(*University of Choice*)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN/KISUMU CAMPUSES

UNIVERSITY EXAMINATIONS
2019/2020 ACADEMIC YEAR

FIRST YEAR FIRST TRIMESTER EXAMINATIONS

FOR THE DEGREE
OF
BACHELOR OF MEDICAL LABORATORY SCIENCES/ CLINICAL MEDICINE/PHYSIOTHERAPHY /HEALTH PROFESSIONS EDUCATION (DIRECT ENTRY/ UPGRADING
MARKING KEY

COURSE CODE: **BML 116/BSP 114/HCM 100/ NUR 100**

COURSE TITLE: **CELL BIOLOGY**

DATE: **TIME:**

INSTRUCTIONS TO CANDIDATES

This paper is divided into three sections, **A B** and **C,** carrying respectively: Multiple Choice Questions (**MCQs**), Short Answer Questions (**SAQs**) and Long Answer Questions (**LAQs**).

TIME: 2 Hours

MMUST observes ZERO tolerance to examination cheating

SECTION A: MULTIPLE CHOICE QUESTIONS (20 MKS)

Instructions to the candidate

- The section has twenty (20) multiple choice questions (MCQs)
- Each question has a stem and four (4) completion options, of which only one is correct
- Write your answers on the provided university examination booklet.

1. Which among the following microscopes gives information about external topography of specimen
   A. Transmission electron microscope
   B. Scanning electron microscope
   C. Dark field microscope
   D. Light microscope
2. The cells that have no nucleus are known as:
   A. Eukaryotic cells
   B. Proliferative cells
   C. Prokaryotic cells
   D. Animalcules
3. One of the following is a function of epithelial tissue. Which one is it?
   A. Internal support for organs
   B. Protection from external environment
   C. Stores nutrients
   D. Contracts to produce movement
4. Respiration reactions involved in oxidation of sugars occur in the
   A. Ribosomes
   B. Lysosomes
   C. Mitochondria
   D. Peroxisomes
5. The organelle that synthesizes proteins is:
   A. Ribosomes
   B. Peroxisomes
   C. Lysosomes
   D. Nucleus
6. Phagocytosis is the process of:
   A. Internalizing particles by a cells
   B. Particles leave the cell
   C. Internalization of extracellular fluid
   D. Fluid leaves the cell
7. Cells of the pancreas contain many _____ because they synthesize many digestive enzymes.
   A. Lysosomes
   B. Secretory vesicles
   C. Centrioles
   D. Vacuoles

8. Which one of the following is a constituent of the phospholipid layer of membrane structure
   A. Fatty acids
   B. Cholesterols
   C. Proteins
   D. Amino acids
9. The cytoskeleton is composed of well-defined filamentous structures know as
   A. Chromatin
   B. Gap junction
   C. Microfilaments
   D. Desmosome
10. The hydrophobic part of the phospholipid layer is made up of:

    A. Choline
    B. Phosphate group
    C. Fatty acids
    D. Cell surface markers
11. The name of the sugar found on an RNA molecule is called
    A. Pentose
    B. Deoxyribose
    C. Ribose
    D. Phosphate group

12. The nucleotides are joined by linking the phosphate on chromosome number
    A. 1'
    B. 3'
    C. 5'
    D. 2'
13. The RNA has Uracil instead of _____ in its structure
    A. Adenine
    B. Guanine
    C. Cytosine
    D. Thymine
14. How many bonds are there between G-C base pair
    A. Four
    B. Two
    C. Three
    D. One
15. A group of three bases that specify an amino acid is known as
    A. Genetic code
    B. Codon
    C. Start signal
    D. Central dogma
16. Which of the following is a start codon
    A. AUG
    B. GAG
    C. UAG

D. GAA

17. The reversible replacement of one differentiated cell type with another mature differentiated cell type is known as
    A. Atrophy
    B. Hyperplasia
    C. Metaplasia
    D. Dysplasia
18. The junctions that link cells together into tissues are
    A. Tight junctions
    B. Adhesive junctions
    C. Gap junctions
    D. Plamodesmata

19. Which of the following is NOT a microdeletion syndrome
    A. Wialliams-Bauren syndrome
    B. Prader-Willi syndrome
    C. Turner's syndrome
    D. Angleman syndrome

20. _____ syndrome involves the inheritance of extra chromosomal 21 material
    A. Downs Syndrome
    B. Turner's syndrome
    C. XXY syndrome
    D. Prader-Willi syndrome

Section B.

