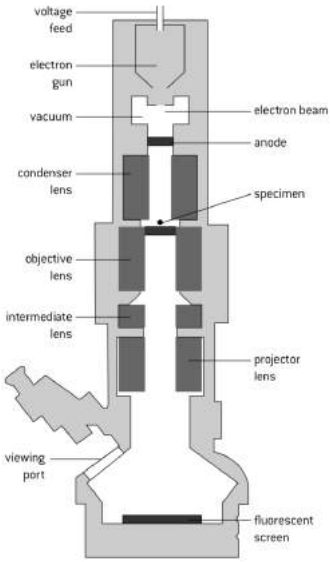
Cells

General Information:

1. All cells share certain common features:
    1. Every living cell is surrounded by a membrane which separates the cell contents from everything else outside
    2. Cells contain some kind of genetic material which stores all of the instructions needed for the cell's activities
    3. Many of these activities are chemical reactions, catalyzed by enzymes produced inside the cell
    4. Cells have their own energy release system that powers all of the cell's activities
2. Necrosis: Cell death
3. Organisms can be unicellular, consisting of one cell or multicellular, consisting of multiple cells
4. Seven functions of life (Mr. Sheng):
    1. Metabolism: Chemical reactions inside the cell, including respiration
    2. Reproduction: Producing offspring either sexually or asexually
    3. Sensitivity/Response: The ability to react to changes in the environment
    4. Homeostasis: Keeping conditions inside the organism within tolerable limits
    5. Excretion: Removal of the waste products of any metabolic activity
    6. Nutrition: Obtaining food to provide energy and the materials needed for growth
    7. Growth: An irreversible increase in size or complexity
5. The metabolic rate of the cell is proportional to the volume of the cell.
    1. For metabolism to start and continue, necessary substances must be absorbed and removed. The substances move in and out through the plasma membranes of the cell and this rate depends on its surface area, thus making the surface area to volume ratio of a cell crucial. Along with the transfer of products, this ratio is also important in relation to heat production and loss
    2. Cells and tissues specializes for gas exchanges will increase their surface area, such as villi in the S.I form ruffles and alveoli within the lungs have membranous extensions called microvilli
6. All cells in an organism share an identical genome
7. Differentiation: Process during development whereby newly formed cells become more specialized and distinct from one another as they mature
8. Magnification: Degree to which the size of an image is larger than the image itself
9. Resolution: Degree to which it is possible to distinguish between two objects that are very close together (Clarity)
10. Ultrastructure: The detailed structure of the cell revealed by examination under the electron microscope
11. Cholesterol is a component of animal cell membranes
12. Membrane proteins are diverse in terms of structure, position in the membrane and function
13. Phospholipids form bilayers in water due to the amphipathic properties of phospholipid molecules
14. Active genes: Usually packaged in an expanded form called euchromatin, that is accessible to transcriptional machinery
15. Amphipathic: Things with hydrophobic and hydrophilic parts
16. Inactive genes: Typically packaged in a more condensed form called heterochromatin (saves space, not transcribed)
17. Dopamine is a neurotransmitter responsible for transmitting signals involved in the production of smooth, purposeful movements



