Exams on Demand: Using Templates to Write Multiple Equivalent Problems

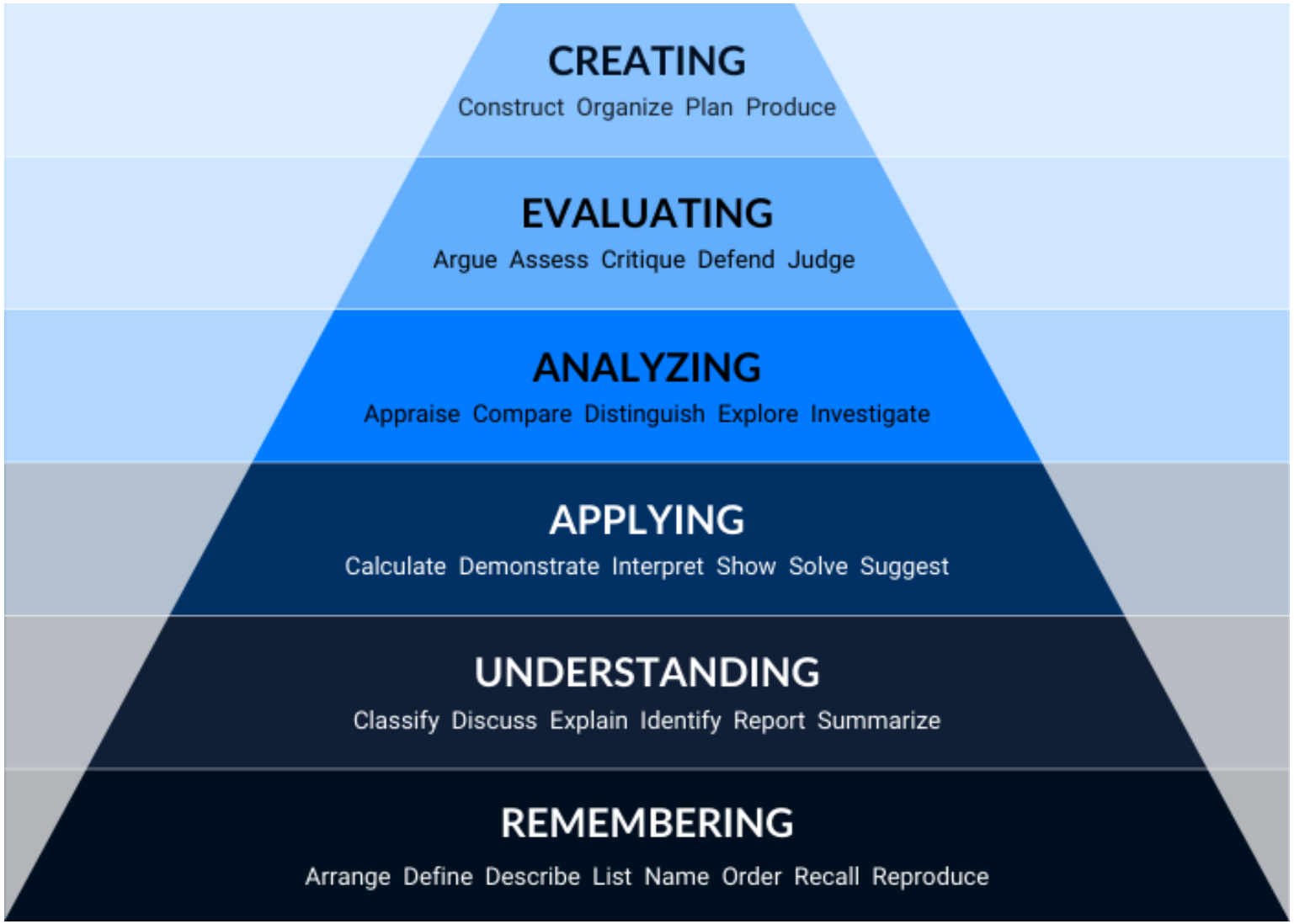
Gregory J. Crowther, Ph.D.

Everett Community College & University of Washington Bothell

Premises

(1) Good tests assess higher-order cognition (HOC).

(2) Good HOC questions are often hard to write.



Bloom's Taxonomy – image by Lorman Educational Services

Approach: Backwards Design + Transparency

- What kinds of problems should students be able to solve?
- Define each problem via 2 bundled parts:
  - the Learning Objective (LO)
  - specific examples of how this LO can be assessed
- Write test questions according to these definitions.

Approach: Backwards Design + Transparency = TQTs

- What kinds of problems should students be able to solve?

