BME205 – Fundamentals of Biomedical Engineering: Final Exam 2023

Final Exam: April 22, 2023

Duration: 2 and ½ hours

Exam Type A: Closed book

Calculator Type 2: Non-programmable

Examiner: J.C. Bouwmeester

First name (please write as legibly as possible within the boxes)

Last name

Student ID number

Instructions for this Exam:

1. Wireless communication (i.e., cell phones, tablets, etc.) and other electronic devices are not permitted. These must be turned **OFF** and kept in your bag/backpack at the front of the room. You are **NOT** permitted to retain these devices in your pant or coat pocket, or on your desk.

2. Textbook, lecture, and lab materials are not permitted on your desk. Pencil (or other) cases are not permitted on your desk. Eating is prohibited. Only clear water bottles may be used.

3. Place your Photo ID (Tcard) at the top right corner of your desk for the duration of the exam.

4. The maximum amount of points for this exam is 75. There are 17 short answer questions that are worth 60 points. There are 15 multiple-choice questions worth 15 points.

5. Each multiple-choice question has only one acceptable answer (i.e., a, b, or c). Answering more than one choice will result in 0 points. Markings on the bubble sheet will be understood as final answers, any other markings will be considered preliminary and will not be considered for any grading.

6. Please read all questions CAREFULLY and select the MOST APPROPRIATE answer for multiple-choice questions.

7. The number of points available per short answer question is indicated in parentheses at the end of each question or sentence if there are multiple parts to a question.

8. One point will be deducted for going outside the short answer boxes provided or over the sentence limit specified.

9. This exam is double-sided. The last page has the multiple-choice bubble sheet.

10. Use the extra blank page for calculations or draft answers. Numerical answers only need to be rounded to one decimal place. Draft answers will not be considered for any grading.

11. The "time remaining" will be announced 10 minutes and 5 minutes before the end of the exam.

12. You may not leave the exam room during the first hour, or after the last announcement given when there are 5 minutes remaining.

13. You have 2.5 hours to complete this exam.

Part 1: Short-Answer Questions

1) Under normal circumstances, the neuromuscular junction is excitatory because somatic motor neurons only release one type of neurotransmitter, which leads to a depolarized end-plate potential and a skeletal muscle action potential that leads to skeletal muscle contraction. List one normal and one abnormal way to stop skeletal muscle contraction. (4)

Normal:

Abnormal:

2) The process of muscle contraction requires energy (i.e., ATP). What is the main contribution (or function) of ATP that is necessary to create muscle contraction? (2) ATP also supports the process of muscle contraction. List one other function of ATP by describing what else it is doing to support muscle contraction and what it acts upon specifically. (2)

3) Using only one sentence: describe what a motor unit is. (2)

4) Explain how motor units function cooperatively to produce contractions of variable grades of strength that are stronger than a twitch. (3)

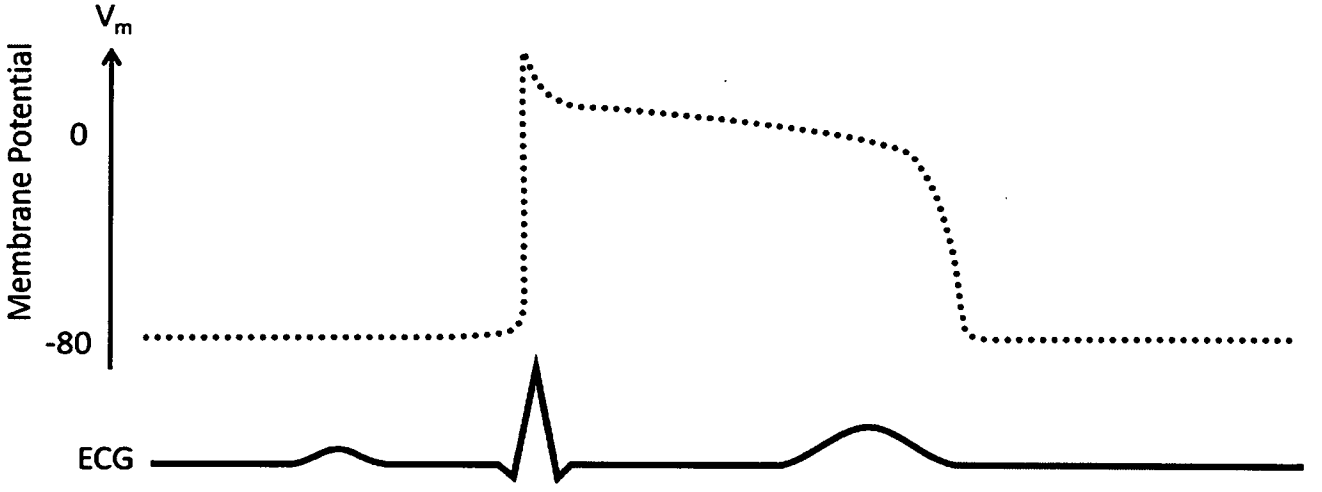
5) Each person has about 600 skeletal muscles, which range in size from the delicate external eye muscles that control eye movement to the powerful leg muscles. Compare how motor units may be different in these two muscle groups. (2)