18. Enucleated: Nucleus removed
19. Archaebacteria – found in extreme environments like high temperatures, salt concentrations or pH (Extremophiles)
20. Eubacteria – traditional bacteria including most known pathogenic forms (E. coli, S. aureus)
21. Plastid: Any of a class of small organelles in the cytoplasm of plant cells, containing pigment or food
22. Intron: A segment of a DNA or RNA molecule which does not code for proteins and interrupts the sequence of genes
23. Plasmodesma: A narrow thread of cytoplasm that passes through the cell walls of adjacent plant cells and allows communication between them
24. The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis
25. Glycoproteins have sugar units called oligosaccharides attached on the outer surface of the protein and are responsible for cell to cell communication
26. Most glycoproteins are receptor cells
27. The extracellular matrix is a mesh of protein fibres and glycoproteins that exist externally of the cell in multicellular organisms
    1. ECM provides structural and biochemical support to surrounding cells:
        1. Providing sites for anchorage by cells within a tissue and segregating separate tissues from one another
        2. Sequestering and storing growth factors until receipt of a chemical signal, regulating intercellular communication
    2. In plant cells, the matrix includes cell wall components like cellulose and is important in:
        1. Regulating water uptake, maintenance of cell turgor
        2. Providing mechanical strength and rigidity to the cell, cell shape
28. Named membrane proteins
    1. Hormone receptor: Integral protein, such as Insulin receptors
    2. Cytochrome c: Peripheral protein, used for electron transport
    3. Cadherin: Integral protein used for cell-to-cell adhesion
    4. Cytochrome oxidase: Integral protein used as an immobilizing enzyme
    5. Calcium pump: Integral pump protein for the active transport of calcium ions
    6. Nicotinic acetylcholine receptor: Integral protein which is a receptor for a neurotransmitter and a channel for facilitated diffusion of sodium ions
29. Osmolarity of a solution: Number of moles of solute particle per unit volume of solution [Pure water has an osmolarity of 0, the higher the concentration of solutes, the higher the osmolarity] (Measured in number of osmoses per litre, osmol/L)
30. Cell cycle: Sequence of events between one cell division and the next, two main phases of which are interphase and cell division
31. Mutagens: An agent, such as radiation or a chemical substance, which causes genetic mutation
32. Oncogenes: A gene which controls cell growth, which in certain circumstances can transform a cell into a tumor cell
33. Metastasis: The development of secondary malignant growths at a distance from a primary site of cancer
34. Correlation: In science, is a relationship between two variable factors [Relationship between smoking and cancer]
    1. Positive correlation: When one factor increases and the other increases too
    2. Negative correlation: When one factor increases, the other decreases
35. Micelle: The balled drop made from an aggregate of amphipathic molecules so that hydrophilic parts of it get balled inside the hydrophobic areas [Only for single membraned molecules]
36. Liposome: The donut-shaped drop made from an aggregate of amphipathic molecules so that hydrophilic parts of it get balled inside the hydrophobic areas [Only for double membraned molecules]
37. Hydrophilic molecules are polar; hydrophobic molecules are non-polar
38. Freeze-etching:
    1. Cells are frozen in liquid nitrogen at -196C, which immobilizes cell activity

2. Blocks of frozen cells are broken up in a vacuum so they fracture along weaknesses
3. Surface ice is removed by a vacuum
4. Carbon vapors are evaporated onto the surface, forming a mask and taking the shape of the parts
5. Stronger metal vapors like platinum strengthen the mould
6. Organic material is dissolved with acid
7. Can be observed under a microscope

Unicellular organisms:
- Paramecium (heterotroph)
  - Sensitivity/response: Surrounded by small hairs called cilia which allow it to move
  - Nutrition: Engulf food via a specialized membranous feeding groove called a cytostome
  - Metabolism: Food particles are enclosed within small vacuoles that digest
  - Excretion: Solid waste leaves through an anal pore and liquid waste is pumped out via contractile vacuoles
  - Homeostasis: Essential gases enter and exit via diffusion
  - Reproduction: Divide asexually through fission but horizontal gene transfer can occur via conjugation
- Scendesmus (autotroph)
  - Nutrition and Excretion: Exchange gases and other essential materials through diffusion
  - Metabolism: Chlorophyll pigments allow organic molecules to be produced via photosynthesis
  - Reproduction: Daughter cells form as non-motile nautospores via the internal asexual division of the plant cell
  - Response/Sensitivity: Exist as unicells or form colonies for protection