- Define each problem via 2 bundled parts:
  - the Learning Objective (LO)
  - specific examples of how this LO can be assessed

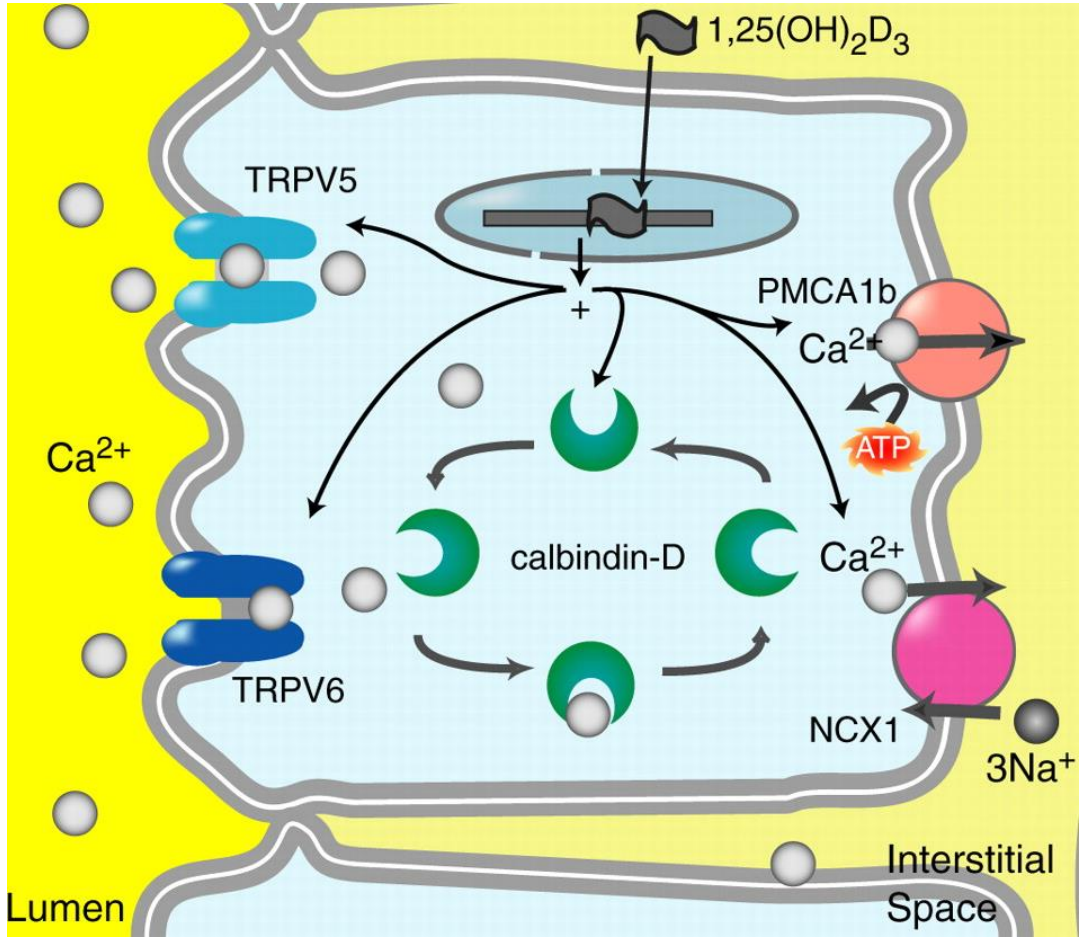
"Test Question Template" (TQT)

- Write test questions according to these definitions.

Crowther et al. (2020), *HAPS Educator* 24(1): 74-81; Crowther (2021), *CourseSource* 8: 42

TQT 3.2. Given a picture or description of a transport process, identify the type of transport that is taking place. Explain your reasoning.

- Example A: What kind of transport is represented by the dark blue structure (TRPV6)? Explain your reasoning.
- Example B: Phosphate (HPO_4^{2-}) is present outside a cell at a concentration of 0.1 mM and inside that cell at a concentration of 10 mM. By what process(es) is it most likely to enter the cell? Explain your reasoning.
- Example C: Make up an example (e.g., find another transport diagram) and ask your classmates!