1. **Outline the procedures followed when Preparing Specimens for Transmission Electron Microscopy (5 marks)**

   1) Fixation--specimens are fixed in glutaraldehyde, or paraformaldehyde-glutaraldehyde mixtures, followed by osmium tetroxide

   2) Dehydration is accomplished by carrying the specimens through an ascending alcohol series, to 100% alcohol (i.e., no water), then to an organic solvent such as acetone or propylene oxide

   3) Specimens are then infiltrated with an epoxy or plastic resin and placed in plastic molds to harden

   - ☐ An instrument called an ultramicrotome is used to section the specimen
   - ☐ Sections are transferred to tiny metal grids for support (the equivalent of the function of the glass slide in LM)
   - ☐ Heavy metal stains such as uranyl acetate and lead citrate are applied to make certain structures electron dense

2. **Tabulate the differences between a Prokaryotic and Eukaryotic cell (5 marks)**

Prokaryote cells	Eukaryote cells

• Has primitive nucleus. • Multiply by binary fission. • Has no nuclear membrane. • The DNA is one set of single circular chromosome of double standard DNA in the cytoplasm. (Haploid) • Has no organelles . • Include bacteria,	• Has true nucleus. • Multiply by mitosis and meiosis . • Has nuclear membrane. • Double set of chromosome inside the nuclear membrane.(diploid) • Has organelles(mitochondria , golgi apparatus..) • Fungi protozoa, plants and animals

3. **Explain the functions of the cytoskeleton as part of the cytoplasm and its inclusion (5 marks)**

Provide structural support that can determine the shape of the cell and resist forces that tend to deform it

2. Responsible for positioning the various organelles within the interior of the cell. This function is particularly evident in polarized epithelial cells, in which certain organelles are arranged in a defined order from the apical to the basal end of the cell

3. Direct the movement of materials and organelles within cells • E.g. the delivery of mRNA molecules to specific parts of a cell, the movement of membranous carriers from the endoplasmic reticulum to the Golgi complex, and the transport of vesicles containing neurotransmitters down the length of a nerve cell

4. The force-generating apparatus that moves cells from one place to another. Single-celled organisms move either by "crawling" over the surface of a solid substratum or by propelling themselves through their aqueous environment with the aid of specialized, microtubule-containing locomotor organelles (cilia and flagella) that protrude from the cell's surface

5. An essential component of the cell's division machinery

• Cytoskeletal elements make up the apparatus responsible for separating the chromosomes during mitosis and meiosis and for splitting the parent cell into two daughter cells during cytokinesis

4. **Enumerate the major functions of membrane proteins (5 marks)**

Transport. (left) A protein that spans the membrane may provide a hydrophilic channel across the membrane that is selective for a particular solute. (right) Other transport proteins shuttle a substance from one side to the other by changing shape. Some of these proteins hydrolyze ATP as an energy ssource to actively pump substances across the membrane.

Enzymatic activity. A protein built into the membrane may be an enzyme with its active site exposed to substances in the adjacent solution. In some cases, several enzymes in a membrane are organized as a team that carries out sequential steps of a metabolic pathway.

