Supplemental Materials

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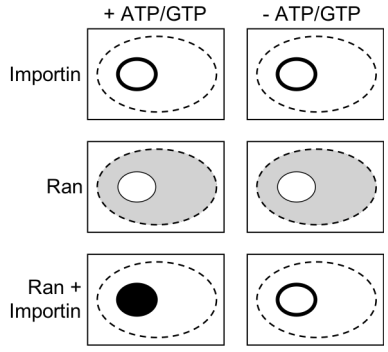
Supplemental Material A

Multi-level Questions

Cell Biology: Nuclear Transport

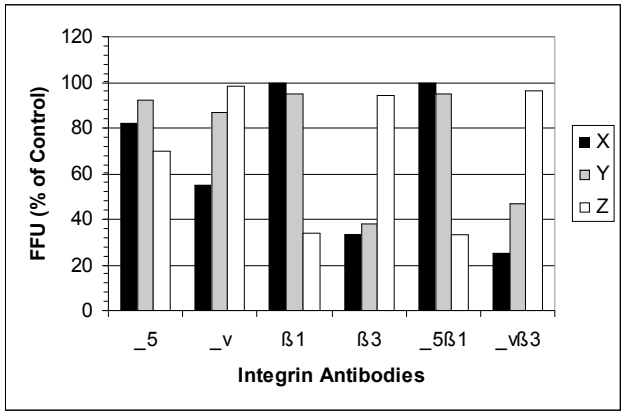
QUESTIONS	DISCUSSION OF BLOOM'S RANKING AND ANSWER
Label the nuclear envelope, nuclear pore and the nucleolus on this diagram of a cell Define nuclear transport	Knowledge (LOCS) Requires the student to recall information provided to them, but not necessarily to understand it (*nuclear transport is defined as the directed movement of proteins through nuclear pores against a gradient*)
Choose one of the following proteins and summarize its role in nuclear transport: Importin, Ran, or Ran-GAP	Comprehension (LOCS) Requires student to summarize a process already describe in text or in class in his/her own words, showing an understanding of how different components relate to one another
If you were able to temporarily block the function of Ran-GAP in a cell, what do you predict would happen to the Ran-GTP/Ran-GDP gradient?	Application (LOCS/HOCS) Requires student to predict the direct effect of altering a system's component (*Without Ran-GAP to convert Ran-GTP to Ran-GDP in the cytosol, the gradient of Ran-GTP/Ran-GDP would decrease until there was an equal amount of Ran-GTP in the nucleus and in the cytosol*)
If you were able to temporarily block the function of Ran-GAP in a cell, what effect would this have on a protein containing a nuclear localization signal (NLS)?	Advanced Application (HOCS) Requires student to predict an indirect effect of altering a system's component (one-step removed from component that was altered) (*Without Ran-GAP to convert Ran-GTP to Ran-GDP in the cytosol, there would be an increase in the level of cytosolic Ran-GTP which would cause premature release of NLS-containing proteins in the cytosol. Thus NLS-containing proteins would not be efficiently transported to the nucleus)*
 Nuclear transport of a NLS-containing protein can be reconstituted in vitro by adding various purified proteins back to a permeabilized cell whose cytoplasm has been drained. The figure below depicts the results of an in vitro nuclear transport assay performed in the presence (left panel) or absence (right panel) of an energy-regenerating system. A fluorescently-labeled NLS-containing protein was added in each panel along with the indicated purified proteins. What role can you infer for Ran from these data? Note: dashed line indicates permeabilized cell membrane, smaller circle	Analysis (HOCS) Requires student to read and understand data and then draw inferences from the data (*Ran uses energy to transport NLS-containing proteins from the nuclear envelope into the nucleus*)

denotes nucleus, fluorescent signal indicated by grey (diffuse staining) or black (concentrated staining).	
Draw the simplest model of nuclear transport that you can construct based solely on the data shown above. Be sure your model is consistent with the data and includes the following components: nuclear pore, nuclear envelope, Importin, Ran and ATP/GTP.	Synthesis (HOCS) Requires student to read and understand data, draw inferences from the data and then create a new model that is consistent with the data (*Importin is sufficient to transport the NLS-containing protein to the nuclear periphery whereas Ran requires energy to translocate the NLS-containing protein into the nucleus*)
You hypothesize that Importin-alpha binds NLS-containing proteins and this complex is shuttled across the nuclear pore in a Ran-dependent process. You perform the following two experiments to test your hypothesis: In vitro nuclear transport assay Result: Ran, Importin-alpha and energy are sufficient to transport a NLS-containing protein into the nucleus Genetic analysis Result: A yeast strain containing Ran and Importin-alpha, but lacking another importin family member, Importin-beta, is lethal due to an inability to transport certain nuclear proteins. Evaluate the relative importance of each piece of data and discuss how you might reconcile the apparent contradiction.	Evaluation (HOCS) Requires student to comprehend two different experimental approaches and what information can be obtained from each approach. Then the student must assess the limitations of each approach and evaluate the relative support each piece of data lends to the overall hypothesis (*Importin-beta may be required in vivo for transport of different classes of NLS-containing proteins not tested in the in vitro assay; alternatively, adding high levels of Importin-alpha and Ran in the in vitro system may compensate for lack of Importin-beta)*

