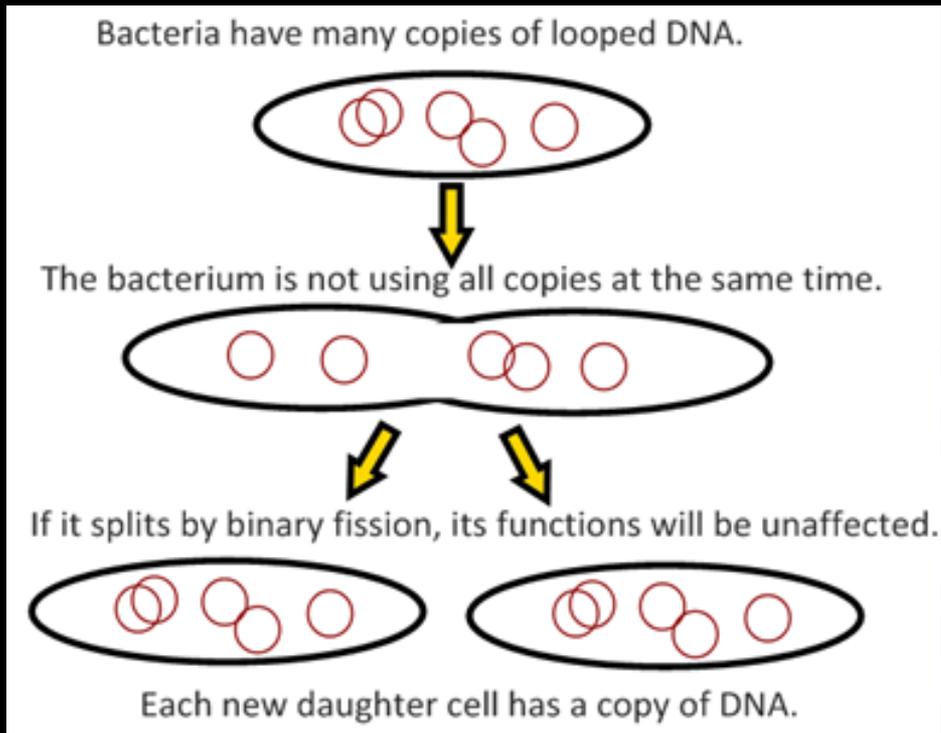
IB Diploma Biology



**Essential idea:** Cell division is necessary to life but must be controlled.

## 1.6.1 Mitosis is division of the nucleus into two genetically identical daughter nuclei

Prokaryotic cells divide their nuclear material in a process called **Binary Fission**



## 1.6.1 Mitosis is division of the nucleus into two genetically identical daughter nuclei

Eukaryotic cells divide their nuclear material in a process called **Mitosis**

This allows for the creation of two *genetically-identical* daughter cells



## 1.6.1 Mitosis is division of the nucleus into two genetically identical daughter nuclei

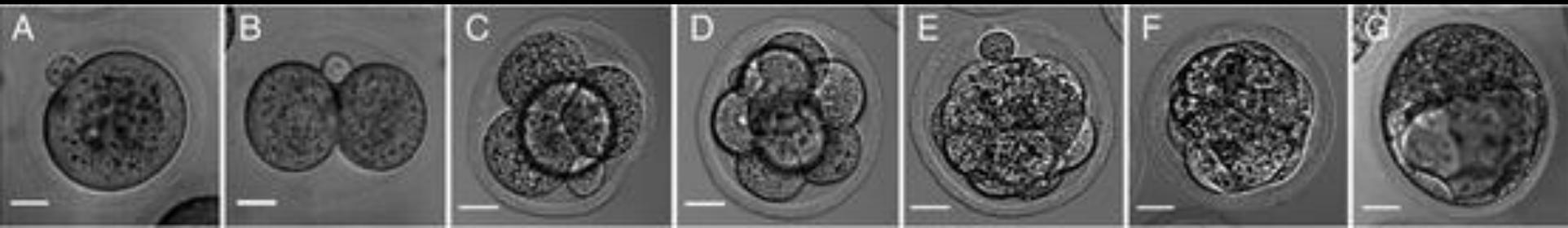
*When new cells are required, Mitosis is needed:*

**Growth:** Multicellular organisms increase their size by increasing their number of cells (individual cell size cannot grow due to SA : V ratio)

**Asexual reproduction:** Certain eukaryotic organisms may reproduce asexually by mitosis (e.g. protozoa, hydra)

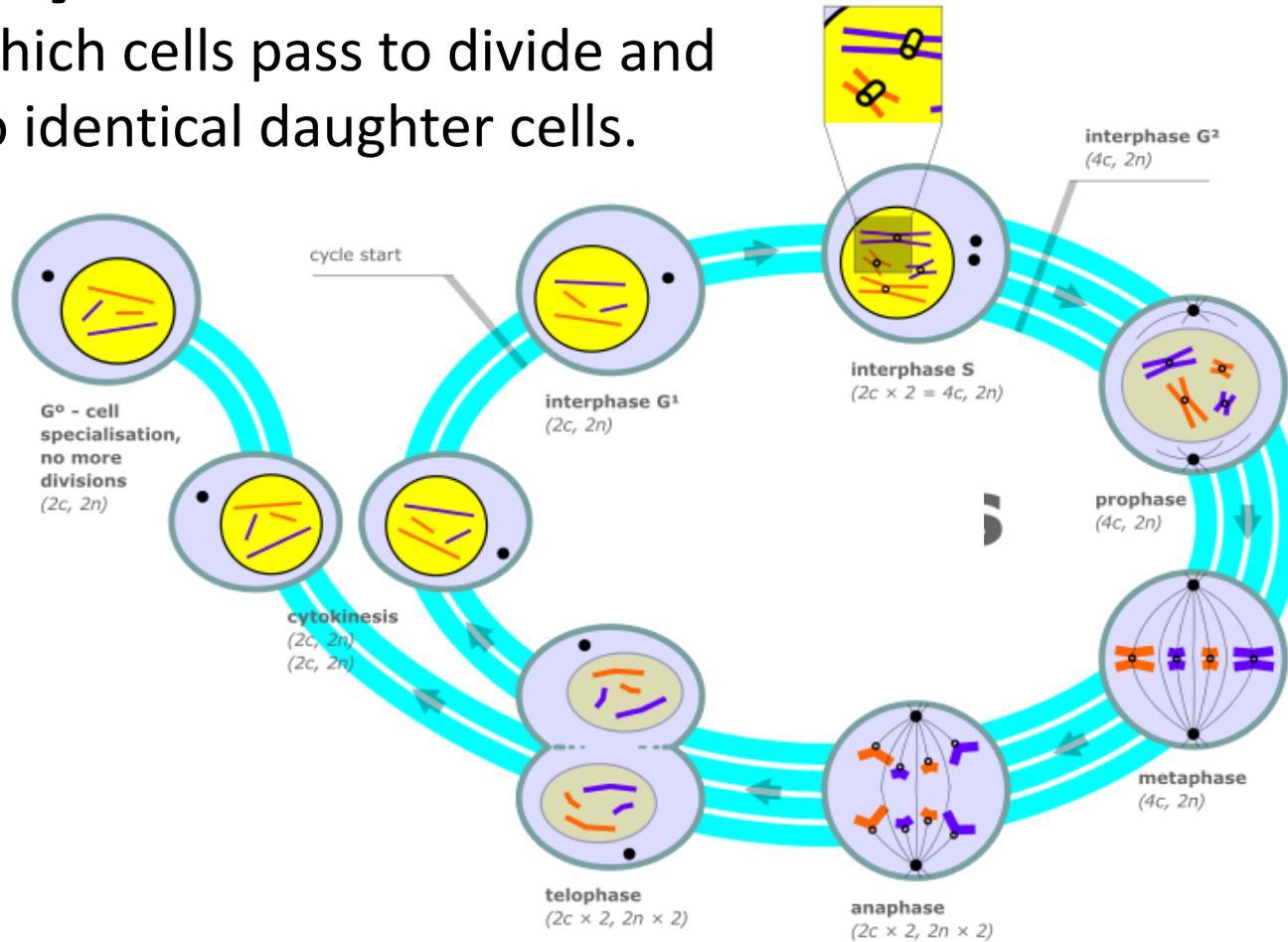
**Tissue Repair:** Damaged tissue can recover by replacing dead or damaged cells

**Embryonic development:** A fertilized egg (zygote) will undergo mitosis & differentiation to develop into an embryo



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

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



A **controlled pattern** of growth, DNA duplication, and division divided between **Interphase** and **Mitosis**

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

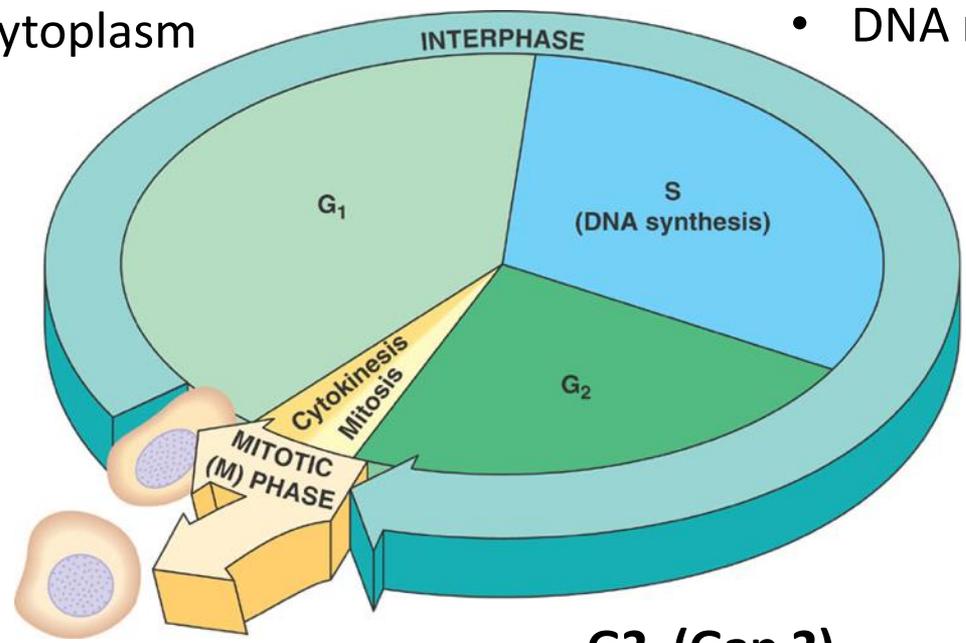
**Interphase** consists of the parts of the cell cycle that don't involve cell division. The average cell spends ~90% of it's life in this phase...

### G1 (Gap 1)

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

### 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 synthesized

# 1.6.4 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.

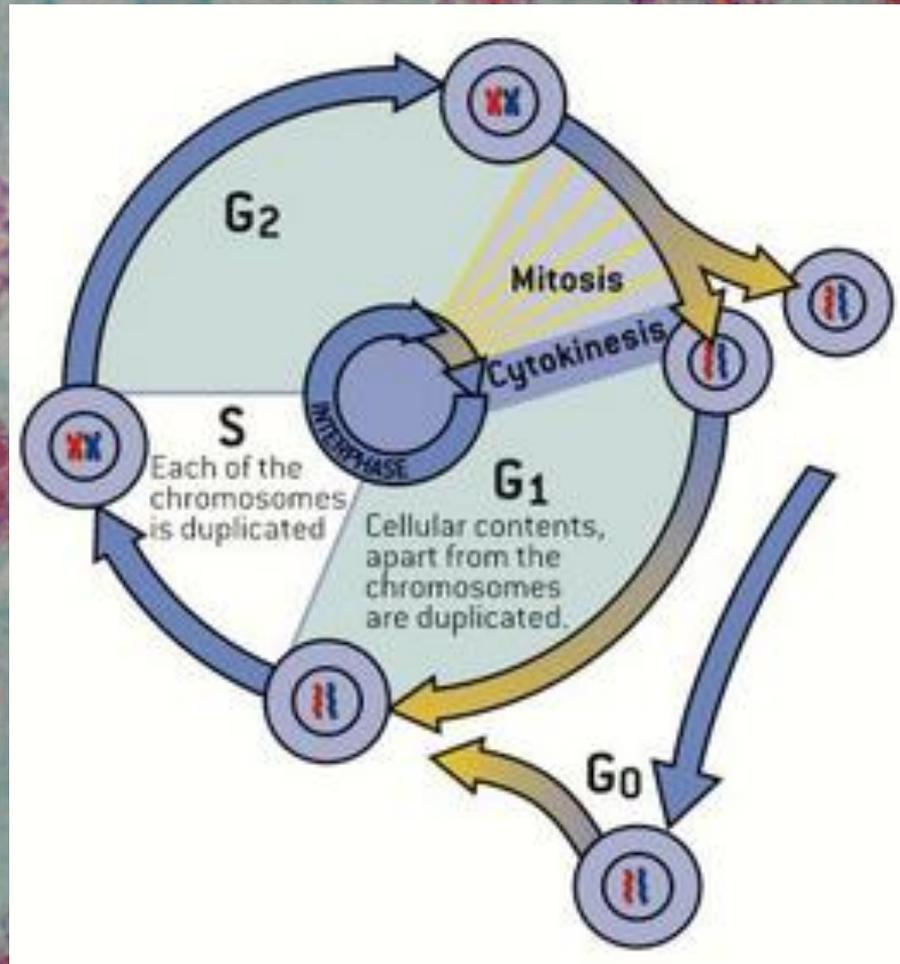
This when the cell carries out it's normal functions...

