Lab T-1
What Can Physics Tell Us About Physiology?

Name:________________________

Section #:________________________

Introduction

Physics aims at discovering the most general underlying order behind natural phenomena at the most fundamental level. The discovered laws of physics can be used to understand a wide range of natural phenomena from planetary motion to optical diffraction.

In order to understand and appreciate the connection of physics and the real world of birds, lions, and flowers, we need to *understand* the specific ways in which certain physics principles apply to some biological facts through *concrete examples.*

In order to study the connection between physics and biology most directly, in this lab, we will engage in ‘model building activity’ of various natural phenomena. We will develop several ‘models’ to explain various natural facts in biology, mostly interesting physiological facts about various organisms. But, we first need to clarify what we mean by ‘models’ and ‘model building activity’.

At the end of the lab, **you will be asked to reflect on your evolving understanding of how physics is relevant to biology**. Final question at the end of the lab are:

1. Compared to before you started the lab, what changed in the way you see the connection between physics and the real world?
2. To what extent do you think physics is useful in understanding the natural world?

Keep these questions in mind as you work through the lab.

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Guidelines for Model Building

- A ‘model’ represents a natural phenomenon in terms of simpler, easy-to-understand terms (often employing pictures).
- The simplification involved in ‘modeling’ is primarily guided by the question one is trying to answer. So, simplification is a decision that must be made by the questioner.
- ‘Models’ are hypothetical; they do not represent nature as it “really is”. This means that in model building some simplifications and assumptions are necessary. These are the limitations of your model.
- ‘Model-building’ does not have rules to use that always work when building a model. It is almost an art – building good models relies on experience, creative thinking and insight.

Build a model in your group: “Tightrope Clown”

Build a model (including a diagram, explanation, and discussion of the simplifications you made) of the “tightrope clown” demonstration you saw. Your model should address why the tightrope clown stays balanced with the poles, but does not balance without the poles.

Write your model so that someone not in your group could read it and understand what is going on. After you have developed your group’s model, copy it to the large sheet of paper at your table and put it on the wall for others to see.

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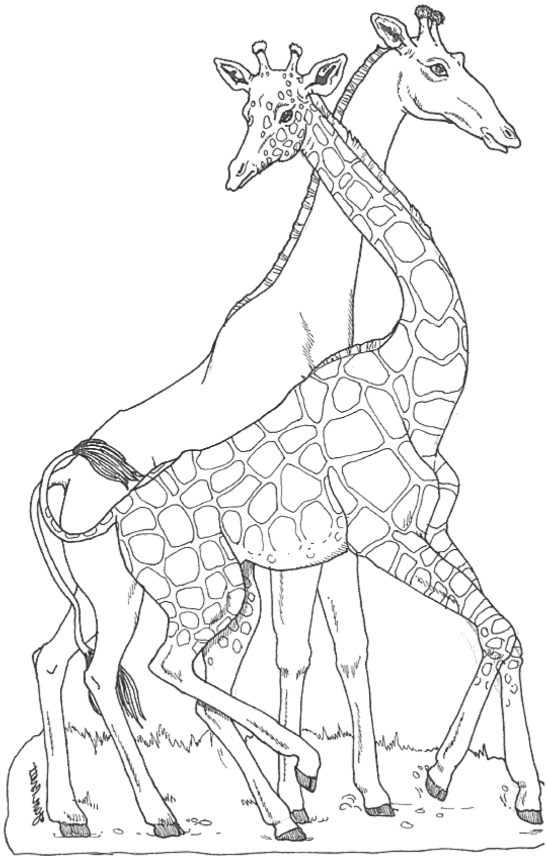
Fact: The skin of giraffes is tighter in their legs than the upper part of their body.



a) On a notecard, *on your own* come up with a possible explanation of this rather strange biological fact based on some physics principles. Try to make the connection between the physics and your explanation as explicit as possible. Write it so that someone other than you can read it!

Figure 1: Giraffes' skins are tighter in their legs

b) Your TA will collect the notecards and redistribute them throughout the class randomly. In your group, use at least one of the notecards you're given (or an idea of your own, if you can't do anything with the cards you have) to create a model explaining the fact above. A good model should have a diagram, explanation of the diagram and how it helps explain the fact, and a discussion of your assumptions and possible limitations.

