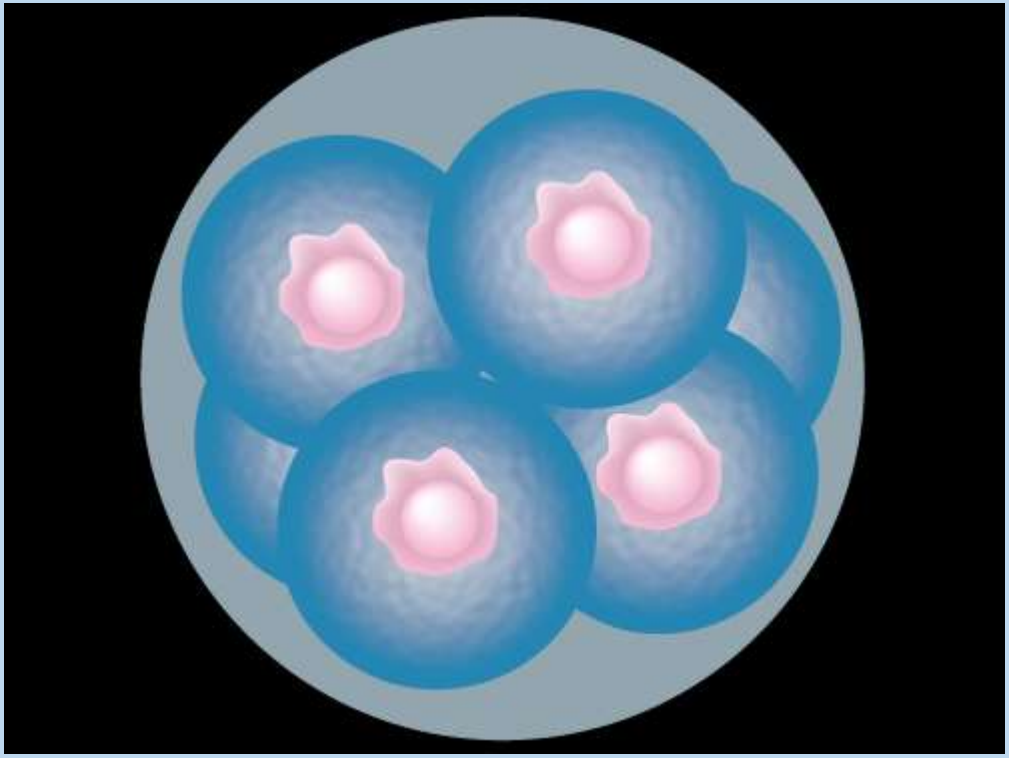
Unit 1: DNA & the Genome

Topic 4: Cellular Differentiation



http://commons.wikimedia.org/wiki/Embryo#mediaviewer/File:8-cell_stage_embryo.png

Learning Outcomes

- Define the term 'cellular differentiation'.
- Define the term 'meristem'.
- Label and say where meristems are found.
- Define the term 'stem cell'.
- Describe the two types of stem cells.
- Give some examples of therapeutic and research uses of stem cells.
- Discuss the ethical issues associated with stem cells.
- Discuss some of the regulations associated with research and uses of stem cells.

Cells Revision

Multicellular plants and animals are complex organisms, consisting of many cells.

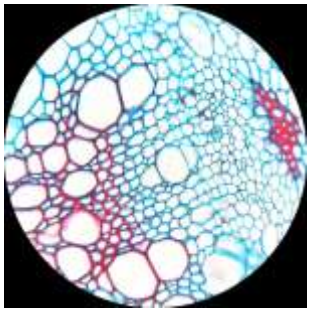
There are about 100 trillion cells in the human body (100 000 000 000 000 cells)

These cells are organised into about 200 different types of cells.

Cells of the same type are organised into groups of cells called tissues.

skin

heart

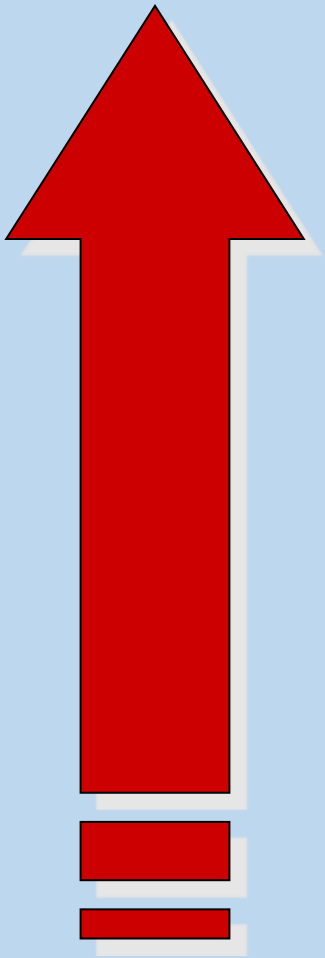


xylem

Each type of tissue has a specific function within the organism.

This is called a **Division of Labour** and results in the efficient functioning of the organism.

Division of Labour



Organism

All the systems working together as a coordinated living unit.

System

A group of organs co-operating to a common purpose.

Organ

Different tissues working together.

Tissue

Cells of the same type grouped together.

Cell

The basic unit of life.

Undifferentiated (not specialised) Cells

We all start of as undifferentiated cells containing exactly the same genetic information in every cell.

Watch this short clip showing cell division immediately after fertilisation of a human egg with a sperm.

