MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

(MAIN CAMPUS)

UNIVERSITY EXAMINATIONS
2019/2020 ACADEMIC YEAR

FIRST YEAR FIRST SEMESTER
END OF SEMESTER EXAMINATIONS

FOR THE BACHELOR OF SCIENCE
IN
MEDICAL LABORATORY SCIENCES

COURSE CODE: BML 113

COURSE TITLE: FUNDAMENTALS OF PHYSIOLOGY

DATE: 9TH DECEMBER 2019 TIME: 9:00-11:00 AM

INSTRUCTIONS:
ANSWER ALL QUESTIONS IN SECTION A AND B, ONLY TWO IN SECTION THREE

TIME: 2 Hours

MMUST observes ZERO tolerance to examination cheating

This Paper Consists of 6 Printed Pages. Please Turn Over

SECTION A: MULTIPLE CHOICE QUESTIONS (20 MARKS)

1. Which one of the following statements is **NOT TRUE** of the field of human physiology
   (a) The function of an organ can be investigated by observing what happens when it is surgically removed from an experimental animal.
   (b) In physiology, the emphasis is on mechanisms and questions begin with word 'how' and answers involve cause and effect sequences.
   (c) Much of the foundation knowledge in human physiology was provided by human experimentation.
   (d) Physiology and anatomy are studied in tandem due to their intrinsic relationship.

2. Which one of the following is a transcellular fluid?
   (a) Plasma
   (b) Ocular fluid
   (c) Cytosol
   (d) Saliva

3. During the process of exocytosis
   (a) The plasma membrane forms a small invagination in which a substance is captured.
   (b) Both solid molecules and solid particles are internalized.
   (c) There is engulfment of the target particle or molecule.
   (d) The membrane of a vesicle fuses with the plasma membrane, extruding its contents to the surrounding medium.

4. An example of positive feedback mechanism in homeostatic control is
   (a) The regulation of blood sugar level via the release of pancreatic enzymes.
   (b) The regulation the blood pressure via vasodilation or vasoconstriction.
   (c) The release of hormone oxytocin to intensify contractions in the uterine muscles during parturition.
   (d) Thermoregulation by increasing or reducing the rate of sweating.

5. In cellular communications
   (a) The ability of cells to perceive and respond correctly to their microenvironment is the basis of immunity, tissue repair but not development.
   (b) Cellular information processing forms the basis of diseases such as cancer, diabetes and autoimmunity.

(c) Cell signalling networks can be understood through theoretical approaches in development and analysis of simulations and modelling.

(d) Cell signalling governs basic cellular activities without coordinating cell actions.

6. An osmole

(a) Is the gram-molecular weight of a substance

(b) Is the molecular weight divided by number of freely moving particles each molecule liberates

(c) Is one mole of an ionized substance divided by its valence

(d) Is the number of moles per Kg of solvent

7. Human cardiac muscles

(a) Lack cross-striations and are controlled involuntarily

(b) Are generally attached by means of tendons to other adjacent tissues.

(c) Are coupled mechanically and electrically by intercalated disks.

(d) Are made up of cells called myofibers that contain numerous mitochondria

8. An adrenergic nerve fiber is a nerve fiber that

(a) Produces vasodilation in skeletal muscles.

(b) Is not active during a state of calmness in an individual.

(c) Produces nerve impulses by releasing acetylcholine neurotransmitter molecules.

(d) Produces vasoconstriction in the digestive tract during emergency responses.

9. In the human visual perception, the cones

(a) Provide black and white vision and contain a photodegradable coneopsin pigment.

(b) Provide perception of a multitude of colours by stimulation of only 3 cone types.

(c) Transmit light in the blue and red spectrum regions while absorbing light in the green spectrum region.

(d) Are more sensitive to light than rods and have a greater visual acuity than rods

10. When an object 20 feet away moves closer to the eyes

(a) Ciliary body muscles relax, bringing ciliary body closer to the lens.

(b) The lens becomes more convex due to its inherent elasticity

(c) Tension is increased in the zonular fibers suspending the lens.

(d) Ciliary body muscles contract, moving the ciliary body further from the lens.