**Metabolic reactions** (e.g. respiration to produce ATP) are necessary for the life of the cell,

**Protein synthesis** - proteins and enzymes are needed for growth,

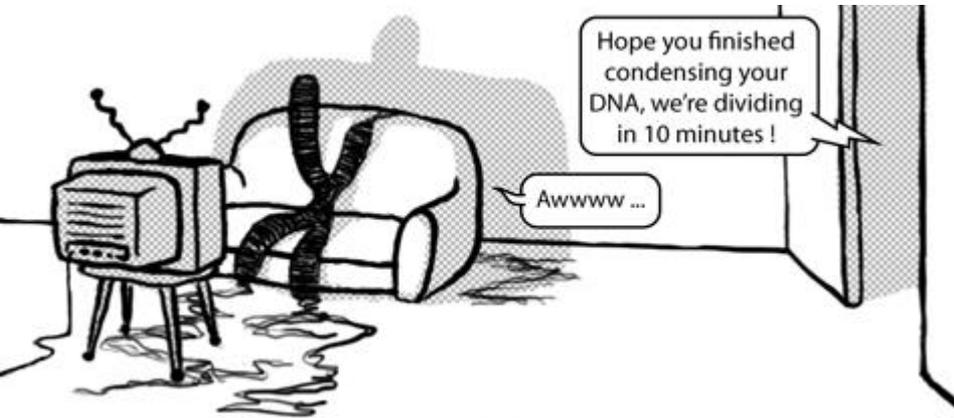
**Organelles numbers are increased** to first support the enlarged cell,

**DNA is replicated** to ensure a second copy is available to enable mitosis.



## 1.6.2 Chromosomes condense by supercoiling during mitosis.

# Why supercoil chromosomes?



During Mitosis, DNA is packed as 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.

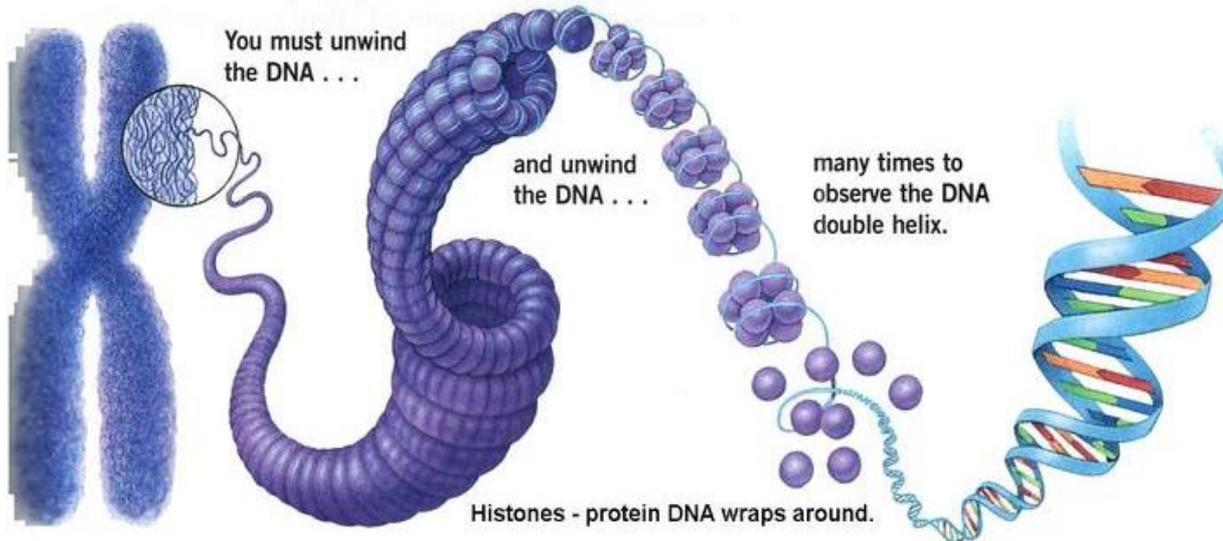
Human chromosomes are  $15\text{mm}$  to  $85\text{mm}$  ( $15,000\mu\text{m}$  to  $85,000\mu\text{m}$ ) in length.

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 ends of cell.

**FIGURE 7.7 Chromosome Structure**

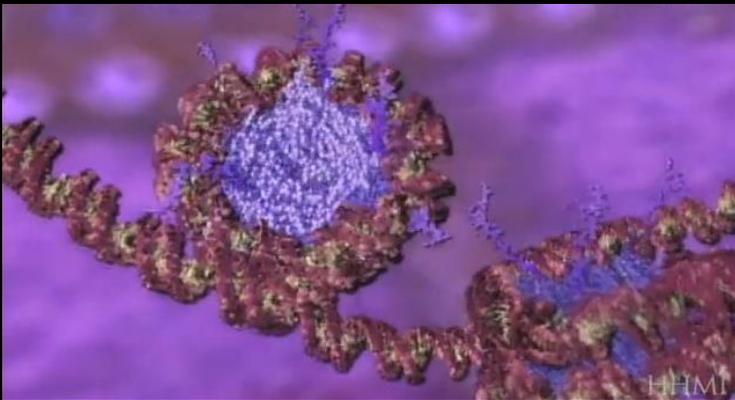
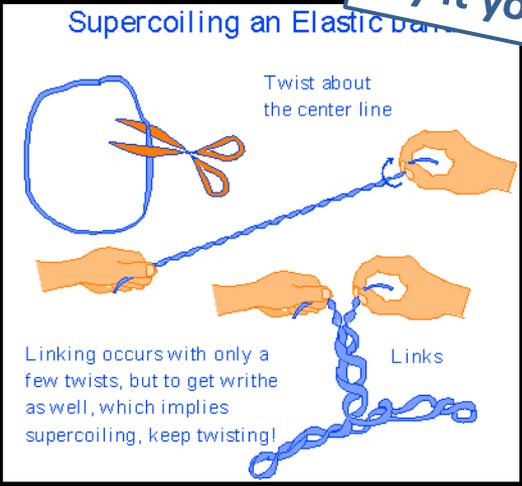
Chromosomes contain very tightly wound DNA



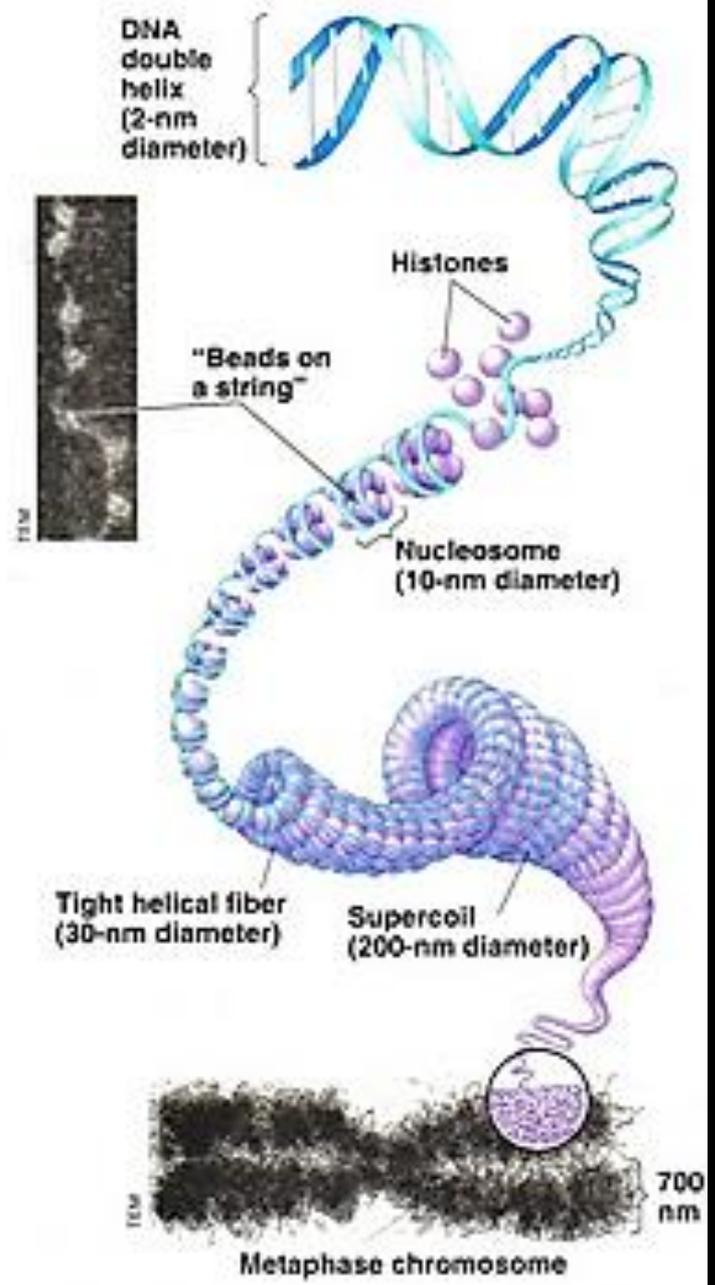
1.6.2 Chromosomes condense by supercoiling during mitosis.

# How are chromosomes supercoiled?

Try it yourself



<http://www.hhmi.org/biointeractive/dna-packaging>

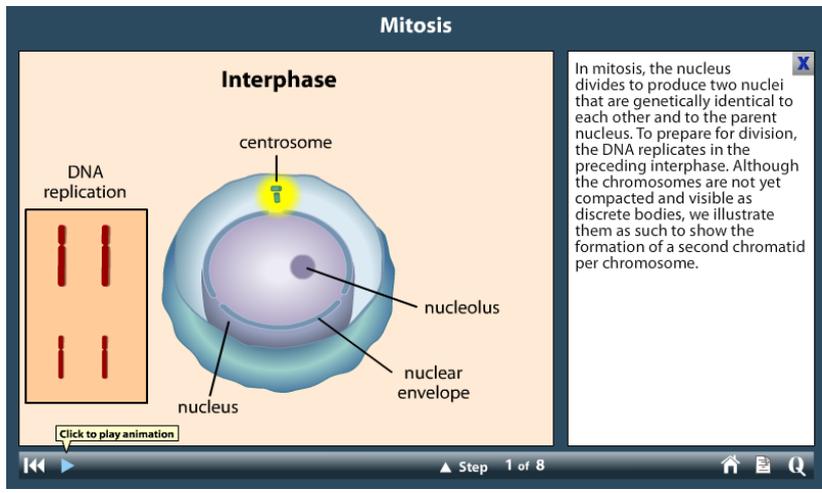


# 1.6.8 Identify phases of mitosis in cells viewed with a microscope.

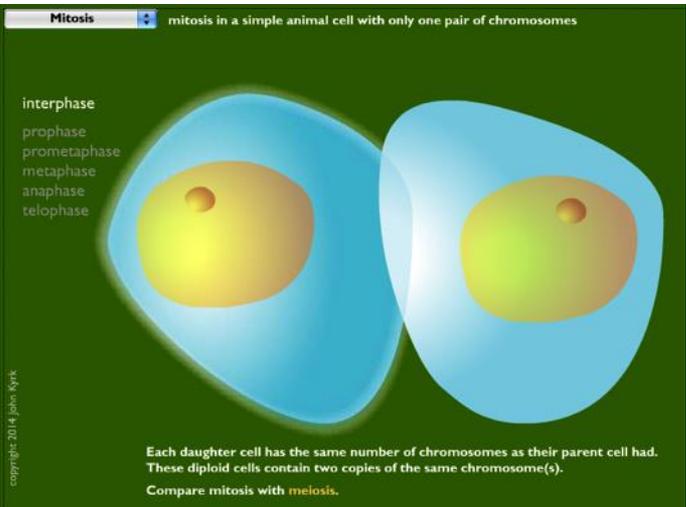
Use the animated tutorials to learn about mitosis



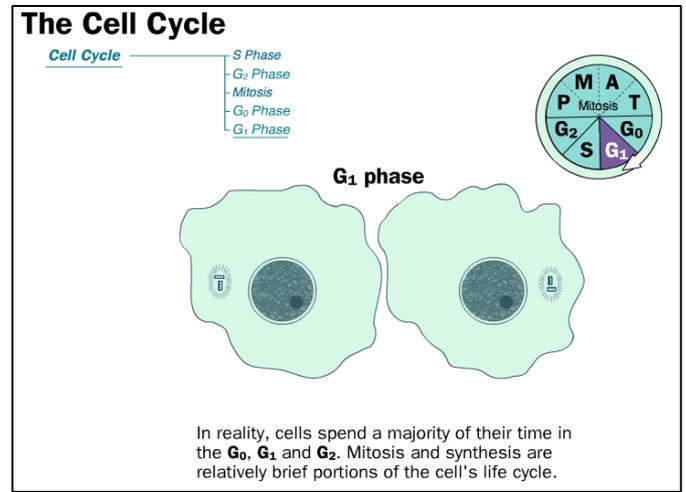
[http://highered.mheducation.com/sites/0072495855/student\\_view0/chapter2/animation\\_mitosis\\_and\\_cytokinesis.html](http://highered.mheducation.com/sites/0072495855/student_view0/chapter2/animation_mitosis_and_cytokinesis.html)