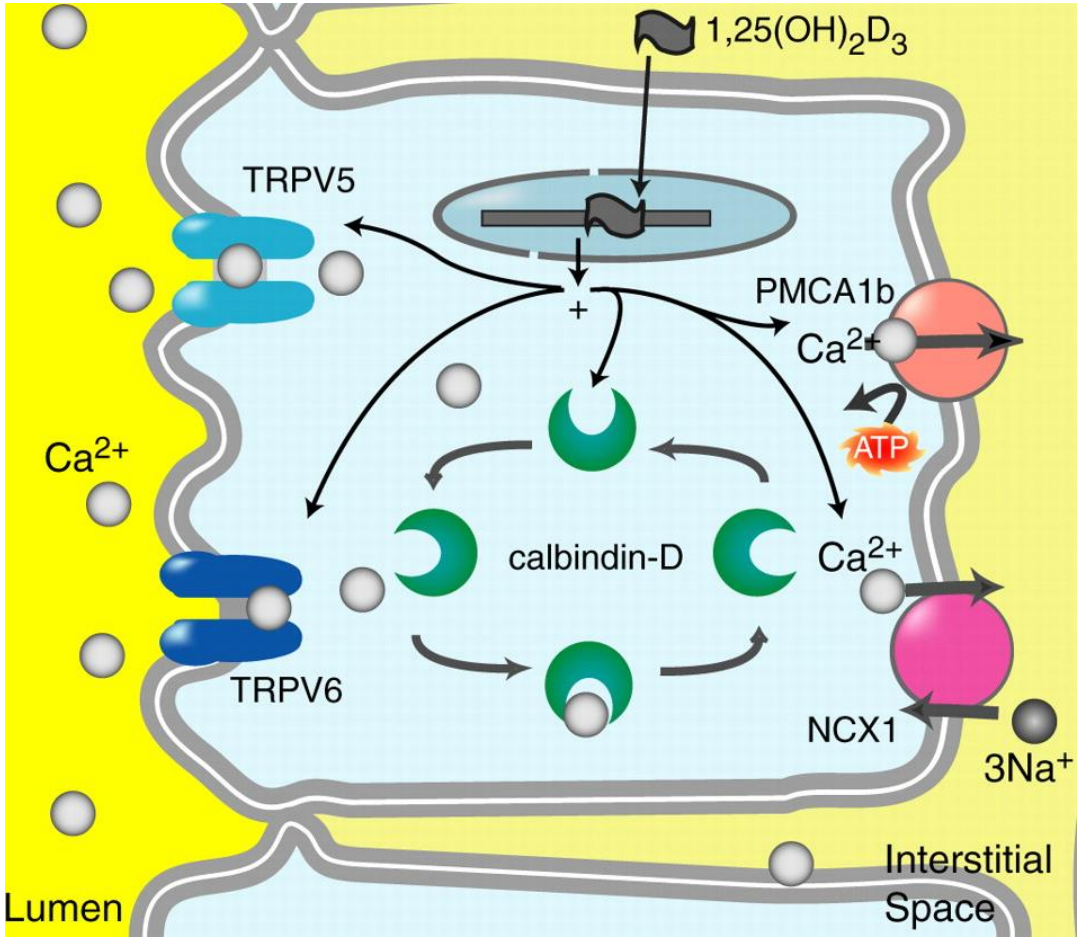
S. F. J. van de Graaf et al., *Am. J. Physiol.* 290: F1295-F1302, 2006

LEARNING OBJECTIVE

TQT 3.2. Given a picture or description of a transport process, identify the type of transport that is taking place. Explain your reasoning.

ASSESSING THE LEARNING OBJECTIVE

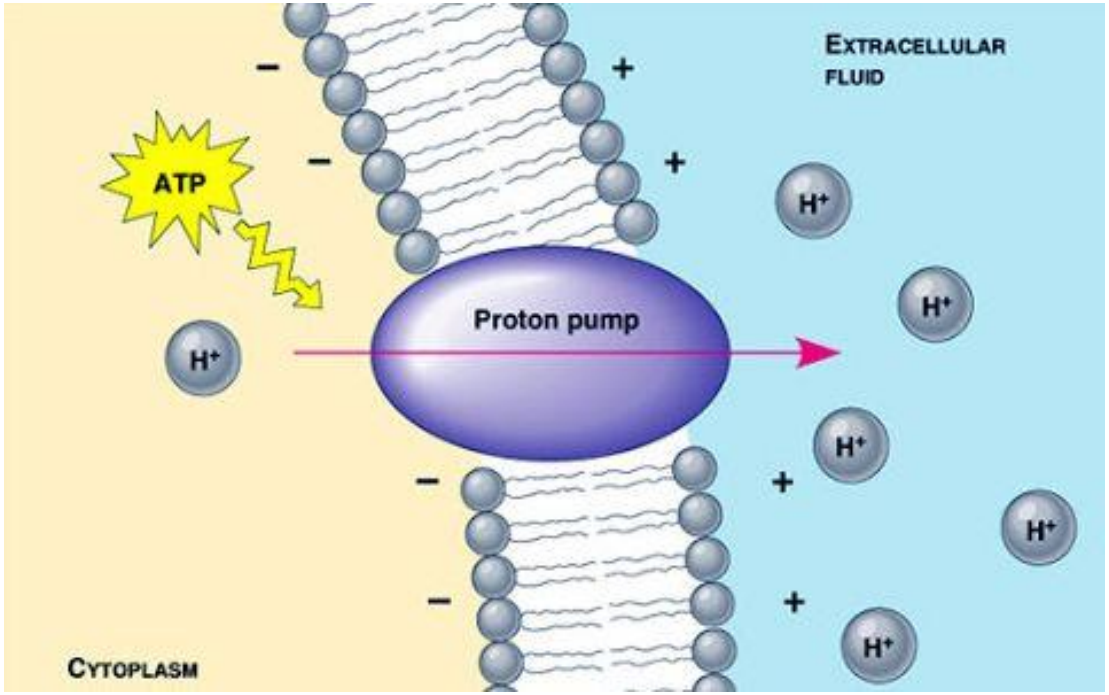
- Example A: What kind of transport is represented by the dark blue structure (TRPV6)? Explain your reasoning.
- Example B: Phosphate (HPO_4^{2-}) is present outside a cell at a concentration of 0.1 mM and inside that cell at a concentration of 10 mM. By what process(es) is it most likely to enter the cell? Explain your reasoning.
- Example C: Make up an example (e.g., find another transport diagram) and ask your classmates!



