Revealing and addressing student misconceptions

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Misconceptions

How do we detect student misconceptions?

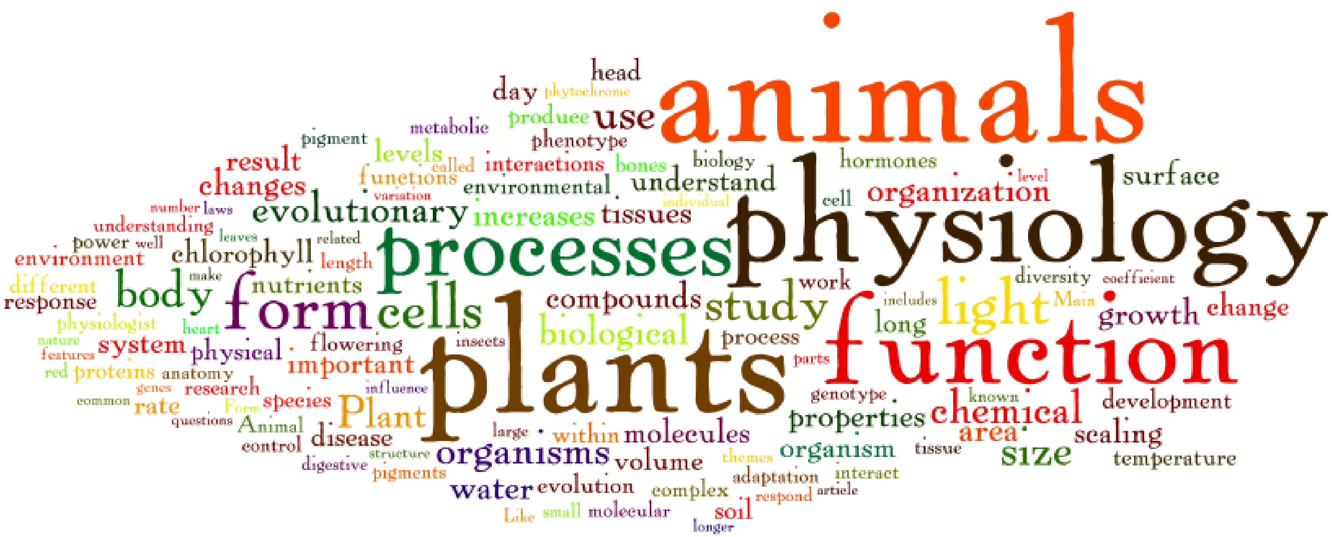
Take home message

- ***From the perspective of the instructor***, one of the great benefits of transforming a course is gaining more insight into student thinking and misconceptions *before* they write the exam

A case study

Biology 260: Fundamentals of Physiology

- Topic: the physiology of animals and plants
- Required course for Biology majors
- Enrollment 550-600 students across two sections
- “Lecture-only” course
- Exams short answer/short essay



The BIOL 260 team

Co-Instructors

Dr. Jae Hyeok Lee (Botany)

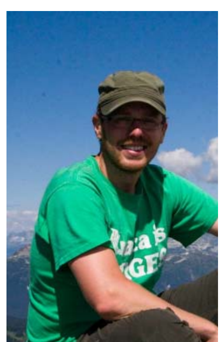
Dr. Philippe Tortell (EOAS/Botany)

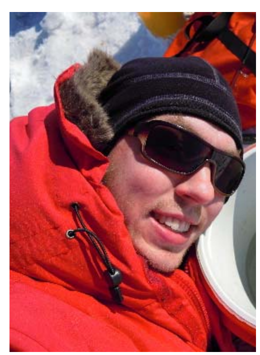
STLFs

Dr. Mandy Banet

Dr. Laura Weir

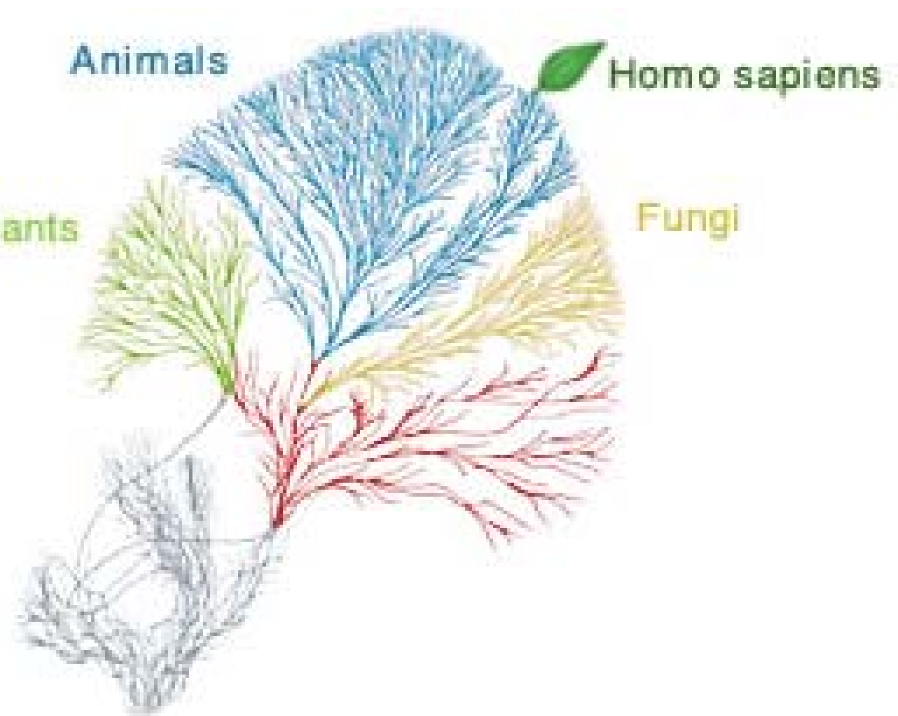
TAs





Dave Metzger
Tim Healy
Dillon Chung

Biology 260: Fundamentals of physiology



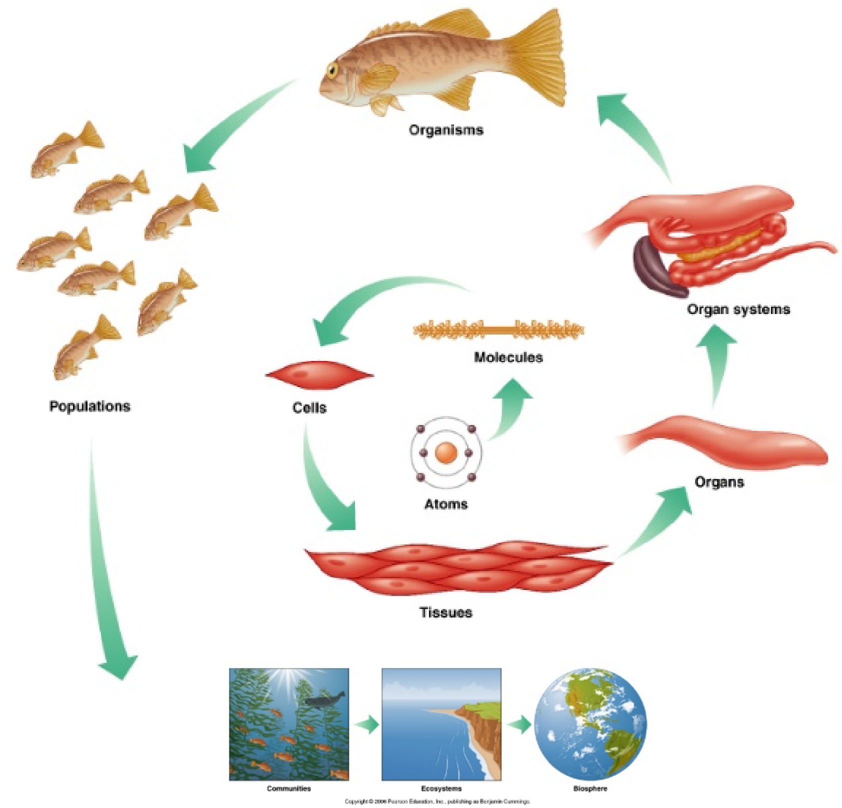
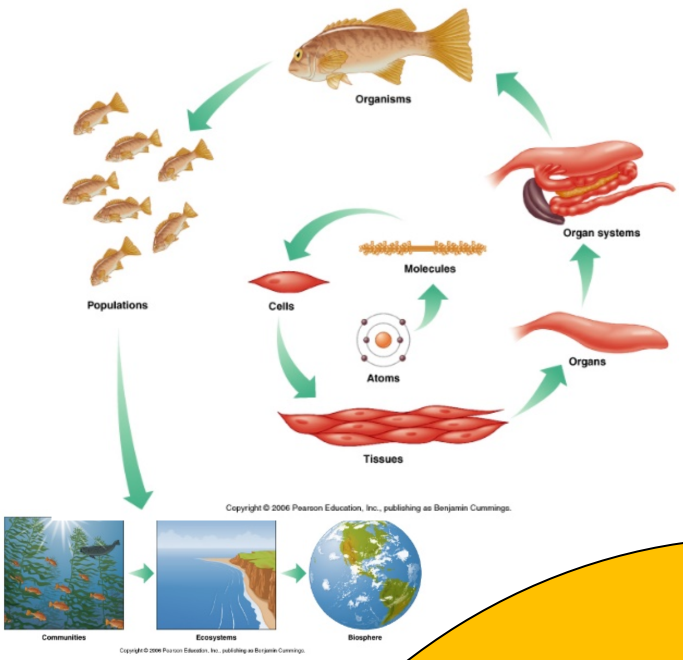