Remember that all of the cells in the zygote are not yet specialised.

https://www.youtube.com/watch?v=nB6gFn0_wr8

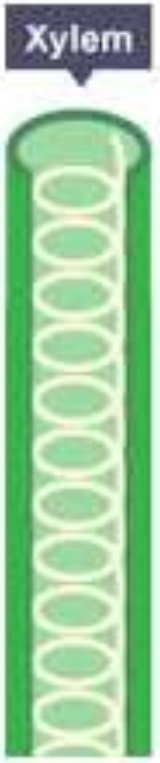
(search for 'cell division video (zygote)' if link does not work)

Differentiated (specialised) Cells

Cells in one type of tissue are called **differentiated** or specialised cells, they have specialised features which enable them to carry out a specific function.

eg
xylem tissue in plants is made up of cells which have strengthened walls and are shaped like cylinders.

This makes them suited to transporting water around the plant and providing support.



Cellular Differentiation

Cellular differentiation is the process by which an unspecialised cell develops more specialised functions by expressing the genes characteristic for that type of cell.

Signals within a cell cause it to become more specialised (differentiate).

Some genes are switched on, others are switched off.

Selective Gene Expression

Every cell in an organism contains the same DNA therefore has the potential to be any cell type.

The switching on or off of selected genes makes the cell differentiate.

During differentiation:

1. Many essential genes remain switched on in **all** cells.
   eg the gene coding for the cellular respiration enzymes

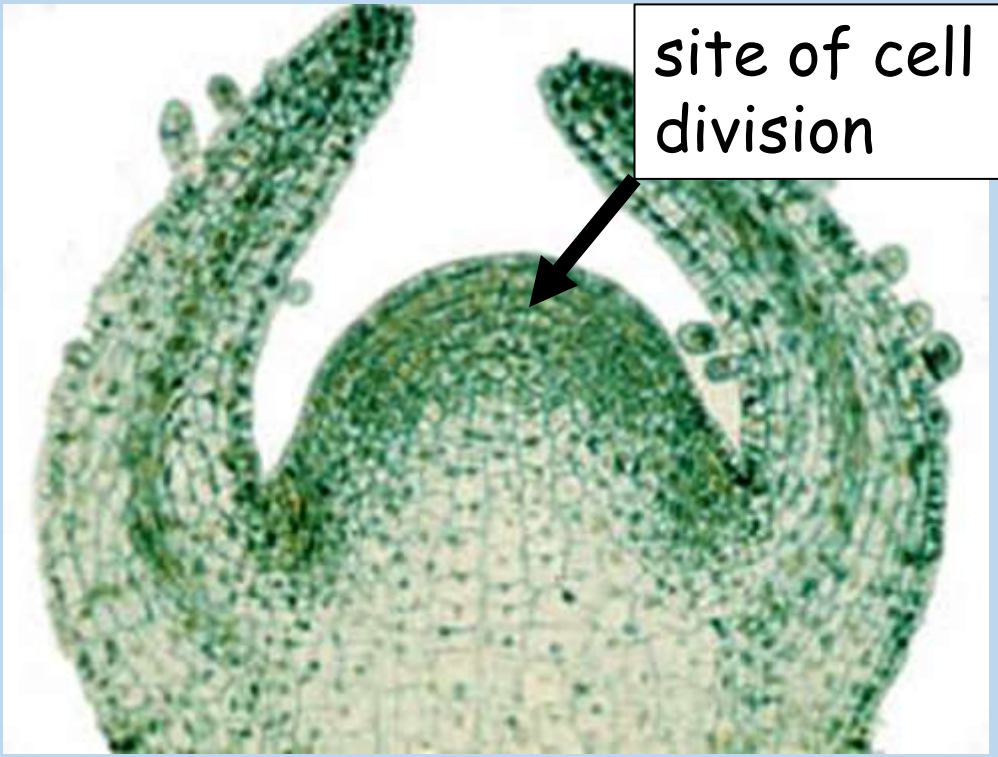
2. Some genes are switched on in certain differentiated cells only.
   eg the gene for haemoglobin in red blood cells(RBC)

3. Unnecessary genes are switched off to prevent the production of proteins that are not required.

Growth and Differentiation in Multicellular Plants

In plants, growth is restricted to an area called a meristem.

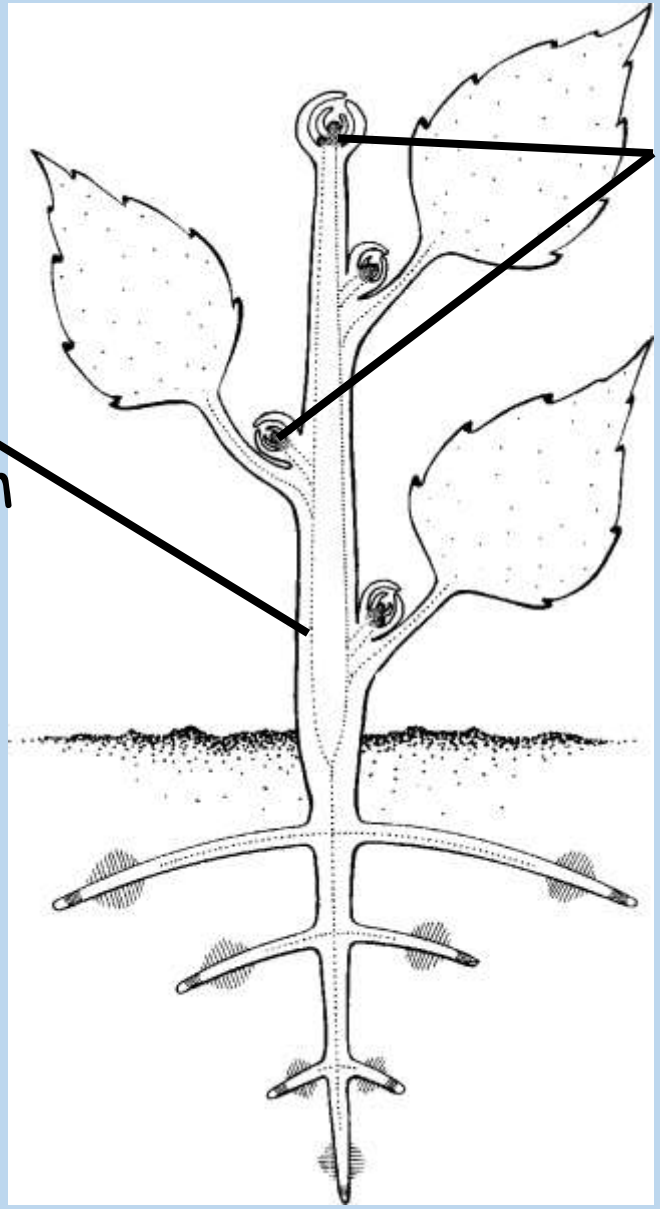
Meristems are groups of unspecialised cells which can divide repeatedly over the lifetime of the plant.