Multicellular Organisms:
- Multicellular organisms have properties that emerge from the interaction of their cellular components
- “The whole is greater than the sum of its parts” - Aristotle
- Can do functions that unicellular organisms cannot due to the collective actions of individual cells combing to create new synergistic effects
- Order:
  - Cells can be grouped together to form tissues
  - Tissues then group together to form organs
  - Organs group to form organ system that carry out specific body functions
  - Organ systems collectively carry out the life functions of an organism
  - Cell —> Tissue —> Organ —> System —> Organism
  - Muscle —> Cardiac —> Heart —> Vascular —> Human

3.1: Cell Theory:
1. All living organisms are made up of cells [Schwann and Schleiden, 1838-39]
2. Cells are the structural and functional unit of life [Schwann and Schleiden, 1838-39]
3. [Biogenesis] All cells come from pre-existing cells [Rudolf Vichrow, 1898]

Exceptions:
- Viruses: Neither dead, nor living and display characteristics of both
- Mitochondria and chloroplasts: Despite being organelles, they have their own genetic material and can reproduce independently
- Where did the first cell come from?
- Tissues and organisms not made of typical cells:
  - Skeletal/Striated muscle fibres:
    - Very long fibres due to the fusion of multiple cells
    - Multiple nuclei being surrounded by a single, continuous plasma membrane
    - Does not function as an autonomous unit
  - Giant Algae:
    - May grow to very large sizes
    - Challenges the idea that larger organisms are always made of many cells

- Aseptate Fungal Hyphae:
  - May have filamentous structures called hyphae which are separated into cells by internal walls called septa
  - Some are not partitioned by septa and thus have a long, continuous cytoplasm
  - Challenges the idea that living structures are composed of discrete cells

Cell Differentiation:
- Specialized tissues can develop by cell differentiation in multicellular organisms
- A tissue includes a set of specialized cells that function together for a common interest
  - By being specialized, the cells can carry out their role more efficiently than if they had many different roles because it enables them to develop the ideal structure with specific enzymes
  - The human body has 220 distinctively specialized cell types developed by differentiation
- Cell differentiation happens because a different sequence of genes is expressed in different cell types, making gene expression the key to development

Stem Cells:
- Stem cell is the name given to the zygote and the cells of the early embryo, meaning that all the tissues of the adult stem from them
- The early stage embryonic stem cells are most versatile because throughout the embryo development cycle, the cells commit themselves to a pattern of differentiation, involving points where cells decide whether to develop along one pathway or the other
- Once committed, the cell develops into one type of cell and can divide to create more similarly-differentiated cells but are then no longer stem cells
- Small numbers of cells remain as stem cells and remain in the bone marrow, skin and liver. They give human tissues considerable powers of regeneration and repair
- Stem cells in other organs only allow for limited repair
- Key properties:
  - Self renewal: Can divide repeatedly to produce large amounts of new cells and are thus useful for the growth of tissues or replacement of lost/damaged cells
  - Potency: Not fully differentiated so they can differentiate later on, to produce different cell types
- Types:
  - Totipotent: Can form any cell type, as well as extra-embryonic tissue (Zygote)
  - Pluripotent: Can form any cell type (Embryonic stem cells)
  - Multipotent: Can differentiate into a number of closely related cell types (Haematopoeitic adult stem cells)
  - Unipotent: Can not differentiate, but are capable of self renewal (Progenitor cells, Muscle stem cells)
- Therapeutic uses:
  - Produce regenerated tissues (potentially for burn victims)
  - Means of healing diseases where a particular cell type has been lost or is malfunctioning (type 1 diabetes)
  - Grow whole replacement organs (Spinal cord for paraplegics)
  - Parkinson's disease:
    - A degenerative disorder of the central nervous system caused by the death of dopamine-secreting cells in the midbrain
    - Symptoms can be hand tremors, rigidity, slowing movements and postural inability
    - Treated by replacing dead nerve cells with living, dopamine producing ones
- Non-Therapeutic uses:
  - To produce large quantities of striated muscle fibres, or meat, for human consumption
- Use of stem cells to treat Stargardt's disease
  - Stargardt's macular dystrophy:
    - Genetic
    - Develops in kids from ages 6-12
    - Most cases are due to a recessive mutation of gene ABCA4