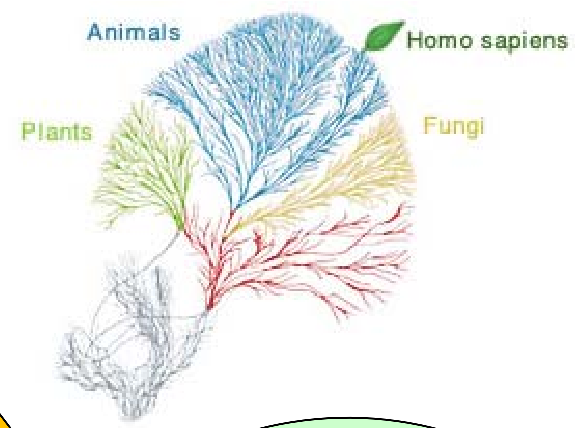
Image source: Tree of Life Project
http://tolweb.org/tree/home.pages/structure.html

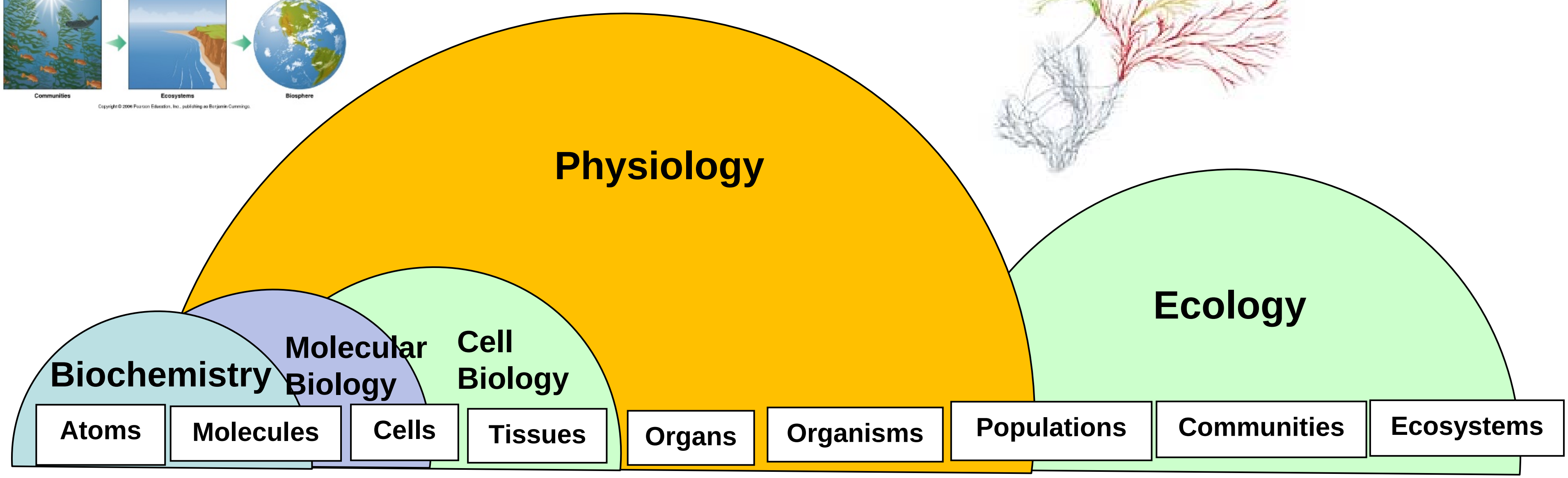
Image source: Moyes and Schulte Principles of Physiology

Biology 260: Fundamentals of physiology



The study of how organisms work

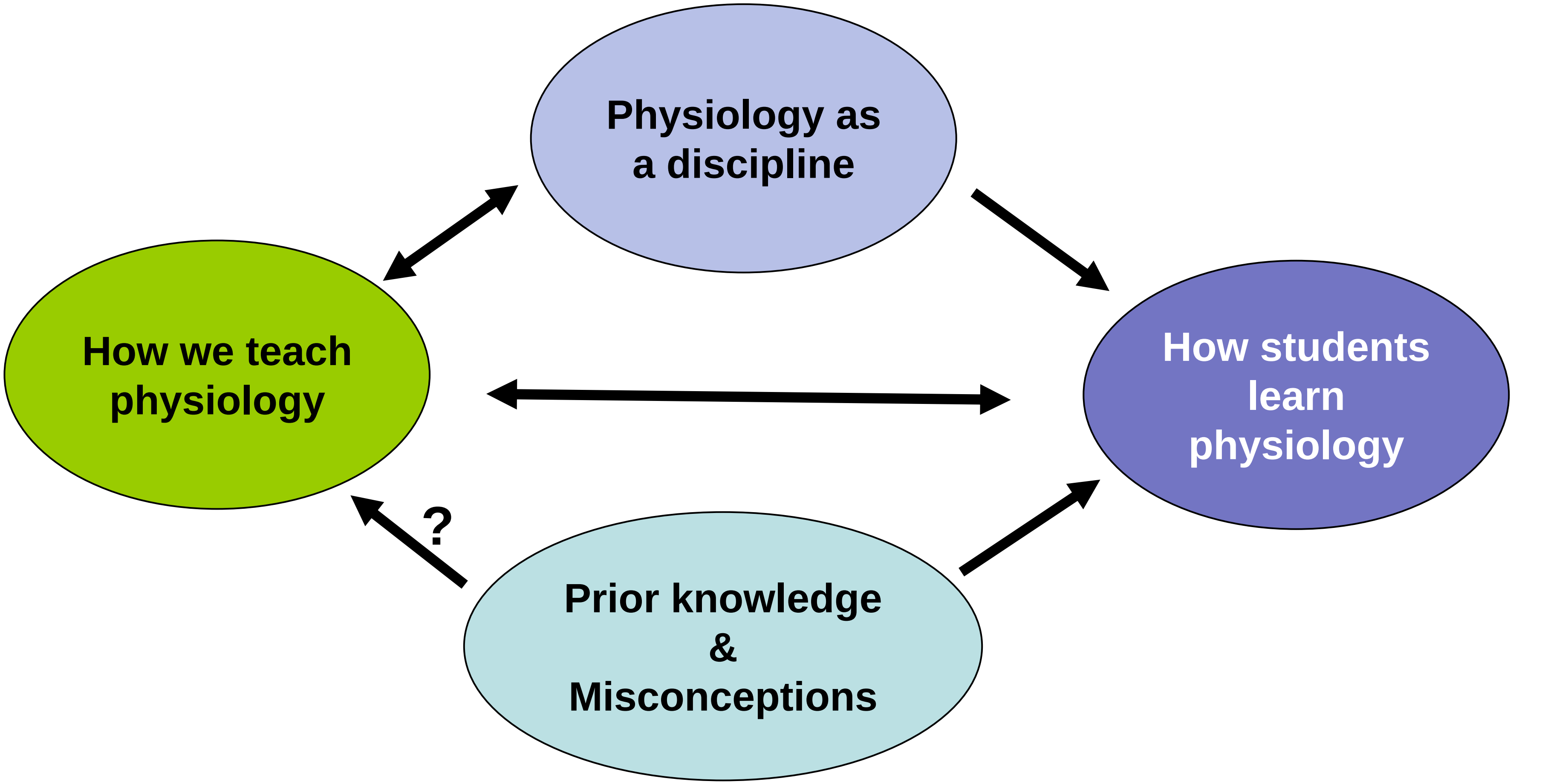




BIOL 260 learning outcomes

- Students will be able to **apply** the principles of chemistry and physics to **explain** the function of physiological systems
- Students will be able to **predict** how a physiological system will respond to an applied treatment (e.g. environmental change, application of drug) and **explain** the reasoning behind their prediction.
- Students will be able to **compare** the mechanisms used by plants and animals to perform physiological functions

Why do students find physiology challenging?



Concept map adapted from:
Michael, J. 2007. What makes physiology hard for students to learn? Results of a Faculty survey. Advances in Physiology Education 31: 34-40.

Why do students find physiology challenging?

Logic: another thing that penguins aren't very good at.