6) For each characteristic, list one (or more) keywords or abbreviations in the blank cells that describe how cardiac muscle is different or similar to skeletal muscle. (4)

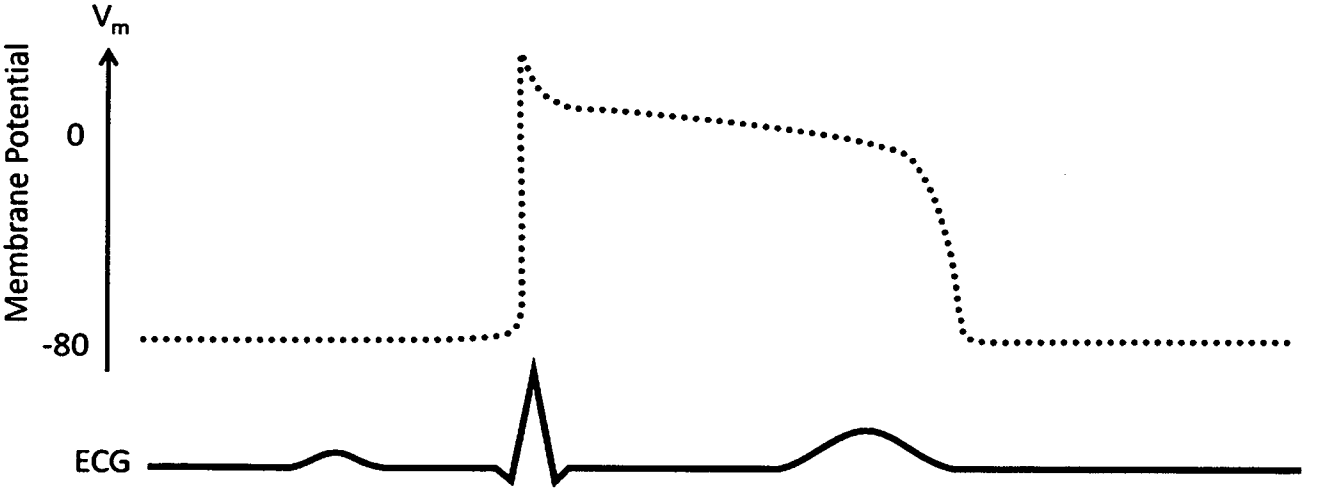
Characteristic	**Skeletal**	**Cardiac**
Source of increased cytosolic Ca^{2+}	Just sarcoplasmic reticulum (SR)	
Contraction regulated by …		Acetylcholine (ACh) and Norepinephrine (NE)
Presence of gap junctions	None	

The pattern of polarization (i.e., action potential) of a cardiomyocyte, located in the **endocardium layer** of the **left ventricle** is shown, as the dotted line, in the figures shown below on this page. For reference, the ECG is shown, with correct timing in relation to the action potential.
N.B. This figure is provided, for convenience, on the last page of this booklet to draft an answer.

