BIO 3303 Animal Physiology I Student #:_____
Midterm #1 A Name:_____

Dr. E.M. Standen

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70min

TOPICS: Biomechanics, Muscle Function and Energetics

Cellular phones, unauthorized electronic devices or course notes (unless an open-book exam) are not allowed during this exam. Phones and devices must be turned off and put away in your bag. Do not keep them in your possession, such as in your pockets. If caught with such a device or document, the following may occur: academic fraud allegations will be filed which may result in you obtaining a 0 (zero) for the exam.

By signing below, you acknowledge that you have ensured that you are complying with the above statement.

Signature:_____

Answer on the question sheet in the space provided. This exam is out of 55 marks.

Read through the exam fully before starting as short answer and multiple choice questions are throughout.

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1. (2 points) What is the difference between acclimatization and acclimation?

Acclimatization: the process of physiological change in response to *naturally* changing environmental conditions **(1 mark)**
Acclimation: process of physiological change in response to a controlled or manipulated environmental variable (i.e. under *laboratory* conditions). **(1 mark)**

2. (4 marks) Explain the difference between plasticity and adaptation. Name an example of each.

Plasticity: a change in physiology/phenotype that may or may not be reversible, but that occurs *within one generation*. **(1 mark)** e.g. Water fleas, polypterus, interlamellar cell mass, muscle fiber type switching following exercise etc. **(1 mark)**
Adaptation: a change in the genetic structure of a population as a result of natural selection **(1 mark)**. e.g. literally any example of adaptation! **(1 mark)**

3. (2 marks) Give one explanation for why existing animals are not perfectly 'designed' for their environments.

Any ONE of the following for two marks depending on completeness of the answer **(2 marks)**:
- The Red Queen Hypothesis: a system must continue to evolve in order to maintain its fitness relative to the other system(s) it is co-evolving with.
- Natural limitations of biomaterials: animals cannot (for example) incorporate steel into their bones, nor can they have wheels in place of legs/fins/wings etc. simply due to the inability of an organism to make such substances/structures; also, wheels are not as good at moving across complex terrain as limbs are
- Local adaptive peaks: in a complex fitness landscape there is more than one fitness peak; an organism that has adapted to the top of one peak cannot move back down from said peak to reach another local peak; some peaks are higher than others (and so individuals do not reach their "ideal" fitness) and there are also trade-offs between adapting for one particular trait at the cost of another.
- Descent with modification/constraints: every organism we see today is a result of selective forces acting on its ancestor, since evolution "tinkers" rather than "reinventing the wheel". So, extant organisms must adapt to new environments only by modifying their form and so may possess remnants of forms that were optimal for other environments/selective pressures.

4. (2 marks) What is the functional difference between a muscle acting as a break and acting as a motor (think muscle activation timing)?

A muscle acting as a *break is active during lengthening* **(1 mark)** while a muscle acting as a *motor is active during shortening* **(1 mark)**.

5. (1 mark) You have 10 sarcomeres to build a muscle and you want it to be as strong as possible. If you put them in _____**parallel** **(1 mark)**_____you will achieve your goal.

6. (2 marks) Name one advantage of a pennate muscle over a strap muscle. What is the major disadvantage?

Pennate muscles allow for greater force production as more sarcomeres are placed in parallel rather than in series (as they would be in a strap muscle) **(1 mark)**. The main disadvantage is that pennate muscles will not as effectively create a fast contraction of the whole muscle as a strap muscle would because their angle of shortening is not perfectly in line with their angle of action **(1 mark)**.

7. (1 mark) Why do vertebrates have antagonistic muscle groups? One sentence.

Muscles only contract **(1 mark)**.

8. (1 mark) Some invertebrates do NOT have antagonistic muscles. What do they do instead?

In place of antagonistic muscles, some invertebrates have elastic structures (resilin) that are compressed while the muscle contracts and therefore allow for passive extension of the joint **(1 mark)**.
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9. (1 mark) What would happen to the cycling of myosin and actin if the troponin/tropomyosin complex was removed?

Myosin and actin can constantly cycle until the cell runs out of ATP at which point it would go into rigor **(1 mark)**. Students may also say that the muscle could not relax. That is a good response as well. (other answer, it would not be regulated)

10. (3 marks) What characteristics allow sonic muscles to contract so quickly? Why is the force production lower than regular muscles of this type?