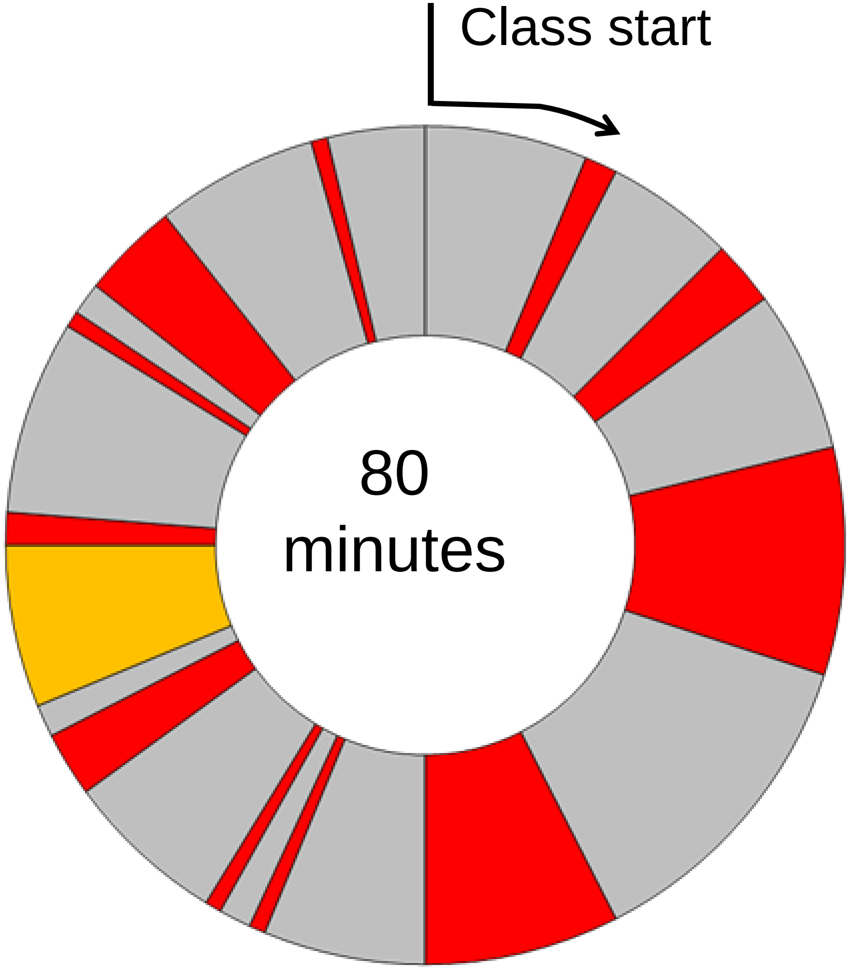
- Students struggle to construct logical answers to exam questions
- Answers reveal fundamental misconceptions and flaws in assigning causality

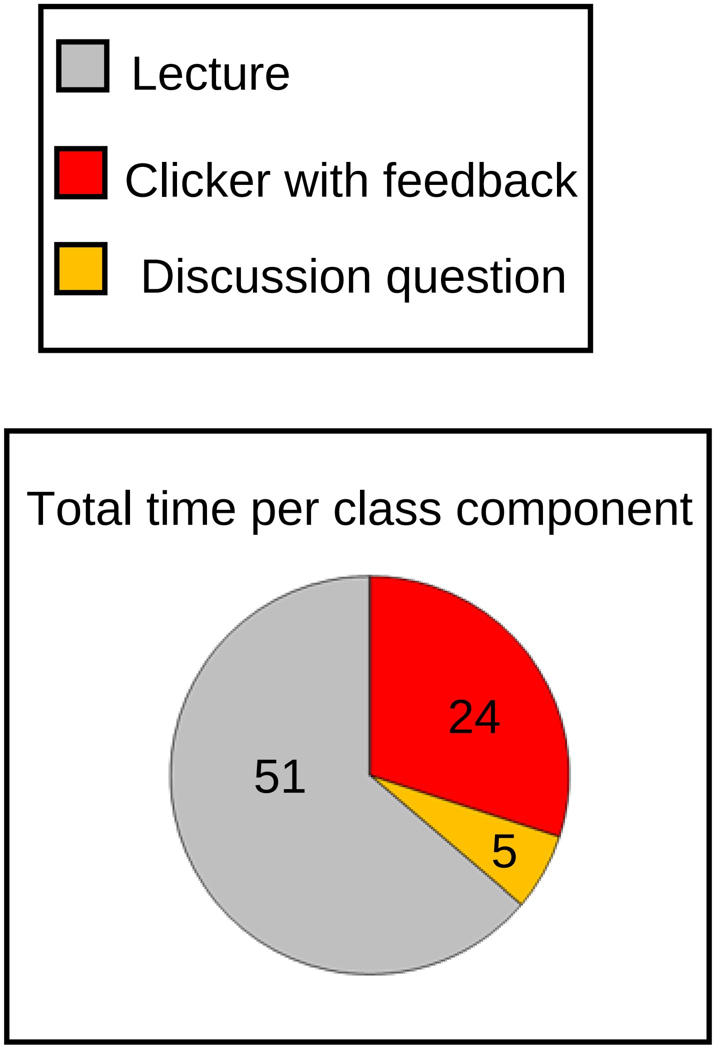
Structure of Biology 260

- Fundamental unit of the course is one week
- Grouped into topic modules (two to four weeks)
- Each week students pre-read part of a textbook chapter and answer an online quiz
- Tuesday’s class clicker-driven lecture
- Online homework problem due Wed. night based on Tuesday’s class
- Thursday’s class more problem-based

What does a typical class look like?

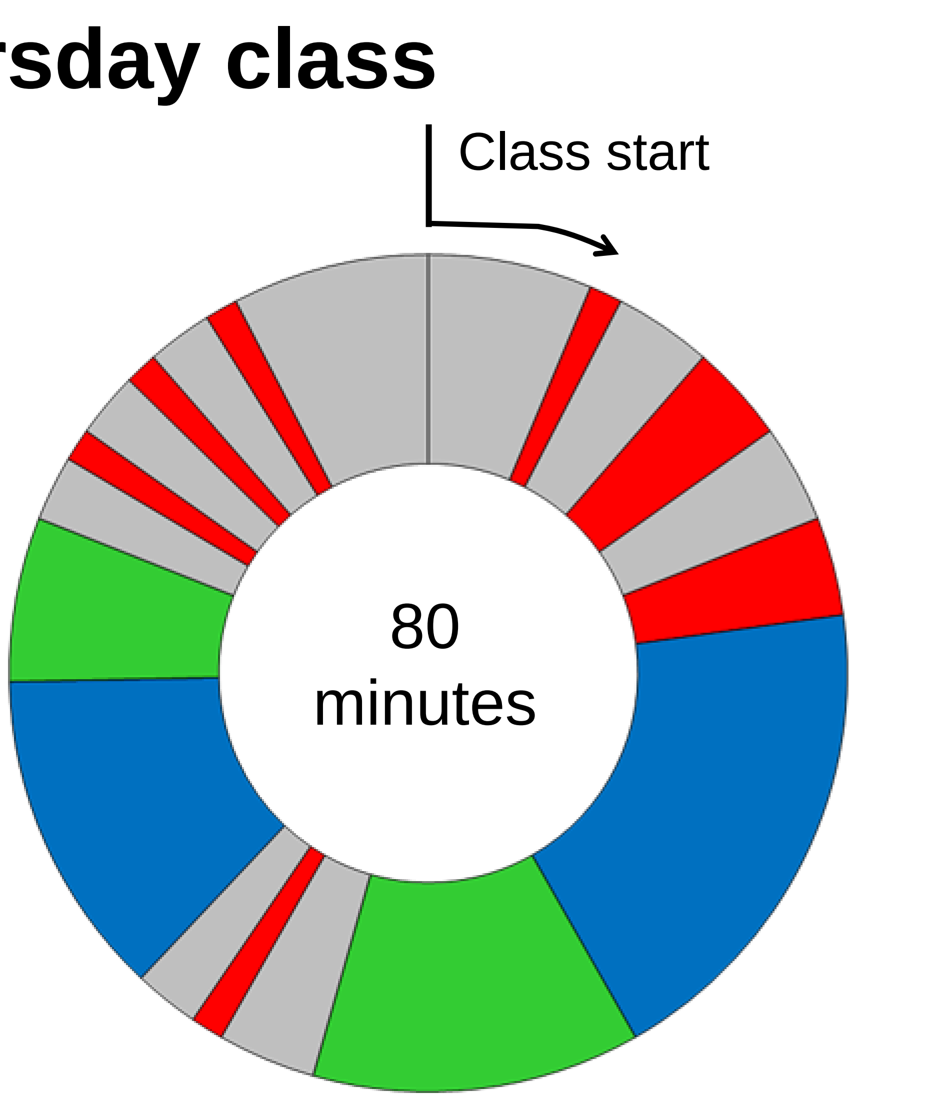
Tuesday class

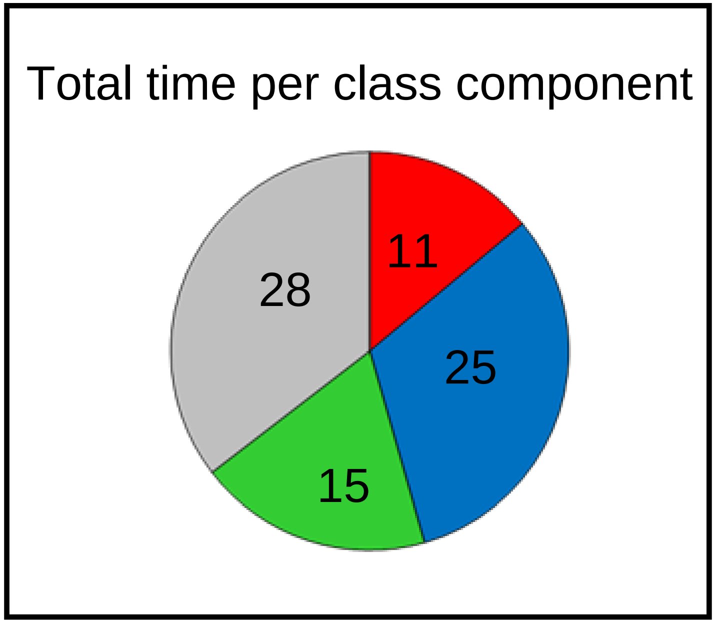




What does a typical class look like?

