Topic 2.1 Cell Theory

Assessment Statements
What you need to know:
2.1.1 Outline the cell theory.
2.1.2 Discuss evidence for the cell theory.
2.1.3 State that unicellular organisms carry out all the functions of life.
2.1.4. Compare the relative sizes of molecules, cell membrane thickness, viruses, bacteria, organelles and cells, using the appropriate SI unit.
2.1.5 Calculate the linear magnification of drawings and the actual size of specimens in images of known magnification.
2.1.6 Explain the importance of the surface area to volume ratio as a factor limiting cell size.
2.1.7 State that multicellular organisms show emergent properties.
2.1.8 Explain that cells in multicellular organisms differentiate to carry out specialised functions by expressing some genes but not others.
2.1.9 State that stem cells retain the capacity to divide and have the ability to differentiate along different pathways.
2.1.10 Outline one therapeutic use of stem cells.

The Cell Theory

Proposed by

The cell theory is made of three parts:

1.

2.

3.

Give one piece of evidence for each of these statements?

1.

2.

3.
What are some exceptions to the cell theory?

This is an interesting article to read about how cells evolved:

http://learn.genetics.utah.edu/content/begin/cells/organelles/

And here is a nice Cell Theory timeline:

http://www.timetoast.com/timelines/the-cell-theory-timeline

**Functions of life**

At GCSE we use MRSGREN to help us remember the characteristics of living things. Define each term and give examples of how unicellular organisms carry out these processes.

- **metabolism**
- **response**
- **homeostasis**
- **growth**
- **reproduction**
- **nutrition**
Relative Sizes

http://learn.genetics.utah.edu/content/begin/cells/scale/

1 metre = 100 cm = 1000 mm = 1000000 um = 1000000000 nm

<table>
<thead>
<tr>
<th>Structure</th>
<th>Actual size</th>
<th>Size in m</th>
<th>Size in scientific notation</th>
<th>Size relative to eukaryotic cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eukaryotic cell</td>
<td>up to 100 um</td>
<td>0.0001m</td>
<td>1 x 10^-4</td>
<td>1</td>
</tr>
<tr>
<td>Cell organelles</td>
<td>up to 10 um</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prokaryotic cell</td>
<td>1 um</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virus</td>
<td>100 nm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell membrane</td>
<td>10 nm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose molecule</td>
<td>1 nm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water molecule</td>
<td>0.1 nm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Imagine a eukaryotic cell was the size of a football field.
Can you find an object to represent each of the other items in the table?

Cell organelles

Prokaryotic cell

Virus

Cell membrane

Glucose molecule

Water molecule
Magnification

Define magnification:

What are the two ways that we can indicate magnification on an image?

What is the formula for calculating magnification?

Rules for magnification calculations:
1. 
2. 
3. 

Calculate the actual size of this drawing:

Drawing of *Paramecium caudatum*
What is the average size of the chloroplasts in this plant cell if the image has a magnification of x9000?

Scale Bars

Scale bars are added to micrographs (photos taken through a microscope) to give us an idea of the actual size of the object we are observing.

To calculate the magnification using a scale bar we have a different formula:

Calculate the magnification of these scale bars:

67 \mu m

Calculate the magnification of this image using the formula above:

What is the width of the fly’s head?
Calculate the actual size of the mitochondria in the diagram below:

Past Paper Questions
1. A student views an image of a cell magnified 50000 times. The image is 60mm long.
   a. What is the actual length of the sample in the image?
   b. Is the cell more likely to be a plant cell, animal cell, bacterium or virus? Explain why.

2. A sperm cell has a tail 50μm long. A student draws it 50mm long. What is the magnification?
Limitations to cell size

Why can’t cells continue to grow larger and larger to become giant cells? Why are most cells, whether from an elephant or an earthworm, microscopic in size? What happens when a cell grows larger and what causes it to divide into two smaller cells rather than growing infinitely larger? This investigation will provide you with a ‘hands-on’ activity that simulates the changing relationship of surface area-to-volume for a growing cell.

Importance: Changes in the surface area to volume ratio have important implications for limits or constraints on organism size, and help explain some of the modifications seen in larger-bodied organisms.

We’ll begin with a reminder of some basic geometric formulae. The surface area and volume of a cube can be found with the following equations:

\[ SA = 6l^2 \quad V = l^3 \]

Purpose: to determine the relationship between a cell’s size and its surface area to volume ratio.

Data collection and processing: Use the plastic blocks to create cubes of various sizes. Build at least 5 different sizes of cubes. Measure and record the side lengths of the cubes you build. Process your data by calculating the surface area, the volume, and the surface area to volume ratio for each cube you built. The surface area to volume ratio is calculated by dividing the surface area by the volume (please do the division calculation don’t leave it as a ratio or fraction).

Show at least one worked example for each calculation.

Create a data table to record the data (with title and labels).
Raw Data:

<table>
<thead>
<tr>
<th>CUBE SIDE LENGTH (cm)</th>
<th>SURFACE AREA (cm²)</th>
<th>VOLUME (cm³)</th>
<th>SURFACE AREA: VOLUME RATIO (cm⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EXAMPLE**

**Data presentation:** Present your data in a line graph. Plot cube side length (l) on the X axis and the surface area to volume ratio on the Y axis. Add a smooth curve between data points.
**Analysis:**

1. Which cube has the largest surface area? Which cube has the largest volume? Which cube has the largest surface area to volume ratio?