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

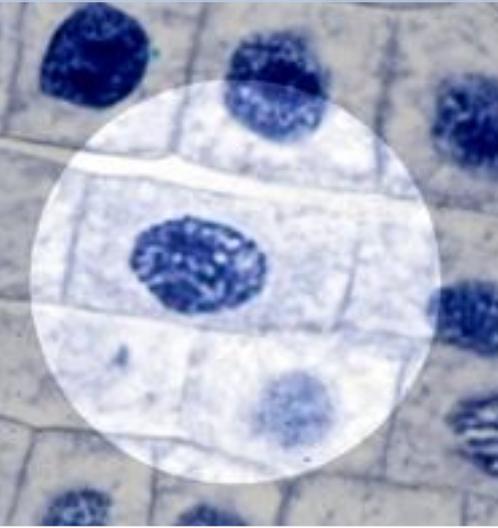


<http://www.johnkyrk.com/mitosis.html>

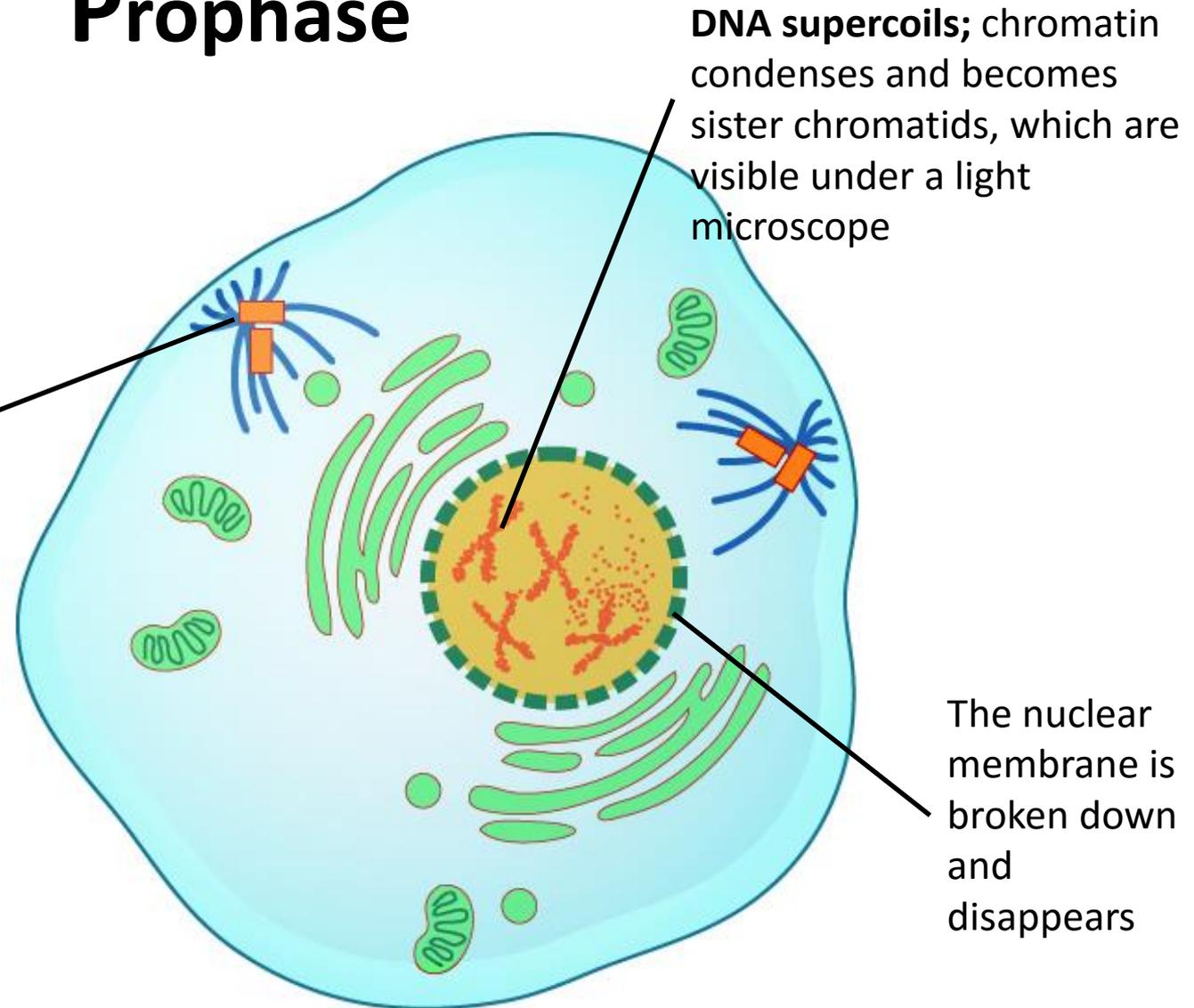


<http://outreach.mcb.harvard.edu/animations/cellcycle.swf>

## 1.6.8 Identify phases of mitosis in cells viewed with a microscope.



# Prophase

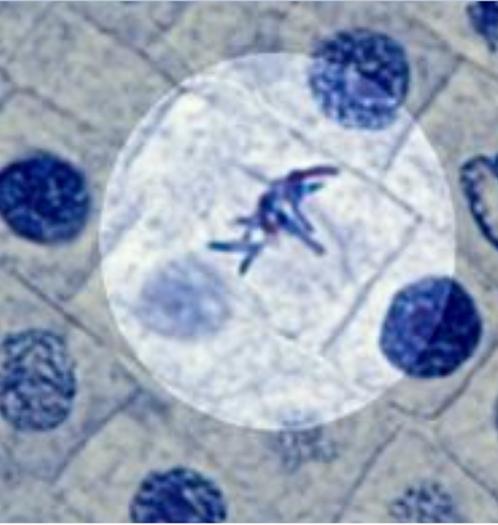


DNA supercoils; chromatin condenses and becomes sister chromatids, which are visible under a light microscope

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

The nuclear membrane is broken down and disappears

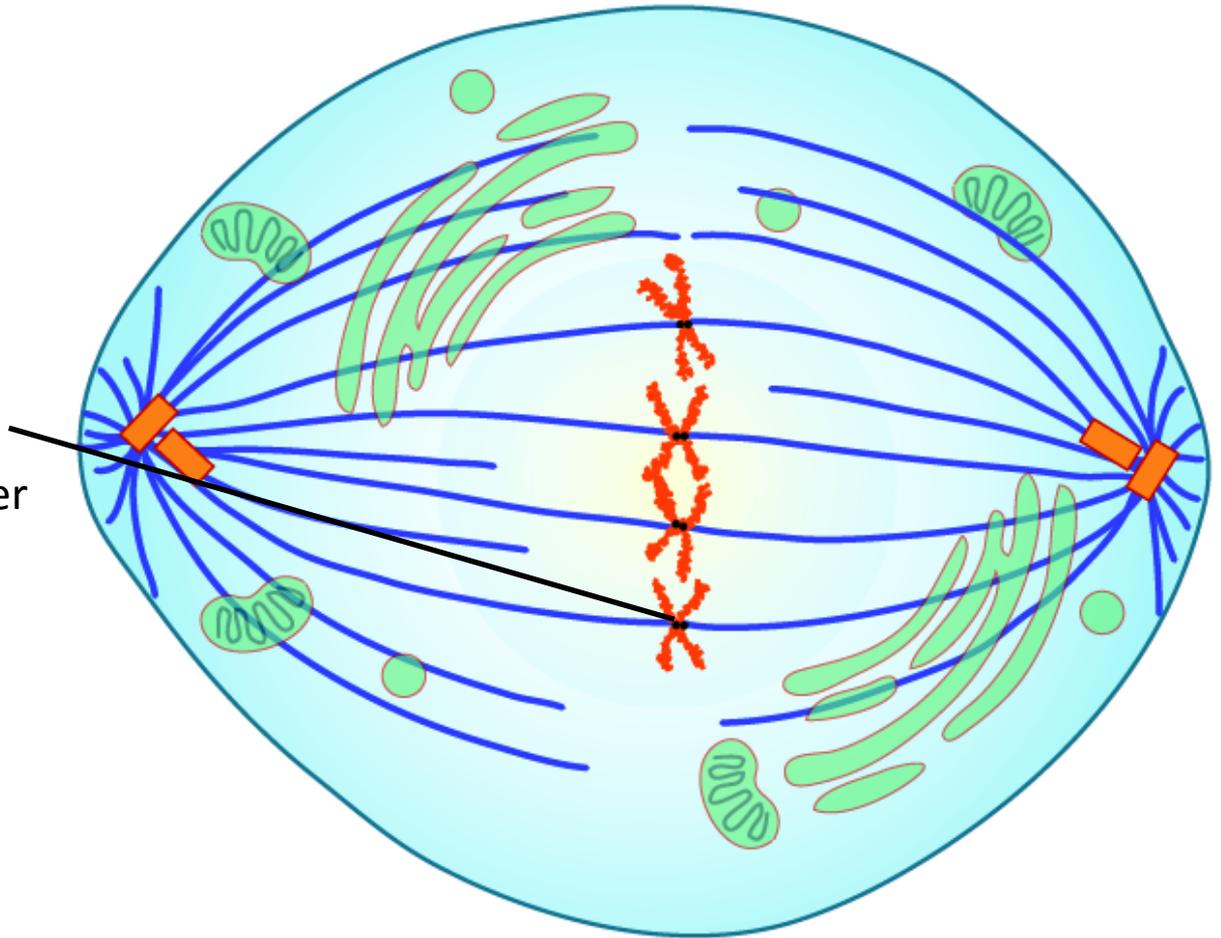
## 1.6.8 Identify phases of mitosis in cells viewed with a microscope.



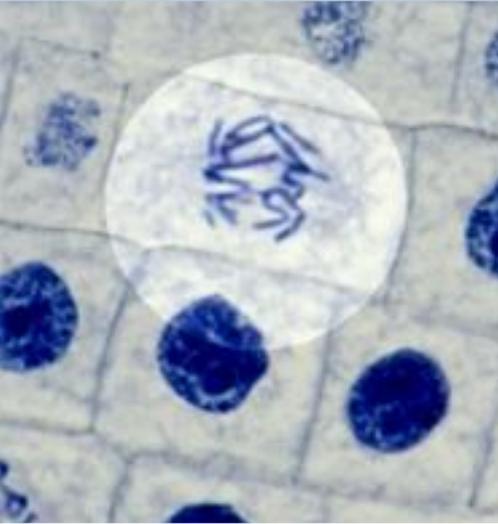
# Metaphase

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

Contraction of the microtubule spindle fibers cause the sister chromatids to line up along the center of the cell.



## 1.6.8 Identify phases of mitosis in cells viewed with a microscope.

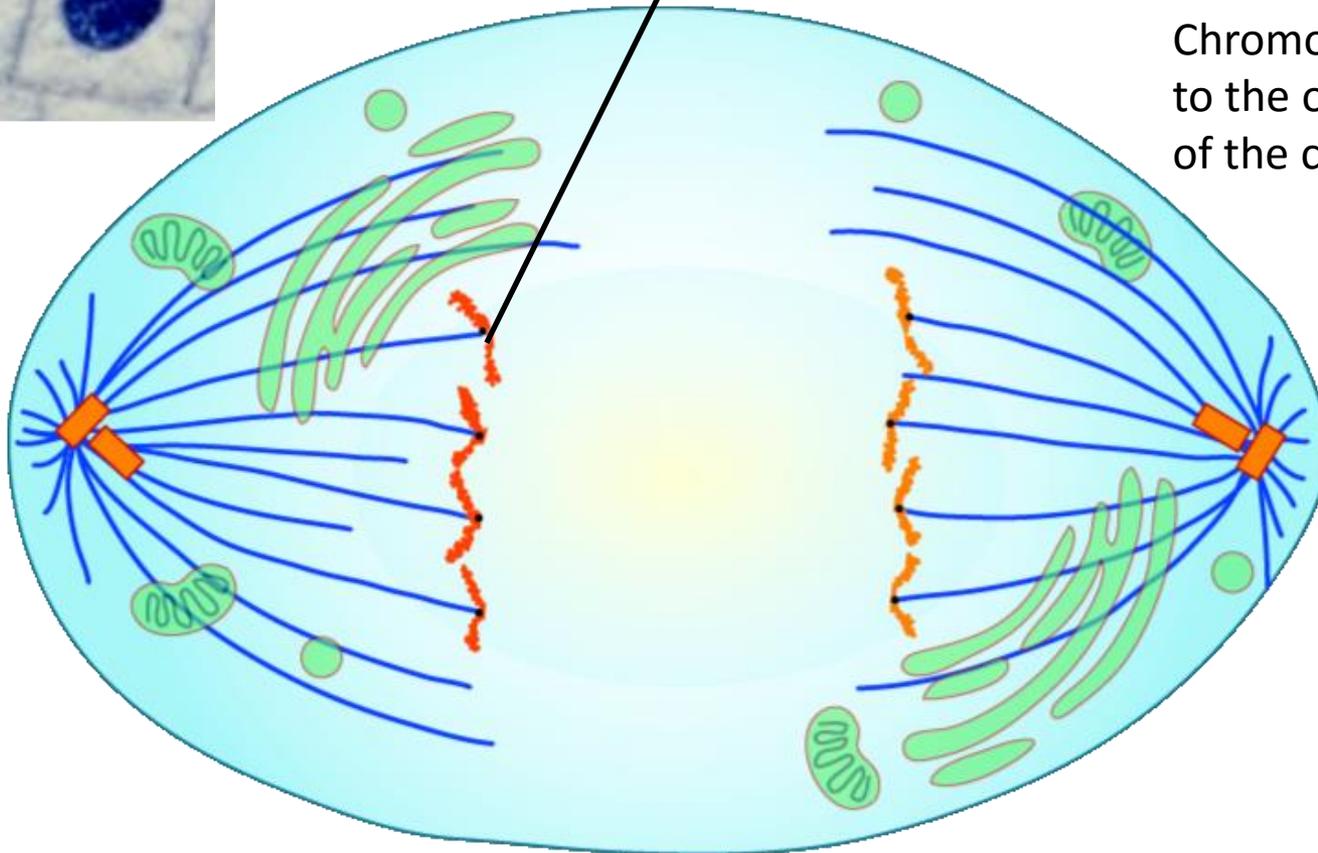


# Anaphase

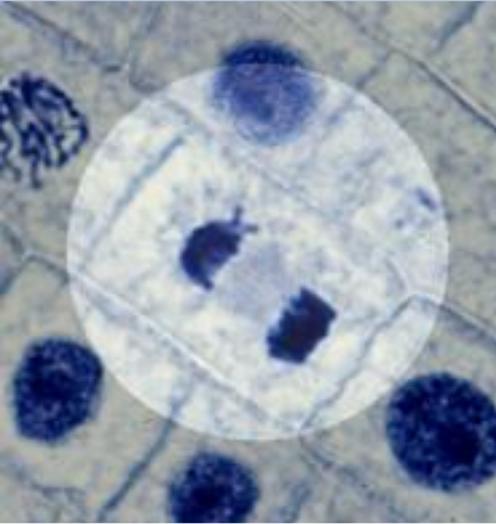
Continued contraction of the microtubule spindle fibers cause the separation of the sister chromatids