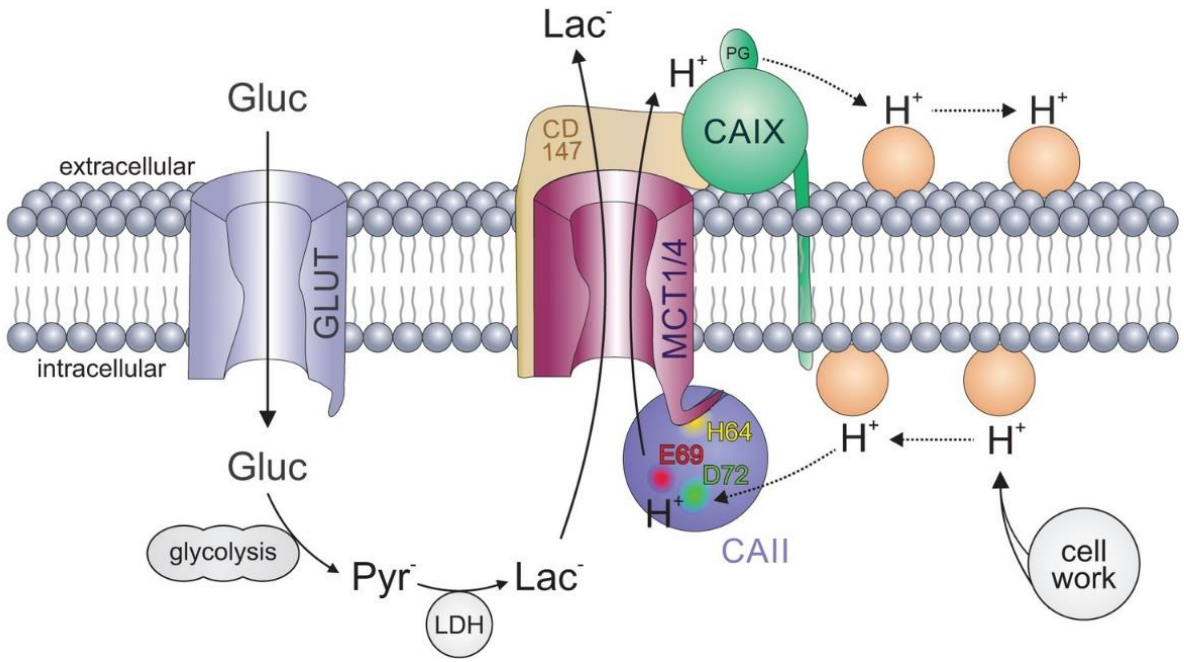
S. F. J. van de Graaf et al., *Am. J. Physiol.* 290: F1295-F1302, 2006

Fall 2020 Test Questions based on TQT 3.2

Is the movement of H^+ ions out of cells in the manner pictured below best considered simple diffusion, facilitated diffusion, primary active transport, secondary active transport, or exocytosis? Explain your reasoning.

