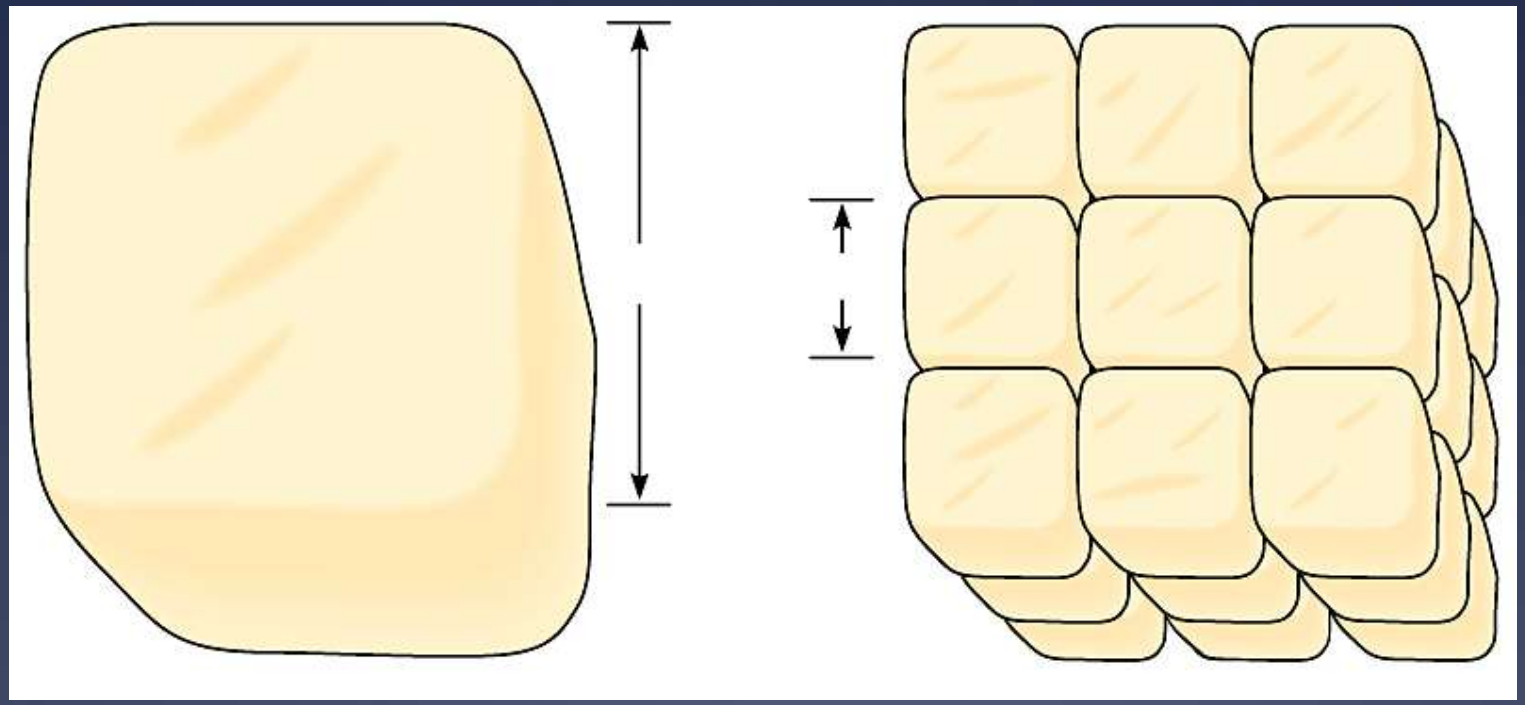
IB Biology

Cell Theory

CELL SIZE LIMITS

* A small cell has a greater ratio of surface area to volume than a large cell of the same shape