Some meristematic cells will remain the same and keep providing new undifferentiated cells.

Others will become differentiated into the cell types required to make up the various tissues in the plant.

Apical and Lateral Meristems



Apical meristems
Found at the apex (tip) of the shoots and roots.

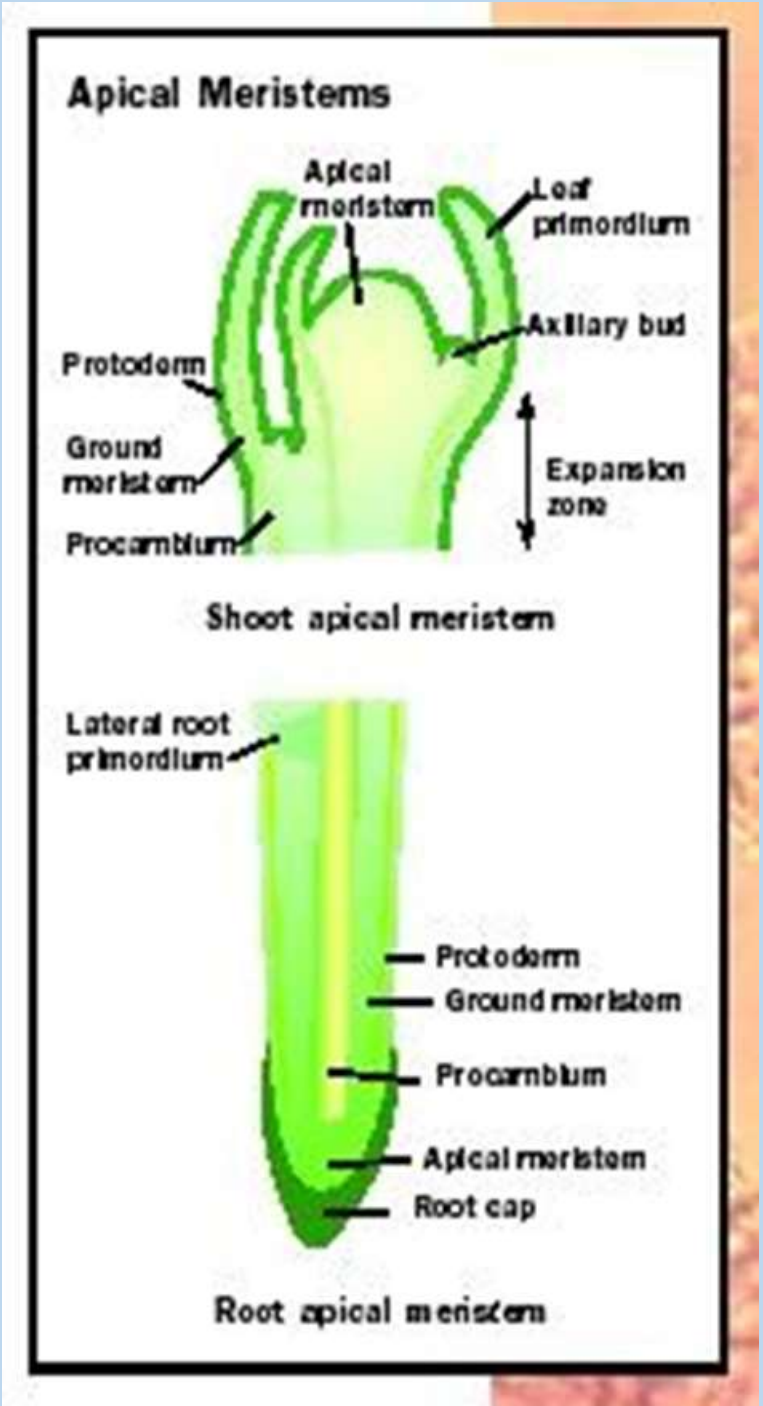
Increase the **<u>length</u>** of the plant (primary growth).

Lateral meristems
Found in the cambium of the vascular bundles.

These increase the **<u>girth</u>** of the plant (secondary growth).

Apical Meristems

Note that apical meristems can be found at the tip of the roots as well as the shoots.



Primary Growth in Apical Meristems

Apical meristems are the site of primary growth in a plant, and can be found at the root and shoot tips.