7) Draw (with a solid line) the correct timing and pattern of a left ventricular cardiomyocyte action potential that is located on the **epicardium layer**. (4)

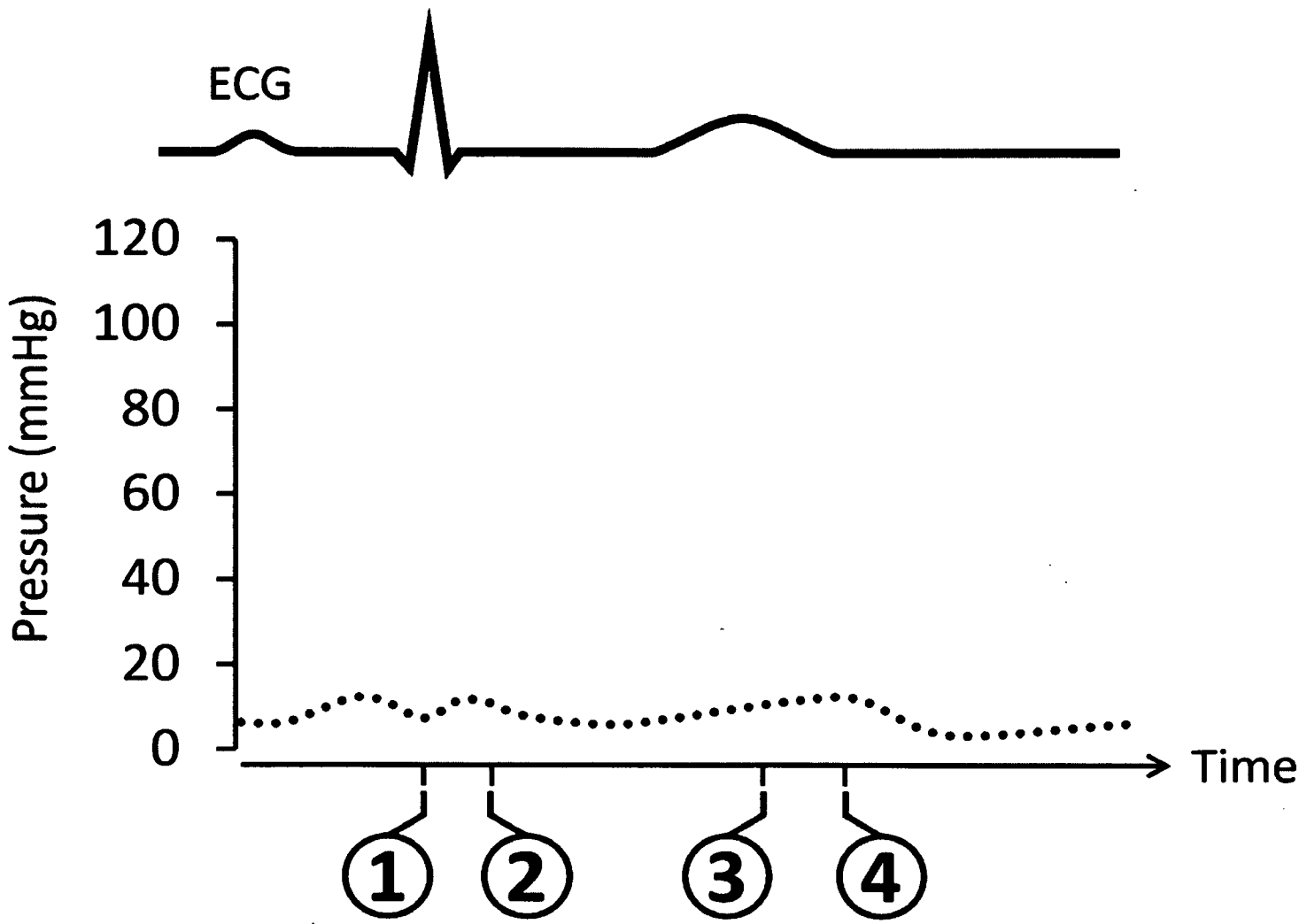


8) Draw (with a solid line) the correct timing and pattern of a **left atrial** cardiomyocyte action potential. (4)



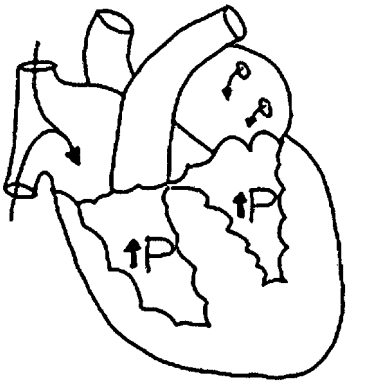
9) The figure below shows an ECG for reference and the dotted line represents left atrial pressure in the heart during one cardiac cycle. The values on the y-axis are accurate and there are four labelled tick marks on the Time-axis that represent key events during the cardiac cycle. Draw (with clear, solid lines) an accurate representation of how: a) left ventricular and b) aortic pressures change throughout a cardiac cycle. (8)

N.B. This figure is provided, for convenience, on the last page of this booklet to draft an answer.