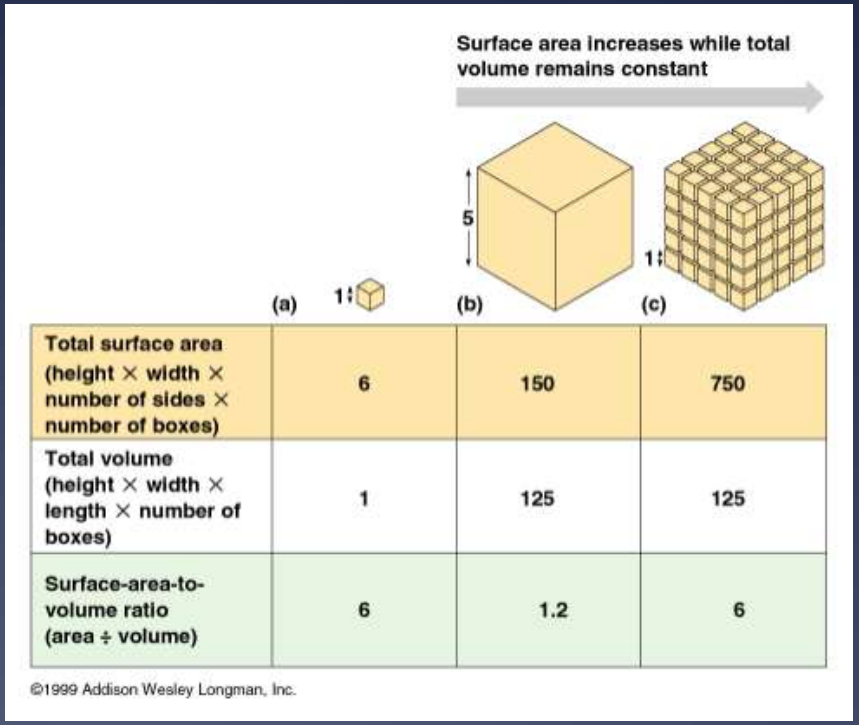
Surface area of one large cube = 5,400 μm²

Total surface area of 27 small cubes = 16,200 μm²

Figure 4.3

Cell size - (surface area:volume)

- As cell size increases, the surface area to volume ratio decreases (sa/vol)
- Rates of chemical exchange may then be inadequate for cell size
- Cell size, therefore, remains small



	(a)	(b)	(c)
Total surface area (height × width × number of sides × number of boxes)	6	150	750
Total volume (height × width × length × number of boxes)	1	125	125
Surface-area-to-volume ratio (area ÷ volume)	6	1.2	6

Natural laws limit cell size

- At minimum, a cell must be large enough to house the parts it needs to survive and reproduce
- The maximum size of a cell is limited by the amount of surface needed to obtain nutrients from the environment and dispose of wastes

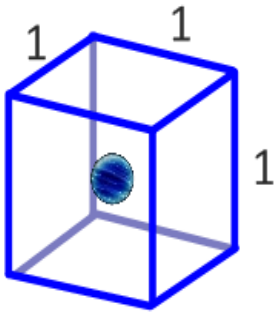
Cell Size

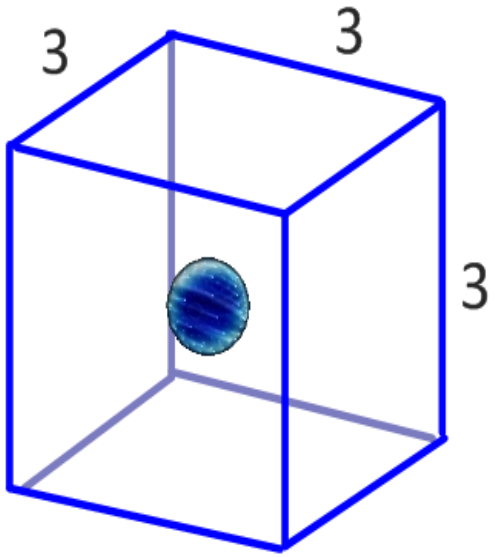
- As the width of the cell increases, surface area also increase, but at a much slower rate than the volume
- Thus a large cell has relatively less surface are to bring in needed materials

Cells

* Large animals do not have larger cells, they have more cells

Big cells vs small cells





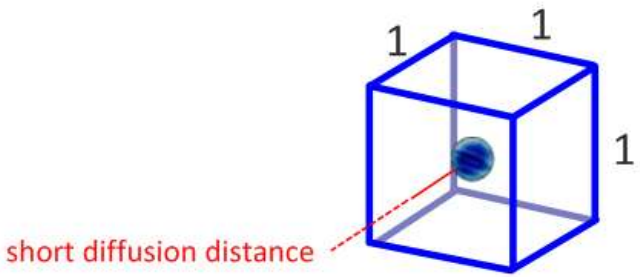
How many units of membrane are there per unit volume?