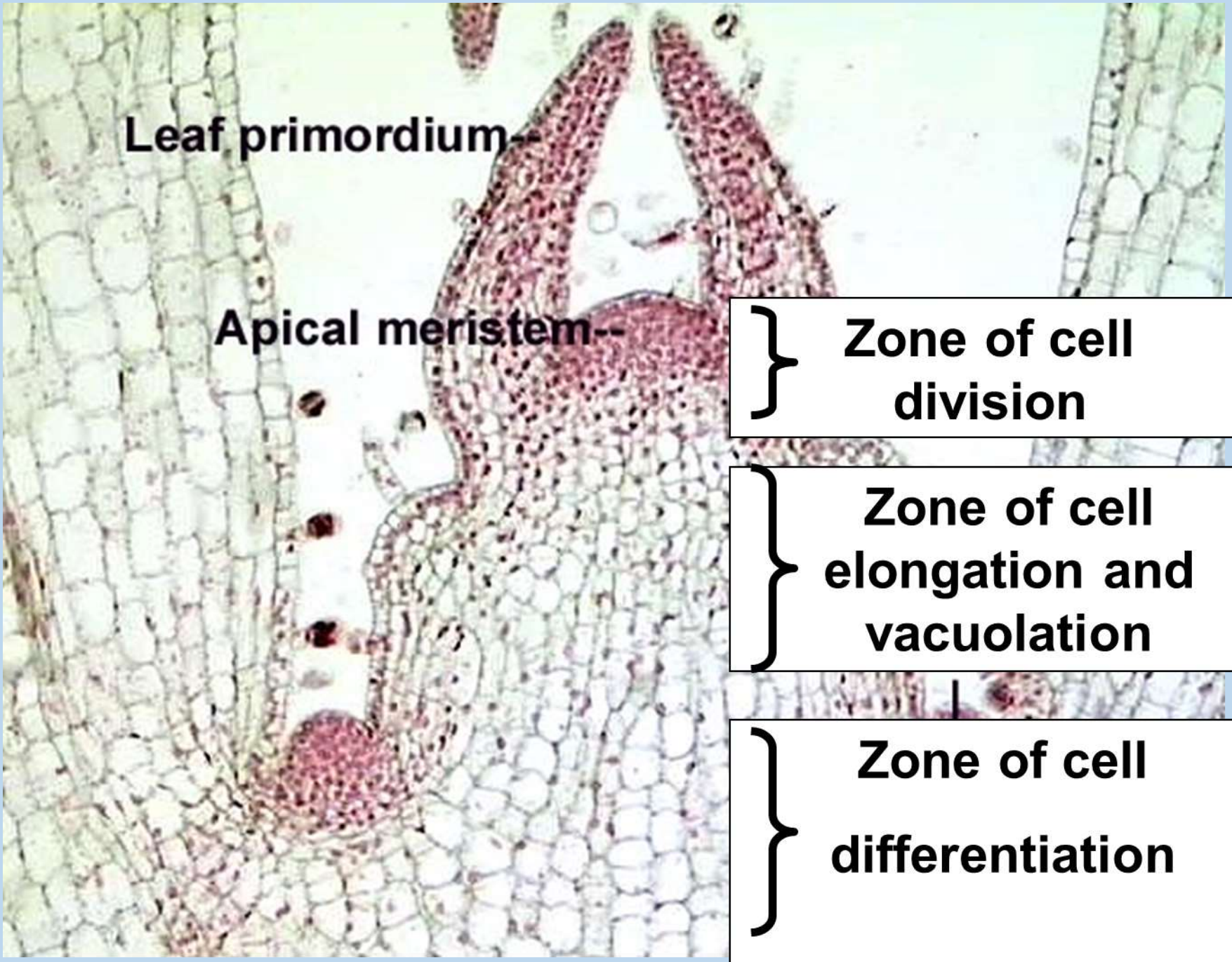
There are 4 main areas within the meristem.

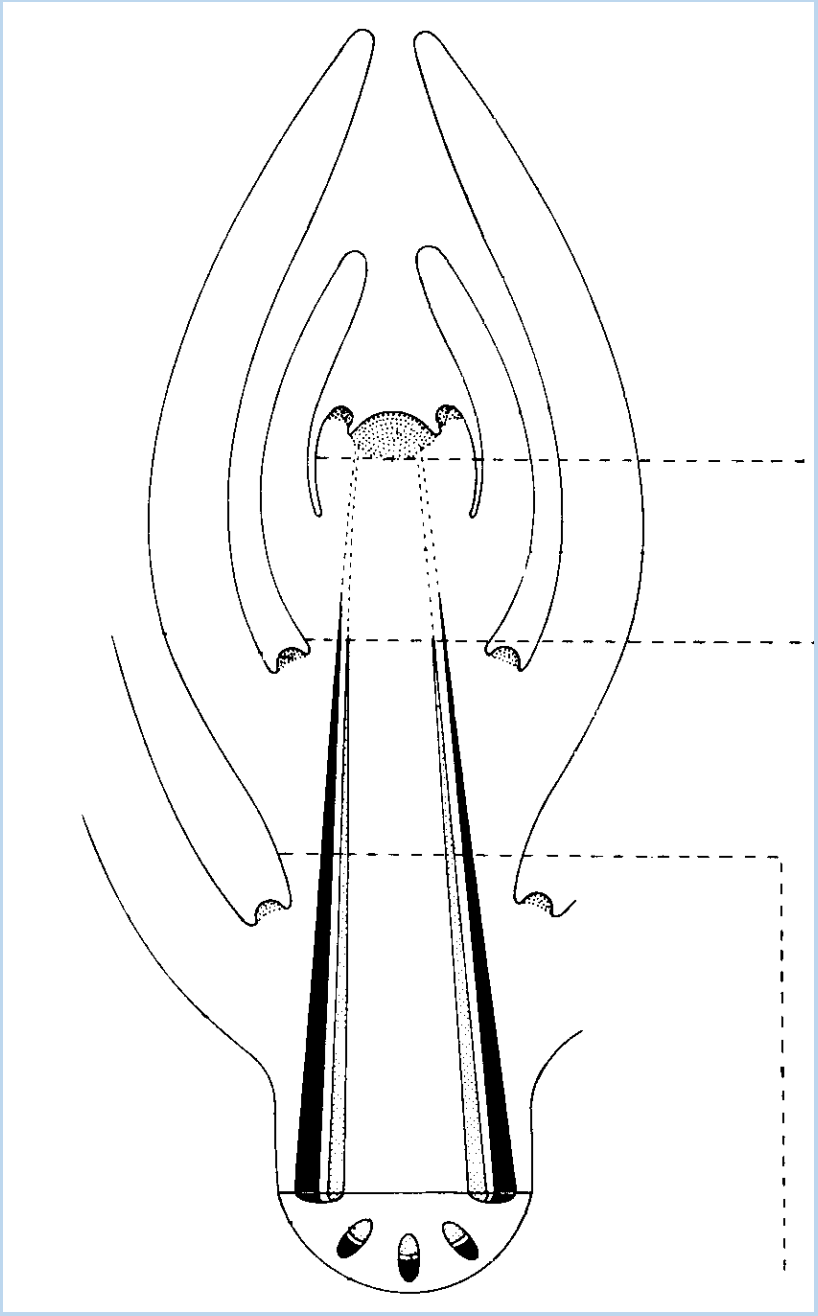
1. Zone of mitosis (cell division)