11. The loss of accommodating ability in the eyes due to loss of elasticity with age can be termed as
    (a) Myopia
    (b) Presbyopia
    (c) Hyperopia
    (d) Astigmatism

12. Identify neurotransmitters that **CANNOT** be classified in the monoamine / biogenic amine group of neurotransmitters
    (a) Acetylcholine and dopamine
    (b) Epinephrine and anandamide
    (c) D-serine and nitric oxide
    (d) Histamine and norepinephrine

13. Which one of the following is a correct depiction of hormones produced by the placenta
    (a) Oestrogens, progesterones and growth hormone
    (b) Oestrogen, hCG and somatomammotrophin
    (c) Progesterone, LH and somatomammotrophin
    (d) hCG, progesterone and LH

14. Identify a correctly described extrinsic agent controlling vascular resistance.
    (a) Prostaglandin I_2 is a vasoconstrictor produced by liver cells
    (b) Vasopressin has effects on vascular resistance and is produced by the anterior pituitary.
    (c) Angiotensin II is a powerful vasodilator and its production is induced by rennin.
    (d) Polypeptide bradykinins produce local vasodilatation and are secreted by sweat glands.

15. Which one of the following body areas **DOES NOT** receive cholinergic parasympathetic innervations in their arterioles?
    (a) The skin
    (b) The digestive tract
    (c) The salivary glands
    (d) External genitalia

16. Select a correctly described body plan terminology among the following
    (a) A longitudinal plane divides the body into the anterior and posterior parts
    (b) A sagittal plane divides the body into the superior and inferior parts

(c) A frontal plane divides the body into the left and right parts.

(d) **A transverse section cuts / divides an organ at a right angle to the long axis**

17. Select a cellular process, among the following in which the cell membrane **DOES NOT** primarily participate in

    (a) Cell adhesion

    (b) DNA repair

    (c) Ion conductivity

    (d) Cell signalling

18. The intracellular fluid

    (a) Is the cytoplasmic matrix in which cellular organelles are suspended

    (b) Is primarily a solution of sodium and organic ions

    (c) Makes up to 35%- 40% of total body water

    (d) Exists in osmotic disequilibrium with the extracellular fluid

19. In the human visual system's image forming mechanism

    (a) Light is refracted the most at the lens than at the cornea

    (b) The refractive properties of the cornea provide full control for focusing light on the retina

    (c) The curvature of the lens and the cornea can be varied

    (d) The visual field projected onto the retina is reversed in each eye

20. The correct arrangement of the components of the neural layer of the eye is;

    (a) Ganglion cells, horizontal cells, amacrine cells, bipolar cells, photoreceptors

    (b) Photoreceptors, horizontal cells, amacrine cells, ganglion cells, bipolar cells.

    (c) Ganglion cells, amacrine cells, bipolar cells, horizontal cells, photoreceptors

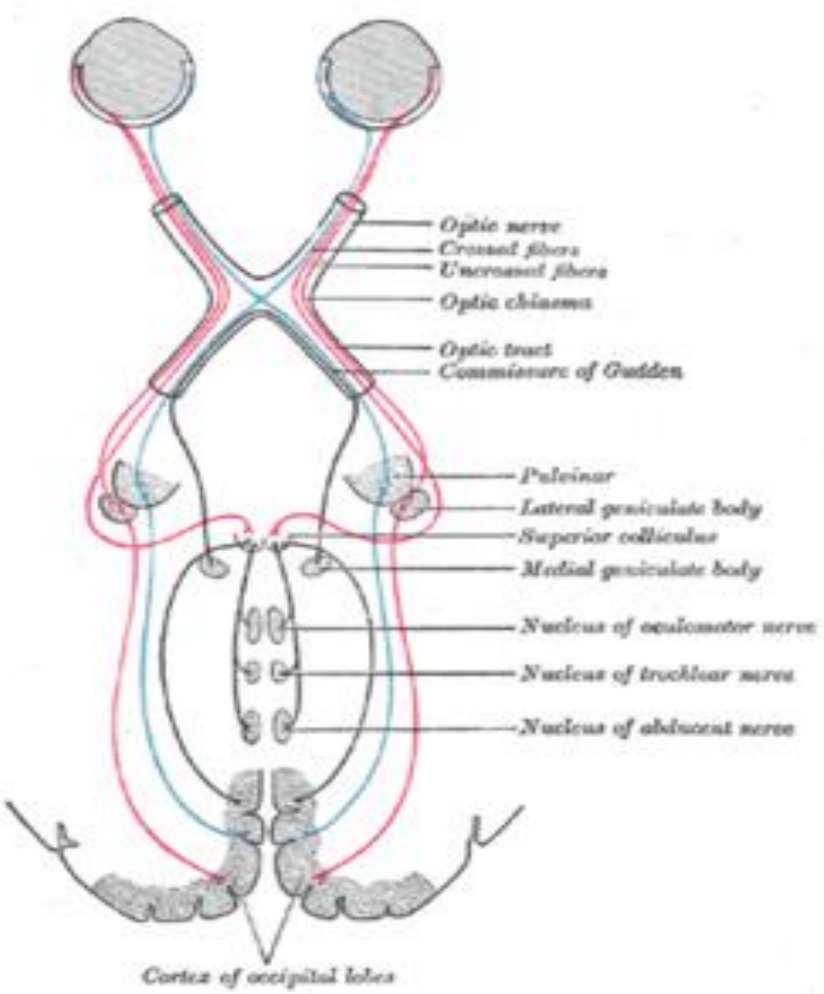
    (d) Photoreceptors, amacrine cells, horizontal cells, bipolar cells, photoreceptors.

