1.1 INTRODUCTION TO CELLS

Essential idea

The evolution of multicellular organisms allowed cell specialisation and cell replacement.

Main topics

- Cell theory
- Multicellular organisms and emergent properties
- Surface area to volume ratio
- Cell differentiation and specialised tissues
- Stem cells

Objectives

- State what is meant by 'cell theory' and examine evidence for it.
- Explain how surface area to volume ratio limits size.
- Examine unicellular and multicellular organisms.
- Compare types of microscope and calculate magnification and size.

Key words: cell theory / microscope / magnification / unicellular / multicellular

Understandings

- According to the cell theory, living organisms are composed of cells.
- Organisms consisting of only one cell carry out all functions of life in that cell.
- Surface area to volume ratio is important in the limitation of cell size.
- Multicellular organisms have properties that emerge from the interaction of their cellular components.
- Specialised tissues can develop by cell differentiation in multicellular organisms.
- Differentiation involves the expression of some genes and not others in a cell's genome.
- The capacity of stem cells to divide and differentiate along different pathways is necessary in embryonic development. It also makes stem cells suitable for therapeutic uses.

Applications

- Questioning the cell theory using atypical examples, including striated muscle, giant algae and aseptate fungal hyphae.
- Investigation of functions of life in Paramecium and one named photosynthetic unicellular organism.
- Use of stem cells to treat Stargardt's disease and one other named condition.
- 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.

Skills

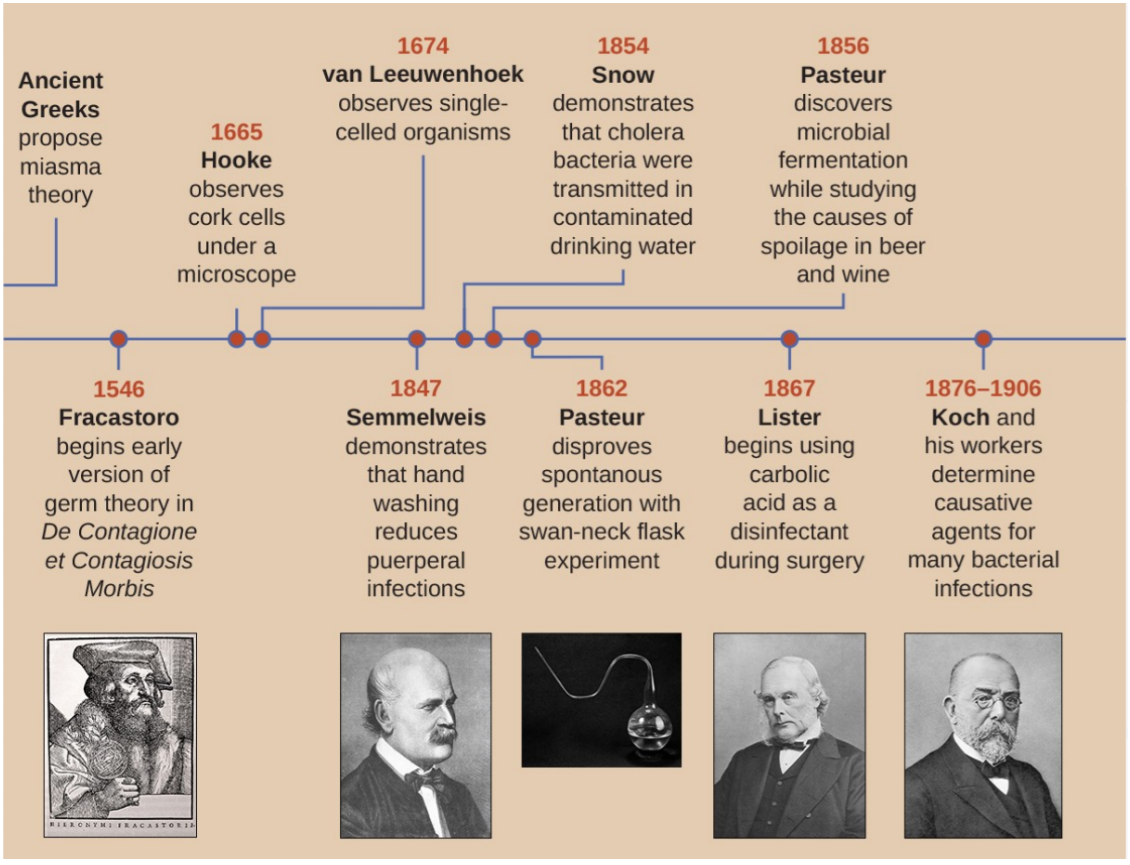
- Use of a light microscope to investigate the structure of cells and tissues, with drawing of cells.
- Calculation of the magnification of drawings and the actual size of structures and ultrastructures shown in drawings or micrographs.