2. These cells then become elongated and vacuolated.

3.Then they become differentiated (specialised) to perform a particular function.

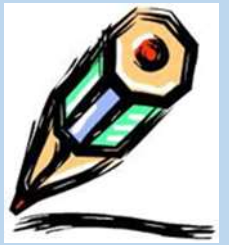
4.They then form part of a permanent tissue which performs a particular role within the plant.


Leaf primordium--
Apical meristem--
Zone of cell division
Zone of cell elongation and vacuolation
Zone of cell differentiation



Use the textbook to draw and label this diagram.

Secondary growth in Lateral Meristems

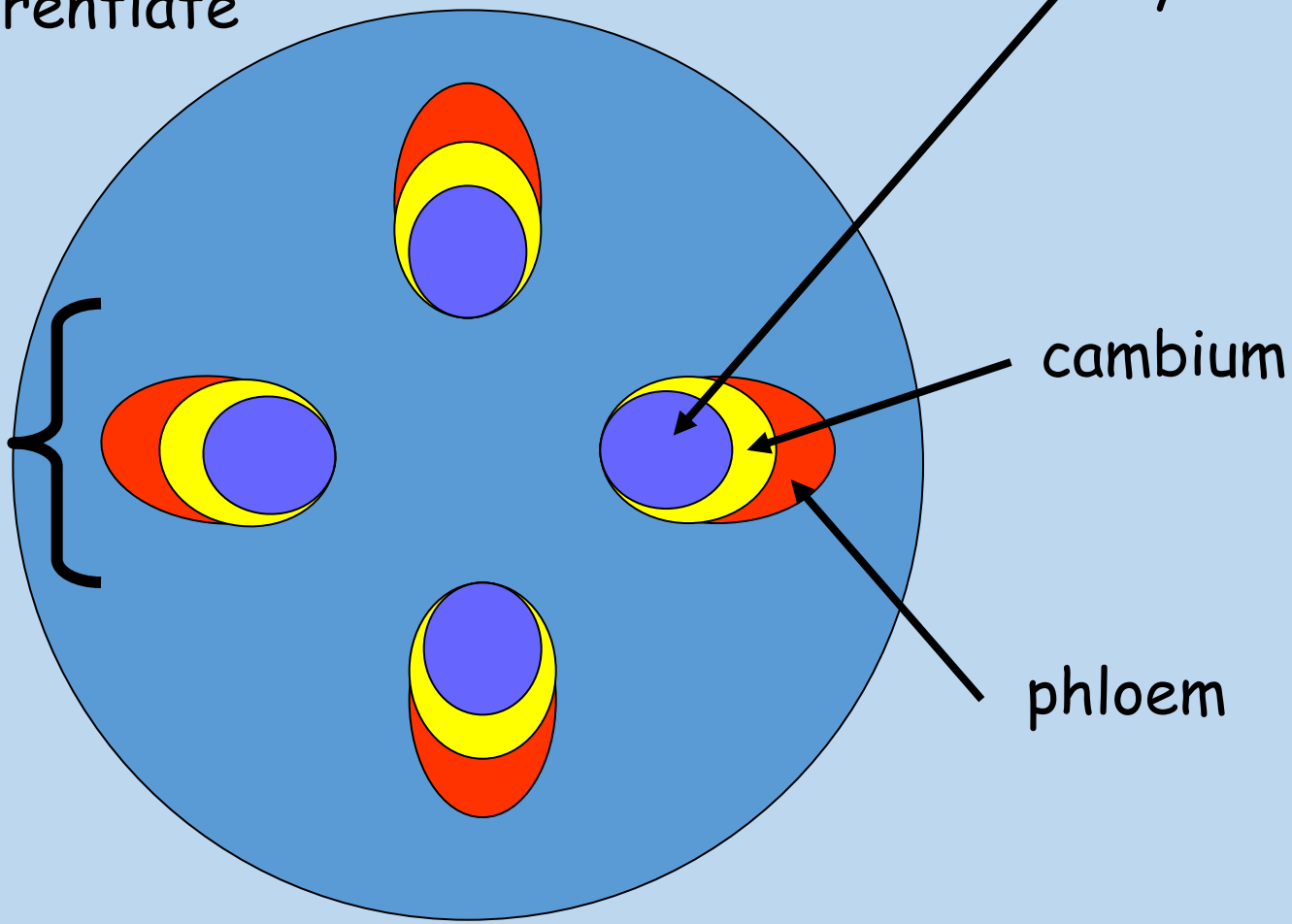


Annual plants only live for one season whereas perennial plants will continue to grow year after year.