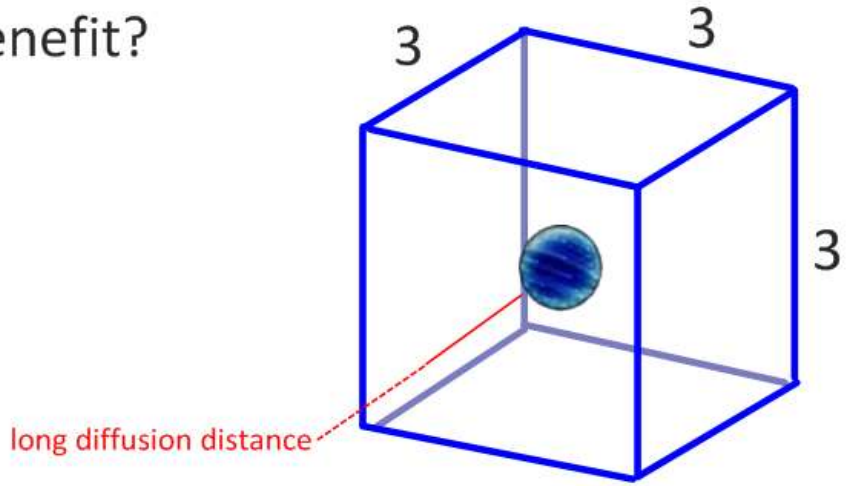
1	volume	27
6	SA	54
6:1	SA:Vol	2:1

The plasma membrane is responsible for import/export in the cell.
Metabolic reactions occur on membranes.

A larger SA:Vol ratio means the cell can act more efficiently: for every unit of volume that requires nutrients or produces waste, there is more membrane to serve it.

How else is a large SA:Vol ratio a benefit?





Diffusion pathways are shorter, so more efficient - molecules do not have to travel so far to get in/out of the cell, so it takes less time and (if it is active transport) energy.

Concentration gradients are easier to generate - which makes diffusion more efficient. (i.e. it takes less solute to make 10% solution in a 100ml beaker than a 10l bucket)

A large SA:Vol ratio is not always an advantage:

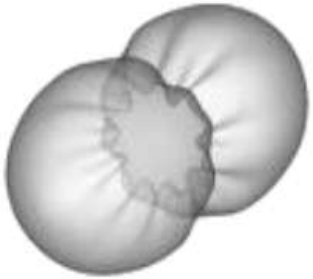
Small, warm-blooded mammals lose heat very quickly due to their large SA:Vol ratio. They need to eat almost constantly! (Think about how hungry you get on a cold day)

shrew

cactus

Desert plants would lose water quickly with flat leaves - so they minimise their SA:Vol ratio in order to conserve water. Some plants change their metabolism (CAM plants) to save water.

So how do organisms maximise SA:Vol ratio?



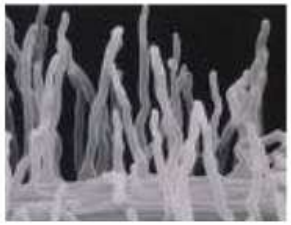
As organisms grow, cells divide.
Two small cells are more efficient than one large cell.
This also allows for cell differentiation, specialised functions and more complex multicellular life.

http://www.a3243g.com/a3243g_images/mitochondria.gif

Cells compartmentalise - they use membranes to carry out metabolic processes. In eukaryotes, these are called organelles.

Organelles themselves, like this mitochondrion, are also made up of membranes - maximising the surface area for reactions.

Some organs (such as the intestines) fold up to maximise SA:Vol ratio - making absorption of food molecule more efficient.
Alveoli in the lungs are thin membranes that maximise the surface for gas exchange.
Roots are long, and branched, with root hairs on the cells to maxiise the surface area for water uptake.