Thursday class





What does a typical class look like?

The student experience

1. Pre-reading

GOAL: Get the students to learn some of the material before class, so that time in lecture is better used, e.g., for discussions and peer instruction

APPROACH: Short, highly targeted reading assignment and online quiz. (5-10 multiple choice questions)

Insight into misconceptions

Each pre-reading quiz contains these questions:

Was there any material in this pre-reading that you found particularly unclear or difficult?

Were there any parts that were too basic (or that you have covered extensively before)?

The student experience

2. In class exercises

GOAL: Have the students grapple with the concepts in class, rather than waiting until they get home and do a homework problem. Gain insight into students misconceptions and address them as soon as possible

APPROACH: Clicker questions followed by peer discussion and instructor feedback; Open ended questions followed by instructor feedback

Using in-class exercises to target misconceptions

Three examples:

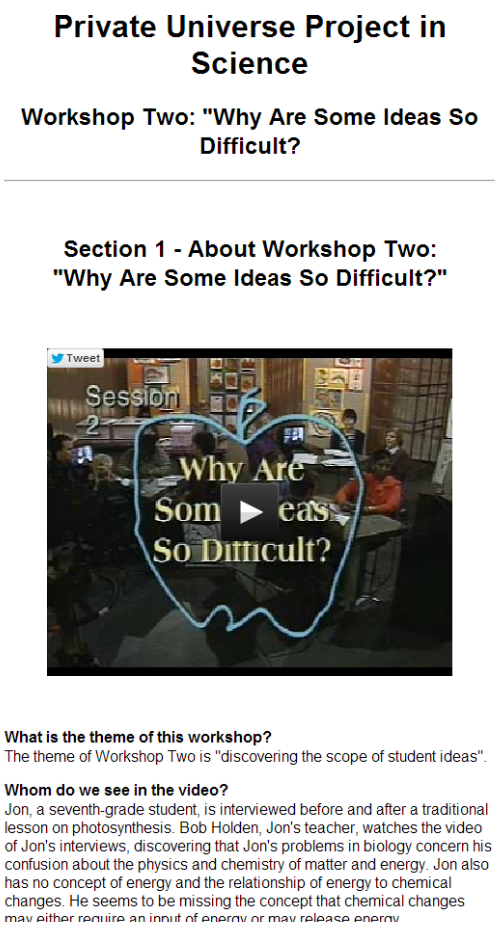
- Known misconceptions from the literature
- Misconceptions we have detected in final exams or in previous years
- Misconceptions uncovered through open-ended questions

Question

A mature maple tree can have a mass of 1 ton or more (dry biomass, after removing the water), yet it starts from a seed that weighs less than 1 gram. Which of the following processes contributes the most to this huge increase in biomass?

A. absorption of mineral substances from the soil via the roots
B. absorption of organic substances from the soil via the roots
C. incorporation of CO_2 gas from the atmosphere into molecules by the leaves
D. incorporation of H_2O from the soil via the roots
E. absorption of solar radiation by the leaves

Known misconceptions


Private Universe Project in Science

Workshop Two: "Why Are Some Ideas So Difficult?

Section 1 - About Workshop Two: "Why Are Some Ideas So Difficult?"

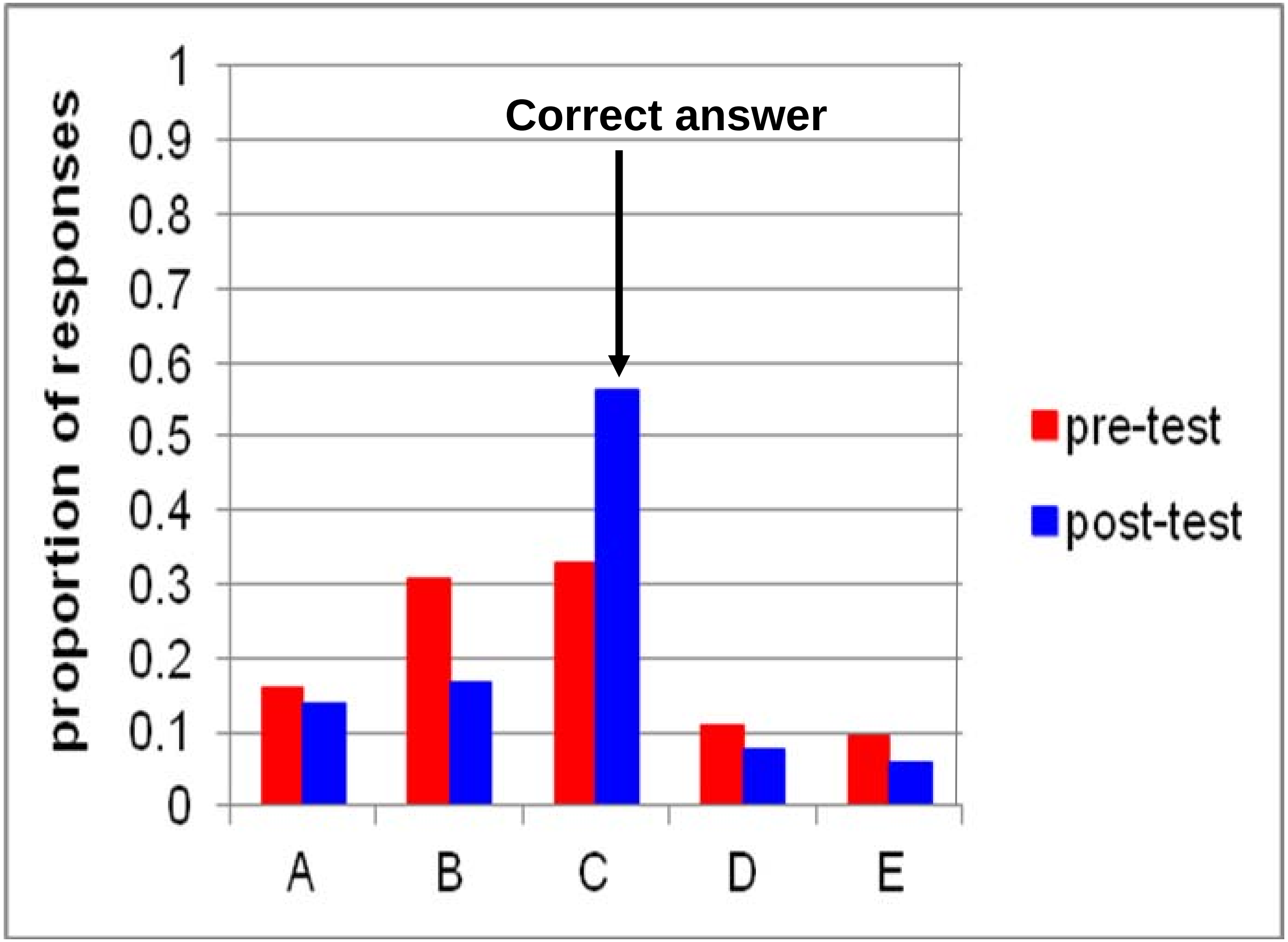
What is the theme of this workshop?
The theme of Workshop Two is "discovering the scope of student ideas".

Whom do we see in the video?
Jon, a seventh-grade student, is interviewed before and after a traditional lesson on photosynthesis. Bob Holden, Jon's teacher, watches the video of Jon's interviews, discovering that Jon's problems in biology concern his confusion about the physics and chemistry of matter and energy. Jon also has no concept of energy and the relationship of energy to chemical changes. He seems to be missing the concept that chemical changes may either require an input of energy or may release energy.