Physiology: Cardiovascular System

QUESTIONS	DISCUSSION OF BLOOM'S RANKING AND ANSWER
To determine cardiac output for an animal, which two variables do you need to know?	Knowledge (LOCS) Requires student to recall information, but not necessarily to understand significance of each variable.*(Heart rate and stroke volume determine cardiac output)*
In your own words, define what cardiac output is and why it is significant.	Comprehension (LOCS) Requires students to summarize a process described in text or in class in his/her own words, showing not only an understanding of how different cardiovascular components relate to one another but also how cardiac output influences other cardiovascular parameters. *(Cardiac output is the volume of blood pumped by the heart in a given period of time, liter/min. Blood pressure and thus blood flow are determined by cardiac output and total peripheral resistance.)*
If cardiac output increases, predict how arterial blood pressure will change. Explain your answer. Lance Armstrong has a normal resting cardiac output of 6 L /min yet his resting heart rate is only 40 beats/min. What is his stroke volume?	Application (LOCS/HOCS) Both questions require students to predict an effect on a new situation not previously encountered. Neither question is complex and if the student knows the equations for cardiac output and blood pressure, they should be able to answer the question correctly. *(If cardiac output increases, blood pressure should increase unless resistance decreases proportionally. Lance Armstrong's stroke volume will be 150 ml/beat*)
Compared to a normal resting male of the same height and weight, Lance Armstrong's stroke volume is greatly increased. Provide a physiological explanation of how he can have such a large stroke volume.	Analysis (HOCS) Requires student draw inferences from the data. *(A greater stoke volume is a result of a more forceful contraction of the left ventricle. As muscle strength is determined by the cross-sectional area of the muscle, then Lance's left ventricle must be very thick.)*
Create a summary sheet that is a pictorial depiction/ flow diagram of how changes in cardiac output influence mean arterial blood pressure. Generate a graph that shows Lance's left ventricle volume during the cardiac cycle.	Synthesis (HOCS) Requires student to draw inferences from the data and then create a new model that is consistent with the data. *(summary sheet would show that if cardiac output increases while resistance is held constant than mean arterial pressure would increase.)* *(graph would show end diastolic volume of 170 ml that drops to 20ml for an end systolic volume)*
If on a CT scan of patient, an enlarged heart was observed, how would you determine if this enlarged heart was pathological or not?	Evaluation (HOCS) Requires student to comprehend two different physiological states, highly trained athlete vs. disease state. They would have to comprehend the information obtained from different diagnostic tests and determine which would be most informative. *(e.g., speaking with the patient and getting his history would show that patient is a highly fit athlete)*

Virology

QUESTIONS	DISCUSSION OF BLOOM'S RANKING AND ANSWER
PART A. As a researcher who studies Hantaviruses, you are currently in the field studying an outbreak in a mining town. Your graduate student, Filo, sends you the following email. He also sends data that he needs help interpreting. *Hi Dr. Bloom,* *I hope your field work is going well. The data below is from the following experiment:* *Duplicate wells of Vero E6 cells were pretreated for 1 hr at 37°C with 20µg/ml of antibodies to specific integrins to inhibit virus binding. Cells were washed and **X**, **Y** or **Z hantaviruses** were subsequently adsorbed. Infected cells were quantitated. Focus Forming Units (FFU) observed 36 hour postinfection are expressed as a percentage of control infections for each viral inoculum.*  *Sincerely,* *Filo* You write back: *Filo,* *Thank you for sending the excellent data. Please answer the following questions and use the information to help you interpret the results.* *Dr. Bloom*	
Define focus forming unit.	<u>Knowledge</u> (LOCS) The student must recall provided information. (*focus forming unit is a measurement of viral infection where one virus led to the formation of a focus*)
Describe why some hantaviruses are pathogenic and others are not.	<u>Comprehension</u> (LOCS) Student must describe information previously provided to them. (*pathogenic hantaviruses use ß3 integrins as a receptor and dysregulate αV ß3- integrins functions, whereas non-pathogenic hantaviruses do not)*