Signal transduction. A membrane protein may have a binding site with a specific shape that fits the shape of a chemical messenger, such as a hormone. Th external messenger (signal) may cause a conformational change in the protein (receptor) that relays the message to the inside of the cell.
Cell-cell recognition. Some glyco-proteins serve as identification tags that are specifically recognized by other cells.
Intercellular joining. Membrane proteins of adjacent cells may hook together in various kinds of junctions, such as gap junctions or tight junctions

5. **Distinguish between Endocrine signaling and paracrine signaling** (5 marks)
    - In **endocrine signaling** hormones are produce by an endocrine gland and sent through the bloodstream to distant cells.
    - Hormones can be: small lipophilic molecules that diffuse through the cell membrane to reach cytosolic or nuclear receptors. Examples are progesterone and testosterone, as well as thyroid hormones.
    - They generally regulate transcription; or water soluble molecules that bind to receptors on the plasma membrane.
    - They are either proteins like insulin and glucagons, or small, charged molecules like histamine and epinephrine.
    - In paracrine signaling the signaling molecule affects only target cells in the proximity of the signaling cell.
    - An example is the conduction of an electric signal from one nerve cell to another or to a muscle cell.
    - In this case the signaling molecule is a neurotransmitter.

6. Describe the three classes of intracellular signaling proteins (5 marks)

    G proteins (GTPase switch proteins) –
    - These proteins change between an active
    - conformation when bound to GTP, and an inactive conformation when bound to GDP.
    - IN the absence of a signal they are bound to GDP. Signal results in the release of GDP and the binding of abundant GTP.
    - After a short period of time they hydrolyse GTP and come back to their "off" state Protein Kinases –
    - Upon activation they add phosphate groups to themselves and/or other proteins at either serine/threonine, or at tyrosine residues.
    - Their activity can be regulated by second messengers, interaction with other proteins, or by phosphorylation itself.
    - They are opposed by phosphatases that remove phosphate groups from specific phosphorylated proteins.

    Adaptor Proteins –

- Many signaling pathways require the formation of large protein complexes that are held together by adaptor proteins.
- These proteins contain several specialized domains that act as docking sites for other proteins (e.g. SH2 domains bind to phosphotyrosines; SH3 domains bind to proline-rich sequences).

7. Describe Calcium signaling in cells (5 marks)
    - The concentration of Ca++ is kept very low in the cytosol (10^{-7} – 10^{-8} M), 10,000 times lower than in the extracellular space, by means of Ca++ pumps that pump these ions out of the cell or into the ER.
    - Regulated Ca++ channels open upon different stimulae to transiently let Ca^{++} into the cytosol where it serves as a secondary messenger in several signaling pathways.
    - The main types of Ca++ channels are the IP3-receptor and the ryanodine receptor.
    - The latter exists in the ER of nerve cells and the sarcoplasmic reticulum of muscle cells where, upon arrival of the action potential, opens to trigger calcium influx into the cytosol that results in muscle contraction.
    - Ryonodine receptors are always in close proximity to voltage-gated Ca^{++} channels and other voltage-sensitive receptors in the plasma membrane that are involved in their activation.
    - Ca^{++} is involved in a number of signaling pathways. Elevation of Ca^{++} levels via the inositollipid signaling pathway involves protein kinase C (PKC).
    - Binding of Ca^{++} to the kinase recruits it to the membrane where its kinase activate is stimulated by interaction with DAG.
    - PKC then phosphorylates a number of substrates further along the pathways.
    - Ca^{++} effects includes exocytosis of secretory vesicles, muscle contraction or the inducement of mitosis in fertilized eggs.
    - To trigger these responses calcium affects a number of cellular effectors.
    - In most cases it does it in conjunction with the calcium-binding protein calmodulin.
    - This protein is found in all eukaryotes and is widely conserved in sequence among species.
    - When the concentration of Ca^{++} increases calmodulin binds 4 Ca++ ions.
    - This results in a large conformational change in the protein that increases its
    - affinity for a number of effector proteins.