- Misconceptions about photosynthesis are widely held
- Stem from basic misconceptions about the nature of gases and the physics and chemistry of matter and energy

http://www.learner.org/resources/series29.html

Pre and post course assessment



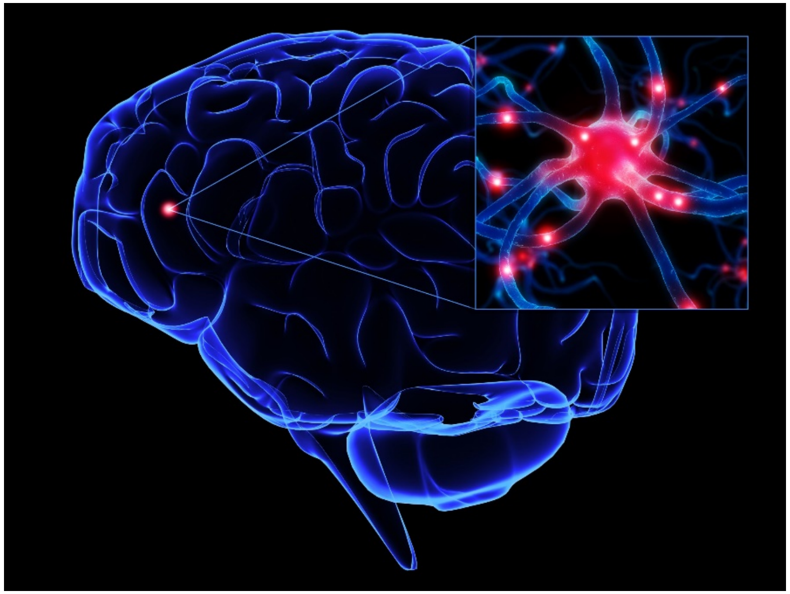
First day of class

Last day of class

Example 1: *take home*

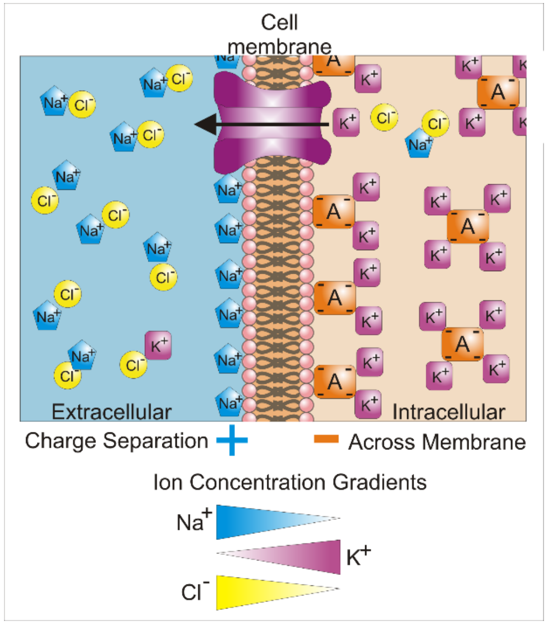
- Using the literature can be an effective way to identify potential misconceptions
- Pre-post assessment to evaluate learning gain
- Clear presentation of material does not necessarily dispel a misconception
- A more targeted intervention may be needed

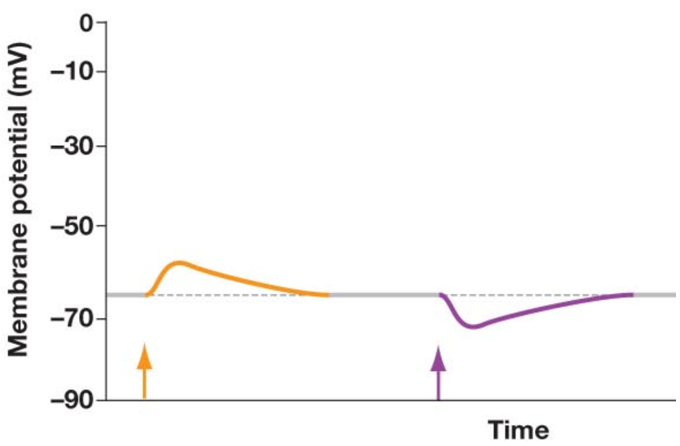
Example 2: misconception observed on exam responses



- Students have some important misconceptions about the physics of electricity and electrochemistry
- Impedes their ability to understand processes in neurons

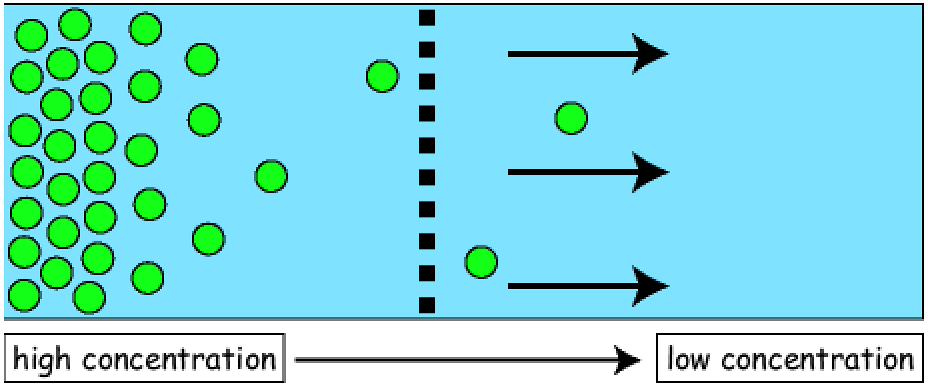
Electrical signals in neurons





- Electrical signaling occurs as a result of opening or closing of ion channels in the membrane
- Results an change in charge distribution across the membrane
- Causes an electrical signal

Fundamental misconception

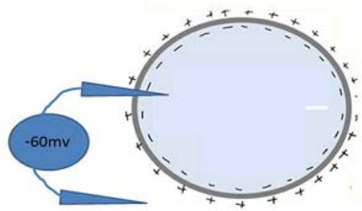


- Students have memorized the “fact” that substances move from areas of high concentration to low concentration
- Have difficulty accepting that an ion can move against its concentration gradient if there is an opposing charge difference across a membrane

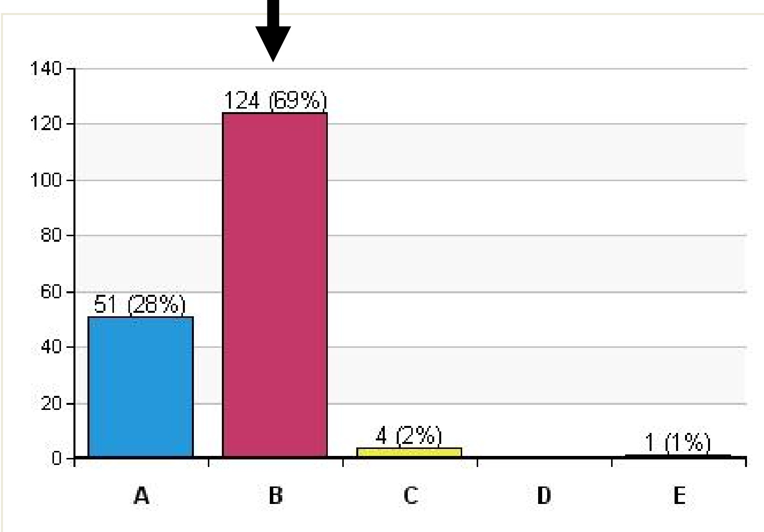
Approach

Question

In the axon of this squid neuron, the membrane potential is -60 mV and the calculated equilibrium potential for K^+ is -76mV. Which way would K^+ move if we added K^+ channels?

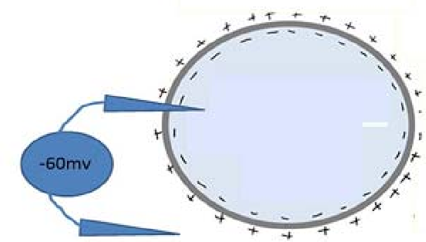


a. Into the cell
b. Out of the cell
c. There will be no net movement



Question

In the axon of this squid neuron, the membrane potential is -60 mV and the calculated equilibrium potential for Na^+ is +55 mV. Which way would Na^+ move if we added Na^+ channels?