The chromatids are now referred to as chromosomes

Chromosomes move to the opposite poles of the cell



## 1.6.1 Mitosis is division of the nucleus into two genetically identical daughter nuclei.



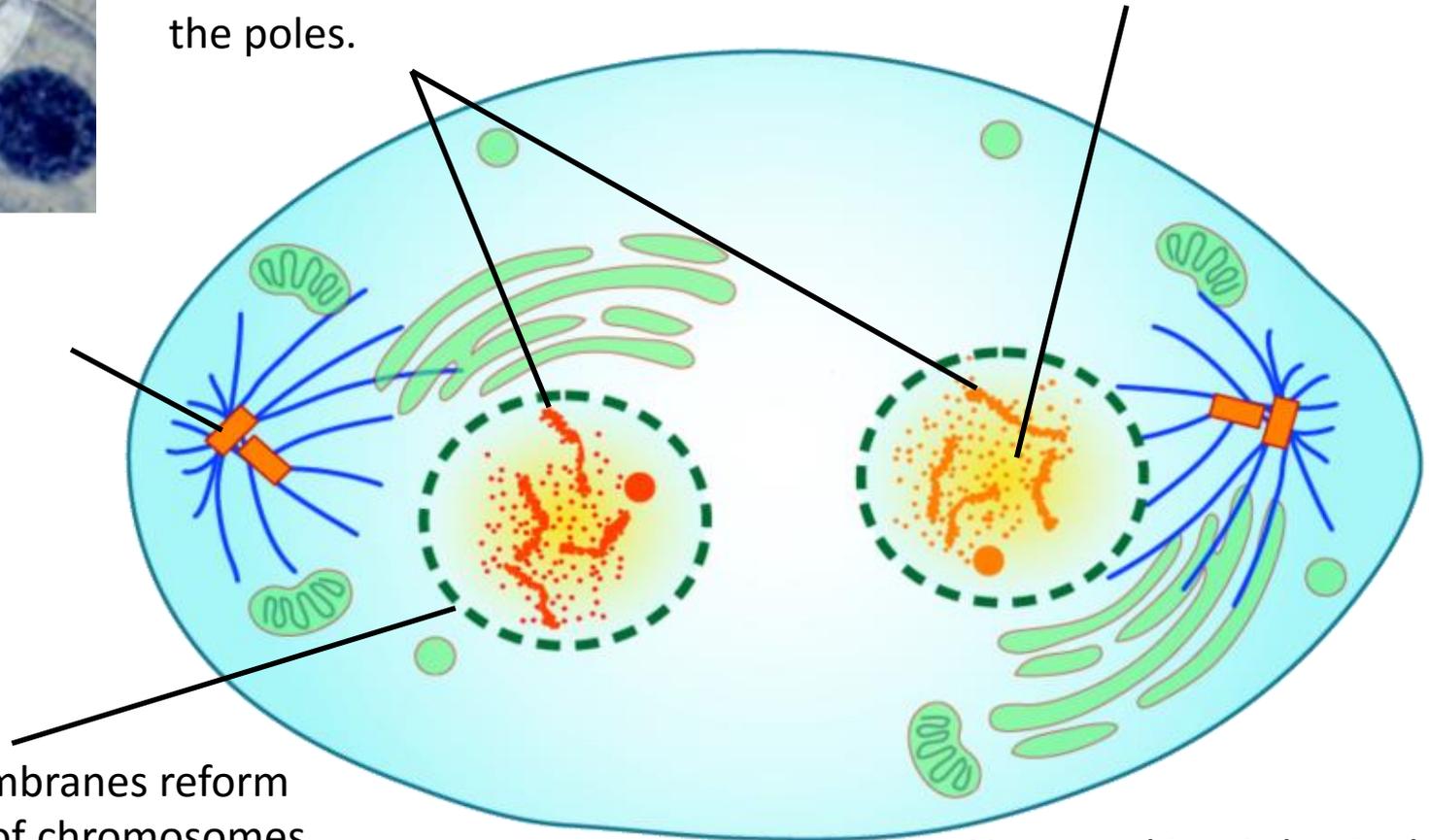
# Telophase

Chromosomes arrive at the poles.

The chromosomes uncoil decondense 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!*

## 1.6.8 Identify phases of mitosis in cells viewed with a microscope.

**P**rophase

**M**etaphase

**A**naphase

**T**elophase

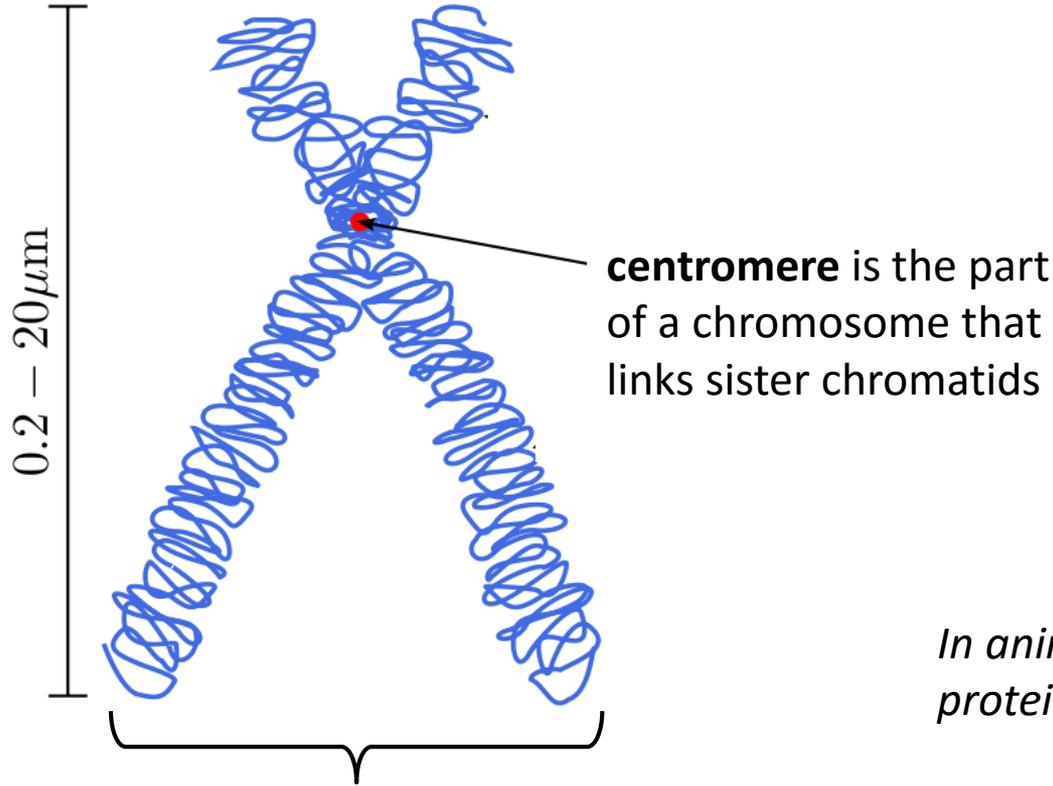
[https://www.youtube.com/watch?v=VG V3fv\\_uZYI](https://www.youtube.com/watch?v=VG V3fv_uZYI)

the stages of mitosis

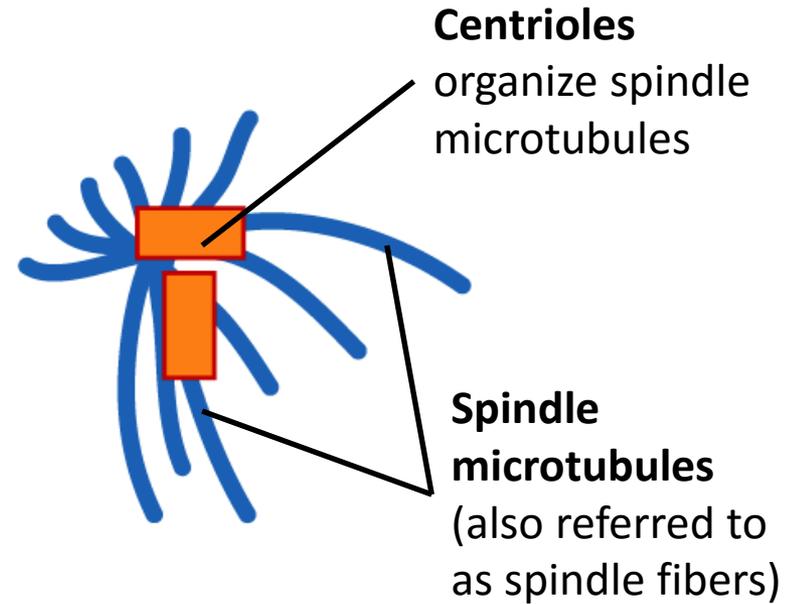
hybrid

## 1.6.8 Identify phases of mitosis in cells viewed with a microscope.

### Getting the terminology right...



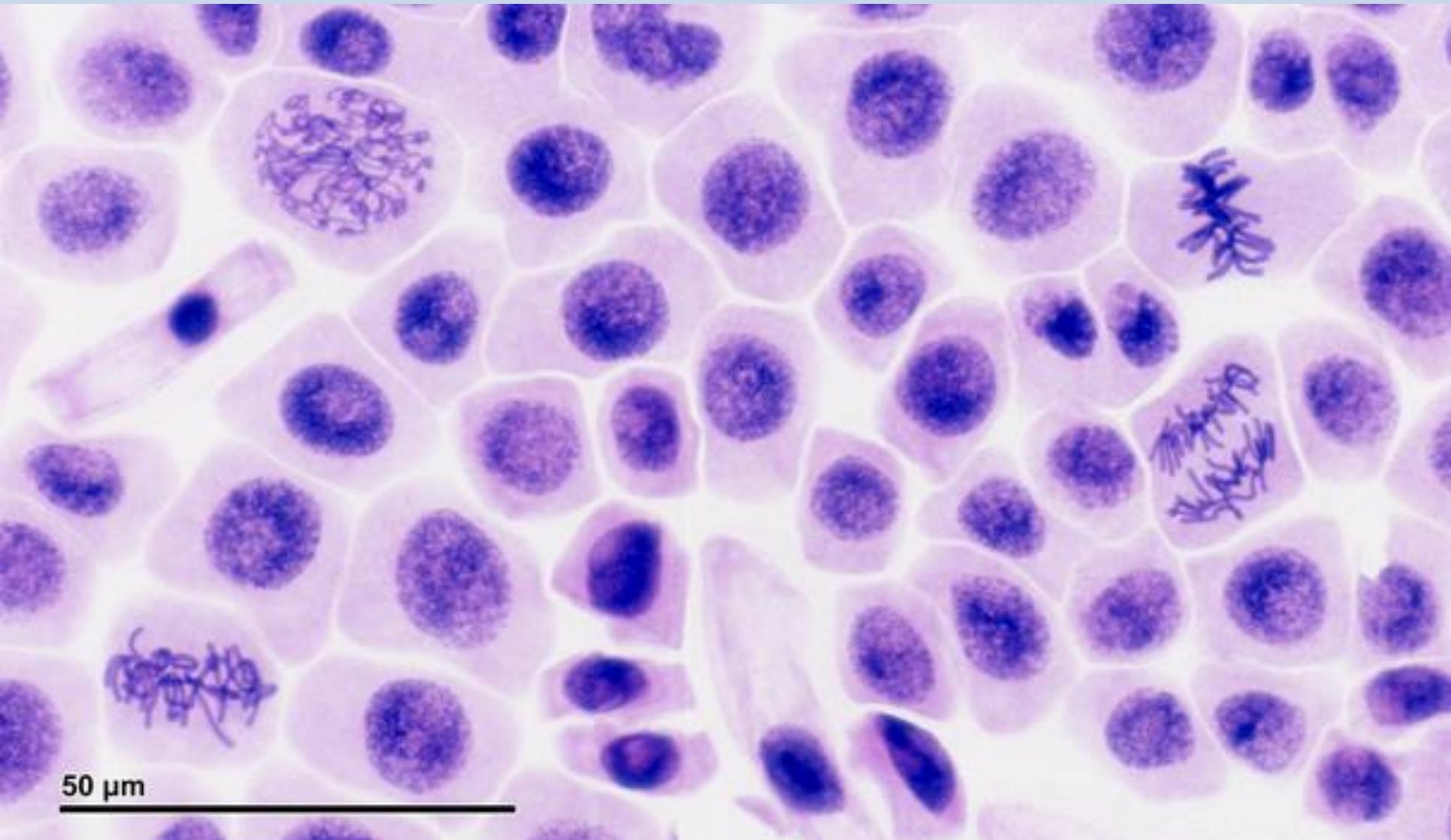
**Sister chromatids** are duplicated chromosomes attached by a centromere  
*After anaphase when the sister chromatids separate they should then be referred to as **chromosomes***