Conclusions

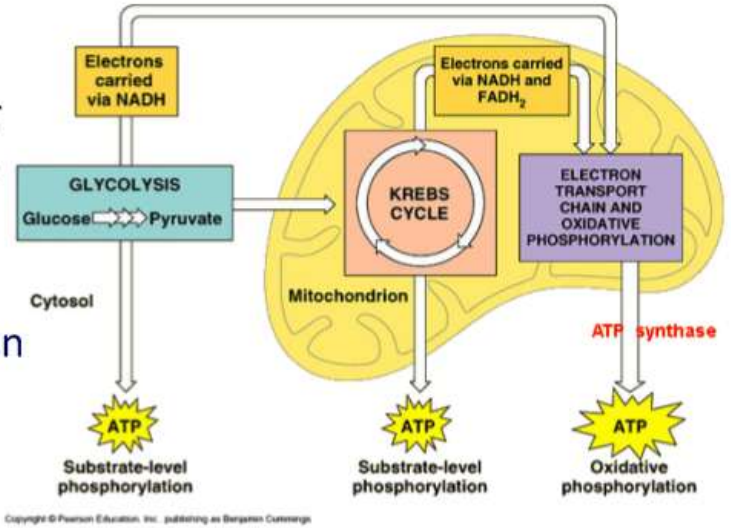
* As the organisms gets bigger its surface area:volume ratio decreases
* This rule is a limiting factor for cell size
* As the cell gets bigger the ratio decreases
* If the ratio decreases the rate of exchange decreases

Emergent Properties

The discipline of Systems Biology looks at the way different parts of a whole organism interact with each other to give emergent properties.

This is a relatively new field, where science has been traditionally reductionist - breaking things down into their component parts. By looking at the whole system, we can see that an organism is more than the sum of its parts.

In this diagram, we see that when this specific combination of molecules and pathways are combined, the ability to carry out aerobic respiration emerges.



http://fig.cox.miami.edu/~cmallery/150/makeatp/c9x6cell-respiration.jpg

Emergent properties are seen at every level of increasing complexity, from the atom to the molecule, to the cell, to the organism to the biosphere.

TOK: How does the failure of one or multiple systems bring about the death of an organism?

One of the main hurdles to AI is the issue of emergent properties: in biosystems, they 'appear' and if they are not detrimental are selected through evolution. Swarm technology is an example of how scientists are trying to generate software that mimics this process.

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http://www.scribd.com/doc/2405989/Emmeche-aLife-Organism-and-Body-The-Semiotic-of-Emergent-Properties

EMERGENT PROPERTIES:

When we break something complex into its component pieces, they each appear to be simple. Combined, they can perform a whole new function.

cell organelles	nucleus, mitochondria, ribosomes...		
↓			
cells	muscle cells	liver cells	skin cells
↓			
tissues	cardiac muscle	liver tissue	epithelium
↓			
organs	heart	liver	skin
↓			
organ systems	circulatory system	digestive system	skin
↓			
organisms	mammal	mammal	mammal