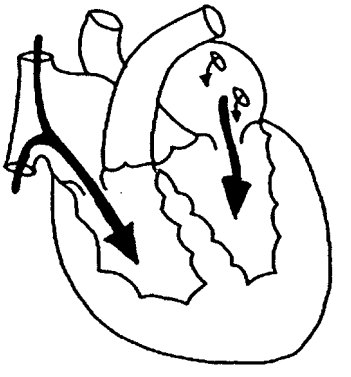


The questions on this page refer to the four labelled tick marks on the Time-axis, in the figure associated with question 9. The arrows shown in the cartoon images of the heart indicate the direction of blood flow, unless otherwise noted.

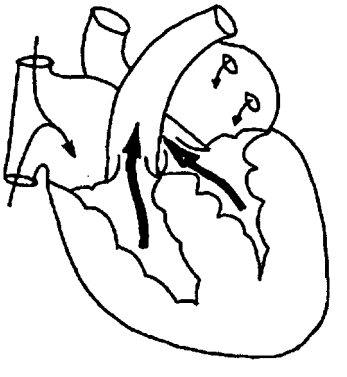
10) This cartoon image depicts a period between two key events, where the label "↑P" is increasing pressure. What are the best keywords that describe the actions that occur inside the heart at two key events that define the start and end of this period? (2)



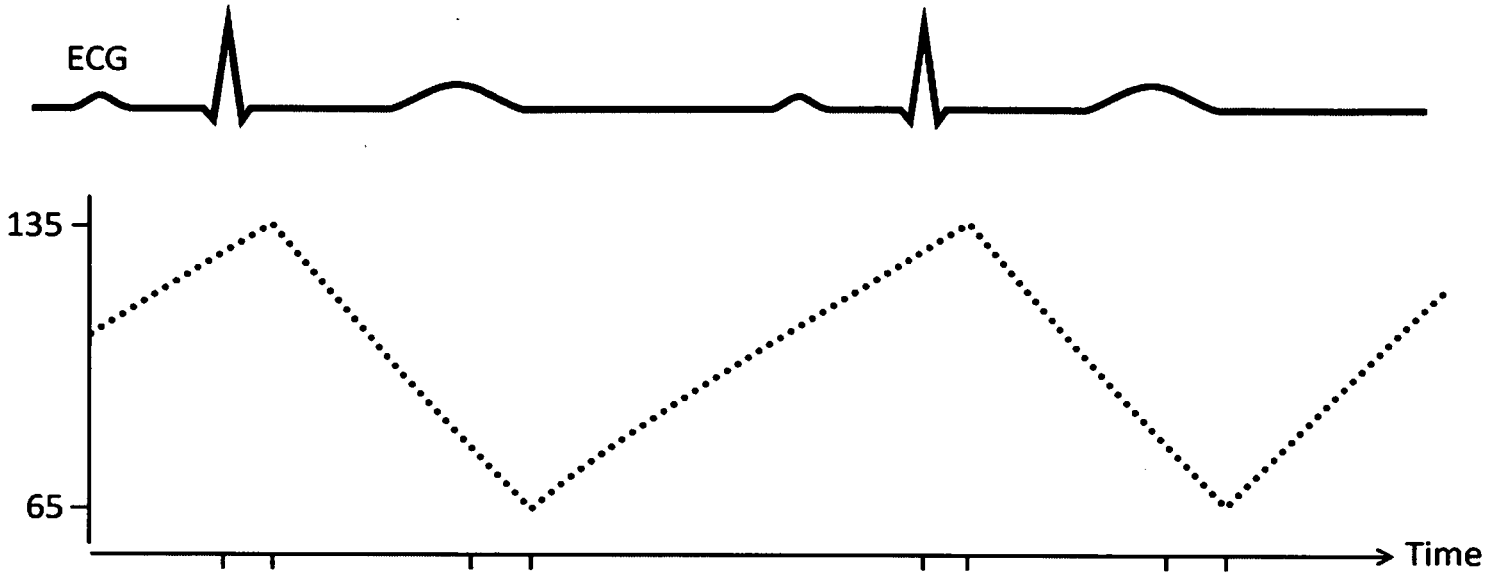
11) This cartoon image depicts a period between two key events. What are the best keywords that describe the actions that occur inside the heart at two key events that define the start and end of this period? (2) What is the period of time between these events called? (1)