Sonic muscles are able to contract so quickly due to:
- Fast Ca^{2+} cycling/dynamics (i.e. more sarcoplasmic reticulum calcium pumps)
- Lower affinity troponin allows faster off-rate for calcium
- Molecular modification of myosin to allow cross-bridges to detach more rapidly
- Fewer sarcomeres to give room for huge Ca+ stores

Force production is lower in these muscles due to:
- The trade-off between sarcoplasmic reticulum volume and myofilament volume

- Less cross-bridges formed per unit time due to a high detachment rate

11. (5 marks) How does the arrangement of muscles in the housefly allow for asynchronous muscles to power flight? How does this arrangement differ in insects that fly using synchronous muscles?

Asynchronus muscles:
- Vertical muscles attach to the roof of the thorax; contraction raises the wings, *stretches* longitudinal muscles and deforms the elastic exoskeleton
- Longitudinal muscles pull on the anterior-posterior axis of the thorax; contraction lowers the wings and *stretches* the vertical muscles.
- In both of these muscles, sensitivity to calcium decreases after contraction, thereby turning off the muscle; because of the arrangement of the muscles when one contracts it stretches the other. Stretched muscles are sensitive to Ca once again and so contract. This alternate contracting/stretching cycle allows multiple cycles to occur with a single AP. So AP and muscle contraction cycle are not linked.

Synchronus muscles have the traditional pair of antagonist muscles (attached directly to wing to lift and lower the wing) and are not stretch sensitized. These muscles require a 1 to 1 ratio with contraction and AP.

12. (2 marks) Why is there a delay between an action potential and muscle force production?

The delay between an action potential occurs due to:
- The time for calcium release to occur **(1 mark)**
- Elastic elements in the muscle must be stretched before force output actually begins **(1 mark)**

13. (3 marks) What is the difference between a concentric, eccentric and isometric contraction?

Concentric: muscle active during the shortening portion of a movement **(1 mark)**
Eccentric: muscle active during the lengthening portion of a movement **(1 mark)**
Isometric: muscle contraction does not result in any length change **(1 mark)**

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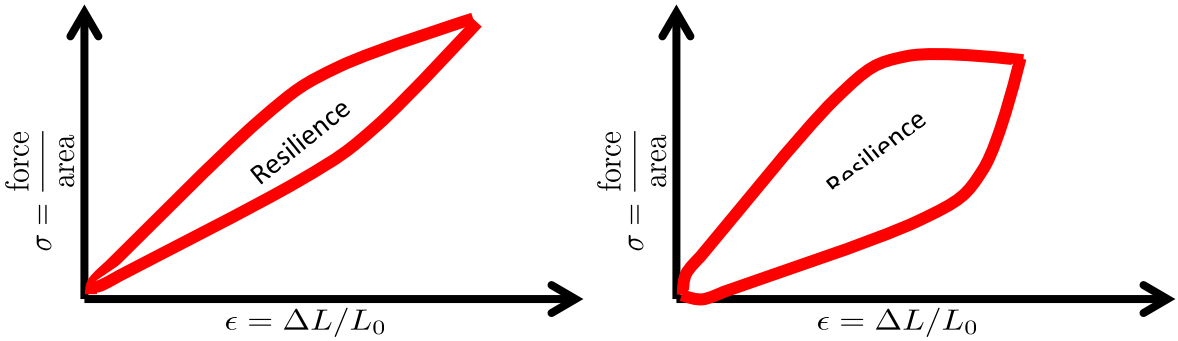
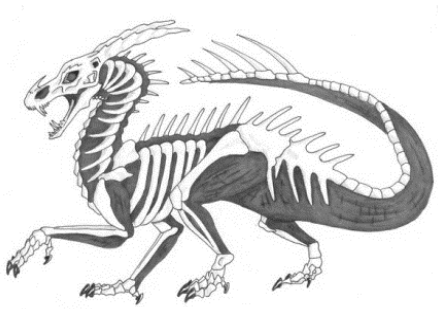
14. (3 marks) Use the stress-strain curves below to compare the loading and unloading of (a) a kangaroo gastrocnemius muscle-tendon unit and (b) a human gastrocnemius muscle-tendon unit, during jumping. Which animal would you expect has the higher resilience?