SECTION B: SHORT ANSWER QUESTIONS [40 MARKS]

1. With the aid of a diagram, describe the projection of the neural pathways from the retina **(8 marks)**

The neural pathway from the retina leads to the lateral geniculate of the brain thalamus then generally to the visual cortex of the cerebral hemisphere. The left lateral geniculate nucleus receives input from both eyes that relates the right half of the visual field. The right lateral geniculate receives input from both eyes that

relates to the left half of the visual field. This is a result of crossing of optic fibers in the optic tracts at the optic chiasma



Specifically, neurons of both lateral geniculate bodies of the thalamus project to the striate cortex of the occipital lobe in the cerebral (visual) cortex (area 17). The geniculostriate system is involved in the perception of the visual field. The tectal system, whose pathway leads to the superior colliculus of the mid brain activates the motor pathway leading to eye and other body movements.

2. Account for catecholamines as a class of regulatory and neurotransmitter molecules and explain their neurotransmission mechanism in chemical synapses **(8 marks)**

Cotecholamines are a group of regulatory molecules derived from the amino acid tyrosine. Examples of cotecholamines include dopamine, norepinephrine and epinephrine. Dopamine and norepinephrine work as neurotransmitters while norepinephrine and epinephrine additionally work as hormones. Cotecholamines and serotonin (a CNS neurotransmitter) belong to a large class of molecules called monoamine molecules.

Cotecholamines are released from the presynaptic cell (neuron) by exocytosis when incoming action potential stimulates on influx of Ca^{2+} (calcium ions) by causing the opening of gated ion channels. Exocytosed catecholamines diffuse across the synaptic cleft and then interact with specific receptor proteins on the post synaptic cell membrane of the post synaptic cell. The binding of catecholamine to its specific receptors then stimulates the intracellular activation of adenylate cyclase via ATP - mediated pathways. Adenylate cyclase the stimulates the intracellular production of cyclic adenosine monophosphate (cAMP) which activates enzymes that catalyse the occurrence of short term and long term events. Short term events include the opening of gated ion channels, long term events involves the influencing of gene expression (Protein synthesis)

Inhibition mechanisms of catecholamines includes; 1) Reuptake of catecholamines into the presynaptic neurone endings, 2) Enzymatic degradation of catecholamines in the presynaptic neurone endings by monoamine oxidase (MAO) and 3) Enzymatic degradation of catecholamines at the post synaptic cell or neurone by catechplamine-O-methyltransferase (COMT). Drugs that inhibit MAO and COMT thus promote the effects of catecholamine neurotransmitters.

3. Define a nerve impulse and briefly explain the process of its conduction through a neuron **(8 marks)**

A nerve impulse is a signal transmitted along a nerve fiber consisting of a wave of electrical depolarization that reverse the potential difference across the nerve cell membrane. An entire nerve impulse passes through a neuron axon in approximately 7 milliseconds.

Initially the neuron is polarized, meaning that the electrical change on the inside of the neuron membrane is negative, while the electrical change on the outside of the neuron membrane is positive. The outside of the neuron contains excess Na+ ions, while the inside contains excess K+ ions. The negative charge inside the cell is due to the presence of negatively charged protein and nucleic acid molecules. A polarized neuron is an inactive, non-conducting neuron and is said to be at resting potential.