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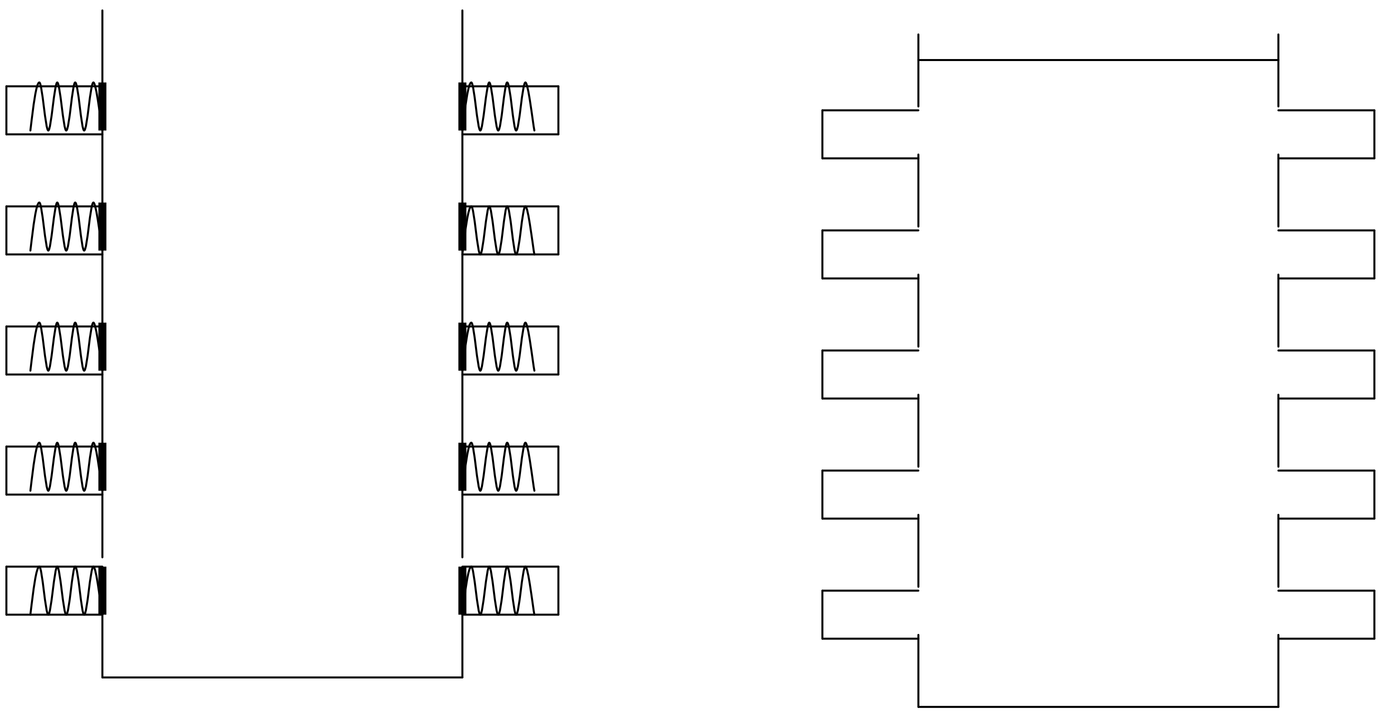
Thought Experiment

A very tall glass tower has holes in the sides, and the holes are covered by spring-loaded plungers inside an enclosed tube (all of the springs have the same spring constant), as in the picture at the left. Water is then poured into the glass, as in the picture on the right.



Q1: Draw the position of the springs as they are pushed by the water in the picture on the right. Are there any variations with depth?

Q2: What are the relevant physics principles involved in your picture?

Q3: Use the physics principles from Q2 to explain the positions of the springs you drew above.

Q4: What would **you** feel if you jumped in and swam to the bottom?

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Activity: Observe the shape of the water filled glove when you hold it in the air from the bottom of the glove.

Question:

a) ***Draw a picture*** of the glove and describe its **shape** when you hold the it up in the air.

b) What physics principle(s) might be relevant in explaining the **shape** of the glove?

