STRUCTURE AND FUNCTION OF CELLS

ABSTRACT: This unit deals with the functions of cells, the structure and function of cellular components, and the introduction of some cellular processes.

REQUIRED READINGS: Martini & Nath (8th ed) pp. 8-12, 36-38, 67-72, 76-83, 98, 106
Tortora & Derrickson (12th ed.) pp 2-8, 62-64, 76, 81-89

OBJECTIVES: To be able to:

1. Specify the characteristics associated with life and explain why the cell is considered to be the basic unit of life.

2. Describe the six levels of structural organisation in the human body, from the simplest to the most complex.

3. Define the terms “cytoplasm”, “cytosol”, and “organelle”.

4. Describe the structures (be able to identify them in a diagram) and specify the functions of the following nuclear components:
   a) nuclear membrane b) chromatin and chromosomes c) nucleolus

5. Describe the structures (be able to identify them in a diagram) and describe the functions of the following cytoplasmic components: a) mitochondria
   b) ribosomes

6. Describe the structures (be able to identify them in a diagram) and describe the functions of the following components of the endomembrane system: a) smooth endoplasmic reticulum (SER) d) lysosomes
   b) rough endoplasmic reticulum (RER) e) vesicles
   c) Golgi complex (apparatus) f) plasma membrane

7. Explain what is meant by cell <u>metabolism</u>, distinguish between <u>anabolism</u> and <u>catabolism,</u> and provide examples of each.

8. Describe these three cellular processes involved in the growth of the human body from a fertilised egg cell to an adult: cell division, cellular growth, and cellular differentiation.

STRUCTURE & FUNCTION OF CELLS

In this unit we investigate why a cell is considered the basic unit of life, and we examine the structure and functions of selected cell components. Finally, we introduce the cellular activities of metabolism, cell division, cellular growth and cellular differentiation.

1. Specify the characteristics we associate with life and explain why the cell is considered to be the basic unit of life.

In this objective, we will examine the general characteristics of life and explain why these characteristics are applied to a cell.

Living organisms **exchange materials** with their immediate environment. This means that some materials are taken in and other materials are released. Our cells take in nutrients and respiratory gases, and release wastes, on an ongoing basis. All of our cells absorb needed materials from, and deposit waste materials into, the extracellular fluid.

Another characteristic of living matter is that it can **obtain energy from organic molecules**. For example, cells take in sugars and metabolise these sugars to obtain cellular energy which can then be used to perform cellular activities.

Living matter can **synthesise complex organic molecules**. For example if you consider proteins or fats, the only place you find these molecules is in living cells or organisms, or in situations where living cells have deposited these molecules.

The fourth characteristic of living matter is that it can **reproduce**.
The fifth characteristic is that living organisms can respond to stimuli present in the environment. For example, cells and organisms respond to cold temperatures by physically moving to a warmer environment, or by altering their physiology to produce more heat.

The cell is considered the basic unit of life because a cell is the simplest structure that possesses all the basic characteristics of living matter. Many of these characteristics are more appropriately assigned to individual cells, rather than the whole organism.

2. Describe the six levels of structural organisation in the human body, from the simplest to the most complex.

The human body can be studied at six different levels of structural organisation, ranging from the level of atoms to the level of a whole person. The structures and functions at each level contribute to the structures and functions of the next level. For example, at the chemical level, a molecule of haemoglobin has atoms arranged in such a way that it can bind to oxygen. At the next level, the cellular level, the haemoglobin is located inside

of red blood cells, which have several unique characteristics that make them ideal cells to carry oxygen through the cardiovascular system.

After reading pp. 8-12 of Martini & Nath (8th ed.) OR pp. 2-4 of Tortora & Derrickson (12th ed.), you should be able to answer questions such as:

1) *Which level of structural organisation is made up of several types of tissues, working together to perform a specific function?*
2) *Which level of structural organisation is made up of many cells, working together to perform a specific function?*
3) *Define the terms "organ", "organism", and "organ system".*
4) *Name and describe the six structural levels of organisation in order, from simplest to most complex.*
5) *Return to the haemoglobin and red blood cell example that was given in the above paragraph. What additional structures and function(s)would be included at the next level of organization above the cells?*

3. Define the terms "cytoplasm", "cytosol", and "organelle".

After reading p. 72 of Martini & Nath (8th ed) OR p. 62 of Tortora & Derrickson (12th ed), you should be able to answer questions such as:

1) *Distinguish between the cytoplasm and the cytosol.*
2) *Define the term "organelle".*

4. Describe the structures (be able to identify them in a diagram) and specify the functions of the following nuclear components:
a) nuclear membrane b) chromatin and chromosomes c) nucleolus

The nucleus houses the DNA, which contains the information required to make the cell's proteins. By determining which proteins will be made, the nucleus regulates all cellular activities. Most cells possess a single nucleus although some larger cells like skeletal muscle cells may possess several nuclei, and one type of cell (red blood cell) does not have a nucleus.