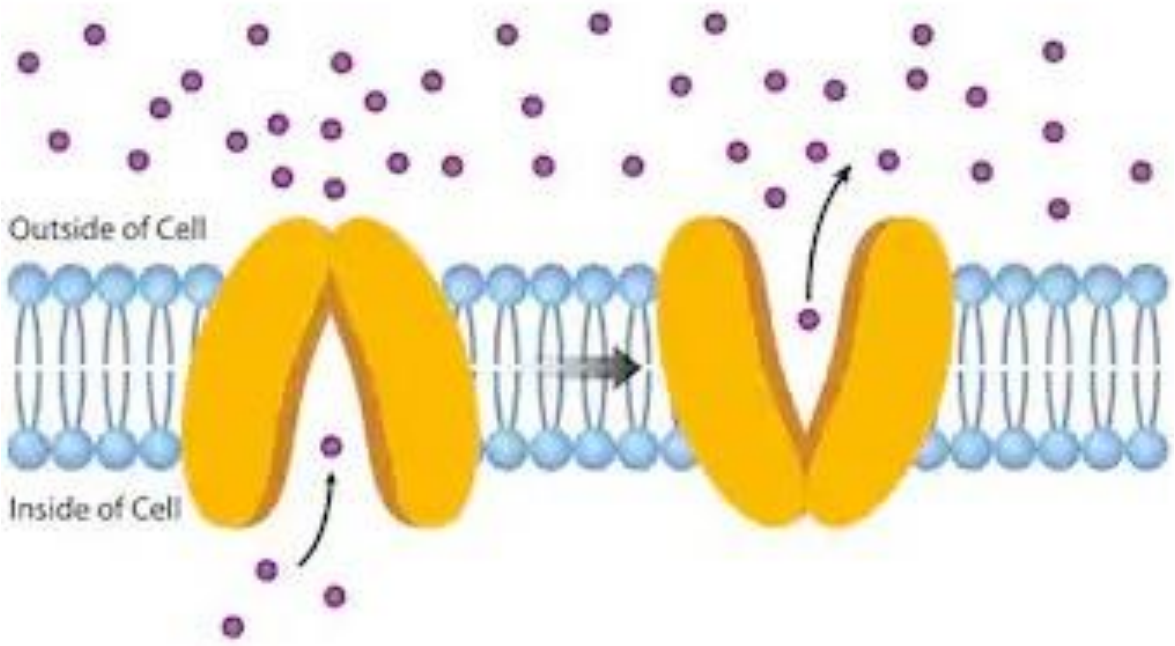


Lactate (Lac^-) goes through plasma membranes via the mechanism shown below. Based on this diagram, would you say that Lac^- crosses the membrane via simple diffusion, facilitated diffusion, primary active transport, secondary active transport, or exocytosis? Explain your reasoning.

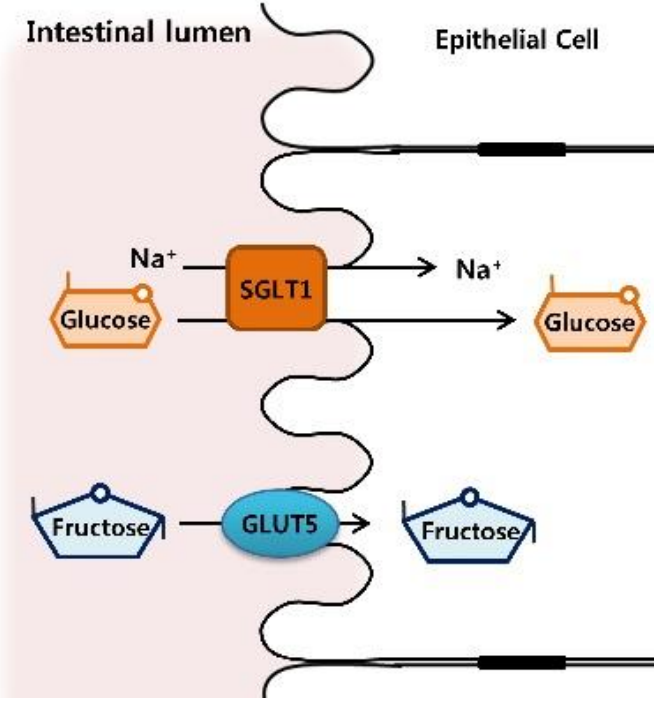


Winter 2021 Test Questions based on TQT 3.2

What kind of membrane transport process is illustrated below (left to right)? Explain your reasoning.



In the picture below, SGLT1 and GLUT5 are both involved in transport across a cell membrane. Are these two processes the same type of transport (simple diffusion, facilitated diffusion, primary active transport, secondary active transport, endocytosis)? Explain your reasoning.



TQT 11.1. Given an ion's intracellular and extracellular concentrations and a membrane potential, determine the direction of the electrical gradient, chemical gradient, and/or (if possible) electrochemical gradient acting on the ion.

- Example A: Imagine that [Fe^{3+}] is 4 nM inside the cell and 2 µM outside the cell. The membrane potential (V_m) is +30 mV at this moment. Which answer below correctly describes the gradients acting on this ion?
  - (A) The chemical and electrical gradients both drive Fe^{3+} into the cell.
  - (B) The chemical gradient drives Fe^{3+} into the cell; the electrical gradient drives Fe^{3+} out of the cell.
  - (C) The chemical gradient drives Fe^{3+} out of the cell; the electrical gradient drives Fe^{3+} into the cell.
  - (D) The chemical and electrical gradients both drive Fe^{3+} out of the cell.
- Example B: Imagine that [F^-] is 1 mM inside the cell and 0.1 mM outside the cell. The membrane potential (V_m) is -50 mV at this moment. Which answer below correctly describes the electrochemical gradient acting on this ion?
  - (A) The electrochemical gradient drives F^- into the cell.
  - (B) The electrochemical gradient drives F^- out of the cell.
  - (C) The chemical and electrical gradients drive F^- in opposite directions, so you'd need the Nernst equation to determine the direction of the electrochemical gradient.
- Example C: Make up an example and ask your classmates!