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

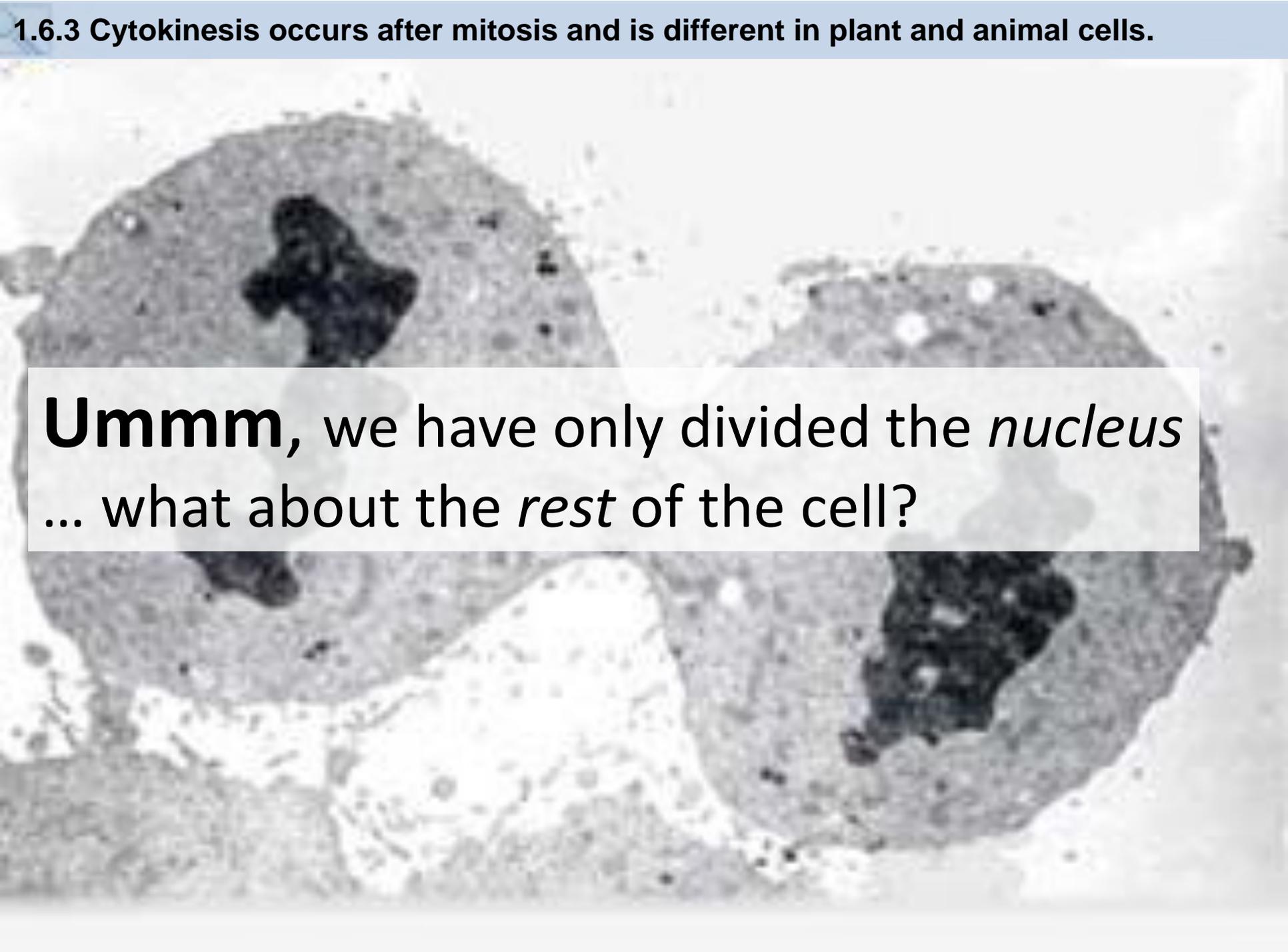
It is easy to misuse the terms chromatid and chromosome. It is even easier to confuse the terms centromere, centriole and centrosome due to their similar spelling. Keep the terms clear in your mind to avoid losing marks.

### 1.6.9 Determination of a mitotic index from a micrograph.



$$\text{Mitotic index} = \frac{\text{number of cells in mitosis}}{\text{total number of cells}}$$

### 1.6.3 Cytokinesis occurs after mitosis and is different in plant and animal cells.



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

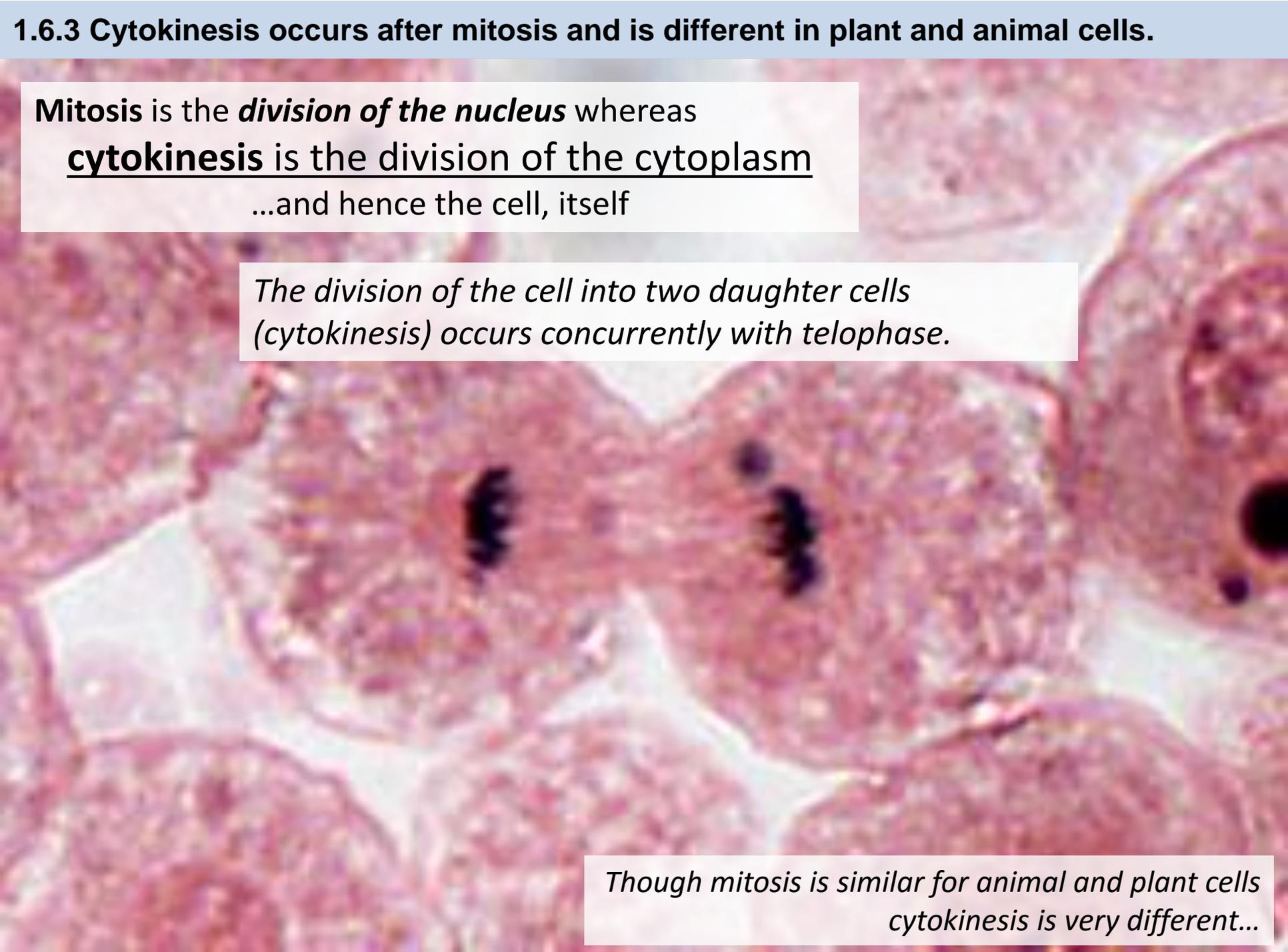
This electron micrograph shows two animal cells in the final stage of cytokinesis. A prominent cleavage furrow is visible between the two cells, where the plasma membrane and underlying cytoskeleton are pinching together to separate the daughter cells. Each cell contains a dark, electron-dense nucleus. The cytoplasm is filled with various organelles and granules.

### 1.6.3 Cytokinesis occurs after mitosis and is different in plant and animal cells.

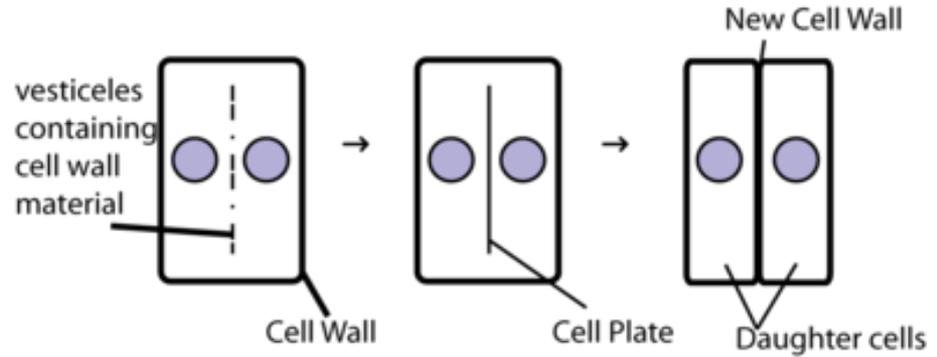
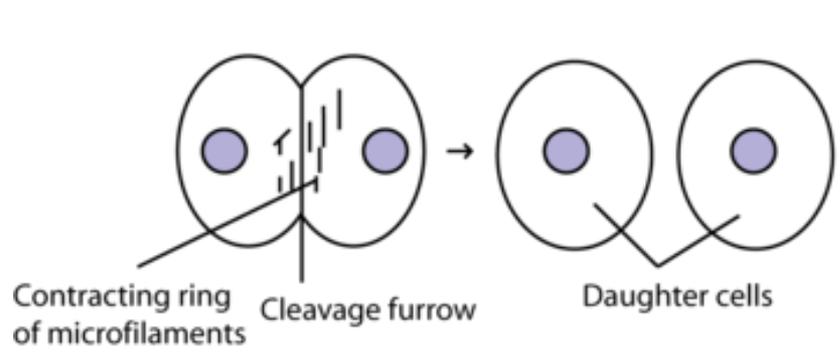
Mitosis is the *division of the nucleus* whereas cytokinesis is the division of the cytoplasm ...and hence the cell, itself

*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...*



**1.6.3 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 center of cell.
- Vesicles fuse to form tubular structures which 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.
- Both daughter cell secrete cellulose to form their new adjoining cell walls.