12) This cartoon image depicts a period between two key events. What are the best keywords that describe the actions that occur inside the heart at two key events that define the start and end of this period? (2) What is the period of time between these events called? (1)



13) The figure below has features that do not reflect what actually happens in the heart, but the maximum and minimum numbers on the Y-axis and labels on the Time-axis are correct. Correct the dotted line by drawing a solid line that represents an accurate tracing throughout the cardiac cycles. (4)
N.B. This figure is provided, for convenience, on the last page of this booklet to draft an answer.

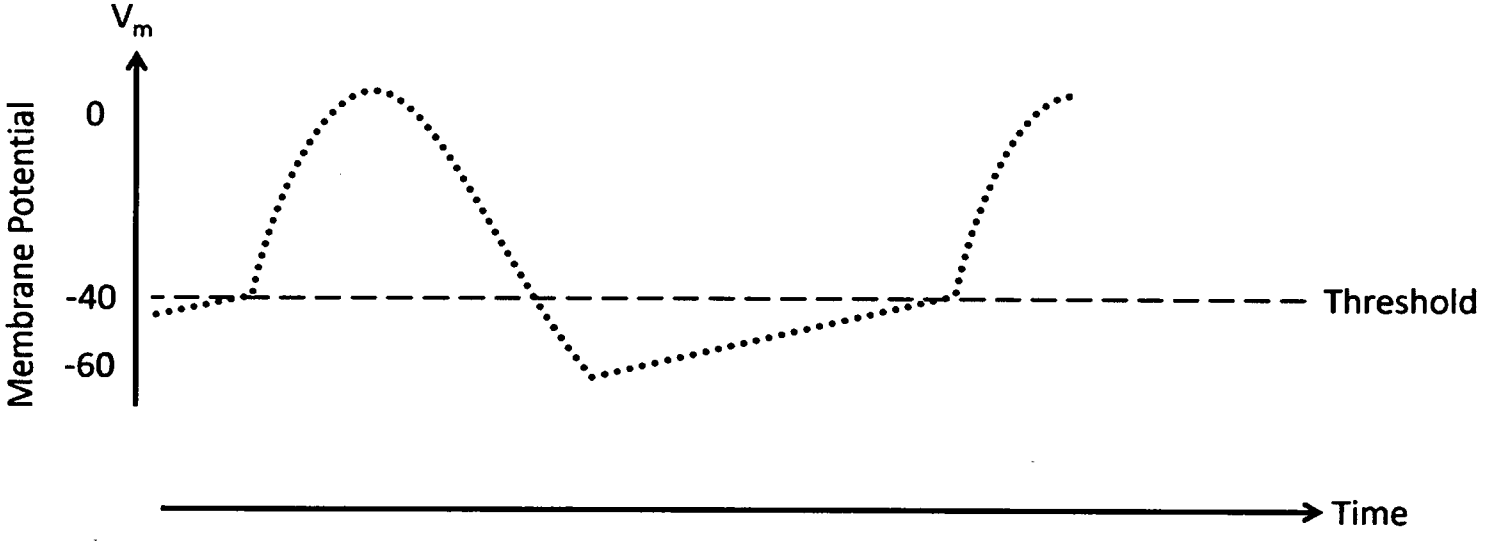


14) What is the name of the line you drew in the figure above? (2)