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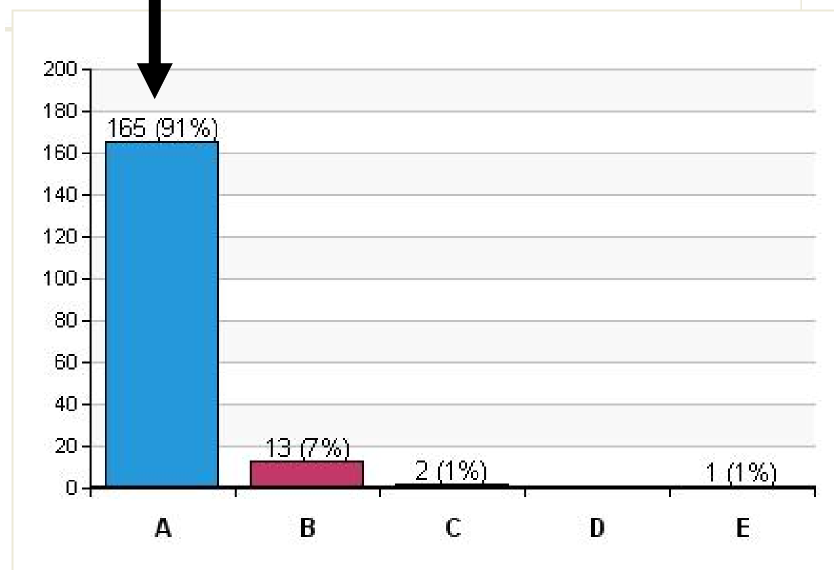
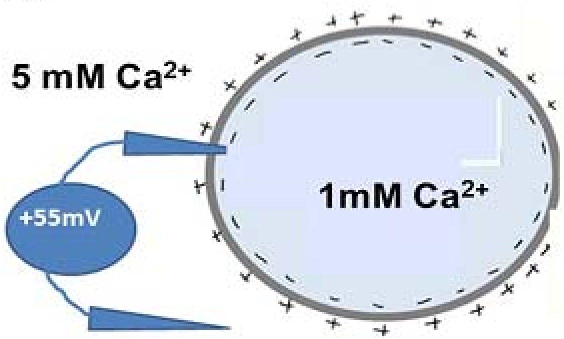


Approach

Question

In this hypothetical neuron, the intracellular [Ca^{2+}] is 1 mM and extracellular [Ca^{2+}] is 5mM. The calculated equilibrium potential for Ca^{2+} is +22mV. The membrane potential is +55mV. Which way would Ca^{2+} move if we added Ca^{2+} channels?



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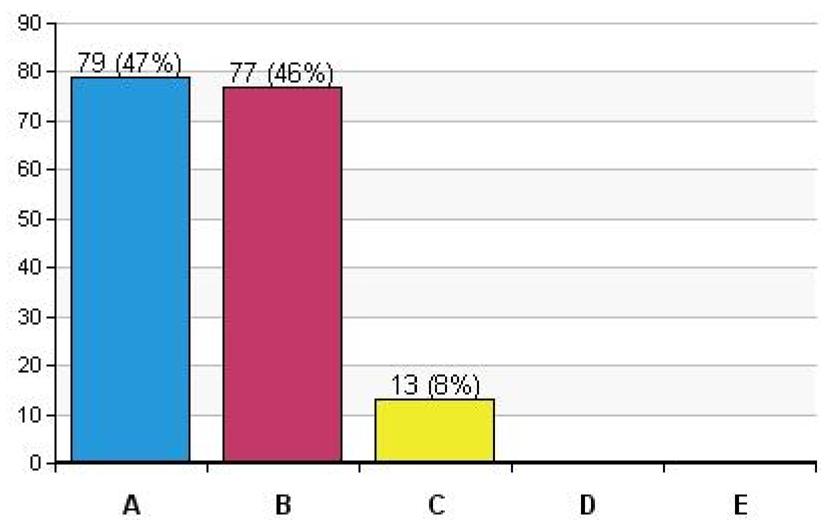
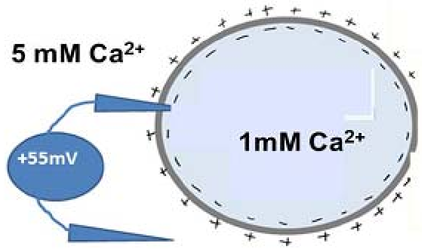


Biology 260

Re-poll the following class session

Question

In this hypothetical neuron, the intracellular [Ca^{2+}] is 1 mM and extracellular [Ca^{2+}] is 5mM. The calculated equilibrium potential for Ca^{2+} is +22mV. The membrane potential is +55mV. Which way would Ca^{2+} move if we added Ca^{2+} channels?



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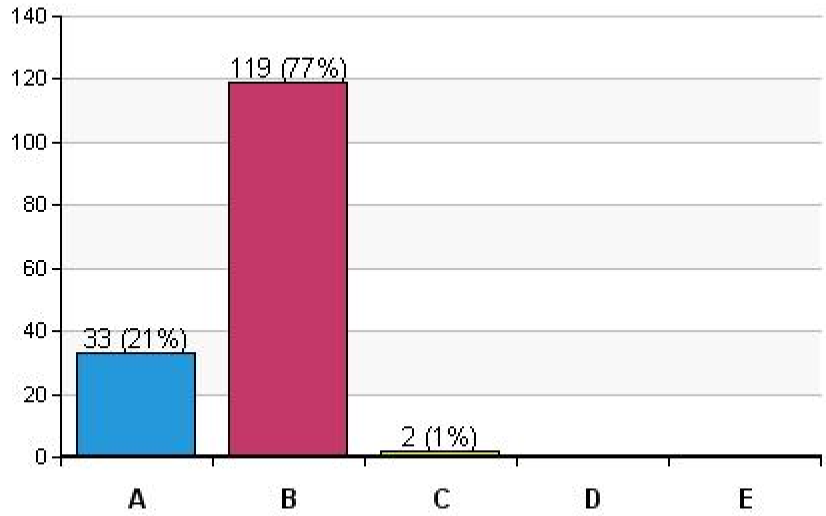
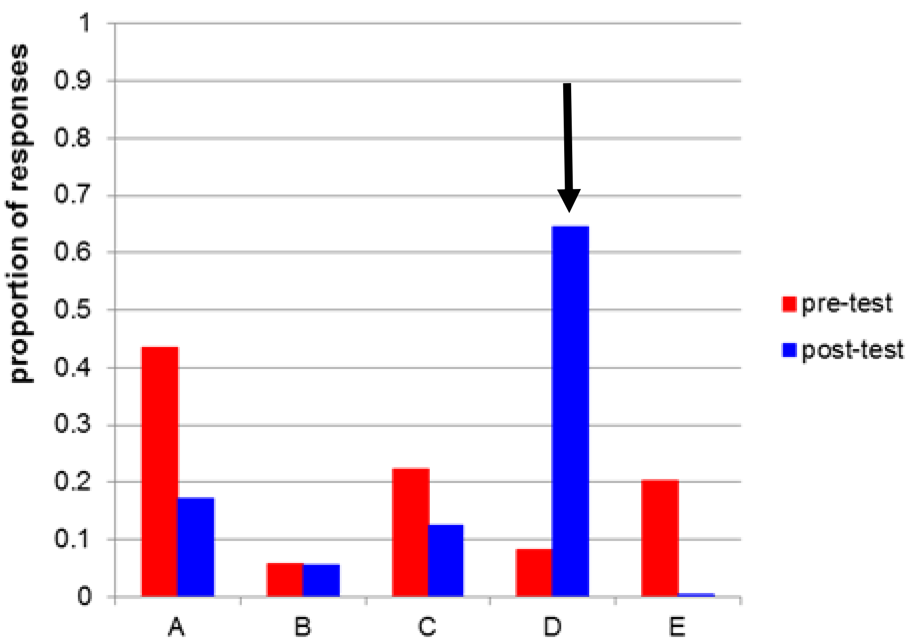


Course learning gain

What direction will Ca^{2+} ions move when Ca^{2+} channels open in a cell under the following conditions:

Extracellular Ca^{2+} = 5mM
Intracellular Ca^{2+} = 1 mM
Resting membrane potential = +55mV
Equilibrium potential for Ca^{2+} = +21.5mV

a.Into the cell along (i.e., in the same direction as) its concentration gradient
b.Out of the cell along (i.e., in the same direction as)its concentration gradient
c.Into the cell along its (i.e., in the same direction as) electrical gradient
d.Out of the cell along (i.e., in the same direction as) its electrical gradient



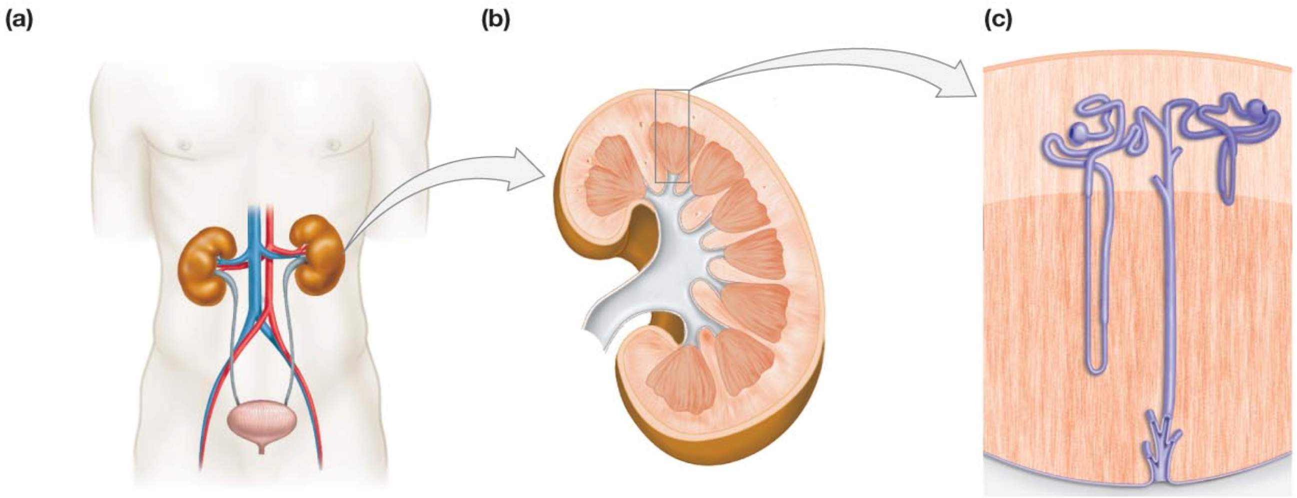
Long term retention

BIOL 260		BIOL 361	
% correct pre-test	% correct post-test	% correct pre-test	% correct post-test
8	64	27	64