8. Describe the sugars and phosphate group of a nucleotide [20 marks]

Sugars

- DNA is typically a very long molecule and is therefore termed a acromolecule For example, within each human chromosome is a single DNA molecule that, if stretched out straight, would be several centimeters in length, thousands of times longer than the cell itself

- In spite of its large size, DNA has a quite simple structure: it is a polymer—that is, a chain made up of many repeating units linked together
- The repeating units of DNA are nucleotides, each comprising three parts: (1) a sugar, (2) a phosphate, and (3) a nitrogen-containing base
- The sugars of nucleic acids—called pentose sugars—have five carbon atoms, numbered 1′, 2′, 3′, and so forth
- The sugars of DNA and RNA are slightly different in structure
- RNA's sugar, called ribose, has a hydroxyl group (–OH) attached to the 2′-carbon atom, whereas DNA's sugar, or deoxyribose, has a hydrogen atom (–H) at this position and therefore contains one oxygen atom fewer overall
- This difference gives rise to the names ribonucleic acid (RNA) and deoxyribonucleic acid (DNA)
- This minor chemical difference is recognized by all the cellular enzymes that interact with DNA or RNA, thus yielding specific functions for each nucleic acid
- Furthermore, the additional oxygen atom in the RNA nucleotide makes it more reactive and less chemically stable than DNA
- For this reason, DNA is better suited to serve as the long-term repository of genetic information

Phosphate group

- The third component of a nucleotide is the phosphate group, which consists of a phosphorus atom bonded to four oxygen atoms
- Phosphate groups are found in every nucleotide and frequently carry a negative charge, which makes DNA acidic
- The phosphate group is always bonded to the 5′-carbon atom of the sugar

Section C.

Evans has been diagnosed to have chromosomal microdeletions. Discuss the health and behavioral implications of this diagnosis [20 marks]

Prader-Willi syndrome

- By age 3 to 7, PWS children usually develop insatiable
- Cognitive development is delayed
- The average IQ is around 65, but the variance in IQ is not markedly different from normal
- As a result, PWS can result in anything from severe mental retardation to IQ well within the low normal range
- Other frequent features include *perseveration* (the repeated and often uncontrolled repetition of a phrase or gestures), mild obsessive-compulsive rituals, intolerance of a change in daily routine, and sleep problems (PWS people often require several naps during the day)

- Although the Prader-Willi child is often talkative and friendly, he is especially prone to stubbornness, argumentativeness, irritability, and verbal and physical aggression
- Short, but very intense tantrums and temper outbursts are common
- Although the unruly behavior is a sometimes a response to the withholding of food, it can frequently occur without provocation

Wialliams-Bauren syndrome

- Williams-Beuren Syndrome (WBS)
  - 1/20,000 all populations
  - Phenotype
    - Dysmorphic facies
    - Growth and mental retardation
    - Distinctive personality
    - Transient hypercalcemia
    - Arterial disease
  - "uniform" 1.5 MB deletion del(7)q11.23
  - Region flanked by duplicated genes---non-homologous recombination

17 genes including *ELN*, which encodes tropoelastin (point mutation causes AD supravalvular aortic stenosis)

Angleman syndrome

- AS cases are characterized by hyperactivity, attention problems, unusual happiness, and a failure to speak
- Infants often express persistent social smiling as early as the first trimester after birth
- Soon they begin to laugh, often uncontrollably, at the proverbial drop of a hat and, in many cases, for no discernible reason.
- AS cases exhibit a striking disparity in their understanding versus expression of
- language.
- Even as adults few AS people have a vocabulary exceeding ten words, and they often use their few words indiscriminately and without symbolic use.
- For example, the word "mama" may be uttered without any reference to mother
- Higher functioning AS people may develop nonverbal communication skills by pointing, gesturing, and signing, but even here communication is rudimentary.
- While formalized IQ and developmental testing usually suggest severe mental retardation, many clinicians are convinced that the communication deficits of AS give invalid results on standard tests and underestimate the cognitive ability of AS
- High functioning adults with AS enjoy socializing and participate in the daily activities of their families

2. Describe the meiosis I of cell division [20 marks]

- During interphase, the chromosomes are relaxed and visible as diffuse chromatin

