SBI OA0

CORE UNIT 2: ENERGY AND THE LIVING CELL

Chapters 3, 4, & 5

Chapter 3: The Functional Cell

- fully understanding how a cell functions is the first step in trying to develop cures for various diseases such as cancer, and AIDS
- a lot is known, however there are still many unanswered questions – for example, how does cancer actually begin?
- there are in fact many cancer-causing agents that have already been identified – scientists know what can cause cancer, but they still don't fully understand how!!

3.1 What is a Cell?

- the **cell theory** states that.....
  1. all living things are made up of one or more cells and the products of those cells
  2. cells are the functional units of life
  3. all cells come from pre-existing cells
- a **cell** is defined as "a confined system of potentially self perpetuating linked organic reactions that are catalyzed stepwise by enzymes that are themselves produced by the system"
- with the invention of the microscope, the beginnings of cell research took place
- as the microscope became more sophisticated, more and more cell structures became apparent
- with the invention of the scanning electron microscope, scientists have been able to investigate the structure and function of cells at the molecular level
- the study of cells is called **cytology**
- various current areas of interest in cytology today are....how are the activiities of a cell controlled?....how are proteins synthesized, modified, and moved around the cell?.....How do cells differentiate, grow, and age?
- some important characteristics of living cells are....
  - *Cells are complex:* Plant or animal cells, have at least fifteen different **organelles** that make them up, along with a great variety of complex molecules and other particles. The complexity of cells is constituted by the highly

sophisticated interactions occur between organelles and between molecules and organelles. Page 49, figure 3.2 is an electron micrograph of a cell – notice the different identifiable organelles.

- *Cells are extremely small:* It would take 20000 red blood cells to stretch across the average person's thumbnail. The unit to measure the larger parts of cells is the micrometer (μm). The unit to measure the smaller parts of cells is the nanometer (nm) – 1000 times smaller than the micrometer.

- *Cells are self-replicating:* The control mechanisms for a cell's ability to divide at a certain stage in its development are not completely understood. Certain cell organelles, like the chloroplasts and mitochondria, can replicated themselves as well.

- *Cells can live as autonomous or semiautonomous entities:* Bacteria and protozoa are single-celled organisms, where each cell must be able to perform all the functions required for life. For the most part, specialized cells in a multicellular organism exist as separate entities that function on their own, however, their success and survival do depend on each other to some degree.

- *Cells can regulate their internal environments:* Chemical recognition, and feedback mechanisms, allow cells to continuously monitor their internal environments – this is to produce necessary stabilizing responses to maintain an internal balance. Healthy cells can control what enters and exits the cell, which is very important to the cell's success.

- there are many types of cells with different sizes, shapes and organelles

- two distinct categories exist..

eukaryotic ("true nucleus")	**prokaryotic** ("before nucleus")
• largest group of the two • includes fungi, protozoa, plantae, and animalia kingdoms • its organelles are separate from the rest of the cytoplasm by membranes • have a nucleolus • larger ribosomes	• smallest of the two groups • includes monera kingdom • its organelles are not membrane-bound • have no nucleolus • smaller ribosomes

- some differences exist between plant and animal cells....

plant cells	**animal cells**
• possess a cell wall • possess chloroplasts • fewer, but larger, vacuoles • cell division takes place via a cell plate	• do not possess a cell wall • do not possess chloroplasts • greater number, yet smaller, vacuoles • cell division takes place via cleavage furrow

3.2 Cell Functions and Structures

- as each individual organ system function is integrated with others, so are each of the activities that take place within any given cell
- each part of any cell has a variety of functions and works in concert with other cell parts

