General Instructions: READ THIS PAGE BEFORE YOU BEGIN THE EXAM.

1. Write your name and PID on all 6 pages. (5 points off for EACH unnamed page.)

2. For your own benefit, write your answers LEGIBLY in the space allotted. If we cannot read your handwriting, we cannot give you credit for your answer.

3. Do not write on the BACK of any page unless you get a TA’s permission FIRST.

4. About writing answers:
   • All questions can be answered briefly.
   • Answer the question that is asked specifically, precisely, and accurately.
   • For full credit, show your calculations when requested.
   • Problems that ask for an answer and for a reason, more credit will be given for a correct reason.
   • If you are asked for one reason, be sure you write down only the best one.

5. About grading:
   • We give credit for correct and relevant answers. We ignore true, but irrelevant statements.
   • We deduct points for statements that are both incorrect and irrelevant. (We don’t just ignore irrelevant answers because we need to let you know that you have some wrong ideas.)

6. Use a pen or pencil to write your answers, but do not use red ink or red pencil, and do not use white-out of any kind. If you want to have your exam regraded, you must use pen.

POTENTIALLY USEFUL EQUATIONS:

\[ \pi = \sigma RT(C_0-C_i) \]

\[ F = A\eta \frac{\Delta V}{\Delta X} \]

\[ R = \frac{8 \eta l}{\pi r^4} \]

\[ Q = \frac{(P_2-P_1) \pi r^4}{8 \eta l} \]

\[ V = IR \]

\[ P = QR \]

\[ J = -PS(C_{out}-C_{in}) \]

\[ R_{Total} = \sum R_i \]

\[ \Delta = \pi r^2 \]

\[ J = k[(P_{cap}+\pi_{int})-(P_{int}+\pi_{cap})] \]

\[ E_X = \frac{RT}{ZF} \frac{[X^+]_{out}}{[X^+]_{in}} \]

\[ \frac{1}{R_{Total}} = \sum \frac{1}{R_i} \]

\[ v = \frac{Q}{A} \]

TOTAL _________

WAIVER: By signing this waiver I give permission that this exam can be left for me to pick up in the hall outside the elevators on the third floor of Pacific Hall. I realize that this procedure may expose my grade to public scrutiny and my exam to theft. If I do not sign this waiver, I understand I will be able to get my graded exam back only as described on the course Web site.
1. **(18 points total)** The concentration of Ca\(^{++}\) in our plasma is regulated primarily by two hormones: calcitonin, a peptide produced by C-cells in the thyroid gland, and parathyroid hormone (PTH), a peptide produced by the parathyroid glands. PTH increases plasma Ca\(^{++}\) levels by causing the release of Ca\(^{++}\) from bones, and calcitonin decreases plasma Ca\(^{++}\) levels by causing Ca\(^{++}\) to be deposited in bones. Low plasma Ca\(^{++}\) acts on parathyroid cells to cause the release of PTH, whereas high plasma Ca\(^{++}\) acts on C-cells to release calcitonin. The boxes below show the organs.

**A. (6 points)** Draw the missing arrows (and boxes, if needed) to show how plasma Ca\(^{++}\) is regulated, labeling the arrows appropriately and adding + or – signs to show the effects of the signals.

**B. (4 points)** How many feedback loops are in this system? Briefly explain whether each loop is positive or negative feedback.

**C. (4 points)** Osteoporosis is a disease in which the amount of Ca\(^{++}\) in bones is diminished. Which of the two hormones, PTH or calcitonin, would be a good treatment for osteoporosis? Briefly explain.

**D. (4 points)** If you receive an injection of PTH, would you expect to see an increase in plasma Ca\(^{++}\) levels within seconds, minutes, or hours? Briefly explain your answer.

2. **(6 points total)** The uterus normally consists of multi-unit smooth muscles, but in the final stages of pregnancy, the uterine muscles become unitary.

**A. (3 points)** What is the major difference between multi-unit and unitary smooth muscle?

**B. (3 points)** Explain the functional significance of this switch-over from multi-unit to unitary smooth muscle in the uterus.
3. (9 points total). A maverick drug company, Bioloonix, Inc., decided to develop a line of drugs that would increase the strength of skeletal muscles that they could sell to weight-lifters. They discovered three drugs that affected different molecules in these muscles. These drugs are listed below, along with their molecular effects. Tell whether each drug would increase the strength of muscle contractions, and briefly explain your answer.

A. (3 points) Bulkup (a total blocker of DHP activity)

B. (3 points) Califtin (a partial blocker of the Ca^{++}-ATPase of the sarcosmal reticulum)

C. (3 points) Pressix (a partial activator of RyR, making it leaky at rest)

4. (10 points total) There is a class of heart diseases that are caused by genetic malformation of the voltage-gated K^+ channels in the contractile muscle fibers. These channels open abnormally slowly.