Example 2: *take home*

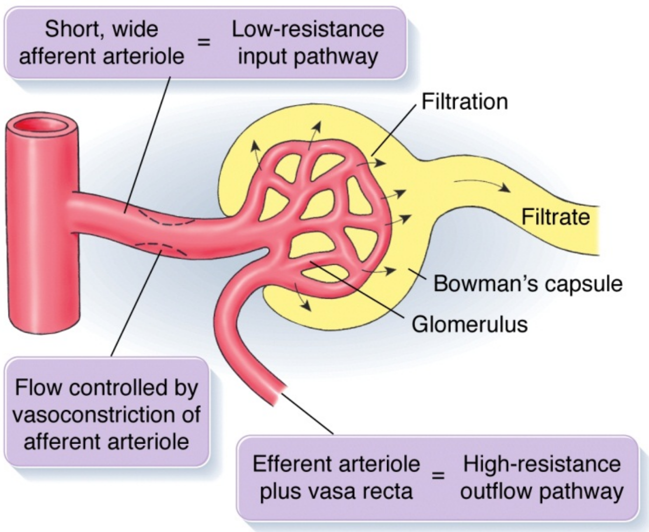
- Identified a serious misconception using last year’s final
- Answers to our “standard” clicker questions conceal this misconception
- Designed a targeted intervention that forces students to directly confront the misconception
- Substantially improved performance

Example 3



- Question about filtration in the kidneys
- Uncovered a surprising misconception about pressure and flow

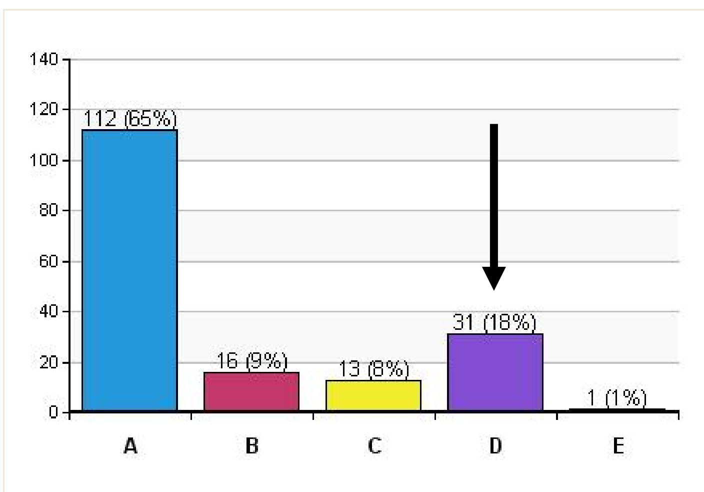
Approach



Question:

Vasoconstriction of the afferent arteriole leading to the glomerulus would:

a. Increase hydrostatic pressure in the glomerulus, increasing GFR
b. Decrease hydrostatic pressure in the glomerulus, increasing GFR
c. Increase hydrostatic pressure in the glomerulus, decreasing GFR
d. Decrease hydrostatic pressure in the glomerulus, decreasing GFR



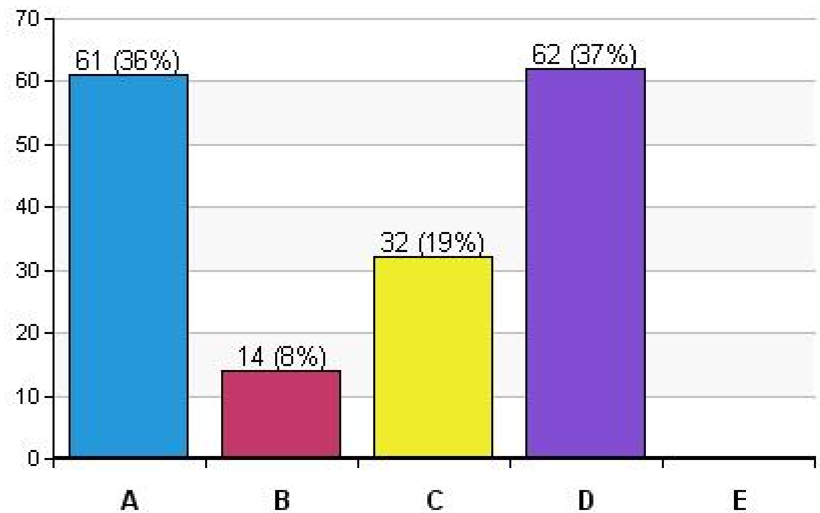
Approach

Peer discussion followed by re-poll

Question:

Vasoconstriction of the afferent arteriole leading to the glomerulus would:

a. Increase hydrostatic pressure in the glomerulus, increasing GFR
b. Decrease hydrostatic pressure in the glomerulus, increasing GFR
c. Increase hydrostatic pressure in the glomerulus, decreasing GFR
d. Decrease hydrostatic pressure in the glomerulus, decreasing GFR

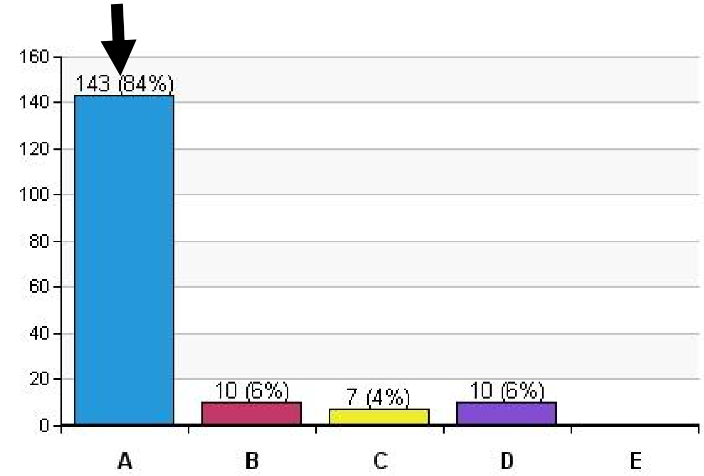


"Iso-morphic" question

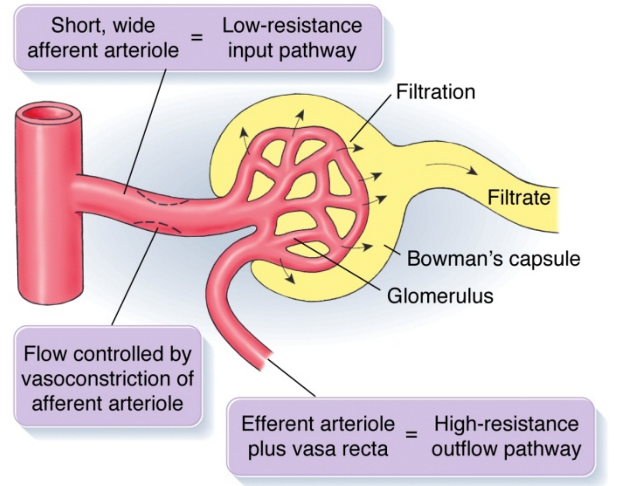
Question:

The diameter of the efferent arteriole (leading away from the glomerulus) can also be altered. Vasoconstriction of the efferent arteriole would:

a. Increase hydrostatic pressure in the glomerulus, increasing GFR
b. Decrease hydrostatic pressure in the glomerulus, increasing GFR
c. Increase hydrostatic pressure in the glomerulus, decreasing GFR
d. Decrease hydrostatic pressure in the glomerulus, decreasing GFR



Sample explanations



Constriction of efferent arteriole (leading away from the glomerulus):

When vasoconstriction occurs, the diameter of the tubing decreases, which leads to an increase of pressure within the tube. Thus, hydrostatic pressure increase. For GFR, as more pressure and a faster speed of the blood passing by, the rate would increase since the blood has high speed to let filtration occur.