Test Questions based on TQT 11.1

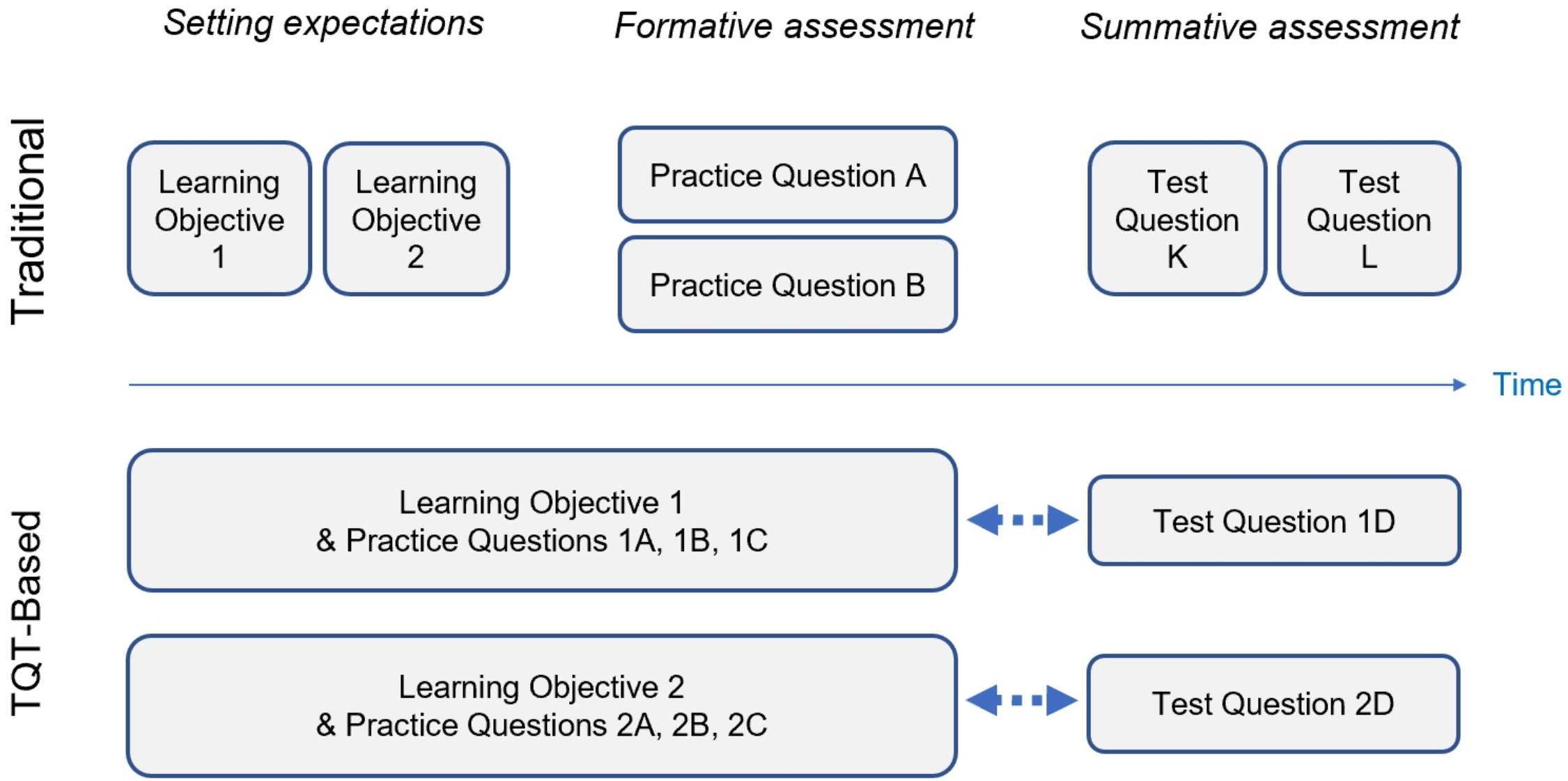
Imagine that [Mg^{2+}] is 0.5 mM outside the cell and 3 mM inside the cell. The membrane potential (V_m) is -70 mV at this moment. Which answer below correctly describes the electrochemical gradient acting on this ion?

- (A) The electrochemical gradient drives Mg^{2+} into the cell.
- (B) The electrochemical gradient drives Mg^{2+} out of the cell.
- (C) The chemical and electrical gradients drive Mg^{2+} in opposite directions, so you'd need the Nernst equation to determine the direction of the electrochemical gradient.

Imagine that [Br^-] is 0.2 nM inside the cell and 40 nM outside the cell. The membrane potential (V_m) is +15 mV at this moment. Which answer below correctly describes the gradients acting on this ion?

- (A) The chemical and electrical gradients both drive Br^- into the cell.
- (B) The chemical gradient drives Br^- into the cell; the electrical gradient drives Br^- out of the cell.
- (C) The chemical gradient drives Br^- out of the cell; the electrical gradient drives Br^- into the cell.
- (D) The chemical and electrical gradients both drive Br^- out of the cell.

Is this approach novel?



Crowther (2021), *CourseSource* 8: 42

TQTs Beyond Biology?

- Chemistry
  - Given a substrate A, a goal product B, and a list of available reagents, explain how to make B from A.
- Medicine
  - Given symptoms, propose and defend a diagnosis.
- Physics
  - Given information about a projectile in motion, solve for a missing value.
- Statistics
  - Given a question about data, select and perform an appropriate statistical test.