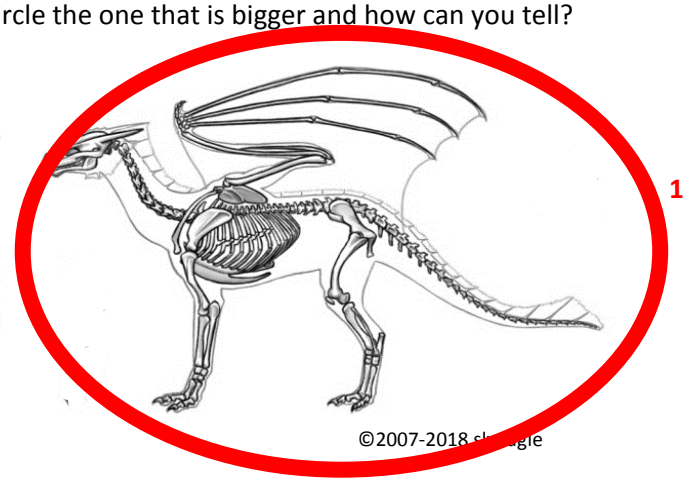
1 mark **1 mark**



Essentially, the kangaroo muscle-tendon unit should have *higher* resilience, therefore the difference between the loading and unloading portions of the stress strain curve will be smaller than that for the human muscle-tendon unit **(1 mark)**. The kangaroo is more efficient and gets more energy returned to the system when the tendon muscle unit relaxes.

15. (2 marks) These pictures have completely different scales associated with them (i.e. the dragons are not the same size in 'real' life). Circle the one that is bigger and how can you tell?





1 mark

This dragon is likely larger due to it's upright posture. This posture reduces the load on the muscles of the dragon, thereby permitting a larger body size **(1 mark)**.

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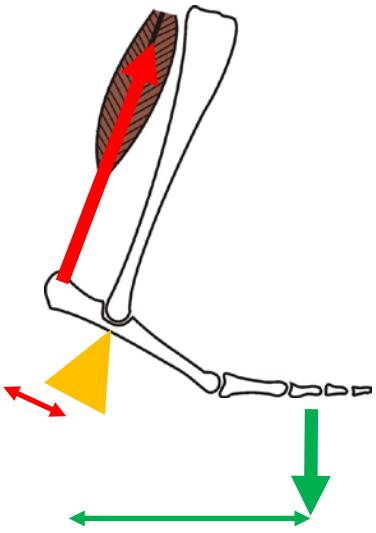
16. (1 mark) Other than muscle fibers where else can you find actin and myosin?

Any ONE of the following (or anything else that actin and myosin do) works **(1 mark each)**:
- Vesicle transport (microfilaments carry hormones from sites of synthesis to sites of release)
- Microvilli (actin supports the villi in the intestinal epithelium)
- Ameboid movement (blood cells invade damaged tissue using ameboid movement)

17. (3 marks) Name three differences between myocytes and cardiomyocytes.

Any THREE of the following **(1 mark each)**:
- Cardiac muscle is made of single cells, while striated muscle is made of multiple fused cells.
- Cardiac muscle excitation is myogenic and involuntary; striated muscle excitation is neurogenic and voluntary (usually)
- The action potential of cardiac muscle has a slow repolarization and thus a long refractory period; striated muscle has a fast repolarization and short refractory period.
- Cardiac muscle excitation-contraction coupling is Ca^{2+} induced Ca^{2+} release, while striated muscle is depolarization induced Ca^{2+} release.
- The sarcoplasmic reticulum of cardiac muscle has less well developed terminal cisternae than those of (fast) skeletal muscle.
- There may be others so if you are in doubt ask me about it

18. a) (2.5 marks) Draw on this diagram of a lower leg, the force vector produced by the muscle, the ground reaction force (force pushing into the ground), the fulcrum and the input and output lever arms.



Thick red arrow = muscle force vector
Thick green arrow = ground reaction force
Thin red double headed arrow = input lever arm
Thin green double headed arrow = output lever arm
Yellow triangle = fulcrum

b) (2.5 marks) If the attachment of the leg bone with the foot gets closer to the toes, what happens to the gear ratio? (Include the gear ratio equation.) How does this change the function of the system?