When a stimulus reaches a resting neuron, the gated ion channels on the resting neuron's membrane open suddenly and allows Na+ ions to go …. from the outside into the inside of the cell and the neurons resting potential polarization is removed, this is called depolarization.

Gated ion channels on the outside of the membrane then open to allow K+ ions to move to the outside of the membrane resulting in repolarisat ionwhich restores electrical balance. Eventually, the neuron gets into a state where there are more potassium ions on the outside than on the inside and the membrane is said to be hyperpolarized.

Finally, a refractory period occurs in which potassium returns to the inside and sodium returns outside.

4. Describe the cell theory and explain the processes of endocytosis and exocytosis **(8 marks)**

The 'cell theory' is a collective phrase that provides the following research derived concepts about the cell/cells;

That the cell is the structural and functional unit of life (living organisms); defining cell properties is in fact defining the properties of life.

The activity of an organism depends on both the individual and collective activities of its cells.

According to the principle of complementarily, the biochemical activities of cells are dictated by the relative number of their specific subcellular structures. Continuity of life has a cellular basis.

Endocytosis is the process in which cells absorbs molecules by engulfing them. The plasma membrane creates a small inward deformation called and invagination, in which the substance to be transported is captured. The deformation then pinches off from the membrane on the inside of the cell, creating a vesicle containing the captured substance. Endocytosis is the pathway for internalizing (solid particles (phagocytosis), small molecule/ions (pinocytosis) and macro molecules. Endocytosis requires energy and therefore is a form of active transport.

In exocytosis membrane of a vesicles fuser with the plasma membrane extruding its contents to the surrounding medium. Exocytosis is important in (i) Removal of undigested residues of substances brought in by endocytosis (ii) Secretion of hormones and enzymes. In exocytosis, the undigested waste-containing food vacuole or secretory vesicle bucked from the golgi apparatus is first moved by the cytoskeleton from the interior of the cell to the inner lining of the membrane where lipid molecules in the bilayers rearrange themselves to allow the vesicle to fuse to the cell membrane and discharge its contents to the exterior.

5. Distinguish between the following; (a) Transcription and Translation **(2 marks)**
(b) Apoptosis and Autophagy **(2 marks)**
(c) The Nucleotide and The Gene **(2 marks)**
(d) Exteroceptors and Enteroceptors **(2 marks)**

(i) Transcription: the first stage in protein synthesis that takes place in the cell nucleus, involving the biosynthesis of an mRNA strand via the action of RNA polymerase which uses a DNA strand as complementary template.

(ii) Apoptosis: the process of programmed cell death (PCD) involving biochemical events that result in characteristic cell morphology and death. Autophagy a catabolic process involving the degradation of cells' own components (autodegradation) through lysosomal machinery.

(iii) Nucleotide: a subunit of DNA or RNA macromolecules composed of a phosphate group, a sugar (deoxyribose or ribose) and a nitrogenous base (either adenine, cytosine or guanine or thymine or uracil)

Gene: A specific section of a DNA macromolecule, comprising of nucleotide sequences that encode for protein synthesis.

(iv) Exteroceptors: are sensory receptor that respond to changes in the chemical composition of the external environment.

Interoceptors are sensory receptors that respond to changes in the chemical composition of the internal environment.

SECTION C: LONG ANSWER QUESTIONS **[60 MARKS]**

1. Discuss transport mechanisms across the cell membrane **(20 marks)**

In cellular biology, **membrane transport** refers to the collection of mechanisms that regulate the passage of solutes such as ions and small molecules through biological membranes, which are lipid bilayers that contain proteins embedded in them. The regulation of passage through the membrane is due to selective membrane permeability - a characteristic of biological membranes which allows them to separate substances of distinct chemical nature. In other words, they can be permeable to certain substances but not to others.

The movements of most solutes through the membrane are mediated by membrane transport proteins which are specialized to varying degrees in the transport of specific molecules. As the diversity and physiology of the distinct cells is highly related to their capacities to attract different external elements, it is postulated that there is a group of specific transport proteins for each cell type and for every specific physiological stage. This differential expression is regulated through the differential transcription of the genes coding for these proteins and its translation, for instance, through genetic-molecular mechanisms, but also at the cell biology level: the production of these proteins can be activated by cellular signaling pathways, at the biochemical level, or even by being situated in cytoplasmic vesicles.