This means that perennial plants must increase their girth (width) to support new vascular tissue (xylem) which will provide the water needed for the additional photosynthesis of a bigger plant.

The increase in girth is produced by the lateral meristem in a tissue called the cambium.

Cambium is said to be meristematic and contains undifferentiated cells which will eventually differentiate into xylem or phloem cells.



The activity of cambium produces new cells that **differentiate** into xylem and leads to an increase in the thickness of the stem.

Each year a complete ring of secondary xylem (inside) and a ring of phloem (outside) forms.

The xylem vessels make up the pattern of annual rings found in trees.

Tissue Culture in Plants

Tissue culture is a technique used to grow new plants from the tissue of another plant.

The ability for plant cells to grow into a new plant is not only due to the undifferentiated meristematic cells but can be done by causing the differentiated cells to switch off the very genes which made them differentiated.

The new plants will be genetically identical to (or clones of) the original plant.

Tissue Culture

How is it possible to grow a new plant with differentiated tissues from any other type of plant cell?

Plant cells are **totipotent**!

That means that any cell from the plant can differentiate into any specialised cell needed to grow a whole plant.

This involves the switching on of characteristic genes using growth regulators.

Practical Activity 1.4.1

You are going to work in groups to investigate growing new plants from an old plant using the tissue culture technique.

Read the handout carefully before beginning.

Your finished report will be in the form of a poster paper and will include the following:

- Aim
- Method with a diagram (labelled and annotated)
- The types of cells which undergo cell division during tissue culture (careful!)
- Information on the uses of tissue culture (p46 Torrance)
- Photographs of your results if possible

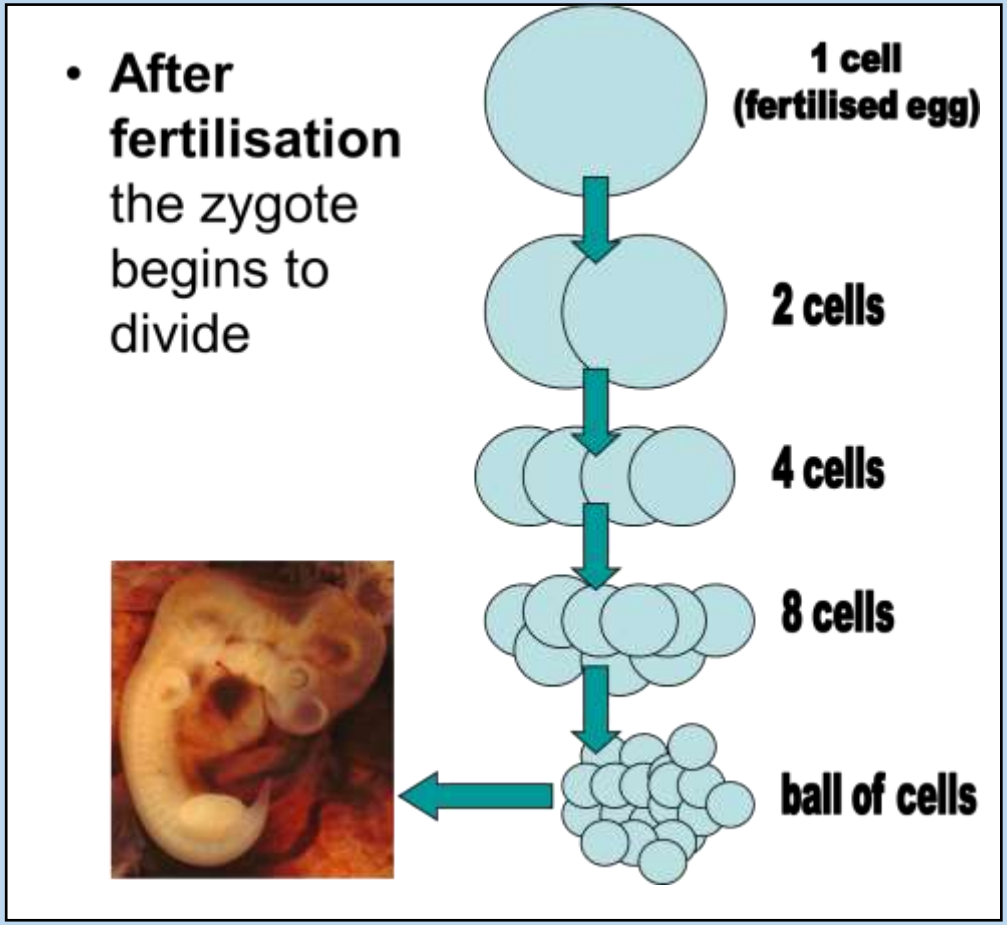
Growth and Differentiation in Multicellular Animals

A multicellular animal begins life as a fertilised egg (zygote) which then divides repeatedly to form an embryo.

Each cell contains all the genes for constructing the whole organism.