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

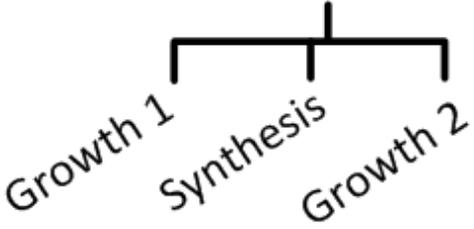
# The Cell Cycle

*All of the life stages of the cell*



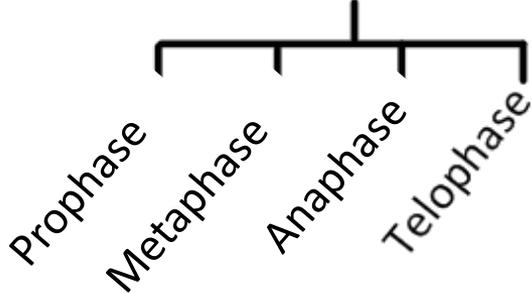
## Interphase

*The phase in which the cell spends most of its time*



## Mitosis

*Division of the diploid eukaryotic nucleus*



## Cytokinesis

*Division of the cytoplasm to form two daughter cells*

## Apoptosis

*'Programmed' cell death - all cells have a limited life span*

## Necrosis

*Premature cell death due to injury, toxins or pathogens*

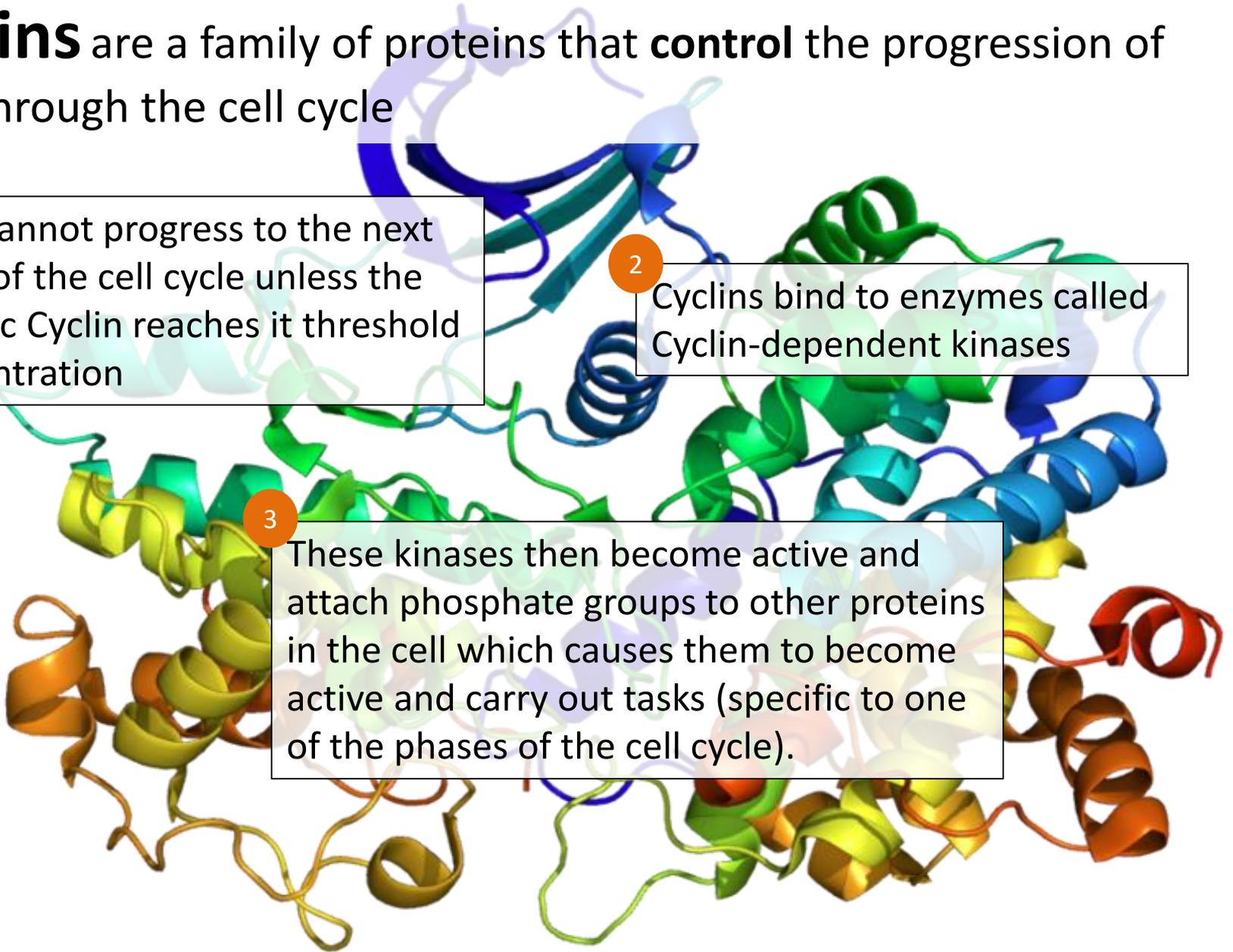
## 1.6.5 Cyclins are involved in the control of the cell cycle.

**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 concentration

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 which causes them to become active and carry out tasks (specific to one of the phases of the cell cycle).



## 1.6.5 Cyclins are involved in the control of the cell cycle.

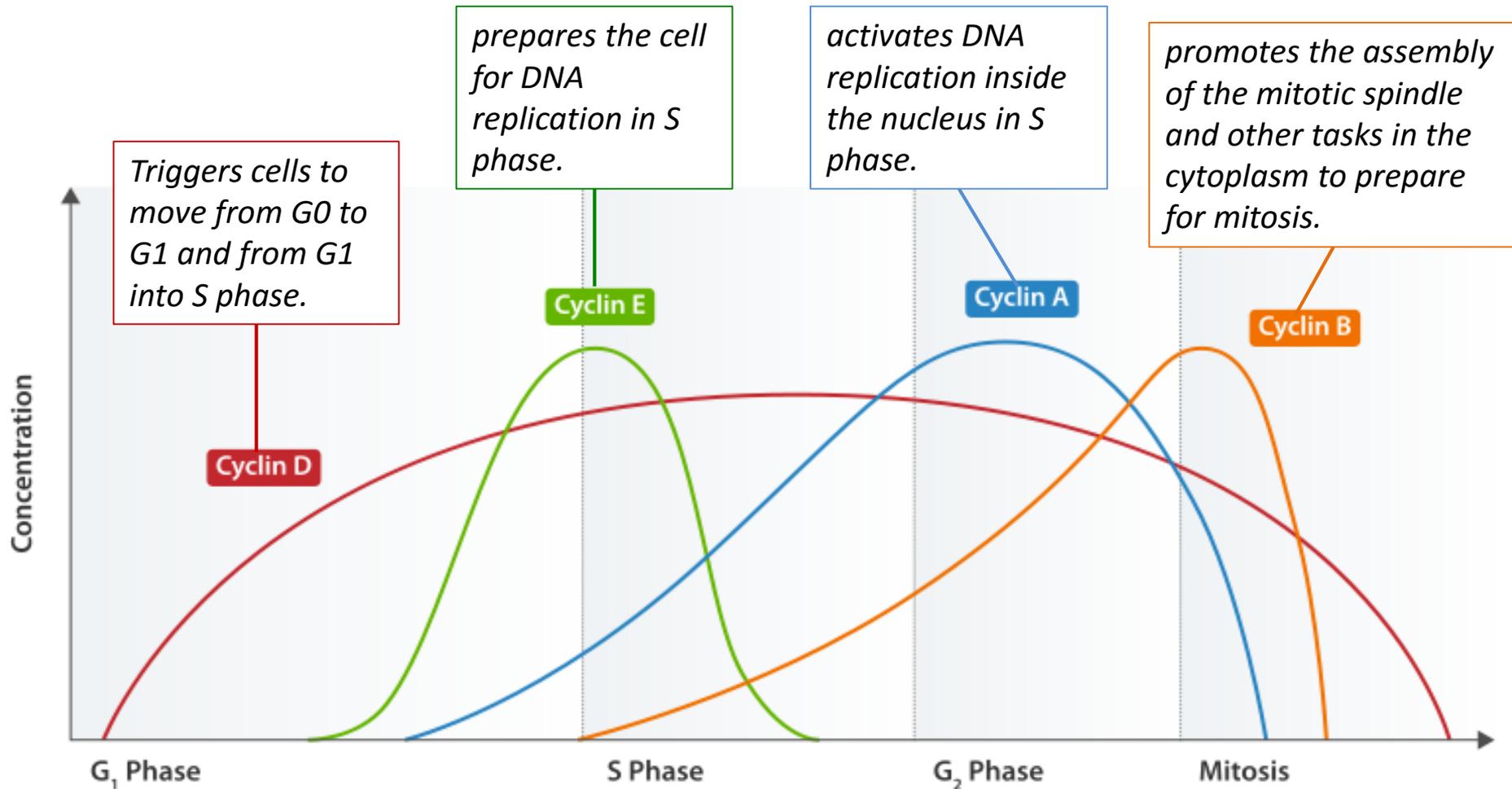
**Cyclins** are a family of proteins that **control** the progression of cells through the cell cycle

**Tim Hunt** discovered cyclins in 1982 *on accident* (!) while researching **sea urchins**... He later won a Nobel Prize (2001) for his accidental discovery.



## 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**



## 1.6.6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumors.

# **CANCER:** *When the cell cycle fails to be controlled...*

**Tumours** are abnormal growths of tissue that develop at any stage of life in any part of the body.

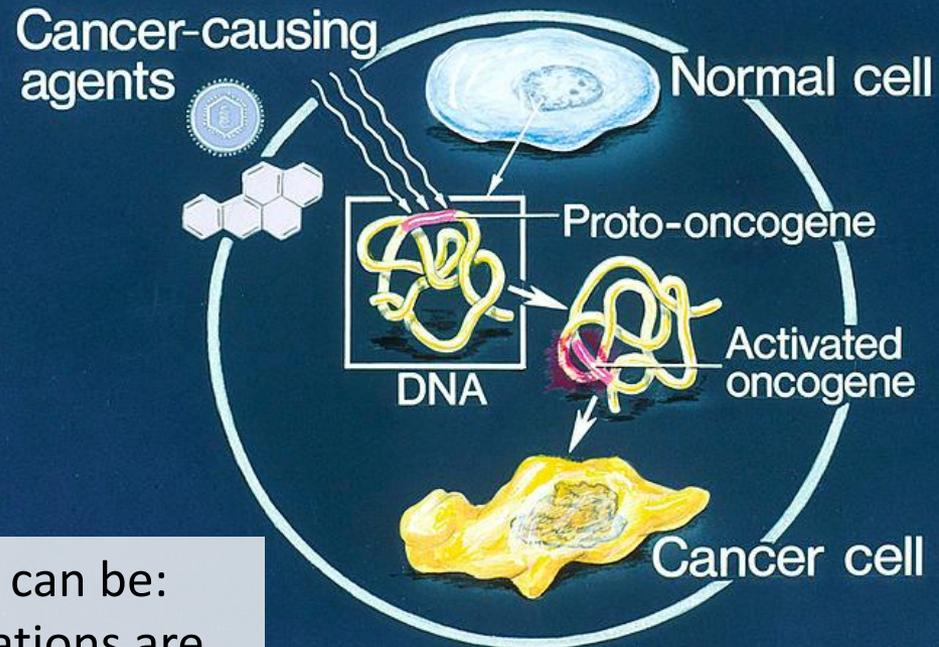
A **cancer** is a malignant tumour and is named after the part of the body where the cancer (primary tumor) first develops.



## 1.6.6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumors.

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 (aka Carcinogens)** can be:

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

## 1.6.6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumors.

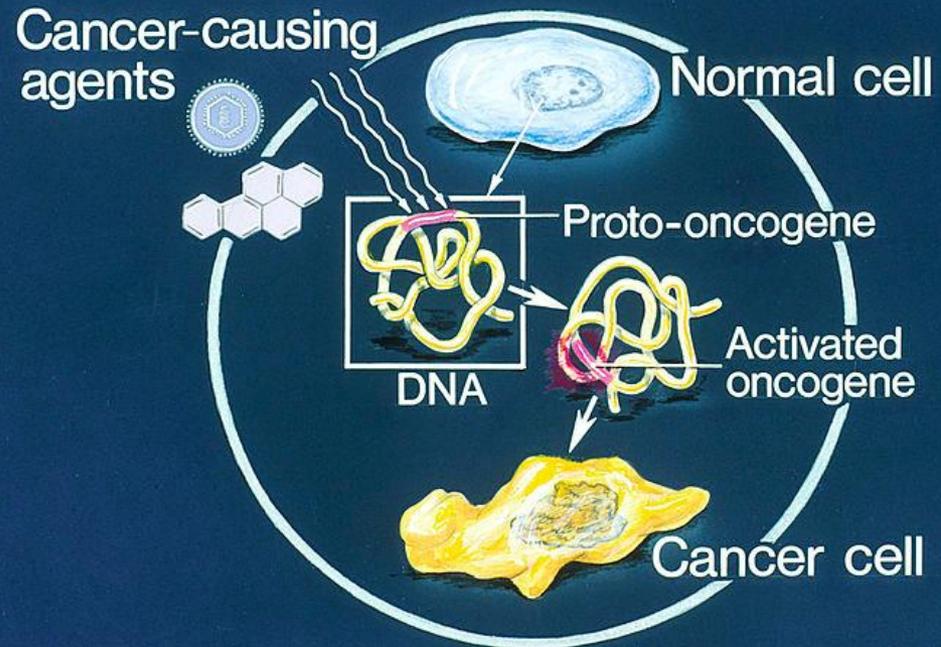
If a mutation occurs in an **oncogene** it can become cancerous. In normal cells oncogenes control the cell cycle and cell division.

mutation in a oncogene

malfunction in the control  
of the cell cycle

uncontrolled cell division

tumor formation

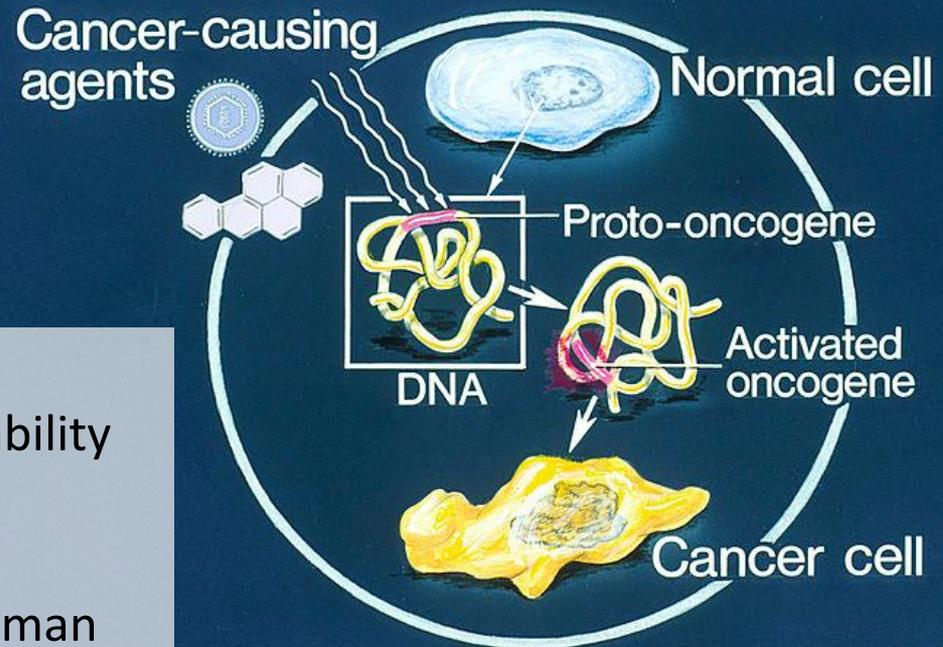


## 1.6.6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumors.

**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



## 1.6.6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumors.

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

A **primary tumour** 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.