Stem Cells

Stem cells retain the capacity to divide

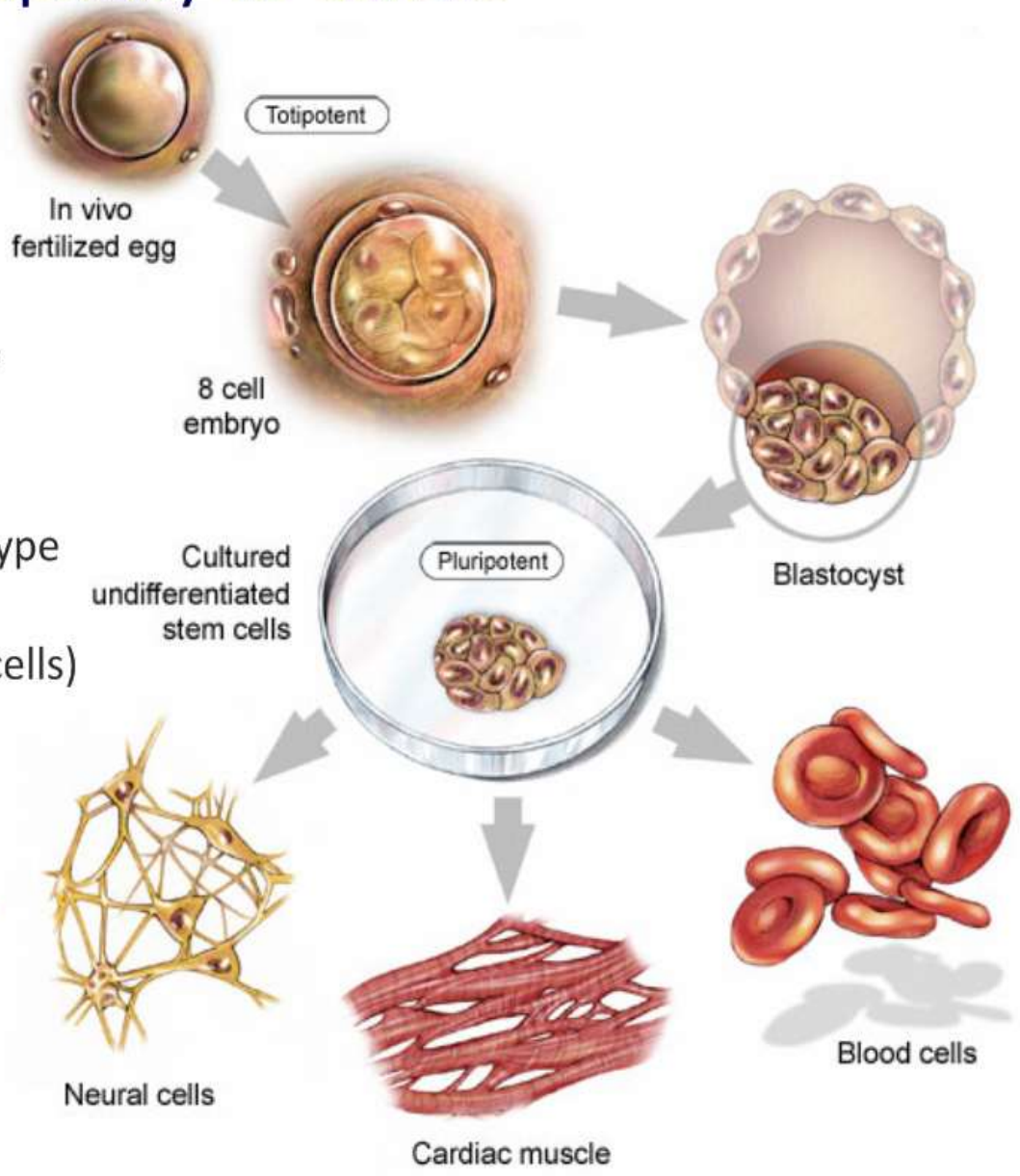
Totipotent: can become any cell type

Pluripotent: can become any type except embryonic membrane

Multipotent: can become a number of different cell types

Unipotent: can only become one cell type

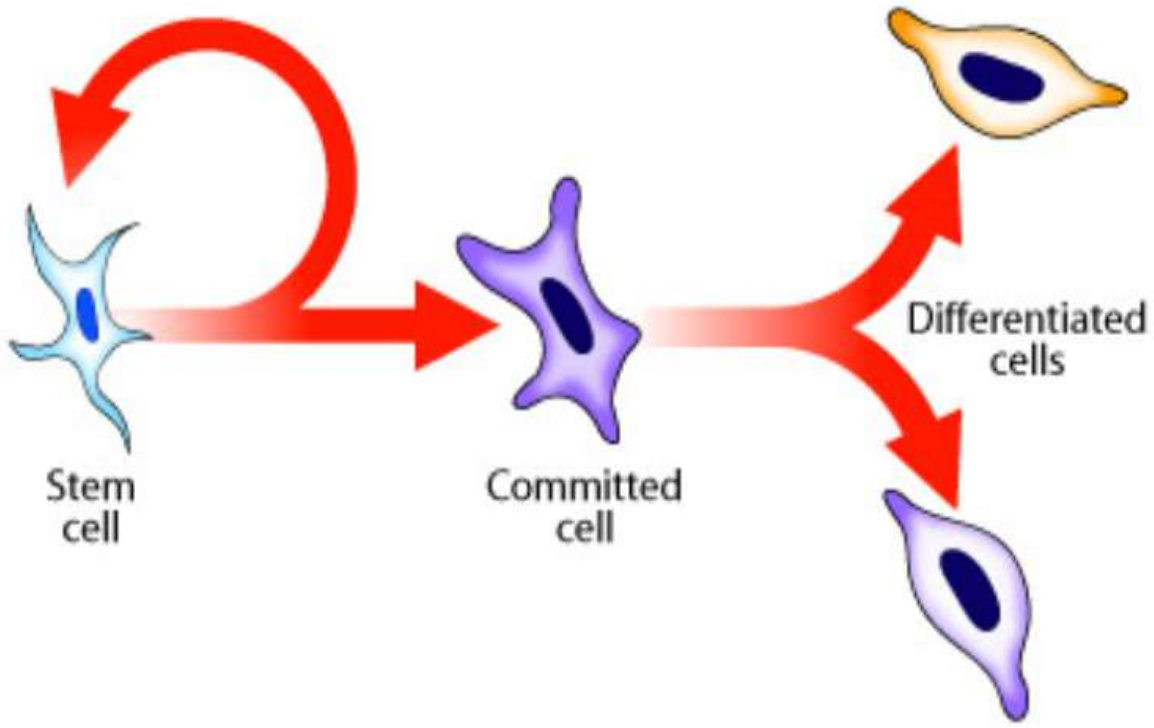
Nullipotent: cannot divide (red blood cells)

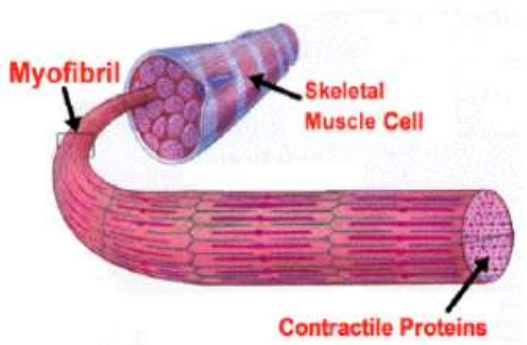


Once a stem cell has differentiated, it can only make more stem cells or the differentiated cell type.