2. Describe the meaning of your graph in words. "As the cube side length increases, the surface area to volume ratio _______________. This means that…

3. Why are cubes used in this mini-lab rather than cells? Does this affect the validity of the results? Why or why not?

4. To maintain life, materials must be able to move into and out of a cell. What might be the advantage of having a large surface area?

5. What might be the disadvantage of having a large volume?

6. Cells are generally very small. Propose an explanation for why large organisms are made of more cells rather than larger cells.
Why SA:V ratio matters to cells:
The rate of exchange of substances into and out of the cell through the cell membrane depends on the organism’s surface area that is in contact with the surroundings. The surface area of a cell is its plasma membrane.
The volume of a cell determines how many nutrients it needs (bigger = more) and how much waste it produces (bigger=more).
As a cell get bigger, its volume and surface area both get bigger, but not by the same amount. The volume increases as the cube but the area of the surface only increases by the square.
As a cell gets bigger, it has more demand for nutrients and makes more waste. However in a bigger cell there is relatively less surface area of the membrane for taking in the nutrients or getting rid of the waste.

Example: Gas exchange of oxygen for respiration.
Cells need oxygen for cell respiration.
A big cell needs more oxygen than a little cell.
Oxygen is obtained from the surrounding environment which could be water or blood (depends on the cell).
Oxygen diffuses across the cell membrane into the cell.
Big cells need to have more oxygen diffuse across the cell membrane than a little cell.
But the big cell has relatively small surface area compared to its volume i.e. the surface area: volume ratio is small.
Cells must not get too big because they cannot obtain sufficient oxygen to satisfy the demands of the cell.

Emergent Properties
Multicellular organisms show emergent properties. Explain what this means using an example.
Review Past Paper Questions

1. Which of the following will contribute to the cell theory?
   I. Living organisms are composed of cells.
   II. All cells come from pre-existing cells by mitosis.
   III. Cells are the smallest units of life.
   A. I only
   B. II only
   C. I and III only
   D. I, II and III

2. What is the correct order of increasing size for the following biological structures?
   I. The width of a virus
   II. The width of a bacterium
   III. The thickness of a cell surface membrane
   IV. The diameter of a eukaryotic cell
   A. I > III > II > IV
   B. I > III > IV > II
   C. III > I > II > IV
   D. III > II > I > IV

3. Which of the following characteristics found in a structure necessarily indicates that it is alive?
   A. The presence of genetic material
   B. The presence of a lipid bilayer
   C. Metabolism
   D. Movement

4. If a mitochondrion has a length of 5 µm and a student's drawing of the mitochondrion is 10 mm, what is the magnification of the drawing?
   A. ×0.0005
   B. ×0.5
   C. ×200
   D. ×2000

5. In a cell, what is the effect of a large surface area to volume ratio?
   A. Slower rate of exchange of waste materials
   B. Faster heat loss
   C. Faster rate of mitosis
   D. Slower intake of food
6. Below is a micrograph of an E. coli bacterium undergoing reproduction. The scale bar represents 0.5 μm. How long are both cells in total?

A. $5.0 \times 10^{-6}$ m
B. $5.0 \times 10^{-9}$ m
C. $2.5 \times 10^{-6}$ m
D. $2.5 \times 10^{-9}$ m

7. How does the surface area to volume ratio change with an increase in cell size?

A. 

<table>
<thead>
<tr>
<th>Surface area / volume</th>
<th>Cell size</th>
</tr>
</thead>
</table>

B. 

| Surface area / volume | Cell size |

C. 

| Surface area / volume | Cell size |

D. 

| Surface area / volume | Cell size |
Stem Cells and Cell Differentiation

Look at the animations at these links:
http://www.sumanasinc.com/webcontent/animations/content/stemcells_scnt.html
http://www.dnalc.org/resources/animations/stemcells.html

Answer the questions using the links below:
http://learn.genetics.utah.edu/content/tech/stemcells/scintro/

a) What is a stem cell?

b) How does differentiation occur?

c) What does pluripotent mean?

d) What is the difference between embryonic stem cells, umbilical cord stem cells and adult stem cells?

e) How do bone marrow transplants help cancer patients?

f) What was damaged by Tuberculosis?

g) How did they remove the cells from the donor airway/trachea?
h) Why did the doctors cover the donated trachea with Ms Castillo's own cells?

i) What could be encouraged to grow into windpipe cells?

j) What does Professor Birchall think will happen in 20 years time?

http://www.bbc.co.uk/schools/gcsebitesize/science/21c_pre_2011/genetics/cloningstemcellsrev2.shtml

A. ___________  Nucleus from a patient's egg put into a cell

Stem cells treated to develop into required
E. ___________

B. ___________

Egg stimulated to develop into a

Cells grown in a container of warm
D. ___________

C. ___________ taken from the embryo

http://www.ns.umich.edu/stemcells/F_030606a.html

l) Why might nuclear transfer be considered superior to stem cells from embryos?

m) Why can’t nuclear transfer blastocysts become cloned humans?
Once removed, stem cells can be ‘coaxed’ into becoming different types of cell. Play with the coaxing agents to generate different types of cell:

n) What combination of coaxing agents do you need to make heart cells?

o) What could heart cells be used for?

p) What combination of coaxing agents do you need to make dopamine neurons?

q) Who could dopamine neurons be used for?

r) What combination of coaxing agents do you need to make red blood cells?

s) Who could red blood cells be used for?