Conclusion

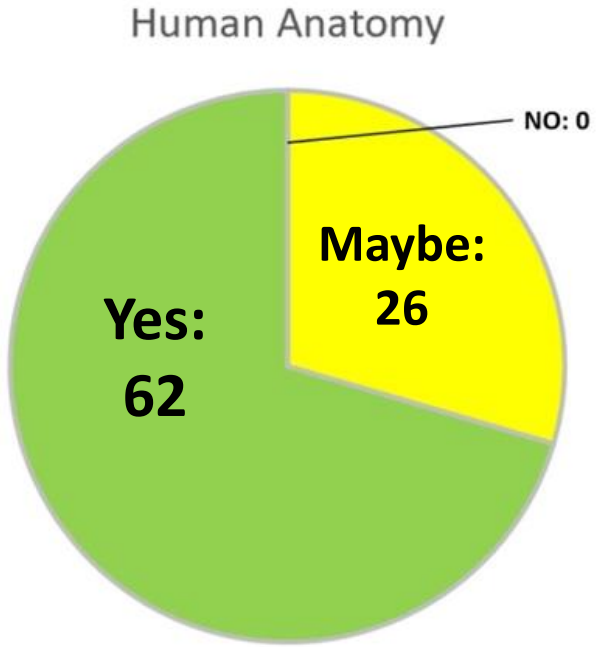
The impact of TQTs, for me:

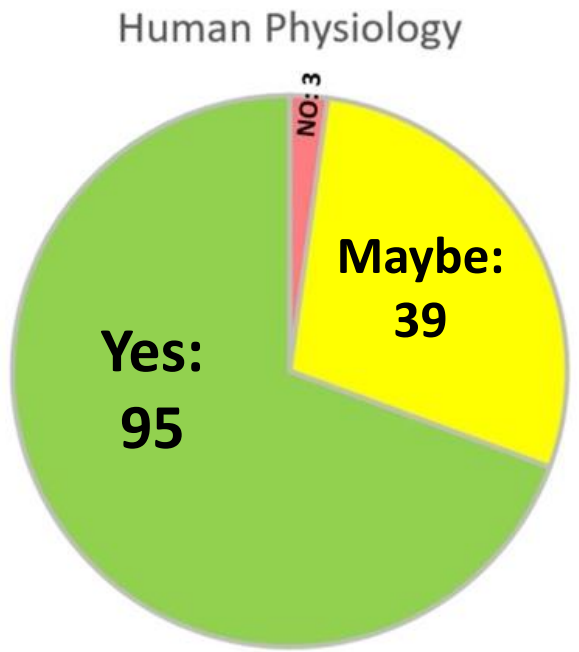
- fairer, better tests
- <u>faster</u> test-writing

more re-take options

more learning & growth

"If you had your choice, would you want instructors in your other science courses to provide you with TQTs (or something similar)?"





Evans et al., in review; data from 5 quarters (Fall 2020 through Fall 2021)

Acknowledgments

Kiki Jenkins (marine policy, Arizona State University)

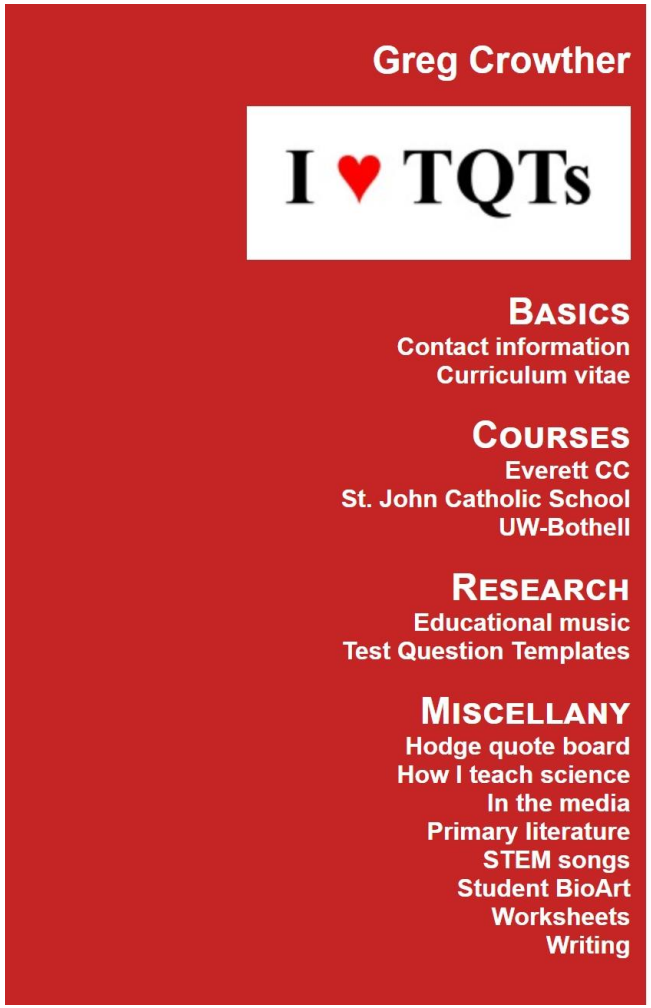
Katie Mattaini (biology, Roger Williams University)

Karen Perell-Gerson (biology, Georgia Gwinnett College)

Marney Pratt (biology, Smith College)

Want to know more?

Google “Test Question Templates” or email gcrowther@everettcc.edu



Test Question Templates

For many years, I struggled with a common teaching dilemma: how can I help my undergraduate students develop transferrable knowledge and skills in biology courses dominated by high-stakes tests that traditionally reward memorization above all else?