Fill in the blanks and circle the best responses. *To enhance the binding of Hantaviruses X and Y one would add _____. Pathogenic hantavirus(es) X, Y, Z (circle one or more) bind the _____ heterodimer by strongly interacting with the _____ monomer, whereas non-pathogenic hantavirus(es) X, Y, Z (circle one or more) bind the _____ heterodimer by strongly interacting with the _____ monomer.*	Application and Analysis (LOCS/HOCS) The student must be able to a) interpret the graph, b) infer the experimental results, c) utilize other information to answer the questions (*Ca2+; X, Y; αV β3; β3; Z; α5 β1;*)
PART B The outbreak you are studying involves several cases of *Sin Nombre* infection in people who have been working in the gold mines near a small Southwestern town in the United States. Almost everyone in the town works in the mines, yet only some of the people have been infected. In fact, those who have been infected work side-by-side daily with those who apparently seem resistant. You are convinced that the uninfected workers have been exposed to the virus. After reviewing Filo's data, you propose a hypothesis to explain this enigma. Your hypothesis is:	Synthesis (HOCS) Students must utilize many pieces of information to create a hypothesis. (*Resistant individuals have a β3-integrin subunit that is not used as a receptor for hantavirus infection.)*
You then design an experiment to test your hypothesis. Your design is:	Synthesis (HOCS) Student must be able to design an experiment that tests their hypothesis. This requires students to use different bodies of knowledge and science process skills. (*One could isolate and sequence the β3-integrin subunit from resistant and susceptible individuals, and then clone the genes into a mammalian expression vectors. The vectors could then be transfected into cells that are normally resistant to hantavirus infection, after which both proteins would be tested for their ability to support hantavirus infection.)*

Supplemental Material B
Using Bloom's to write multiple-choice questions

Websites with information to guide development of multiple choice questions at each level of Bloom's cognitive domains.

1. Guidelines for creating multiple choice questions using Bloom's developed by University of Texas:
http://www.utexas.edu/academic/diia/assessment/iar/students/plan/method/exams-mchoice-bloom.php (accessed July 28, 2008)

2. Companion site to above website that provides the philosophical framework and the references for creating good multiple choice questions:
http://www.utexas.edu/academic/diia/assessment/iar/students/plan/method/exams-mchoice.php (accessed July 28, 2008)

3. Annotated bibliography of website resources for creating good multiple choice questions created by the University of Medicine and Dentistry of New Jersey:
http://cte.umdnj.edu/student_evaluation/evaluation_constructing.cfm (accessed July 28, 2008)

4. Designing and managing multiple choice questions. A manual developed by the University of Cape Town Home page:
http://web.uct.ac.za/projects/cbe/mcqman/mcqman01.html
http://web.uct.ac.za/projects/cbe/mcqman/mcqappc.html (accessed July 28, 2008)

5.Wrtiting multiple choice questions that demand critical thinking (guided by Bloom's) created by Northern Essex Community College, Haverhill, MA:
http://cit.necc.mass.edu/atlt/TestCritThink.htm (accessed July 28, 2008)

6. Using Bloom's to create a Knowledge survey to be used for assessment of student learning (E. Nuhfer and D. Knipp):
http://www.isu.edu/ctl/facultydev/KnowS_files/KnowS.htm (accessed July 28, 2008)

7. We also direct the reader to the practice GRE subject tests available on-line, as many of the multiple choice questions which refer to graphs or figures are good examples of questions at analysis and evaluation levels of Bloom's:
http://www.ets.org/portal/site/ets/menuitem.1488512ecfd5b8849a77b13bc3921509/?vgnextoid=5689a552d81b5010VgnVCM10000022f95190RCRD&vgnextchannel=095b46f1674f4010VgnVCM10000022f95190RCRD (accessed July 28, 2008)

Supplemental Material C
Comparison of classroom implementation strategies

Summary of Bloom-based activities used by faculty and/or students in three different classroom settings			
Faculty and Student Activities using the BBT	Faculty Centered	Faculty and Student Centered	Student Centered
Faculty Activities			
Identified student's cognitive levels	X	X	
Explicitly introduced BBT		X	X
Designed activities to help students identify the cognitive levels at which they work	Rubrics	exam diagnostics	create learning materials
Assigned activities for helping students' achieve competency at higher cognitive levels	-Students evaluate peers' research proposals	-"Blooming" questions -Use of BLASt	-Students write questions at each Bloom's level
Student Activities			
Student evaluation of peer's work using a rubric ranked with BBT	X		
Students ranked questions using BBT		X -Old exam questions	X -Old exam questions -GRE -Peer questions
Students created questions at each cognitive level using the BBT			X
Students answered questions at different cognitive levels		X	X
Reflect on faculty identified cognitive levels with which the student struggles		X	
Guided self-assessment of cognitive levels		X	X
X indicates that this activity was used in this classroom setting			

Strengths and challenges of each implementation strategy		
	Strengths	Challenges
Faculty Centered	-Helped faculty identify areas of cognitive weakness -Faculty analysis of data did not require class time	-Use of Bloom's is not made transparent to the student -Students need training in peer review to effectively evaluate other students' work -Providing written feedback on student research proposal drafts is very labor intensive
Faculty and Student Centered	-Helped students identify their cognitive weaknesses. -Offered targeted and focused study strategies to strengthen specific level of Bloom's.	-Students must make meaningful changes to established study habits. -Students must learn to differentiate between questions at each level of Bloom's
Student Centered	-Helped students learn to identify questions at different cognitive levels. -Students learned how to write study questions at different cognitive levels. -Activities provided students with knowledge to assess their understanding of material.	-Activities require a significant amount of time outside of lecture. -Students need training, inclusive of modeling, to write good exam questions at higher cognitive levels. -Students must be trained to effectively work in groups.