Passive diffusion and active diffusion

A semipermeable membrane separates two compartments of different solute concentrations: over time, the solute will diffuse until equilibrium is reached.

As mentioned above, passive diffusion is a spontaneous phenomenon that increases the entropy of a system and decreases the free energy.The transport process is influenced by the characteristics of the transport substance and the nature of the bilayer. The diffusion velocity of a pure phospholipid membrane will depend on:

- concentration gradient,
- hydrophobicity,
- size,
- charge, if the molecule has a net charge.

Active and co-transport

In active transport a solute is moved against a concentration or electrochemical gradient; in doing so the transport proteins involved consume metabolic energy, usually ATP. In primary active transport the hydrolysis of the energy provider (e.g. ATP) takes place directly in order to transport the solute in question, for instance, when the transport proteins are ATPaseenzymes. Where the hydrolysis of the energy provider is indirect as is the case in secondary active transport, use is made of the energy stored in an electrochemical gradient. For example, in co-transport use is made of the gradients of certain solutes to transport a target compound against its gradient, causing the dissipation of the solute gradient. It may appear that, in this example, there is no energy use, but hydrolysis of the energy provider is required to establish the gradient of the solute transported along with the target compound. The gradient of the co-transported solute will be generated through the use of certain types of proteins called biochemical pumps.

The discovery of the existence of this type of transporter protein came from the study of the kinetics of cross-membrane molecule transport. For certain solutes it was noted that the transport velocity reached a plateau at a particular concentration above which there was no significant increase in uptake rate, indicating

a log curve type response. This was interpreted as showing that transport was mediated by the formation of a substrate-transporter complex, which is conceptually the same as the enzyme-substrate complex of enzyme kinetics. Therefore, each transport protein has an affinity constant for a solute that is equal to the concentration of the solute when the transport velocity is half its maximum value. This is equivalent in the case of an enzyme to the Michaelis-Menten constant.
Some important features of active transport in addition to its ability to intervene even against a gradient, its kinetics and the use of ATP, are its high selectivity and ease of selective pharmacological inhibition.

Secondary active transporter proteins

Uniport, symport, and antiport of molecules through membranes.
Secondary active transporter proteins move two molecules at the same time: one against a gradient and the other with its gradient. They are distinguished according to the directionality of the two molecules:

- antiporter (also called exchanger or counter-transporter): move a molecule against its gradient and at the same time displaces one or more ions along its gradient. The molecules move in opposite directions.
- symporter: move a molecule against its gradient while displacing one or more different ions along their gradient. The molecules move in the same direction.

Both can be referred to as co-transporters.

Pumps

Simplified diagram of a sodium potassium pump showing alpha and beta units.
A pump is a protein that hydrolyses ATP to transport a particular solute through a membrane, and in doing so, generating an electrochemical gradient membrane potential. This gradient is of interest as an indicator of the state of the cell through parameters such as the Nernst potential. In terms of membrane transport the gradient is of interest as it contributes to decreased system entropy in the co-transport of substances against their gradient. One of the most important pumps in animal cells is the sodium potassium pump.

2. Describe the organization, hormonal secretions and hypothalamic regulation of the functioning of the pituitary gland **(20 marks)**

The pituitary gland or hypophysis is located on the inferior aspect of the brain in the region of the diencephalon and it is attached to the hypothalamus by a stalk-like structure called the infundibulum. It is structurally and functionally divided into an anterior lobe (adenophypophysis) and posterior lobe (neurohypophysis). There are 8 important hormones secreted by the pituitary gland, six of which are secrete by the anterior pituitary and two of which are secreted by the posterior pituitary gland. Posterior pituitary hormones are produced in the hypothalamus, transported through axons in the infundibulum to the posterior pituitary and their secreted by the posterior pituitary gland into the blood.