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

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

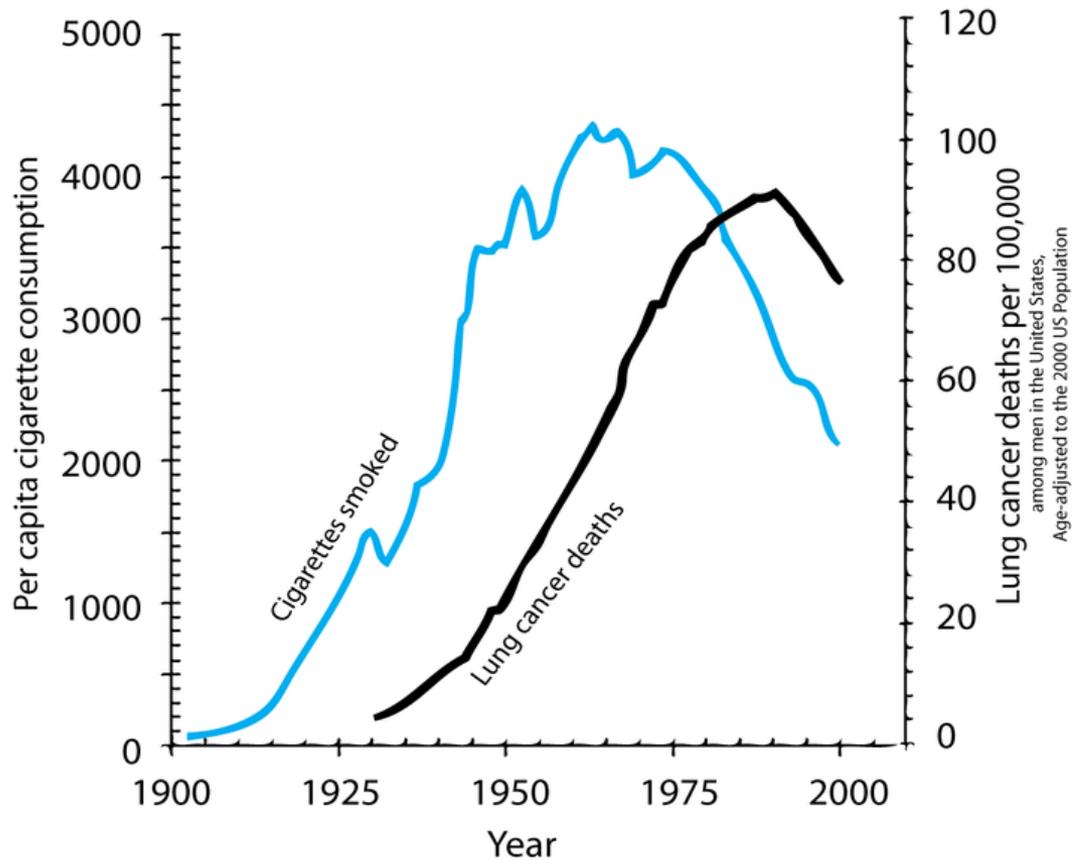


### 1.6.6 Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumors.



Due an incredibly rare genetic disorder, these French twins' cells are not able to repair DNA mutations caused by the sun's UV radiation. Direct exposure to sunlight could cause them to develop cancer.

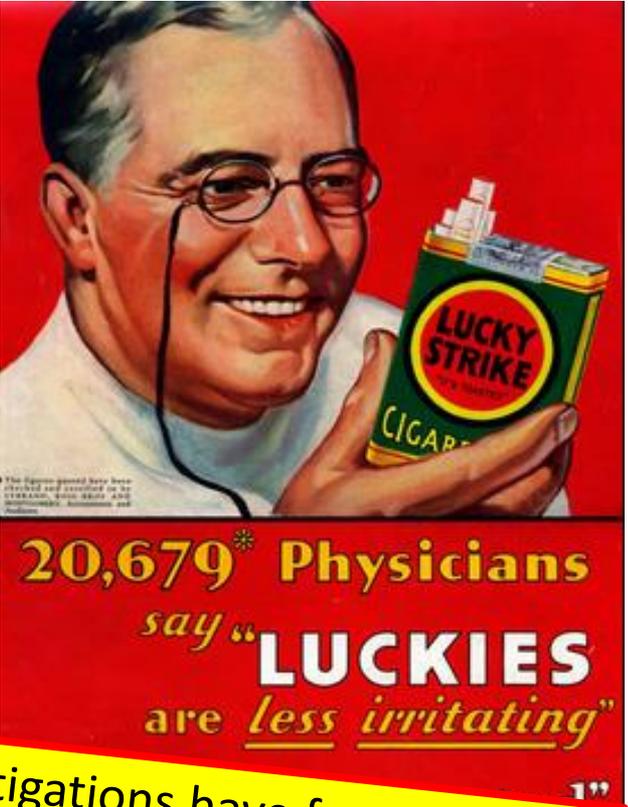
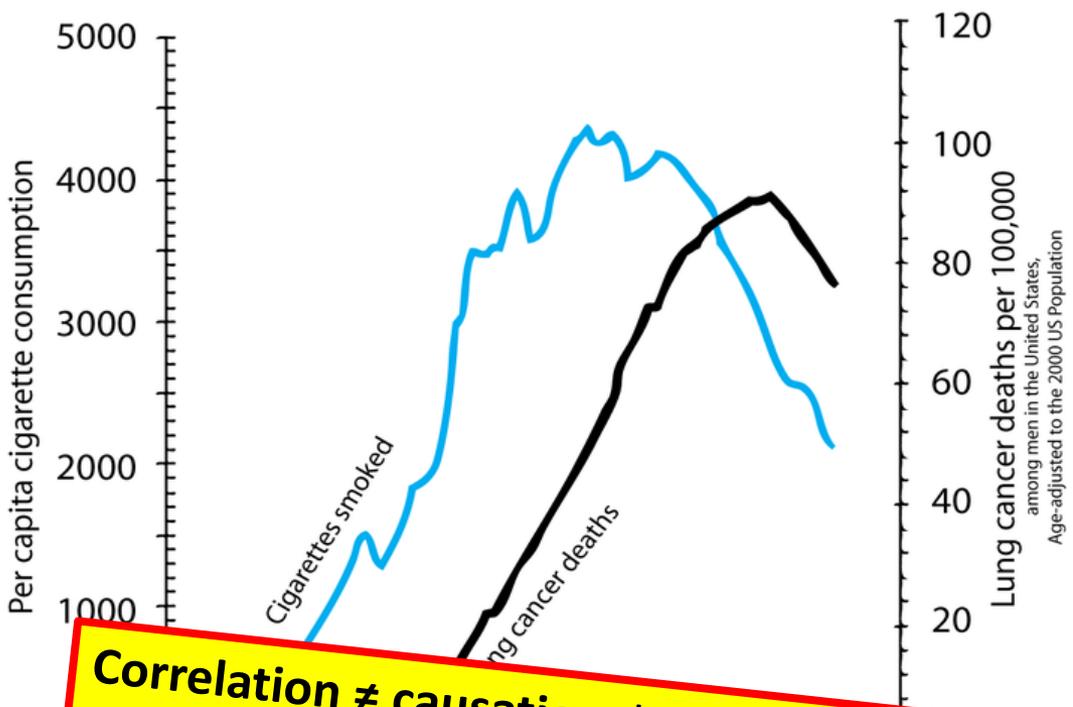
## 1.6.7 The correlation between smoking and incidence of cancers.



There are many surveys in many 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

# 1.6.7 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**

They show similar trends in areas where smoking is common as these areas are in direct contact with tobacco. That is, that the following cancers are also more common in smokers:

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

## 1.1.5 Specialized tissues can develop by cell differentiation in multicellular organisms



- 220 recognized, different highly-specialized cells types in humans
- **EX: Rod cells in retina of the eye are light-sensitive**
- EX: Red blood cells carrying oxygen and nutrients
- Groups of similar cells form tissues (epithelial, muscle, connective, and nervous)

# 1.1.6 Differentiation involves the expression of some genes and not others in the cell's genome

## Differentiation (specialization) of cells:

All diploid (body) cells have the same chromosomes.

So they **carry all the same genes** and alleles.

**BUT**

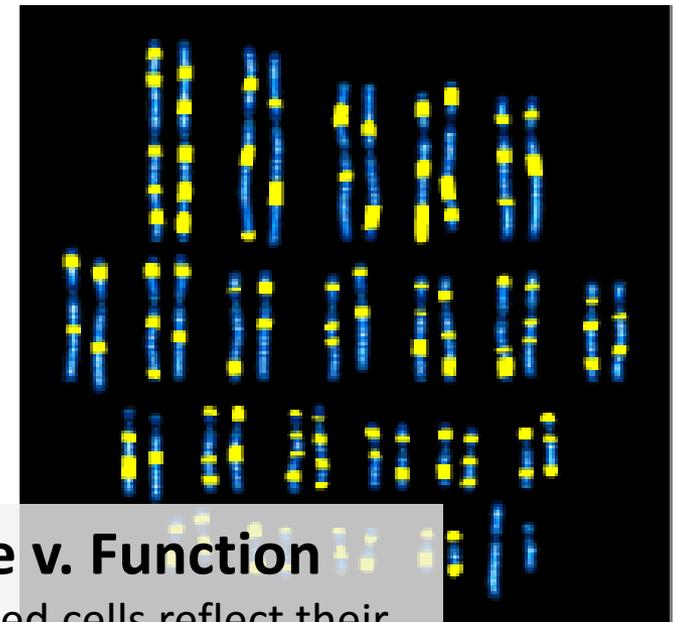
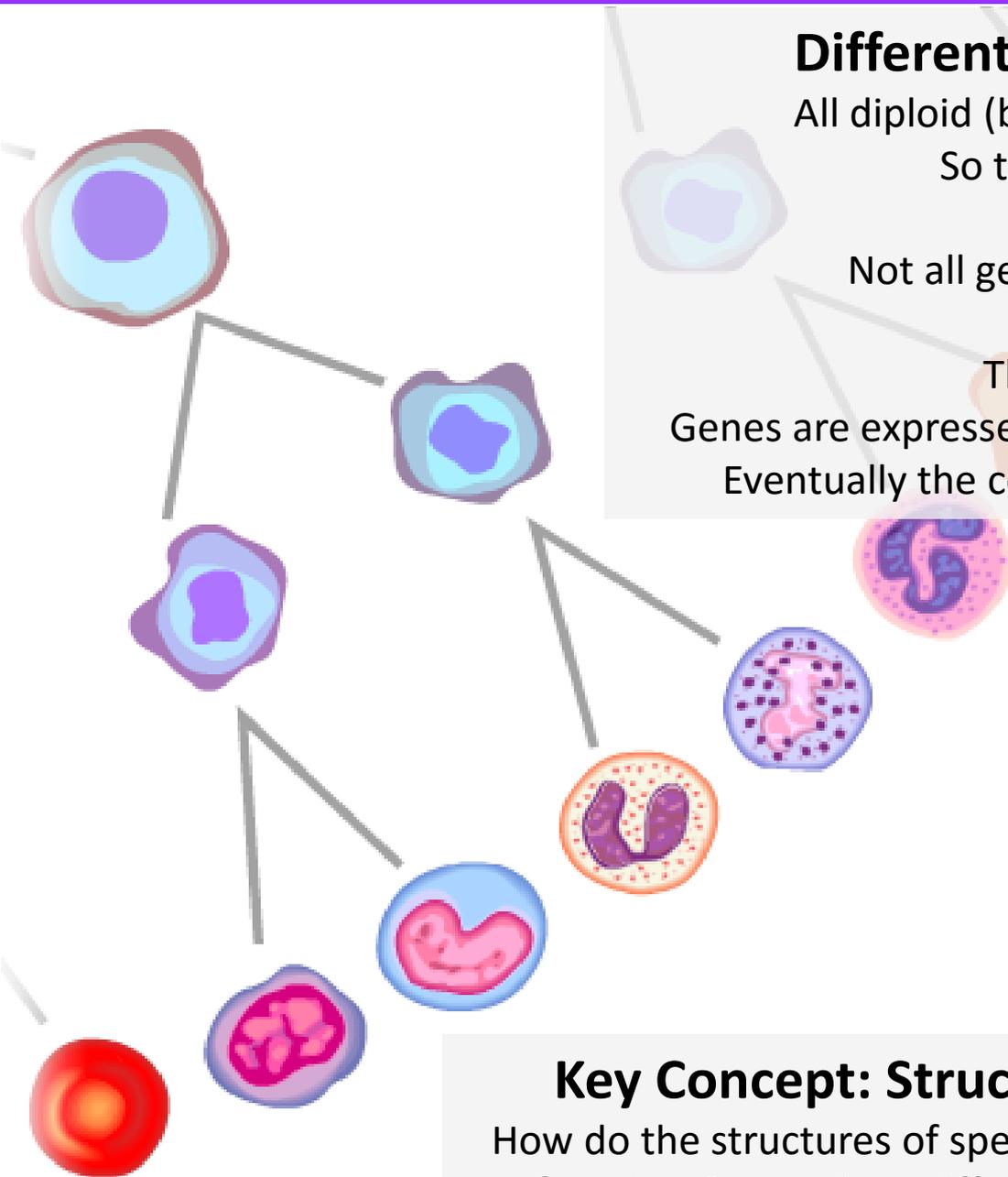
Not all genes are expressed (activated) in all cells.

