TOPIC: CELL THEORY

Key Knowledge:

- Surface area to volume ratio as an important factor in the limitations of cell size and the need for internal compartments (organelles) with specific cellular functions

FUNCTIONS OF LIFE

All living things carry out seven basic functions integral to survival:

- **Metabolism:** Living things undertake essential chemical reactions
- **Reproduction:** Living things produce offspring, either sexually or asexually
- **Sensitivity:** Living things are responsive to internal and external stimuli
- **Homeostasis:** Living things maintain a stable internal environment
- **Excretion:** Living things possess the capacity to remove waste products
- **Nutrition:** Living things exchange materials / gases with the environment
- **Growth / movement:** Living things can move and change shape or size

Hint: MR SHENG

CELL THEORY

The cell theory describes the structural organisation of all living things. According to the cell theory:

- The cell is the smallest unit of life (unicellular organisms are capable of all seven functions of life)
- All living things are composed of cells (or their cellular products – such as hair, nails, etc.)
- Cells only arise from pre-existing cells (spontaneous generation of life is no longer possible on Earth)

CELL SIZE

Cells and their components are measured according to the metric system. Most cells will be measured in **micrometres** (10^{-6} metres), while subcellular components may be measured in **nanometres** (10^{-9} metres).

Unit	1	10^{-2}	10^{-3}	10^{-6}	10^{-9}
Prefix	metre (m)	centimetre (cm)	millimetre (mm)	micrometre (μm)	nanometre (nm)

MICROSCOPES

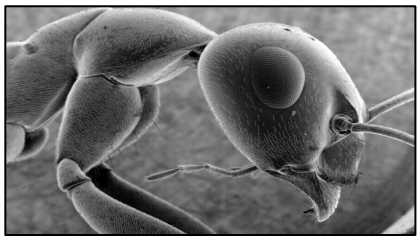
As cells are typically too small to view with the naked eye, they may be visualised instead via the use of microscopes (i.e. light versus electron).

Light Microscopy:

- Views **living** specimens in **natural colour** (uses lenses to bend light)
- Has a much **lower** resolution and magnification (roughly 100-fold)

Electron Microscopy:

- Views **dead** specimens in **monochrome** (uses electromagnets)
- Has a much **higher** resolution and magnification (can view in nm)
  - **Transmission** electron microscopes generate a cross-section
  - **Scanning** electron microscopes will render a 3D surface map



Light *(top)* vs **Electron** *(bottom)*

MAGNIFICATION

To calculate the linear **magnification** of a drawing or image, the following calculations may be used (mnemonic = MIA):

- **MIA: M**agnification = **I**mage size ÷ **A**ctual size

To calculate the **actual size** of a specimen within an image, the following calculations may be used (mnemonic = AIM):

- **AIM: A**ctual size = **I**mage size ÷ **M**agnification

Any calculation requires all sizes (image and actual) to be in the same units (e.g. both represented by micrometres)

EXAMPLE: COMMON DUST MITE

Image = 6.3 cm **Actual** = 350 μm

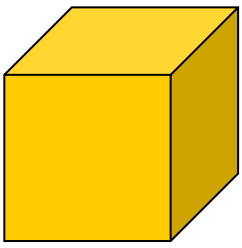
Magnification = × 180 *(63,000 ÷ 350)*

SURFACE AREA : VOLUME RATIO

Surface area and volume are important determinants in the limitation of cell size. Cells must remain small in order to maintain a viable surface area : volume ratio. Cells need to produce chemical energy to survive (via metabolism) and this requires the exchange of materials with the environment (nutrition / excretion).

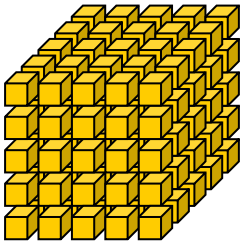
- The rate of metabolism of a cell is a function of its mass / volume (larger cells will need more energy)
- The rate of material exchange is a function of a cell's surface area (more membrane = more exchange)

If the metabolic rate (volume) exceeds the rate of material exchange (surface area), the cell will be unable to maintain homeostasis and will eventually die. Hence, a cell will require a **high SA : Vol ratio** to order for it to survive. However, as a cell grows, the volume (cubic units) increases more rapidly compared to the surface area (squared units), leading to a decreased ratio. Consequently, growing cells will tend to **divide** and remain small in order to maintain a viable SA : Vol ratio. Additionally, certain cells and tissues that are specialised for material exchange (e.g. lung and intestinal tissues) may modify their structure to increase their surface area and optimise material transfer (e.g. cell membranes may be ruffled to form **microvilli**).



SINGLE STRUCTURE
Volume = 125 units^3
Surface Area = 150 units^2
SA:Vol Ratio = **1.2** *(low)*

DIVIDED STRUCTURE
Volume = 125 units^3
Surface Area = 750 units^2
SA:Vol Ratio = **6** *(high)*



MULTICELLULAR ORGANISMS

Multicellular organisms are composed of multiple cells combining to complete synergistic functions. While all cells in a multicellular organism are clones (genetically identical), groups of cells may differentiate in order to specialise and perform specific functions. A group of cells of the same type that perform a common function is called a **tissue**. Different tissues may interact to form specific **organ systems** that carry out a particular body function (e.g. circulatory systems transport materials around the body). The process by which the genetically identical cells of an organism become functionally distinct is called **differentiation** and occurs as a result of the selective expression of genetic instructions (genes) within a particular cell. Cells that have yet to differentiate and retain the capacity to form any type of cell are called **stem cells**.