As the embryo grows, the cells start to differentiate and form specialised cells within tissues.

This is because only the genes coding for the proteins needed to work that particular type of cell are switched on.

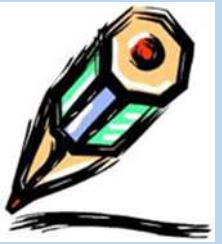


Stem Cells

Stem cells are unspecialised cells that can:

- Reproduce themselves by repeated mitosis and cell division while remaining undifferentiated.
- Differentiate into specialised cells when required to do so by the multicellular organism that possesses them.

Embryonic and Tissue (Adult) Stem Cells



There are two types of stem cells, embryonic and tissue (adult) stem cells.

Embryonic

- taken from early embryos
- pluripotent
- can differentiate into any type of specialised cell

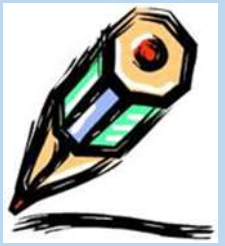
blastocyst

Tissue (Adult)

- found in many tissues in an adult organism
- Unipotent
- can divide and differentiate to become only one type of cell

bone marrow

Stem Cells and Research



Stem cell research can be carried out to:

1. Find out more about cell processes such as cell growth, differentiation and gene regulation.

2. Study the development of diseases.

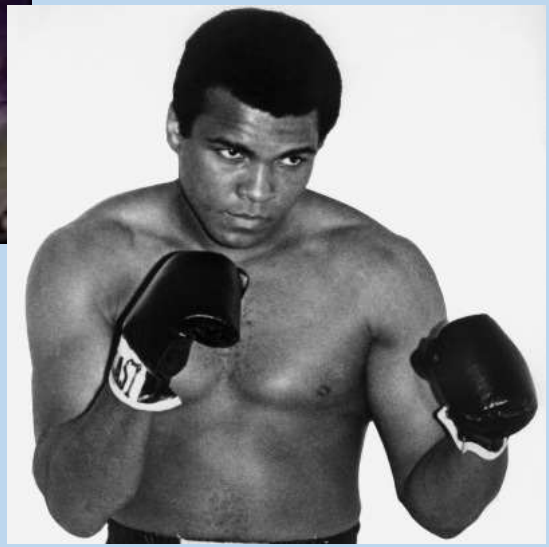
3. Test drugs.

Most of the research to date has been carried out using stem cells from mice and humans.

Therapeutic Use of Stem Cells

Current Uses

- Bone marrow transplants to treat cancer of the blood
- Corneal grafts of stem cell tissue
- Treatment of burns or scars