A. Barriers and Defence

- the cell membrane serves to separate the cell from its external environment, but still allows it to be sensitive to its contents
- the membrane is more of a chemical protection barrier than a mechanical or physical protection barrier
- it can detect and restrict the entry of chemicals that might harm the cell
- healthy membranes of internal cells of multi-cellular organisms, usually have chemical markers in them (like identity tags) that helps white blood cells and antibodies to determine which cells are healthy and which are foreign
- cells that may have allowed harmful chemicals to enter them also have markers on their membranes, which in turn, helps white blood cells identify and kill them
- a major component of all membranes is a fat molecule called phospholipid
- other constituents include proteins and carbohydrates (see figure 3.4, p. 52)
- plant cells have an additional barrier called a **cell wall** (figure 3.5, p. 52)
- four functions of cell walls are:
    1. link cells into colonies
    2. prevent cells from bursting due to osmotic pressure
    3. protect cells from infection of viruses
    4. supports plant
- although it is an extremely effective barrier, it still possesses pores which allow the plant cell to exchange material with its environment and to communicate with other cells

B. Structure and Support

- cell membranes give cells their shape by having adhesive properties – one cell membrane is loosely attached to another cell membrane of another cell
- every cell wall of every plant cell contributes to the entire plant' s support

- as the large vacuoles of plant cells fill up with water, the membrane puts pressure onto the cell walls – this is called **turgor pressure**
- this results in plant tissue, and consequently the entire plant, to become rigid and oppose gravity during growth towards the sun
- along with cell membranes and cell walls, **microtubules** and **microfilaments** (both of which are made of protein molecules) also play a major role in providing cells with structure and support (figure 3.6, p. 53)
- microtubules are tubular and are relatively wider than microfilaments, which are solid and much thinner
- both microtubules and microfilaments create a cytoskeleton that supports the entire cell and probably form loose attachments with various organelles in the cell

C. Movement

- microtubules and microfilaments are mostly responsible for the movement of the entire cell, movement of materials within the cell, and for changes in cell shape
- the major components of **cilia** and **flagella** of cells are microtubules (figure 3.7, p. 53)
- cilia are smaller and larger in number than flagella
- cilia cover all or large sections of a cell's surface, whereas flagella are few in number
- the wave action of cilia also differs from that of flagella (figure 3.8, p. 54)
- flagella -- use a wave action down the length of the flagella to create movement
- cilia – use a back and forth action, like an oar, to create movement

D. Control of Cell Activities and Manufacture of Molecules

- the basis for the control of cell activities is through the availability of three factors:
    1. the reacting chemicals to create necessary molecules
    2. a source of energy to induce the chemical reactions
    3. enzymes to help the reaction proceed (the most important of the three)
- enzymes are produced under the control of the nucleus of a cell
- the nucleus contains encoded information in its DNA molecules
- the code in the DNA consists of a series of molecules with specific patterns – each pattern contains a blue print for a specific enzyme
- when the chromosomes are extended as long strands (chromatin), the code on the DNA is available for the production of enzymes as they are needed

- the movement of large molecules into, and out of, the nucleus is thought to play a large role in the control of enzyme production
- these large molecules move through relatively large pores found in the double membrane of the nucleus (or nuclear envelope) – seen in figure 3.10, p. 55
- inside the nucleoplasm is the **nucleolus** – a dark visible mass suspended in the nucleus (fig. 3.11, p. 56)
- the nucleolus is thought to be the centre where **ribosomes** are made
- when a specific enzyme is required, the following happens....
    1. messenger molecules enter the nucleus and “kick-start” the code on the DNA to make the enzyme
    2. the code for the specific enzyme on the DNA molecule is transferred to an RNA molecule
    3. the RNA molecule carries this code out of the nucleus and to a ribosome
    4. the ribosome, along with other special molecules in the cytoplasm, uses the information on the RNA to make the specific required enzyme
- other molecules like carbohydrates and lipids are manufactured on the surface of membranes
- one of these membranes that is associated with the production of many different molecules is the **endoplasmic reticulum** (ER) – figure 3.13, p. 57
- basically, the ER is an extensive extension of the nuclear membrane, consisting of a system of tubules and channels that separate the cytoplasm into two compartments, one which is enclosed with the ER and one which is not
- two functions...
    1. provides a site where molecules are assembled
    2. provides a path that allows chemicals to move easily through its channels
- if ribosomes are on the ER, they cause it to look rough – therefore called **rough ER** or RER
- if no ribosomes are present, the ER is smooth – therefore called **smooth ER** or SER
- RER is involved in the production of proteins – this type is abundant in cells that secrete proteinaceous materials (i.e. pancreas cells)
- SER is involved in the production of steroids and phospholipids – this type is abundant in cells of the gonads and adrenal cortex (i.e. steroid-producing cells)
- another associated organelle that is responsible for manufacturing molecules is the **Golgi apparatus** – look like closely stacked, flattened sacs (figure 3.14, p. 57)
- Golgi apparatus is involved in modifying proteins by the addition of fats and sugars to them
- once this happens, the modified proteins pinch off from the Golgi complex and either remain in the cytoplasm, move to the cell membrane where they are included into it, or move to the cell membrane where they are expelled out of the cell