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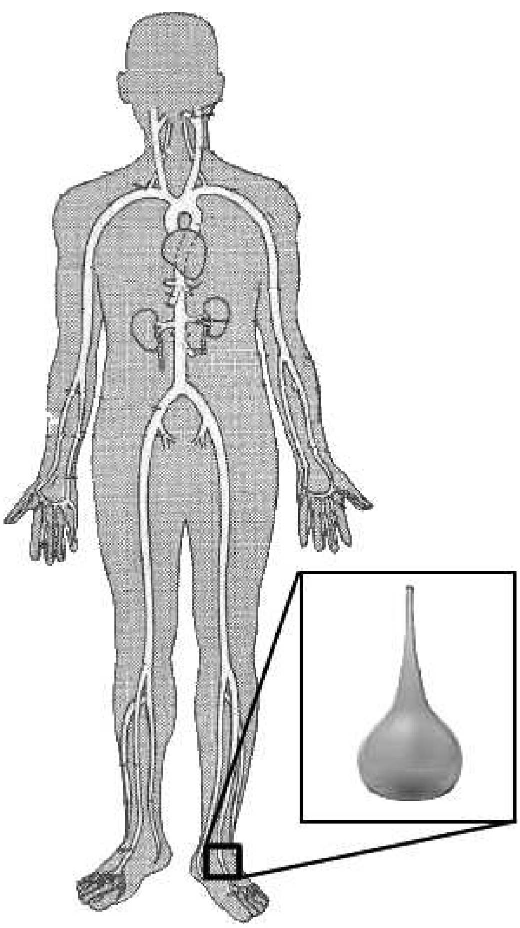
c) Based on the relevant physics principles that you identified, develop a model that explains the **shape**? In other words, explain why the glove is **shaped** this particular way. A good model should have a diagram, explanation of the diagram and how it helps explain the fact, and a discussion of your assumptions and possible limitations.

d) ***Connection to the real world***: In the diagram below, the latex glove you investigated above is identified with a piece of a vein in the leg of a human (the water in the glove is interpreted as blood in the veins).



If the vein really did balloon out and collect water as you saw above, what could go wrong for the human? (Hint: What are some symptoms the human would experience?)

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e) What can be done to fix this problem from happening?

f) Using the ideas explored in c), d) and e) above, build a model to explain the skin on a giraffe's lower leg is tighter than other parts of it's body. A good model should have a diagram, explanation of the diagram and how it helps explain the fact, and a discussion of your assumptions and possible limitations.

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Testing the model – Measuring human blood pressure

a) Do you expect blood pressure measured on your arm to be different than on your leg? Write your prediction and reasoning below. *By the way, nurses* ***almost always*** *measure blood pressure on your arm…*

b) Using the blood pressure cuff at your table, measure the blood pressure of one of your group members ***on the arm and on the leg*** (see inset on how to operate cuff machine). Compare this to your qualitative prediction. Were you right?

Using the Automatic Blood Pressure Cuff Machine

To measure your blood pressure, all you need to do is to wrap the cuff around your arm (or calve), and push the button labeled "Start". The machine will pump the pressure automatically to about 160~180mmHg (a pressure at which, one may feel a little uncomfortable, but don't worry; it won't sever your arm!) and then the pressure will start to drop slowly with a clicking sound. After it is done, it will give you a systolic and a diastolic pressure. All you have to do is wait. If it says "ERR" there was an error and you need to redo the measurement.

Blood pressure is typically written as (systolic)/(diastolic), e.g. 120/80, a typical value for healthy adults (see the next page for an explanation of what systolic and diastolic pressures are).

Arm:

Leg:

c) Based on your measurement, identify the fact that you observed (e.g. how does blood pressure in the legs compare to the arms?)

Fact:

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Systolic vs Diastolic Pressure

Blood pressure cuffs measure the pressure in your arteries (not your veins) by squeezing your arm. There are two numbers that are given when your blood pressure is taken: **Systolic** and **Diastolic** (e.g. your blood pressure given as 120/80 is 120 mmHg Systolic and 80 mmHg Diastolic). (The pressures given are relative to atmospheric pressure).