After you have read pp. 82-83 of Martini & Nath (8th ed.) OR pp. 86-87 of Tortora & Derrickson (12th ed.), you should be able to answer questions such as:

1) *Describe the structures of the nuclear membrane, chromatin and the nucleolus, and be able to identify these structures in a Figure like Fig 3-10 on p. 82 of Martini & Nath (8th ed.) OR Fig 3.24 on p. 86 of Tortora & Derrickson (12th ed.)*
2) *Distinguish between chromatin and chromosomes.*
3) *What is the function of nuclear pores?*
4) *What is produced at a nucleolus?*

5. Describe the structures (be able to identify them in a diagram) and describe the functions of the following cytoplasmic components: a) mitochondria
b) ribosomes

The number of mitochondria may vary widely, from about 100 per cell to several thousand. The size of mitochondria may also vary. Nevertheless, mitochondria can easily be recognized by their bean-like shape and their very distinctive double membrane, with the inner membrane being highly folded [see Figure 3-9 on p. 81 of Martini & Nath (8th ed) OR Fig 3.23 on p. 84 of Tortora & Derrickson (12th ed)].

Ribosomes provide the sites where information from the DNA is used to make proteins. Ribosomes can be separated into two groups, based on whether they are floating free in the cytoplasm or are attached to a membranous organelle called the rough endoplasmic reticulum (RER). See Figure 3-5 on p.77 of Martini & Nath (8th ed) OR Fig 3.19 on p. 80 of Tortora & Derrickson (12th ed). These two groups of ribosomes have been termed respectively "free ribosomes" and "fixed ribosomes" (or "bound ribosomes"). Free ribosomes produce proteins that are used in the cytosol of the cell. Attached ribosomes produce three distinct groups of proteins: proteins to be exported out of the cell, cell membrane proteins, and proteins to be used inside membranous organelles.

After reading pp. 76 & 80-81 of Martini & Nath (8th ed.) OR pp. 80-81 & 85 of Tortora & Derrickson (12th ed.), you should be able to answer questions such as:

1) Identify mitochondria and ribosomes on a figure like Fig 3-1 on p. 68 of Martini & Nath (8th ed.) OR Fig 3.1 on p. 62 of Tortora & Derrickson (12th ed.)
2) What is the main function of mitochondria?
3) Under what conditions would a cell have a large number of mitochondria? (Remember structure and function are highly correlated!) Explain your answer.
4) What kind of cell is likely to have many ribosomes? Explain your answer.
5) Specify the three types of proteins that are synthesized by fixed ribosomes on the RER.

6. Describe the structures (be able to identify them in a diagram) and describe the functions of the following components of the endomembrane system:
a) smooth endoplasmic reticulum (SER)
b) rough endoplasmic reticulum (RER)
c) Golgi complex (Golgi apparatus)
d) lysosomes
e) vesicles
f) plasma membrane

The organelles listed above, as well as the nuclear membrane, are often grouped together as the endomembrane system because their membranes are all derived from the ER and they are all interconnected: The membranes of the RER, the SER and the nuclear envelope are continuous, while the rest of the structures "receive" membrane by fusion with vesicles which have budded off from other organelles within the system.

Work through each organelle of the endomembrane system, using Table 1 (on the following page) to locate the specific text reading and figure for each organelle. Try to

form a mental image of each organelle. Consider the function(s) of the organelle and try to think beyond the 2D text image to mentally picture a 3D and very dynamic scene (vesicles budding off and rejoining other membranes somewhere else, the cell membrane engulfing a bacteria cell, and digesting it with a lysosome, etc.). Make sure that you can identify each endomembrane organelle on Figure 3-1 on p. 68 of Martini & Nath (8th ed.) OR Fig 3.1 on p. 62 of Tortora & Derrickson (12th ed.)