E. Intake and Use of Nutrients

- a variety of cell organelles are involved in the extraction of molecules from the external environment, followed by the chemical processes that break down the nutrient molecules into the desired chemicals
- the cell membrane surrounds the desired materials or forms channels through which the nutrients pass
- a complete surrounding of the material creates a **food vacuole** that pinches off the cell membrane (figure 3.15, p. 58)
- once in the cytoplasm, digestive juices enter the vacuole to break down the nutrients enclosed
- the useful chemicals that result move out of the vacuole and are directly used, or are further broken down – the waste is then expelled into the cell's external environment
- full food vacuoles often join with **lysosomes** – single membrane-bound structures that have digestive enzymes in them (figure 3.16, p. 59) – read top of p. 59
- in addition to the necessary chemicals and enzymes for a reaction to proceed in a cell, energy is required – the chemical most frequently involved with the energy supply for the cell is the carbohydrate, glucose
- **chloroplasts** help make glucose, and **mitochondria** help break it down
- chloroplasts (figure 3.17, p. 60) have two membranes – the inner one forms sacs called grana, which is the site of glucose production
- the number of mitochondria (figure 3.18, p. 60) in each cell depends on what type of cell it is – sperm cells have a few hundred around their tails, egg cells have approx. 500 000 per cell
- the inner membranes of mitochondria form cristae
- in the mitochondria, usable energy is incorporated into ATP, which then moves out of the mitochondria and through the cytoplasm to where it is needed

Homework: define from "cytology" to "crista" in vocabulary, pp. 74-75, and do ques. 1-11, p. 75

3.3 Cell Division and Growth

- the human body is made of approx. 6×10^{13} cells
- there are approx. 100 different types of cells
- every second, millions of cells die and are replaced

A. The Cell Cycle (figure 3.19, p. 62)

- the M phase - cell reproduction which includes the division of the nucleus (**mitosis**), and the division of the cell (**cytokinesis**)
- the interphase part of the cycle is split into three separate phases:
  1. G_1 phase - initial growth phase (G stands for "gap" phase where there is a gap in DNA synthesis – but differentiation or specialization takes place here)...usually if a cell differentiates, it does not replicate
  2. S phase - the duplication of DNA (S stands for "synthesis" phase where DNA is synthesized)
  3. G_2 phase - triggering mechanism for mitosis occurs here, or cell dies before it reproduces

B. Cell Growth

- occurs mainly during G_1 phase
- cell growth is controlled by the presence or absence of various enzymes, as well as the release of various chemical messengers and growth regulators – i.e. adrenocorticotrophic hormone (ACTH) and interferon stunt growth, while insulin and somatomedin stimulate growth

C. Variability in the Cell Cycle

- the presence or absence of various phases, as well as the length of each phase, varies from cell to cell
- inhibiting chemicals, as well as stimulating chemicals, are released by cells depending on their condition or state – for example, wounded skin cells release chemicals that stimulate mitosis and regeneration of cells, whereas healthy skin cells release chemicals that inhibit mitosis
- this effect could be very useful in discovering a control or cure for cancer