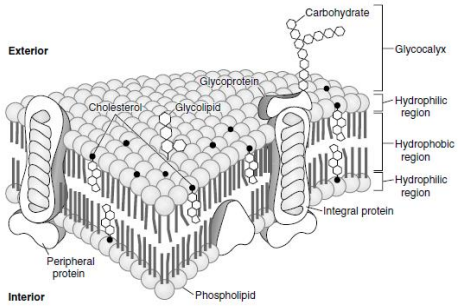
Prophase I

- This is a lengthy stage, divided into five sub-stages
- In leptotene, the chromosomes contract and become visible
- In zygotene, the chromosomes continue to condense; homologous chromosomes pair up and begin **synapsis**, a very close pairing association
- Each homologous pair of synapsed chromosomes consists of four chromatids called a **bivalent** or **tetrad**
- In pachytene, the chromosomes become shorter and thicker, and a three-part synaptonemal complex develops between homologous chromosomes
- The function of the synaptonemal complex is unclear, but the chromosomes of many cells deficient in this complex do not separate properly
- **Crossing over** takes place in prophase I, in which homologous chromosomes exchange genetic information
- Crossing over generates genetic variation and is essential for the proper alignment and separation of homologous chromosomes
- The centromeres of the paired chromosomes move apart in diplotene; the two homologs remain attached at each chiasma (plural, chiasmata), which is the result of crossing over
- In diakinesis, chromosome condensation continues, and the chiasmata move toward the ends of the chromosomes as the strands slip apart; so the homologs remain paired only at the tips
- Near the end of prophase I, the nuclear membrane breaks down and the spindle forms, setting the stage for metaphase I
- **Metaphase I**
- This is initiated when homologous pairs of chromosomes align along the metaphase plate
- A microtubule from one pole attaches to one chromosome of a homologous pair, and a microtubule from the other pole attaches to the other member of the pair
- **Anaphase I**
- This is marked by the separation of homologous chromosomes
- The two chromosomes of a homologous pair are pulled toward opposite poles
- Although the homologous chromosomes separate, the sister chromatids remain attached and travel together
- **Telophase I**
- The chromosomes arrive at the spindle poles and the cytoplasm divides

3. Give a detailed account of the cell membrane.[20 marks].

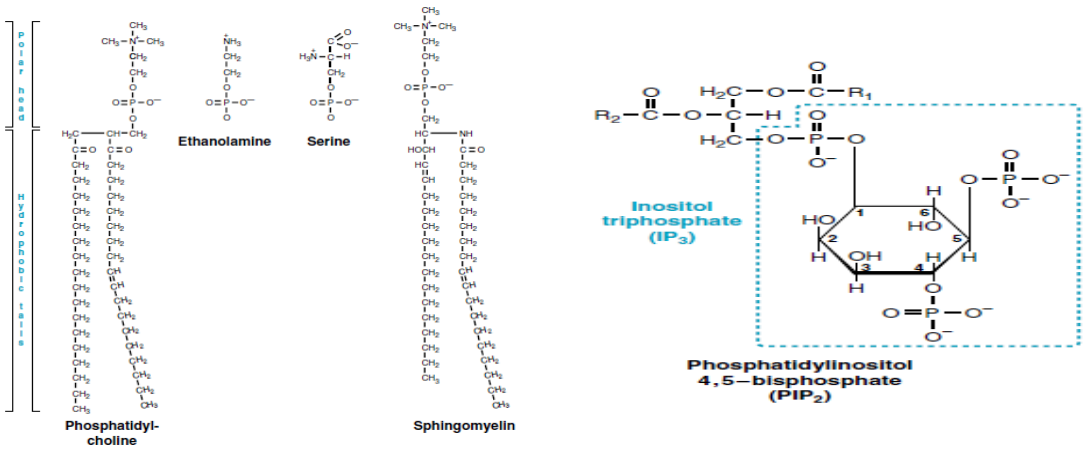
a) Lipids in the Plasma Membrane -12 Marks