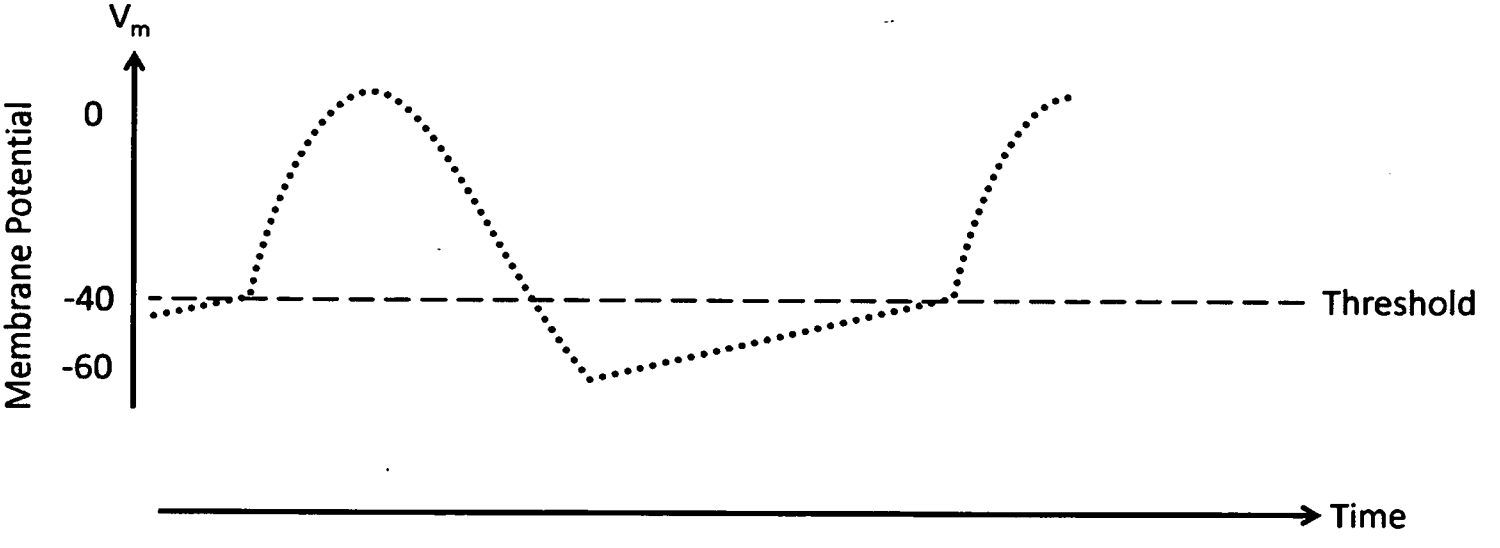
15) Describe, using keywords, the three most critical features that you added to the figure, shown immediately above, which are necessary for the heart to function in a normal, coordinated fashion. (3)

The figures on this page show the representative action potentials of a sinoatrial node cardiomyocyte as a dotted line, changing throughout one cardiac cycle (plus a little extra before and after, for orientation).
N.B. This figure is provided, for convenience, on the last page of this booklet to draft an answer.

16) What effect does the Vagus nerve have on the sinoatrial node? Draw a solid line on the figure, immediately below, that shows just one way that the action potential pattern can be altered with parasympathetic stimulation. (4)



17) What effect do sympathetic nerves have on the sinoatrial node? Draw a solid line on the figure, immediately below, that shows just one way that the action potential pattern can be altered with sympathetic stimulation. (4)



Part 2: Multiple-Choice Questions

Indicate the answer choice that best completes the statement or answers the question.

1. Which of the following statements best describes the relationship between actin and myosin?
   a. Actin is like a turnstile (which allows for rotation in one direction, but locks in the reverse direction, in order to allow for the one-way flow of human traffic in places like the subway or a sporting event), while myosin is like the handle that turns it.
   b. Actin and myosin are like a rack and pinion gear combination, with the relative movement generating force. In this case, actin would be the rack (a flat linear gear) and myosin would be the pinion (a circular gear that meshes with the rack and the rotation of the pinion causes the rack to translate).
   c. Actin is like a door latch, while myosin is like the gate door that swings open or closed.

2. Which of the following statements best explains why there are multiple nuclei within a single skeletal muscle fibre?
   a. A muscle fibre is like a computer with multiple processors that can expand the capacity to handle different simultaneous tasks.
   b. A muscle fibre is like a city with multiple mayors overseeing different districts.
   c. A muscle fibre is like a construction site with multiple supervisors giving directions to workers who are repairing a damaged structure.