One of the primary functions of the endomembrane system, as a whole, is the production, storage, and transport of proteins from the RER until they reach their final destinations. Recall that we have already covered the three final destinations for these proteins that were made by fixed ribosomes on the RER. These same three groups of proteins are shown leaving the Golgi complex in Figure 3-7 on p. 78 of Martini & Nath (8th ed.) OR in Figure 3.21 on p. 83 of Tortora & Derrickson (12th ed). Think about how these proteins got to this location from the RER, and how they will continue on till their final destinations. You may wish to return to this figure when considering questions 3 and 4 (below).

After completing this objective, you should be able to answer questions such as:

1) *Identify any of the cellular components specified in objectives 4-6 on a figure like Fig 3-1 on p. 68 of Martini & Nath (8th ed) OR Fig 3.1 on p. 62 of Tortora & Derrickson (12th ed), and provide the major function(s) for that organelle.*
2) *Compare and contrast the SER and the RER in terms of both structure and function.*
3) *Describe the pathway that a lysosomal protein (a digestive enzyme) would take from the time it is produced up until the time it gets to the lysosome. Specify what happens to the protein at each new location or organelle that it encounters.*
4) *Repeat question 4, but for a membrane glycoprotein (a protein that has been modified by the addition of a short carbohydrate chain) that acts in cell-to-cell recognition on the outside surface of the cell membrane. If the glycoprotein has a Y shaped carbohydrate chain sitting on the cell surface, as shown in Figure 1, then draw the glycoprotein as it would appear:*
   - *(i) at the RER*
   - *(ii) at the Golgi complex*
   - *(iii) at the membrane vesicle moving the glycoprotein to the cell membrane.*

7. Explain what is meant by cell metabolism, distinguish between anabolism and catabolism, and provide examples of each.

To complete this objective, refer to pp 36 & 38 of Martini & Nath (8th ed) OR p 5 in Tortora & Derrickson (12th ed).

8. Describe these three cellular processes involved in the growth of the human body from a fertilised egg to an adult: cell division, cell growth, and cell differentiation.

To complete this objective, refer to pages 36 & 38 of Martini & Nath (8th ed) OR page 5 in

Tortora & Derrickson (12th ed).

Table 1: Components of the Endomembrane System

ORGANELLE	RELEVANT FIGURES *[1] Martini	Tortora	BASIC STRUCTURE	BASIC FUNCTIONS
RER	Figure 3-5 on page 77.	Figure 3.19 on page 81.	- mostly flattened sacs (cisternae) - studded with ribosomes - continuous with SER and Golgi	- make, modifies, sort and ship proteins TO the GOLGI COMPLEX - adds carbohydrates to proteins to make glycoproteins - produces membrane
SER	Figure 3-5 on page 77.	Figure 3.19 on page 81.	- more tubes than sacs - no ribosomes - continuous with RER	- makes lipids (including steroids and phospholipids) - detox of alcohol and other drugs - makes carbohydrates
Golgi Complex	Figures 3-6 and 3-7 on page 78.	Figures 3.20 & 3.21 on pp. 82-83.	- stack of flattened sacs (cisternae) - no ribosomes	- receives transport vesicles with proteins from RER - modifies, sorts and ships proteins for the cell membrane, for secretion and for lysosomes & other membrane bound organelles (phagocytosis)
lysosomes	Figure 3-8 *[2] on page 79.	Figure 3.22 *[2] on page 84.	- small vesicle containing digestive enzymes - buds off of Golgi	- digest and remove damaged organelles (autophagy) - fuse with food vacuole, digest and release nutrients
cell (plasma) membrane	Figure 3-2 on page 70.	Figure 3.2 on page 63.	- single bilipid layer - membrane is constantly being added from secretory and membrane vesicles (from Golgi	- selectively permiable barrier between cell and environment - protection/support
vesicles and vacuoles			- small membranous sacs that bud off from various parts of endomembrane system and fuse with other parts	- transport proteins, membranes, (etc) between endomembrane organelles

*[1] Figure numbers and pages refer to Martini & Nath (8th ed.) and Tortora & Derrickson (12th ed.)

*[2] Students with the Tortora text may wish to copy the better lysosome picture from Martini.

Figure 1: A Glycoprotein on the cell surface