- Each layer of the plasma membrane lipid bilayer is formed primarily by phospholipids, which are arranged with their hydrophilic head groups facing the aqueous medium and their fatty acyl tails forming a hydrophobic membrane core.
- The principle phospholipids in the membrane are the glycerol lipids **phosphatidylcholine**, **phosphatidylethanolamine**, and **phosphatidylserine** and the **sphingolipid sphingomyelin**.
- The lipid composition varies among different cell types, with phosphatidylcholine being the major plasma membrane lipid in most cell types and sphingolipids the most variable.
- The lipid composition of the bilayer is asymmetric, with a higher content of phosphatidylcholine and sphingomyelin in the outer leaflet and a higher content of phosphatidylserine and phosphatidylethanolamine in the inner leaflet. Phosphatidylserine contains a net negative charge that contributes to the membrane potential and might be important for binding positively charged molecules within the cell.
- **Phosphatidylinositol**, which is found only in the inner membrane, functions in the transfer of information from hormones and neurotransmitters across the cell membrane into the cell.



- **Cholesterol**, which is interspersed between the phospholipids, maintains membrane fluidity. In the phosphoacylglycerols, unsaturated fatty acid chains bent into the *cis* conformation form a pocket for cholesterol, which binds with its hydroxyl group in the external hydrophilic region of the membrane and its hydrophobic steroid nucleus in the hydrophobic membrane core.
- The presence of cholesterol and the *cis* unsaturated fatty acids in the membrane prevent the hydrophobic chains from packing too closely together. As a consequence, lipid and protein molecules that are not bound to external or internal structural proteins can rotate and move laterally in the plane of the leaflet.
- This movement enables the plasma membrane to partition between daughter cells during cell division, to deform as cells pass through capillaries, and to form and fuse with vesicle membranes.

The fluidity of the membrane is partially determined by the unsaturated fatty acid content of the diet.



b) Proteins in the Plasma Membrane -4 marks

- The integral proteins contain trans-membrane domains with hydrophobic amino acid side chains that interact with the hydrophobic portions of the lipids to seal the membrane.
- Hydrophilic regions of the proteins protrude into the aqueous medium on both sides of the membrane. Many of these proteins function as either channels or transporters for the movement of compounds across the membrane, as receptors for the binding of hormones and neurotransmitters, or as structural proteins
- Peripheral membrane proteins, which were originally defined as those proteins that can be released from the membrane by ionic solvents, are bound through weak electrostatic interactions with the polar head groups of lipids or with integral proteins.

- One of the best-characterized classes of peripheral proteins is the **spectrin family** of proteins, which are bound to the intracellular membrane surface and provide mechanical support for the membrane. Spectrin is bound to actin, which together form a structure that is called the inner membrane skeleton or the cortical skeleton.
- A third classification of membrane proteins consists of lipid-anchored proteins bound to the inner or outer surface of the membrane. The **glycophosphatidylinositolglycan** (GPI) anchor is a covalently attached lipid that anchors proteins to the external surface of the membrane.
- A number of proteins involved in hormonal regulation are anchored to the internal surface of the membrane through palmityl (C16) or myristyl (C14) fatty acyl groups or through geranylgeranyl (C20) or farnesyl (C15) isoprenyl groups. However, many integral proteins also contain attached lipid groups to increase their stability in the membrane.

c) The Glycocalyx of the Plasma Membrane -4 marks

- Some of the proteins and lipids on the external surface of the membrane contain short chains of carbohydrates (oligosaccharides) that extend into the aqueous medium. Carbohydrates therefore constitute 2 to 10% of the weight of plasma membranes.

- This hydrophilic carbohydrate layer, called the **glycocalyx**, protects the cell against digestion and restricts the uptake of hydrophobic compounds.
- The glycoproteins generally contain branched oligosaccharide chains of approximately 15 sugar residues that are attached through N-glycosidic bonds to the amide nitrogen of an asparagine side chain (N-glycosidic linkage), or through a glycosidic bond to the oxygen of serine (O-glycoproteins).
- The membrane glycolipids are usually galactosides or cerebrosides. Specific carbohydrate chains on the glycolipids serve as cell recognition molecules.

1.