http://www.csa.com/discoveryguides/stemcell/overview.php

Cell differentiation is a result of expression of different genes.





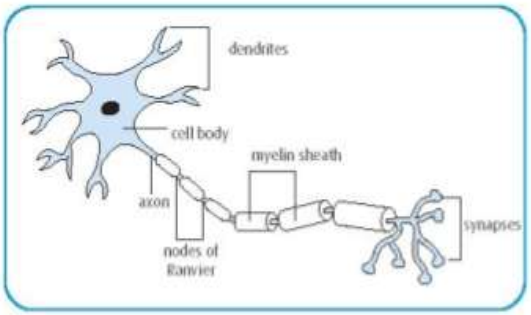


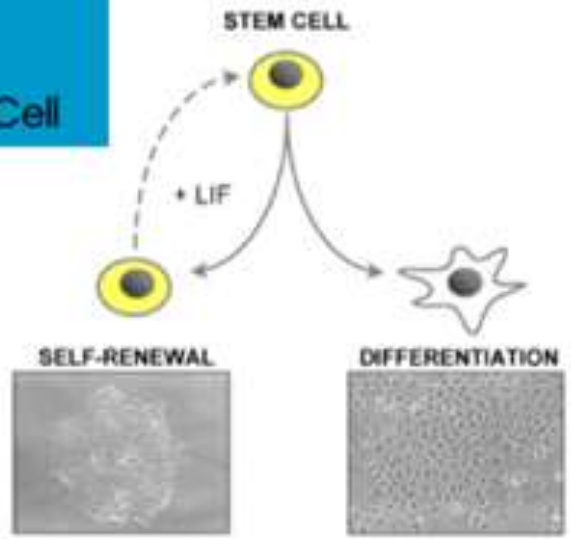
Illustration by Cell Imaging Core of the Center for Reproductive Sciences.

SPECIALISED CELLS are those which perform a specific function.

STEM CELLS are non-committed and can potentially become any type of cell.