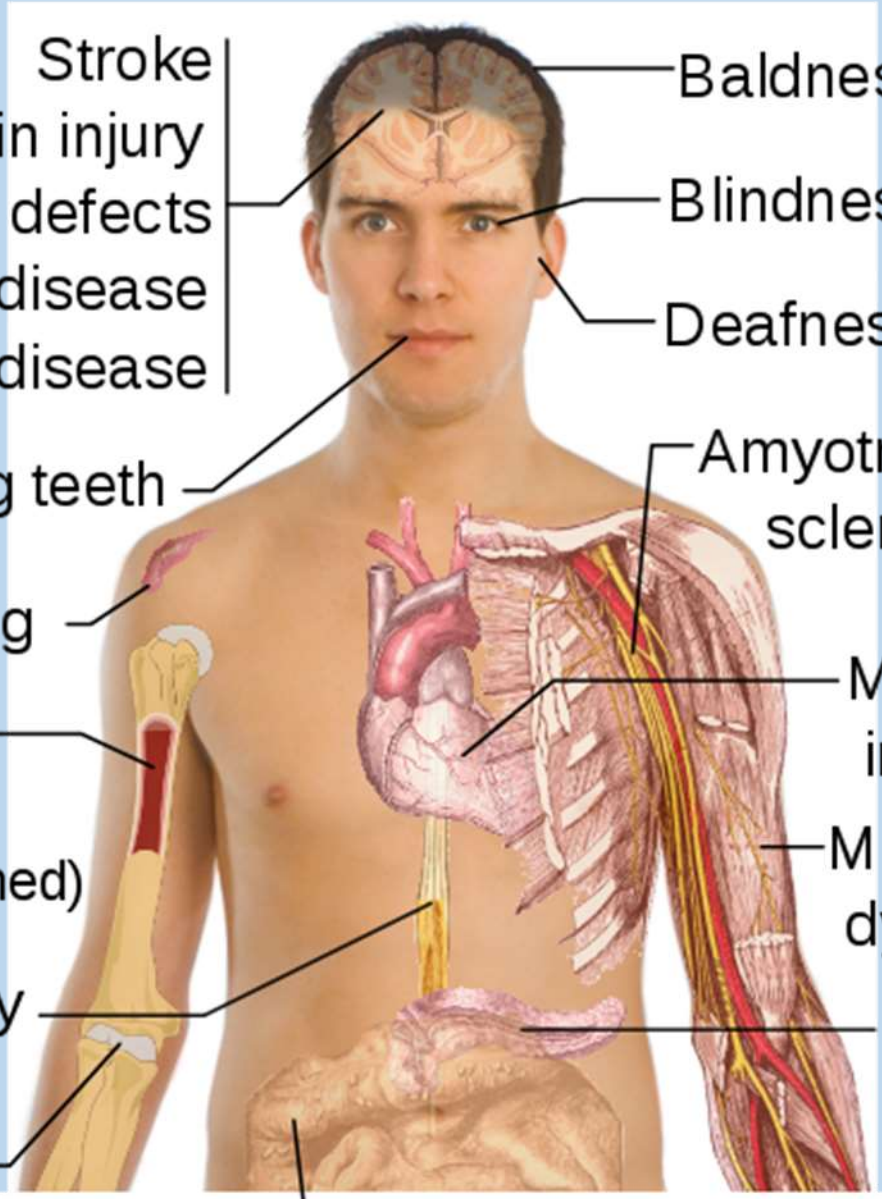


Future Uses

- Parkinson's disease
- Diabetes
- Alzheimer's disease
- Multiple Sclerosis

Potential uses of

Stem cells



Stroke

Traumatic brain injury

Learning defects

Alzheimer's disease

Parkinson's disease

Baldness

Blindness

Deafness

Missing teeth

Amyotrophic lateral-sclerosis

Wound healing

Myocardial infarction

Bone marrow transplantation (currently established)

Muscular dystrophy

Spinal cord injury

Diabetes

Osteoarthritis

Rheumatoid arthritis

Crohn's disease

Multiple sites: Cancers

Use the Lab in a Box to produce a powerpoint on the therapeutic use of stem cells.

Choose one of the examples below and describe how stem cells are being used for that particular condition.

Leukaemia

Corneal Repair

Burn Victims

Missing Teeth!

Ethical Issues

There are many different views and opinions on the moral values and rules that govern the way we act as humans.

The use of stem cells creates debate not only amongst the scientific community but also amongst people from all cultures.

You have a few minutes to discuss with your neighbour your personal views on the point at which a human life begins.

Class Debate

Everyone must read the Case Study on Embryonic Stem Cell Debate and the Sources of Stem Cells on pages 51 **and** 52 of the textbook.

The class will be divided into two teams. One team will be 'for' and the other will be 'against' using human embryos in stem cell research (your teacher will decide which is which).

Within each team decide on two people who will present the team's argument to the rest of the class.

Everyone in the team should then contribute to the discussion and a written argument should be prepared.

The speakers (all 4 of them) will have between 4 and 7 minutes to present to the class (a timer will be used to keep it fair!).

At the end both teams can ask questions around the issues raised.

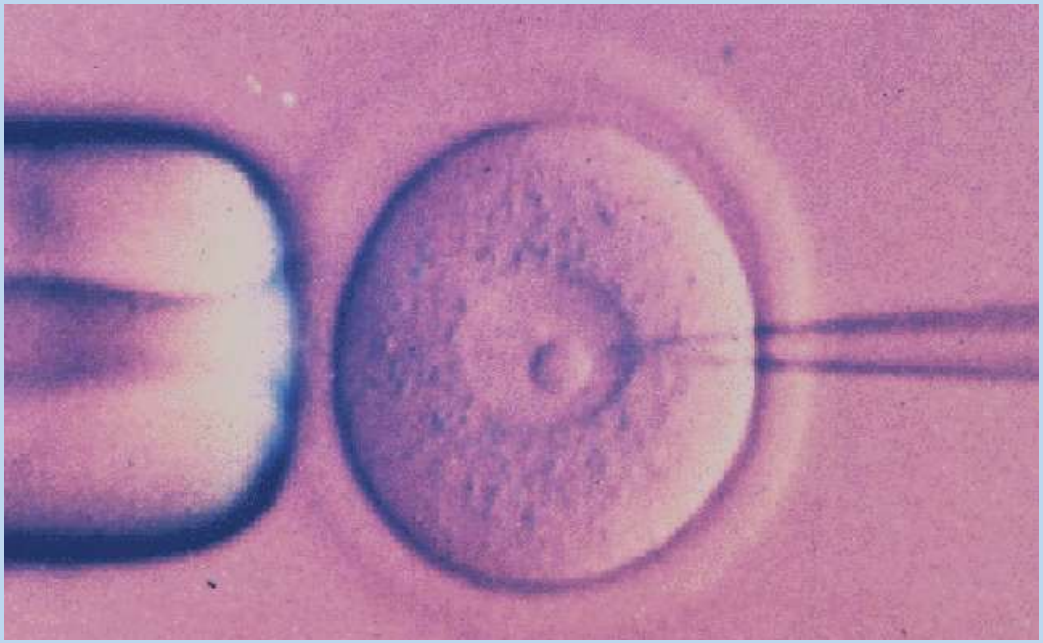
Nuclear Transfer Technique

A nucleus from a human cell can be removed and placed inside an animal cell (eg cow) which has had its own nucleus removed.

These cells are now part animal cell and part human cell.

There is ongoing debate as to the ethics of mixing materials from animals and humans.

However, these cells are an excellent source of stem cells and alleviate some of the problems associated with using human embryonic stem cells.



Laws Governing the Use of Stem Cells

In the UK, the use of stem cells for research is regulated by laws such as:

Human Fertilisation and Embryology Act

and the

Human Reproductive Cloning Act

A licence must be obtained before carrying out any stem cell research.

A licence will only be granted if:

- the use of human embryos is absolutely necessary
- the purpose of the work is to increase knowledge about serious disease
- the knowledge obtained will be applied in the development of treatments for the serious disease

Embryos must be either used or destroyed before 14 days as this is considered to be the point at which nerve cells start to form.

Hybrid cells (part human, part animal) cannot be implanted in either a human or animal uterus.

Other Safeguards

In Europe, a directive entitled Tissues and Cells ensures further safeguards such as:

- Safety and quality of stem cells is ensured
- Donors are selected carefully
- Transfer of stem cells from donor to recipient is tracked
- Adverse effects (such as illness) following stem cell transplants are reported
- Sources of all materials used are able to be traced