D. Mitosis (pp. 62-64)

- at the end of interphase, mitosis begins
- the phases of mitosis are **prophase**, **metaphase**, **anaphase**, and **telophase**
- look at figures 3.20-3.24, pp. 63-65), and make own notes on the major occurrences of each phase (pp. 62-64)

E. Cytokinesis

- occurs at the same time as mitosis
- the cytoplasm begins to divide during anaphase

- animal cell cytokinesis is via a **cleavage furrow** - in plants, a plate of microtubules (called a phragmoplast) forms in the central region of the spindle (figure 3.25, p. 65)

3.4 Modern Techniques in Cytology

A. Microscopy

- the ability to distinguish objects that are close together is called **resolving power**
- the shorter the wavelength of light used to illuminate the specimen (i.e. blue light), the greater the resolving power
- light microscopes are sufficient to study cell shapes and size, but are limited when it comes to studying organelles
- electron microscope uses a beam of electrons rather light to illuminate the specimen
- the two types of electron microscopes used today are....

1. the transmission electron microscope (TEM) - figure 3.27, p. 68
    - electrons are shot out of a cathode gun and accelerated by high voltage to the anode
    - the beam goes through a vacuum tube where it is focused by electromagnets
    - the thin specimen is placed in the path of the electron beam
    - some of the electrons of the beam reflect off the specimen, others don't
    - those that don't pass through an aperture and are further focused onto a viewing screen
    - the limit to a TEM is that only thin specimens can be viewed

2. the scanning electron microscope (SEM)
    - this microscope scans the surface of specimens with a beam of electrons
    - the scanning beam that hits the specimen causes some electrons to be emitted by the specimen itself, called secondary electrons, which in turn, are captured by a detector and used to create an image on a video screen

- the electron microscope specimen is placed in gluteraldehyde, which actually kills it, maintains its structure in its most natural configuration, and also stains it

B. Separating and Identifying Cell Constituents

- the three techniques used to separate cellular particles are...

1. **centrifugation** (figs 3.29 - 3.31, pp. 70-71)

   - the tissue is mashed up and homogenized in a cold isotonic medium, which is then put into a centrifuge tube and spun at high g forces
   - the most dense cell particles settle at the bottom
   - each time a supernatant is removed and re-centrifuged at a higher g force, until the desired fraction is achieved – for example the first centrifuge (at 700g force could remove out nuclei, the second at 20 000g could remove out mitochondria, chloroplasts, and lysosomes

2. **electrophoresis** (figs 3.32-3.33, pp. 71-72)

   - molecules move through a gel of starch or polyacrylamide, or even through paper
   - the molecules move in response to an electrical field that is set up across the medium
   - any charged molecule will move towards the opposite charge, up the gel
   - the greater the charge on the molecule, the quicker it will move up the gel
   - the movement of the molecule up the gel is affected by its size and shape, and its ability to thread through the gel network
   - different molecules will take up different positions on the gel – each position is cut out, and the chemicals in each section can be extracted

3. **chromatography**

   - molecules, dissolved in a solvent, are carried by the solvent through a medium via gravity, capillary action, or pumping action
   - the medium impedes the movement of the cellular molecules because of either their size, charge, or attractive force on other molecules

- **radioactive labeling** is a technique used to track a biochemical reaction and identify the "players" in chemical reactions
  - radioactive labels like ^{3}H, ^{24}C, ^{32}P, ^{35}S, ^{125}I, or ^{131}I, are added to molecules
  - these decay and emit high energy electrons called β particles, which allow for the molecule that contains the isotope to be detected
  - **autoradiography** is used to view the markers
    - labeled molecules are allowed to incorporate themselves in living tissue
    - the tissue is then cut and prepared on slides

- a photographic emulsion is placed on the slide
- the slide is placed in the dark for several days
- the β particles emitted by the markers will develop the photographic film and create an image of the cell showing their locations in the cell

Homework: define from "mitosis" to "autoradiography" in vocabulary, p.75, and do ques.12-19, p. 75

- ***Review: answer objectives 1-5, pp. 74***