3. What is the function of transverse tubules?
   a. To store and release calcium when triggered by an action potential.
   b. To hold the A bands and I bands in place.
   c. To ensure even distribution of action potentials throughout all portions of the muscle fibre.

4. Compared to an unfatigued muscle fibre, what will happen to the resting membrane potential (RMP) of a skeletal muscle fibre during strenuous exercise?
   Provided is: a) the table of measured ion concentrations during strenuous exercise and b) the reduction in intracellular pH from 7.28 when unfatigued to 6.89 during strenuous exercise. The Nernst Equation is provided for convenience. $E_X = \frac{61}{z} \log \frac{[X_{ECF}]}{[X_{ICF}]}$

Ion	K^+	Na^+
ICF (mMol/L)	90	24
ECF (mMol/L)	14	130

   a. The exercised fibre will have a RMP that is depolarized because of excess potassium ion buildup outside the cell with repeated muscle stimulation.
   b. The exercised fibre will have a RMP that is depolarized because of excess lactic acid buildup inside the cell.
   c. The exercised fibre will have no change in RMP because the excess potassium ion buildup outside the cell is counterbalanced by excess sodium ion buildup inside the cell

5. Compared to a skeletal myocyte, which of the following statements best explains why a cardiomyocyte has more mitochondria (as measured by percentage of muscle fiber volume)?
   a. Cardiac muscle is like a high-end computer that needs a larger hard drive to store more data.
   b. Cardiac muscle is like a laptop with extra batteries supplying more kWh to keep it running for longer periods.
   c. Cardiac muscle is like a computer program that requires a central processing unit that has more cores to multitask and run efficiently.

6. The role and function of the "pacemaker current" (i.e., the ion currents that dominate between the minimum diastolic potential and threshold) in controlling the periodic actions of the heart can best be thought of as:
   a. An adaptive traffic light which signals when cars should stop and go but has green-light timings which can be adjusted to respond to changes in the wider traffic system or emergency vehicles that need priority.
   b. A pedestrian countdown signal which is programmed (at a constant value based on the width of an intersection) to indicate when the movement of pedestrians can occur.
   c. A line of jaywalking ducks who cross the street whenever they like and cause regular traffic to stop and wait, until the line of cute little ducks has passed, before continuing.

7. If the end-diastolic volume were held constant, what could accomplish increased stroke volume?
   a. Increased sympathetic nerve activity to the heart.
   b. Increased parasympathetic nerve activity to the heart.
   c. Decreased contractility.

8. What happens when epinephrine binds to beta-2 receptors in smooth muscle?
   a. Vasoconstriction of arterioles in all vascular beds.
   b. Vasodilation of arterioles that supply blood to skeletal muscles.
   c. Vasoconstriction of arterioles that supply blood to skeletal muscles.

9. Why can systemic veins be called capacitance vessels?
   a. They can stretch and hold onto blood for a longer period of time when the need for blood in tissues is low.
   b. They can relax in response to activity of the sympathetic nervous system.
   c. They have the ability to return blood to the heart at a fast rate.

10. Massage therapists have to follow safety protocols when they give neck massages because pressing down on and stretching the tissue around your carotid sinus can artificially stimulate the baroreceptors located in that area. This might be especially dangerous if a client has a condition called Carotid Sinus Hypersensitivity. What is likely happening to a client, who has this condition and losses consciousness, in response to a neck massage?
    a. Increased heart rate and increased cardiac output
    b. Decreased heart rate and decreased arteriolar radius.
    c. Decreased heart rate and decreased cardiac output

11. Which of the following analogies best describes lung ventilation?
    a. The lungs are like the ebb and flow of ocean tides, taking in and releasing air.
    b. The lungs are like a sponge that absorbs oxygen and releases carbon dioxide.
    c. The lungs are like a forest that takes in carbon dioxide and produces oxygen.