The cell receives a **signal**.

This signal **activates or deactivates genes**.

Genes are expressed accordingly and the **cell is committed**.

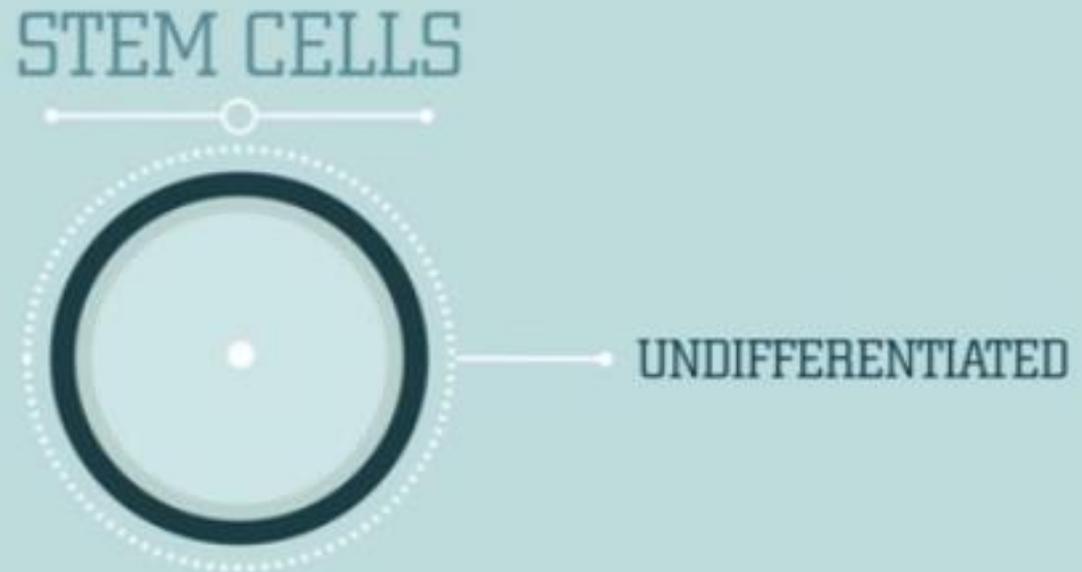
Eventually the cell **has become specialized** to a function.



## Key Concept: Structure v. Function

How do the structures of specialized cells reflect their functions? How does differentiation lead to this?

**1.1.7 The capacity of stem cells to divide and differentiate along different pathways is necessary in embryonic development and also makes stem cells suitable for therapeutic uses.**



# 1.1.7 The capacity of stem cells to divide and differentiate along different pathways is necessary in embryonic development and also makes stem cells suitable for therapeutic uses.

**Stem cells** are *unspecialized* cells that can:

- Can continuously divide & replicate
- Have the capacity to differentiate into specialized cell types

## Totipotent (embryonic)

Can differentiate into any type of cell.

## Pluripotent (embryonic)

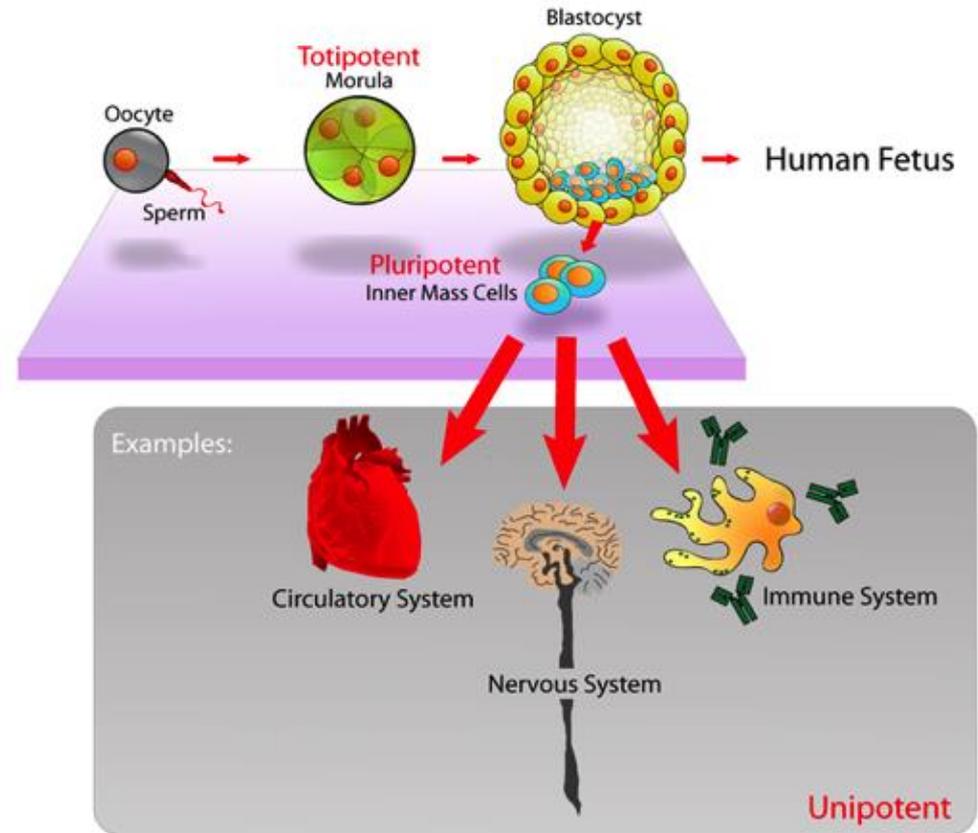
Can differentiate into many types of cell.

## Multipotent (embryonic)

Can differentiate into a few closely-related types of cell.

## Unipotent (adult)

Can regenerate but can only differentiate into their associated cell type (e.g. liver stem cells can only make liver cells).



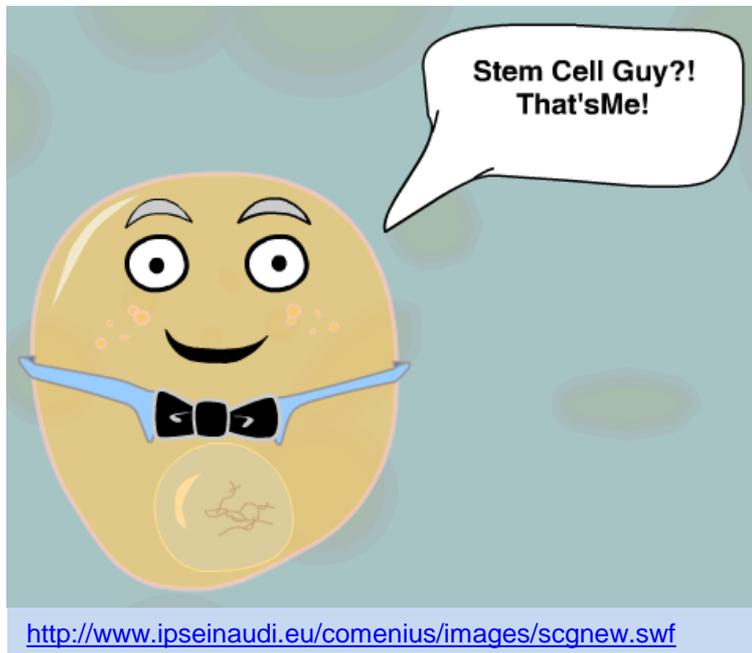
**1.1.7 The capacity of stem cells to divide and differentiate along different pathways is necessary in embryonic development and also makes stem cells suitable for therapeutic uses.**

Learn about stem cells using the tutorials



[http://ns.umich.edu/stemcells/022706\\_Intro.html](http://ns.umich.edu/stemcells/022706_Intro.html)

**Stem Cells Explained**  
an interactive tutorial



<http://www.bbc.com/news/health-14072829>

## 1.1.7 Use of stem cells to treat Stargardt's disease and one other named condition.

### Stargardt's macular dystrophy



<b>The problem</b>	<ul style="list-style-type: none"><li>• Affects around 1 in 10,000 children</li><li>• Recessive genetic (inherited) condition</li><li>• The mutation causes an active transport protein on photoreceptor cells to malfunction, causing photoreceptor cells to degenerate</li><li>• That causes progressive, and eventually total, loss of central vision</li></ul>
<b>The treatment</b>	<ul style="list-style-type: none"><li>• Embryonic stem cells are treated to divide and differentiate to become retinal cells</li><li>• The retinal cells are injected into the retina</li><li>• The retinal cells attach to the retina and become functional</li><li>• Central vision improves as a result of more functional retinal cells</li></ul>
<b>The future</b>	<ul style="list-style-type: none"><li>• This treatment is still in at the stage of limited clinical trials, but will likely be in usage in the future</li></ul>

# Leukemia

<b>The problem</b>	<ul style="list-style-type: none"><li>• Cancer of the blood or bone marrow, resulting in abnormally high levels of poorly-functioning white blood cells.</li></ul>
<b>The treatment</b>	<ul style="list-style-type: none"><li>• <b>Hematopoietic Stem Cells (HSCs)</b> are harvested from bone marrow, peripheral blood or umbilical cord blood</li><li>• Chemotherapy and radiotherapy used to destroy the diseased white blood cells</li><li>• New white blood cells need to be replaced with healthy cells.</li><li>• HSCs are transplanted back into the bone marrow</li><li>• HSCs differentiate to form new healthy white blood cells</li></ul>
<b>The benefit</b>	<ul style="list-style-type: none"><li>• The use of a patient's own HSCs means there is far less risk of immune rejection than with a traditional bone marrow transplant.</li></ul>

### 1.1.11 Ethics of the therapeutic use of stem cells from specially created embryos, from the umbilical cord blood of a new-born baby and from an adult's own tissues.

<b>Comparison of stem cell sources</b>			
	<b><i>Embryo</i></b>	<b><i>Cord blood</i></b>	<b><i>Adult</i></b>
<b>Ease of extraction</b>	Can be obtained from excess embryos generated by IVF programs.	Easily obtained and stored. Though limited quantities available	Difficult to obtain as there are very few and are buried deep in tissues
<b>Ethics of the extraction</b>	Can only be obtained by destruction of an embryo	Umbilical cord is removed at birth and discarded whether or not stem cells are harvested	Adult patient can give permission for cells to be extracted
<b>Growth potential</b>	Almost unlimited	Reduced potential (compared to embryonic cells)	
<b>Tumor risk</b>	Higher risk of development	Lower risk of development	

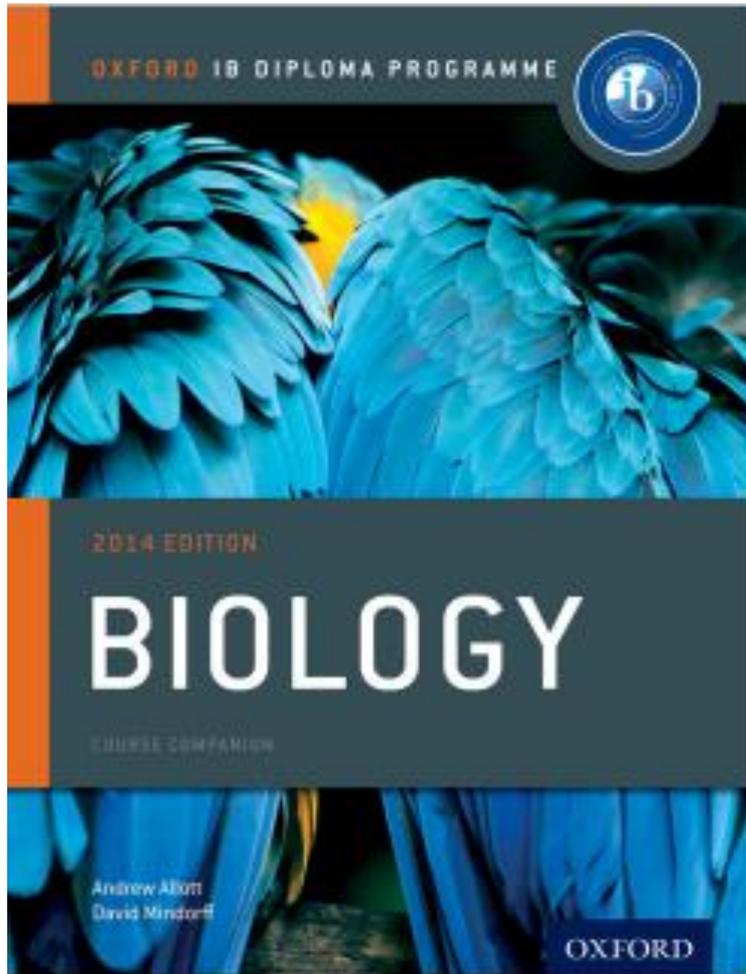
**1.1.11 Ethics of the therapeutic use of stem cells from specially created embryos, from the umbilical cord blood of a new-born baby and from an adult's own tissues.**

<b>Comparison of stem cell sources</b>			
	<i><b>Embryo</b></i>	<i><b>Cord blood</b></i>	<i><b>Adult</b></i>
<b>Differentiation</b>	Can differentiate into any cell type	Limited capacity to differentiate (without inducement only naturally divide into blood cells)	Even more limited capacity to differentiate (dependent on the source tissue)
<b>Genetic damage</b>	Less chance of genetic damage than adult cells		Due to accumulation of mutations through the life of the adult genetic damage can occur
<b>Compatibility</b>	Stem cells are not genetically identical to the patient	Fully compatible with the patient as the stem cells are genetically identical	

# Bibliography / Acknowledgments

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