<u>Systolic</u>: Your blood is pumped throughout your body in "squirts". The systolic pressure is the pressure of the "squirt" of blood. The blood pressure cuff measures this by squeezing your artery so hard that it blood flow stops, then slowly releasing the pressure. When the external pressure is small enough that the "squirt" of blood from the heart is able to push through and un-pinch the artery, this is called the "Systolic" blood pressure.

<u>Diastolic</u>: The blood pressure cuff continues to loosen until your artery is no longer pinched off and snaps back open. The amount of squeezing at which this happens is your Diastolic blood pressure.

d) Develop a quantitative model of this fact. <u>A good **quantitative** model should have a diagram, explanation of the diagram and how it helps explain the fact, and a discussion of your assumptions and possible limitations **and should make quantitative numerical predictions**</u>. It may help to use some of the physics ideas discussed earlier in the lab in building your model.

e) Measurement Plan:
In the next step you will make measurements to test your model. **BEFORE MAKING YOUR MEASUREMENTS** write here: what measurements do you need to make in order to best test your model? [Note: There is more than one way to test this model, and you may want to consider the merits of your approach.]

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f) Measurement:
Now you will make quantitative measurements to support your model. Below is a table that contains the minimal amount of data that needs to be taken to test the model.

In order to verify your model you must make many measurements of the difference in pressure between your arms and your legs (right and left), standing and lying down, and compare them to the quantitative predictions that your model makes.

Be sure to make many measurements and take into account errors!

Some useful conversion factors:

$1\text{atm} = 1.013 \times 10^5 \text{ Pa} = 760\text{mmHg}$

$\rho_{air} = 1.29 \text{ kg/m}^3$

$\rho_{blood} = 1050\text{-}60 \text{ kg/m}^3$

$\rho_{water} = 1000 \text{ kg/m}^3$

Δ p = (Leg Pressure - Arm Pressure)

Person	Trial # standing /lying Right/Left	Arm Pressure (mmHg)	Leg Pressure (mmHg)	Height Difference	ΔP Measured (mmHg) (+/- error)	ΔP Predicted (mmHg)
SAMPLE	Standing/Right	132/80	207/110	.9 m	75/30 +/- 2	69

Using your model, calculate a predicted difference in pressure between arm and leg (ΔP Predicted) and convert it to mmHg.

g) Compare the adequacy and limitations of the model by comparing your measured difference in pressure to the difference in pressure predicted by your model. Are the differences completely explained by error?

h) What are the limitations of the model? How could you modify the model to address these limitations?

i) Do you think your model of how human blood pressure varies with depth is relevant for giraffes? Estimate the change in blood pressure ΔP between a giraffe's heart and it's lower leg (in mmHg).

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Final Model

Fact: The skin of giraffes is tighter in their legs than the upper part of their body.

Write below the final model you have developed throughout the lab to explain this fact. Remember to include:

- a picture
- a written description of how the picture helps explain the fact
- identify the relevant physics principles
- assumptions you have made,
- and include any evidence you have collected that lead you to think your model is correct.

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Post-Lesson Questionnaire

As mentioned in the beginning of the lab, your final task is to reflect on your evolving understanding of the relevance of physics to biology. Please answer the following questions based on what your learning about the relevance in this lab.

"Compared to before you started the lab, what changed in the way you see the connection between physics and the real world?"

"To what extent do you think physics is useful in understanding the natural world?"

In order to improve this lab, we would like your feedback. Do you have any comments about the lab?

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How confident are you that you achieved these *immediate* learning goals below? (Circle one)

In general…

"You understand how the principle of pressure is relevant to understanding various physiological facts about different organisms, particularly blood circulation in the absence and presence of gravity"

Very Confident   Confident   Neutral   Unconfident   Very Unconfident

More specifically…

"You are able to provide real examples of the relevance of the pressure to understanding various physiological facts about different organisms."

Very Confident   Confident   Neutral   Unconfident   Very Unconfident

"You are able to provide quantitative analysis of these examples of how pressure is relevant to biology.

Very Confident   Confident   Neutral   Unconfident   Very Unconfident

"You are able to discuss limitations of the models involving the principle of pressure that you developed."

Very Confident   Confident   Neutral   Unconfident   Very Unconfident

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