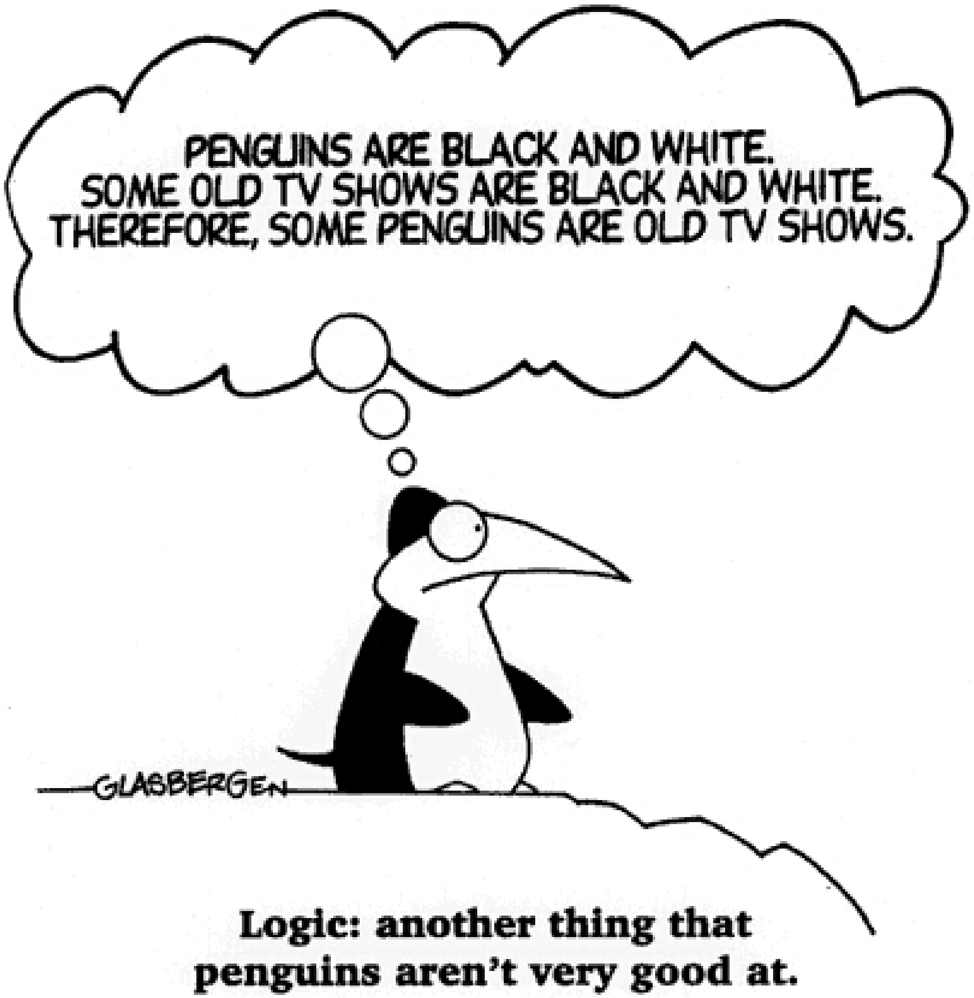
Since the flow decreases in the efferent arteriole there is less pressure acting on it. But since the flow of blood decreases leaving the glomerulus blood stays there longer and there is more time for H2O and ions to diffuse into the Bowman's capsule so GFR increases.

The constriction of the efferent arteriole would increase hydrostatic pressure in the glomerulus because the efferent artery would be at a lower pressure than in normal conditions and this would increase the pressure gradient from the glomerulus to the efferent artery which would increase hydrostatic pressure, therefore increasing GFR.

Example 3: *take home*

- Correct answers can be based on faulty reasoning
- Open ended questions can help reveal these problems

Critical thinking

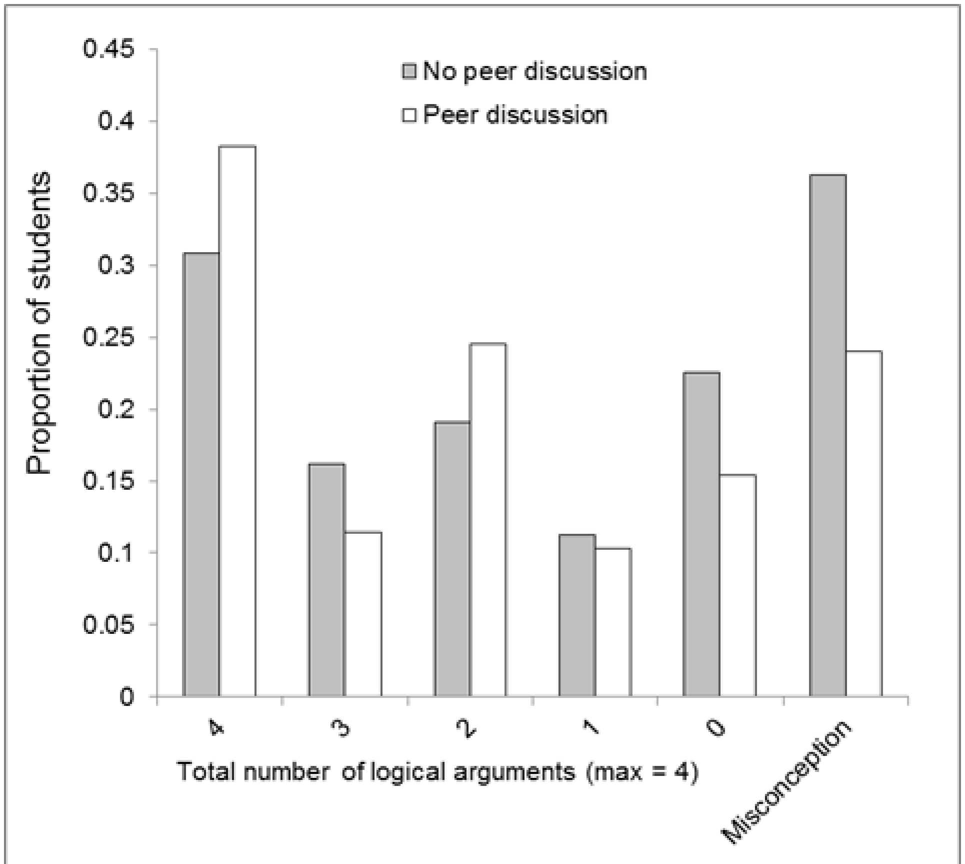


- Students need explicit practice in causal reasoning
- But first, they need to directly confront and deal with their misconceptions

A ⟶ **B** ⟶ **C** ⟶ **D**

Help with causal reasoning

See the poster:



The influence of peer discussion on the development of logical arguments in BIOL 260

Dr. Mandy Banet

Dr. Laura Weir

The student experience

3. Weekly homework problem

GOAL: Give the students practice with causal reasoning and explanation of their reasoning.

APPROACH: Exam-style open ended question online. For participation with sub-sample grading. Feedback online and in class on Thursday

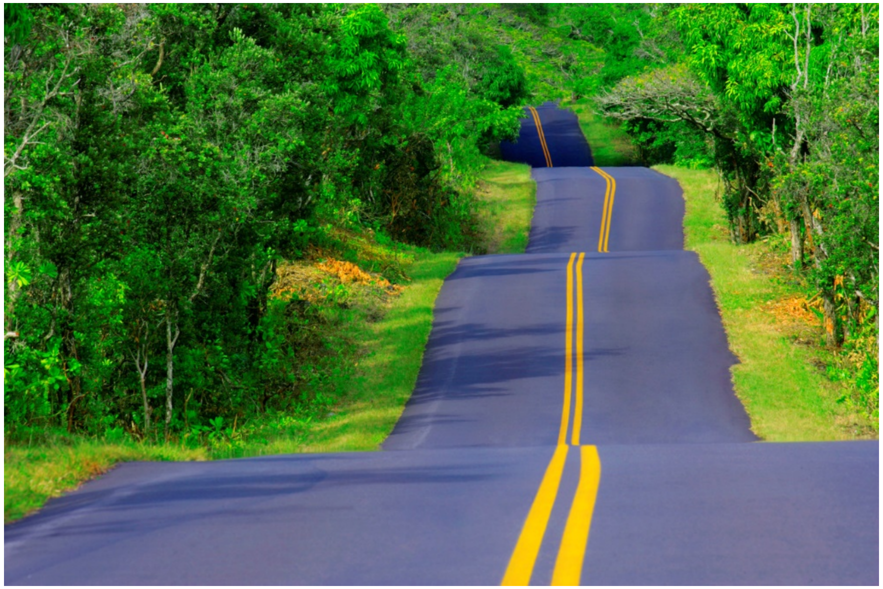
Take home message

- ***From the perspective of the instructor***, one of the great benefits of transforming a course is gaining more insight into student thinking and misconceptions *before* they write the exam

Take home messages

- ***<u>From the perspective of the instructor</u>***, one of the great benefits of transforming a course is gaining more insight into student thinking and misconceptions *before* they write the exam
- Even a modest change in the way you teach can have big impacts on your ability to detect and help students correct these misconceptions

A final thought



- Not everything you try will work, but you learn a lot in the attempt

CWSEI Life Sciences

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