Gear ratio = output lever arm/input lever arm **(0.5 marks)**, therefore moving the leg bone closer to the toes makes the gear ratio *smaller* **(1 mark)**. This would increase the potential force output of the system, but would lower the output speed **(1 mark)**.

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19. (3 marks) Compare and contrast the shape of the action potentials in skeletal and cardiac muscle. Why is the shape of the action potential important for the function of these muscles?

The action potential of cardiac muscle has a slow repolarization and thus a long refractory period; striated muscle has a fast repolarization and short refractory period **(1 mark)**. This means that cardiac muscles cannot reach tetanus **(1 mark)** (i.e. the rate of contraction is constrained by the long refractory period) which is a good thing because it keeps your heart beating; when action potentials in cardiac muscle are too close together, arrhythmia occurs **(1 mark)**. The shorter refractory period in skeletal muscle allows for tetanus and therefore temporal summation, leading to increased force output from the muscles.

20. (5 marks) Two types of muscle fatigue are listed below (Type 1 and Type 2)? Note their timelines and physiological causes in the table below.

	Type 1	Type 2
Duration	Short	Long
Intensity	High	Low
Onset and recovery	Rapid Onset and Recovery	Slow onset and recovery
Cellular Cause 1	Elevated [H^+] and [Pi]	Depletion of muscle glycogen
Cellular Cause 2	Decreased Ca^{2+} release from SR	Changes in muscle protein activity

Note: The "type" of fatigue is not important (i.e. the columns could be flipped here to have the characteristics of short duration, high intensity fatigue in the "Type 2" column) and the order of the causes doesn't matter. **(0.5 marks) per blank**.

21. (1 mark) What is specific dynamic action?

The energetic costs of food processing **(1 mark)**.

22. (3 marks) Why are the two figures below both correct? What is one explanation for the fact that larger animals operate more efficiently?

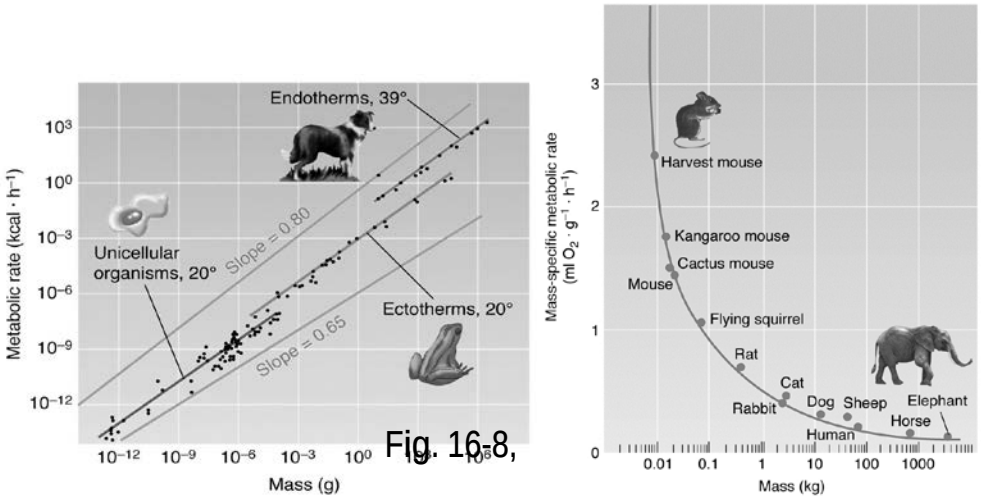

Fig. 16-8,

These two figures are correct as the left figure is metabolic rate (NOT mass specific) while the right figure is mass-specific metabolic rate **(1 mark)**. Total metabolic rate increases with body mass, while mass specific metabolic rate decreases with body mass **(1 mark)**.
Any of the following explanations for large animals operating more efficiently is acceptable **(1 mark)**:

- Drag: smaller animals have a larger surface area to volume ratio and therefore experience more drag and less muscle power, so they are more costly to run
- Speed of shortening: smaller animals have faster rates of contraction and must take more steps/distance and so are more costly to run.