The following are the anterior pituitary hormones with each of the functions

i) Growth hormone (GH or somatotrophin); this stimulates the growth of all body organs and promotes the movement of amino acids into tissue cells, and the incorporation of these amino acids into tissue proteins.

ii) Thyroid-stimulating hormone (TSH, or thyrotrophin); This stimulates the thyroid gland to produce and secrete thyxine (tetraiodothyronine) or (T_4) and triodothyronine.

iii) Adgenocusticotropin hormone (ACTH or corticotrophin). Stimulates the growth and secretion of ovarian follicles in the ovaries of females and sperm production in the male testes.

iv) Luteinizing hormone (LH or Luteotrophin): This hormone and FSH are collectively called gonadotrophic hormones. In females, LH hormones stimulate ovulation and the conversion of an ovulated ovarian follicle into an endocrine structure called corpus/luteum. In males, LH (also called interstitial cell stimulating hormone : ICSH), stimulates the secretion of male sex hormones (mainly testosterone) from the interstitial cells of the leydig tissue the testes.

v) A follicle stimulating Hormone (FSH), stimulates the growth and secretion of ovarian follicles on female ovaries and sperm production in male testes

vi) Prolactin, secreted in both males and females. It stimulates milk production only in females after the birth of babies where it has a highly pronounced function.

The following are the anterior pituitary hormones with each of their functions

i) Antidiuretic hormone (ADH or Vasopressin): It stimulates the kidneys to retain water so that less water is excreted in the urine and more water is retained in blood. This hormone also causes vasoconstriction.

ii) Oxytocin; In females it stimulate uterine contractions during labour and contraction in the mammary gland alveoli and ducts leading to milk ejection reflex during lactation.

Regulation of the functioning of the pituitary gland is achieved through the following mechanisms.

i) Secretion of ADH and oxytocin from the posterior pituitary is controlled by neuroendocrine reflexes.

Oxytocin has been shown to affect individuals by increasing, sexual arousal, trust, reducing anxiety and fear. It also modulates inflammation by increasing the concentrations of certain cytokines.

ii) Secretion of anterior pituitary hormones is regulated by the hypothalamus through a portal system called the hypothalama-hypophyseal portal system. It forms the vascular link between the hypothalamus and the anterior pituitary. Through the portal system, the hypothalamus regulates anterior pituitary hormonal secretions by releasing hormones called releasing hormones into this portal system. These releasing hormones include the thyroid releasing hormone (TRH) which stimulates the secretion of the thyroid stimulating hormone,

corticotrophin releasing hormone (CRH) which stimulates the secretion of the ACTH, Gonadotrophin, releasing hormones (G_nRH) stimulates the secretion of the FSH and LH. Prolactin inhibiting hormone (PIH) regulates the secretion of the hormone prolactin somatostatin regulates the secretion of the growth hormone.

Anterior pituitary hormonal secretions are controlled by a negative feedback inhibition mechanism from the target gland hormone e.g. the secretion of TSH is inhibited by rise in the secretion of thyroxin from the thyroid gland.

3. Explain properties and Excitation mechanisms that take place in skeletal muscles

(20 marks)

These are made up of building blocks called muscle fibers or myofibers arranged in parallel between the tendinous ends so that the force of contraction of the units is additive.

Skeletal muscles mostly begin and end in tendons. Each muscle fiber is a single cell, multinucleated, long, cylindrical, and surrounded by a cell membrane, the sarcolemma. Muscle fibers contain myofibrils, made up of individual filaments, made up of contractile proteins.

Contractile mechanisms in skeletal muscles depend on the proteins tropomyosin, troponin (troponin T, troponin I and troponin C), actin, alpha-actinin, and myosin.

Muscle fibrils have a sarcotubular system which is made up of a T system, and sarcoplastic reticulum. The T system which is continuous with the sarcolemma, functions in the rapid transmission of action potential from the cell membrane to all the muscle fibrils. The sarcoplastic reticulum functions in movement of calcium ions and muscle metabolism.

Electrical events in skeletal muscles and the ionic fluxes underlying them are similar to those in nerves, although there are quantitative and qualitative differences in timing and magnitude. Ionic distribution across the muscle fiber membrane is similar to that across the nerve cell membrane.

Muscle fiber membrane depolarization normally starts at the motor end plate; the specialized structure under the motor nerve ending; the action potential is then transmitted along the muscle fiber and it initiates the contractile response through causing the binding of calcium ions on troponin C followed by the formation of cross linkages between actin and myosin that result in the sliding of thin filaments on thick filaments producing shortening. In muscle relaxation, calcium ions are released from troponin leading to the cessation of interactions between actin and myosin.

A muscle twitch is a single action potential that causes a brief contraction followed by a relaxation. An isometric contraction is a contraction that occurs without an appreciable decrease in the length of the whole muscle. The hydrolysis of ATP yields the energy requirements for muscle contraction to occur.

\