THE CELL THEORY

All living organisms are composed of cells.

The origins of cell theory

The discovery of cells was linked to the development of the microscope.



Cell theory states that:

- all living organisms are made of one or more cells
- cells are the smallest units of life.
- cells can only be formed from the division of other cells.*

*cell theory refutes **spontaneous generation**

All cells exhibit the features of living organisms:

M	Movement	Travel from one place to another
R	Respire	Release energy from food
S	Sensitive	Respond to stimuli or their environment
G	Grow	Increase in size or mass
R	Reproduce	Produce offspring
E	Excrete	Remove toxic waste products
N	Nutrition	Either make their own food or eat other organisms
(C)	Control	Keep their internal environment within fine limits

The cell theory debate

For	Against
The microscope has shown all living things to be made of cells or cell products.	Skeletal muscle is made of large fibres and have multiple nuclei.
Cells removed from tissue can grow independently for a short amount of time.	Fungal hyphae have multiple nuclei and are not clearly divided.
Nothing smaller than a cell has been found to be able to carry out all the functions of life.	Giant algae can grow to 100mm despite having just 1 nucleus.
Experiments by Pasteur and Redi proved spontaneous generation of cells did not occur.	Life may have originated from smaller organelles (mitochondria & chloroplasts) that then became encapsulated within cells.

	Phloem sieve cells have few internal organelles and their metabolism is controlled by companion cells.

Exceptions to the cell theory

1. Striated muscle fibres:
    - Muscle cells fuse to form fibres that may be very long (>300mm).
    - They have multiple nuclei despite being surrounded by a single, continuous plasma membrane.
    - Challenges the idea that cells always function as autonomous units.
2. Aseptate fungal hyphae:
    - Fungi have filamentous structures called hyphae, which are separated into cells by internal walls called septa.
    - Some fungi are not partitioned by septa and hence have a continuous cytoplasm.
    - Challenges the idea that living structures are composed of discrete cells.
3. Giant algae:
    - Certain species of unicellular algae may grow to very large sizes (e.g. *Acetabularia* > 7 cm in length).
    - Challenges the idea that larger organisms are always made of many microscopic cells.

UNICELLULAR ORGANISMS

Organisms consisting of only one cell carry out all functions of life in that cell.

Unicellular organisms carry out at least seven functions of life:

- Nutrition
- Metabolism
- Growth
- Response
- Excretion
- Homeostasis
- Reproduction

SURFACE AREA TO VOLUME RATIO

Surface area to volume ratio is important in the limitation of cell size.

A cell's:

- Rate of metabolism is a function of its volume (larger cells need more energy to sustain essential functions)
- Rate of material exchange is a function of its surface area (large membrane surface equates to more material movement)
- As a cell grows, volume (units^3) increases faster than surface area (units^2), leading to a decreased SA:Vol ratio. If the ratio is too small:
    - substances will not enter the cell as quickly as they are required and waste products will accumulate because they are produced more rapidly than they can be excreted.

- cells may overheat because the metabolism produces heat faster than it is lost over the cell's surface.

Total surface area (height × width × sides × number of boxes)	**6**	**150**	**750**
Total volume (height × width × length × number of boxes)	**1**	**125**	**125**
SA:Vol ratio (surface area ÷ volume)	**6**	**1.2**	**6**

MULTICELLULAR ORGANISMS

Multicellular organisms have properties that emerge from the interaction of their cellular components.

Emergent properties

- arise from the interaction of the component parts of a complex structure.
- a whole is greater than the sum of its parts.
- allows multicellular organisms to complete functions that individual cells cannot.

CELL DIFFERENTIATION AND GENE EXPRESSION

Specialised tissues can develop by cell differentiation in multicellular organisms.
Differentiation involves the expression of some genes and not others in a cell's genome.

Differentiation

- the process during development whereby newly formed cells become more specialised and distinct from one another as they mature.
- all cells of an organism share an identical genome (each cell contains the entire set of genetic instructions for that organism).
- caused by the activation of different instructions (genes) within a given cell by chemical signals.

Cell packaging

Within the nucleus of a eukaryotic cell, DNA is packaged with proteins to form chromatin:

- Active genes: is transcribed.
  - usually packaged in an expanded form (euchromatin).
- Inactive genes: not transcribed.