    - Causes a membrane protein used for active transport in retina cells to malfunction so photoreceptive cells in the retina degenerate
    - Causes vision to become progressively worse and can lead to blindness
  - Embryonic stem cells have been shown to develop into retina cells, done initially with mouse cells and injected into mice's eyes, those with a condition similar to Stargardt's
  - The injected cells were not rejected, did not develop into tumors or cause problems. They moved to the retina where they attached themselves and remained, causing an improvement in the vision of the mice
  - In November 2010, human trials were commenced and have since proved effective and productive with no harmful side effects
- Use of stem cells to treat Leukemia:
  - Leukemia:
    - Type of cancer
    - Caused my genetic mutations that lead to abnormal changes in cell division
    - For a cancer to develop, several specific mutations must occur in these genes in one cell which is highly unlikely but due to the large amount of cells in the body, the overall chance becomes larger
    - The cancer-inducing mutations in the cell cause it to grow and divide repeatedly, making more of the same cells
    - Said cancer involves the production of an abnormally large number of white blood cells with no trace of a tumor or a limo
    - White blood cells are created in the bone marrow, soft tissue in the hollow centre of large bones such as the femur and are then released into the blood, both in leukemia patients and non-leukemia patients
    - A normal adult white blood cell count is 4,000-11,000 per mm^3 of blood
    - Counts above 30,000 per mm^3 suggest that a person may have leukemia. If there are 100,000 per mm^3 , it is likely that the person has acute leukemia
  - To cure it, the cancer cells in the bone marrow producing the extensive number of WBCs need to be destroyed and can be done with chemotherapy, a procedure that includes exposure to certain chemicals that kill dividing cells
  - Stem cells that can produce blood cells must be present but can be killed by chemotherapy
  - Following procedure is therefore used:
    - Large needle is inserted into the pelvic bone and fluid is removed from the bone marrow
    - Adult stem cells with the potential to produce blood cells are extracted from this fluid and are frozen
    - High dose of chemotherapy drugs are given and the bone marrow loses its ability to produce blood cells
    - Stem cells are then returned to the body and re-establish themselves in the bone marrow, creating fresh blood cells
- Sources of stem cells and their ethical issues:
  - The types of stem cells vary in their properties and thus, their uses
  - Embryonic stem cells
    - Can be created by fertilizing egg cells with sperm and allowing the resulting zygote to develop until there are 4-16 cells present and using those cells
    - Highly controversial because the acquiring of these leads to the embryo dying [Is an early stage embryo as human as a new born baby?] [Is it right to create human lives solely for the purpose of stem cells?]
  - Cord blood stem cells

Embryonic stem cells	Cord blood stem cells	Adult stem cells
• Almost unlimited growth potential. • Can differentiate into any type in the body. • More risk of becoming tumour cells than with adult stem cells, including teratomas that contain different tissue types. • Less chance of genetic damage due to the accumulation of mutations than with adult stem cells. • Likely to be genetically different from an adult patient receiving the tissue. • Removal of cells from the embryo kills it, unless only one or two cells are taken.	• Easily obtained and stored. • Commercial collection and storage services already available. • Fully compatible with the tissues of the adult that grows from the baby, so no rejection problems occur. • Limited capacity to differentiate into different cell types – only naturally develop into blood cells, but research may lead to production of other types. • Limited quantities of stem cells from one baby's cord. • The umbilical cord is discarded whether or not stem cells are taken from it.	• Difficult to obtain as there are very few of them and they are buried deep in tissues. • Less growth potential than embryonic stem cells. • Less chance of malignant tumours developing than from embryonic stem cells. • Limited capacity to differentiate into different cell types. • Fully compatible with the adult's tissues, so rejection problems do not occur. • Removal of stem cells does not kill the adult from which the cells are taken.