A. (4 points) Using words or diagrams, indicate what effect would these mutations have on the action potentials in these cardiac fibers.

B. (4 points) Using words or diagrams, indicate what effect would these mutations have on the ECG.

C. (2 points) These diseases can cause ventricular fibrillation in “flight, fight, or fright” responses. Propose a mechanism for how these mutations might lead to fibrillation during such responses.
5. **(10 points)** Dexter, a friend of yours, moved to Denver (the “Mile-high city”). You saw Dexter six months later and he told you about his cardiovascular problems from living at the high altitude. His blood pressure has increased, and his hematocrit has increased so much that the viscosity of his blood has doubled. He has decided to take a drug that causes vasodilation, to lower his blood pressure. He remembered that viscosity and blood vessel diameter have opposite effects on blood pressure, so he has decided to take enough of this drug to double the diameters of his blood vessels. Use the appropriate equation to explain whether Dexter’s plan is a good one.

6. **(8 points)** Each skeletal muscle generates maximal force when it starts its contraction at its rest length, but the maximal force generated by a cardiac muscle is at a longer length (about 1.4X of the rest length). Explain the functional significance of these two observations.

A. **(4 points)** Skeletal muscle (maximal force at rest length):

B. **(4 points)** Cardiac muscle (maximal force at 1.4X rest length):
7. (10 points) People with right heart failure have (1) high blood pressure, as measured in the upper arm, and (2) edema, especially in their legs.
   A. (4 points) Why do such people have high blood pressure?

   B. (4 points) Using the Starling Equation, explain why they have edema.

   C. (2 points) Why is the edema worse in their legs than in their arms?

8. (12 points total) You decide to do some Pilates exercises. Before you start, you sit down quietly and measure your heart rate (HR) and blood pressure (BP) in your upper arm, at heart level. Both are normal (BP = 120/70, PR = 70).
   A. (4 points) You lie on your back on your Pilates mat. Do you expect there to be any changes in BP and HR compared to when you were sitting up? Briefly explain your answer.

   B. (4 points) Your decide to start your session with leg exercises, so you raise your legs to a vertical position, straight up. Would this change your BP and HR? Briefly explain your answer.

   C. (4 points) You start to pump your legs as though you are riding a bicycle. After 60 seconds of this exercise, do you expect additional changes in BP and HR? Briefly explain your answer.
9. (5 points) Digitalis is an extract from the foxglove plant that inhibits the Na\(^{+}\)-K\(^{+}\) ATPase. In low doses, it is an effective medication for people with weak hearts because of its inotropic effect. Explain how blocking the Na\(^{+}\)-K\(^{+}\) ATPase in cardiac muscles can have an inotropic effect.

10. (12 points total) For the following three groups of statements, circle every letter that makes a TRUE statement. Note that any number of statements may be true (including none of them), and that not circling a letter indicates that you think that the statement is false. You will receive one point for each correct answer that is circled and each incorrect answer that is not circled. [Note: If any part of the statement is incorrect, the statement is false.]

   A. Bones and muscles around joints act as levers and fulcrums:
      a. in most joints, the fulcrum is at one end of the lever, the load is at the other end of the lever, and the muscle is attached between the fulcrum and the load.
      b. the closer the muscle attaches to the fulcrum, the faster the speed of the movement and the less work required of the muscle.
      c. genetic variability in the attachment site of the muscle along the bone affects the force required to move a load.
      d. over a large range, the speed of muscle contraction is independent of the load on the muscle.
         (pp. 428-31 in Silverthorn, 5\(^{th}\) edition)

   B. The contraction of vascular smooth muscle can result from many local factors:
      a. increases in blood pressure stretches vascular smooth muscle cells, which open mechanically-gated Ca\(^{++}\) channels that causes the smooth muscles to contract.
      b. paracrine (including the gases O\(_{2}\), CO\(_{2}\), and NO) produced by the vascular epithelial cells, can cause vasoconstriction and vasodilation.
      c. an increase in tissue blood flow following a period of low blood perfusion to an area is known as active hyperemia.
      d. serotonin, released from platelets from damaged blood vessels causes a strong vasoconstriction that helps slow blood loss.
         (pp. 523-4, in Silverthorn, 5\(^{th}\) edition)

   C. Steroid hormones:
      a. are stored in vesicles and released by peptide releasing factors.
      b. are not very soluble in plasma and other body fluids, so they are often bound to protein carrier molecules in the blood.
      c. diffuse across the lipid bilayer of target cells by mass action.
      d. such as estrogens, in addition to their effects on genes, also have membrane receptors that trigger effects on signal transmission pathways that are similar to peptide hormones.
         (pp. 222-5, in Silverthorn, 5\(^{th}\) edition)