Stem Cells Resources

EuroStemCell



A stem cell is an unspecialised cell type. When it divides it can either produce identical daughter cells (self-renewal) or it can produce more specialised cell types (differentiation). A central goal in stem cell research is to understand how this choice between self-renewal and differentiation is determined.

http://www.eurostemcell.org/

http://learn.genetics.utah.edu/units/stemcells/whatisse/

Stem Cells poster

http://www.seedmagazine.com/news/2005/11/cribsheet_1_stem_cells.php

Stem Cell Basics

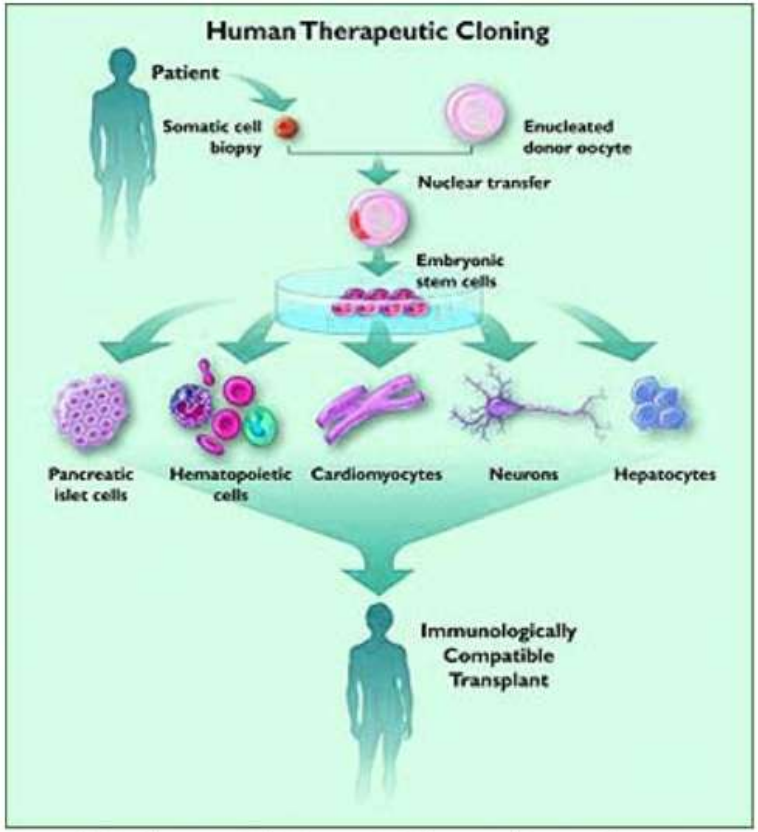
Stem cells have the remarkable potential to develop into many different cell types in the body. Serving as a sort of repair system for the body, they can theoretically divide without limit to replenish other cells as long as the person or animal is still alive. When a stem cell divides, each new cell has the potential to either remain a stem cell or become another type of cell with a more specialized function, such as a muscle cell, a red blood cell, or a brain cell.

NEW Watch a QuickTime video of stem cells dividing

http://stemcells.nih.gov/info/basics/

Therapeutic Cloning of Stem Cells:

Therapeutic cloning involves the in-vitro culturing of tissues using patient or donor stem cells. It can be used to replace tissues lost in disease, burned skin or even nerve cells.



http://whyfiles.org/148clone_clash/images/thera_diagram.jpg

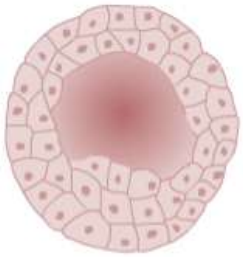
Trachea grown with stem cells:

http://www.youtube.com/watch?v=XL72Dn3rJ_E

Because embryonic stem cells are the most versatile, they have been at the centre of research and controversy.

source unknown

Embryonic stem cells are derived from blastocysts – embryos that are about a week old. At this stage, the blastocyst has about 100 cells. Human blastocysts like this have been donated to research from *in vitro* fertilization clinics.



BLASTOCYST

CONTINUE

Next class you will turn in. .

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Read and outline 16-19 in your text

Microscope Skills Worksheet

Review Cell Theory Assessment Statement