12. Which of these variables is responsible for producing the changes in alveolar pressure necessary for inspiration?
    a. Transpulmonary pressure b. Pleural pressure c. Lung recoil pressure

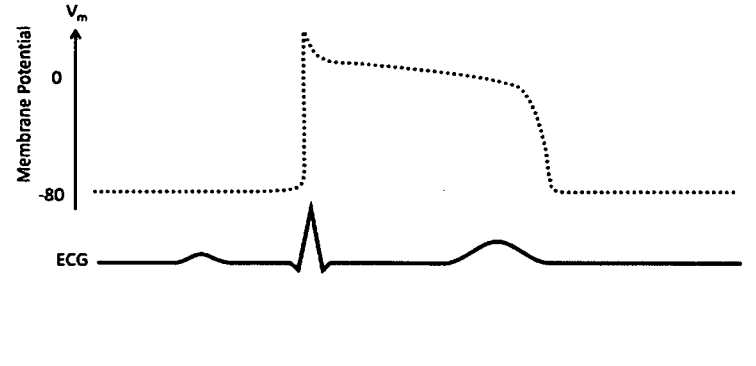
13. Which of these statements describes vital capacity?
    a. The maximum volume that can be moved in or out during a single breath.
    b. The volume normally entering or leaving the lungs during a single breath.
    c. The maximum volume the lungs can hold.

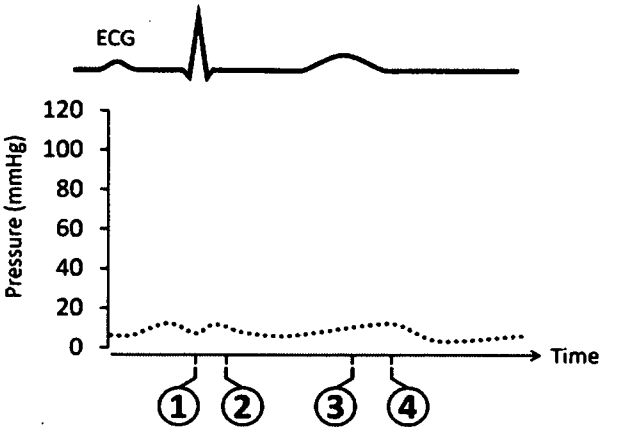
14. Consideration of the anatomic dead space volume is important, when considering alveolar ventilation, because ____
    a. it reduces the surface area of the alveoli and therefore, reduces gas exchange.
    b. it represents the volume of air that does not reach the alveoli and cannot participate in gas exchange.
    c. it reduces the O_2 content of inspired air, which affects alveolar gas exchange.

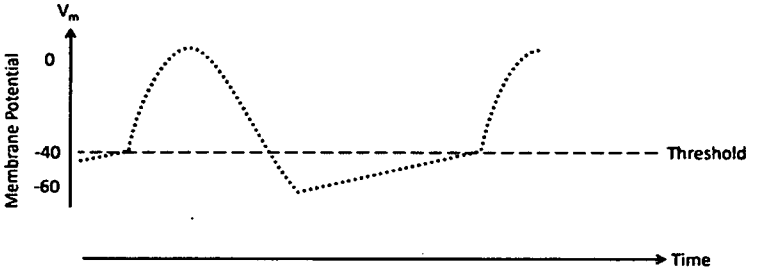
15. What is the primary signal and sensory receptor that allows the regulation of lung ventilation in normal (i.e., breathing at rest) circumstances?
    a. The P_{O2} of the arterial blood, which is monitored by peripheral chemoreceptors.
    b. The P_{CO2} of the arterial blood, which is directly monitored by central chemoreceptors.
    c. The H^+ concentration of the brain extracellular fluid, which is directly monitored by central chemoreceptors.

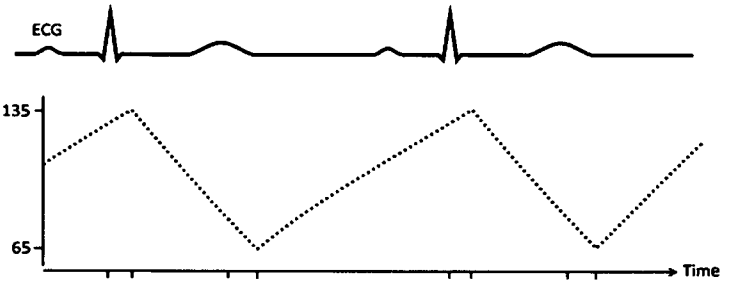
---- Use this page for draft answers only. ---

---- Anything on this page will not be considered for grades. ----









Name: _____ **Student ID Number:** _____

Instructions:

Please completely fill in the rectangle associated with your response. Example: ■ ☐B ☐C ☐D ☐E

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