In 2019, with the help of **Ben Wiggins** and **Kiki Jenkins**, I had a breakthrough idea -- a framework that helps students prepare for interesting, complex test questions, while also making it easier for instructors to write such questions! I call the framework Test Question Templates (TQTs).

Fundamentally, a TQT is a student-facing resource that explicitly connects a Learning Objective (LO) with multiple specific examples of how that LO might be assessed on a test. TQTs thus show students what they will need to do on tests, and how to practice, without revealing all details of the tests. From the instructor side, TQTs' pre-specification of test question formats means that test-writing becomes more straightforward; with the freedom to vary certain details within a structured template, we can generate new questions each term with relative ease.

Beyond making tests less stressful and more rewarding for students and instructors, TQTs should generally promote students' transfer of knowledge to new contexts by encouraging practice on multiple examples with different surface features (**Kaminske et al. 2020**).

Since TQTs emphasize (A) abundant opportunities for collaborative student practice and (B) transparent alignment of practice and testing, they may be considered a cousin of **TILT**, **mastery grading**, **Deb Donovan's Learning Targets and Success Criteria**, and Ben Wiggins' public exams (**blog post**; ***bioRxiv* preprint**).

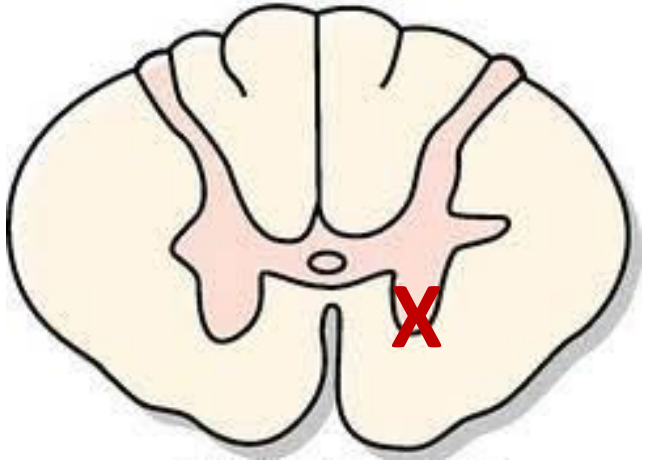
I welcome comments, questions, and comments-masquerading-as-questions! Feel free to email me at gcrowther at everettcc dot edu.

https://faculty.washington.edu/crowther/Research/TQTs.shtml

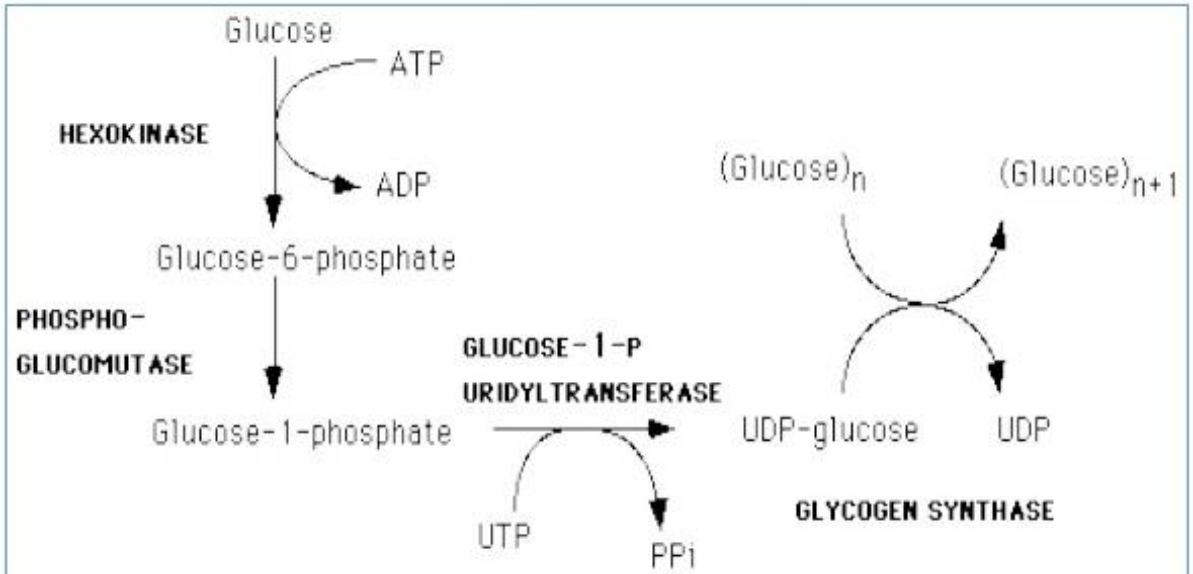
Building the perfect TQT

- Can your favorite problems be TQT-ized? (Do they represent examples of general types of problems?)
- **2-step problems: find "linkable" facts.**
- **Classify novel examples according to previously defined categories.**
- Analyze novel pictures.
- Solve math/graph problems.
- Navigate multi-step processes.
- Draw conclusions from evidence.

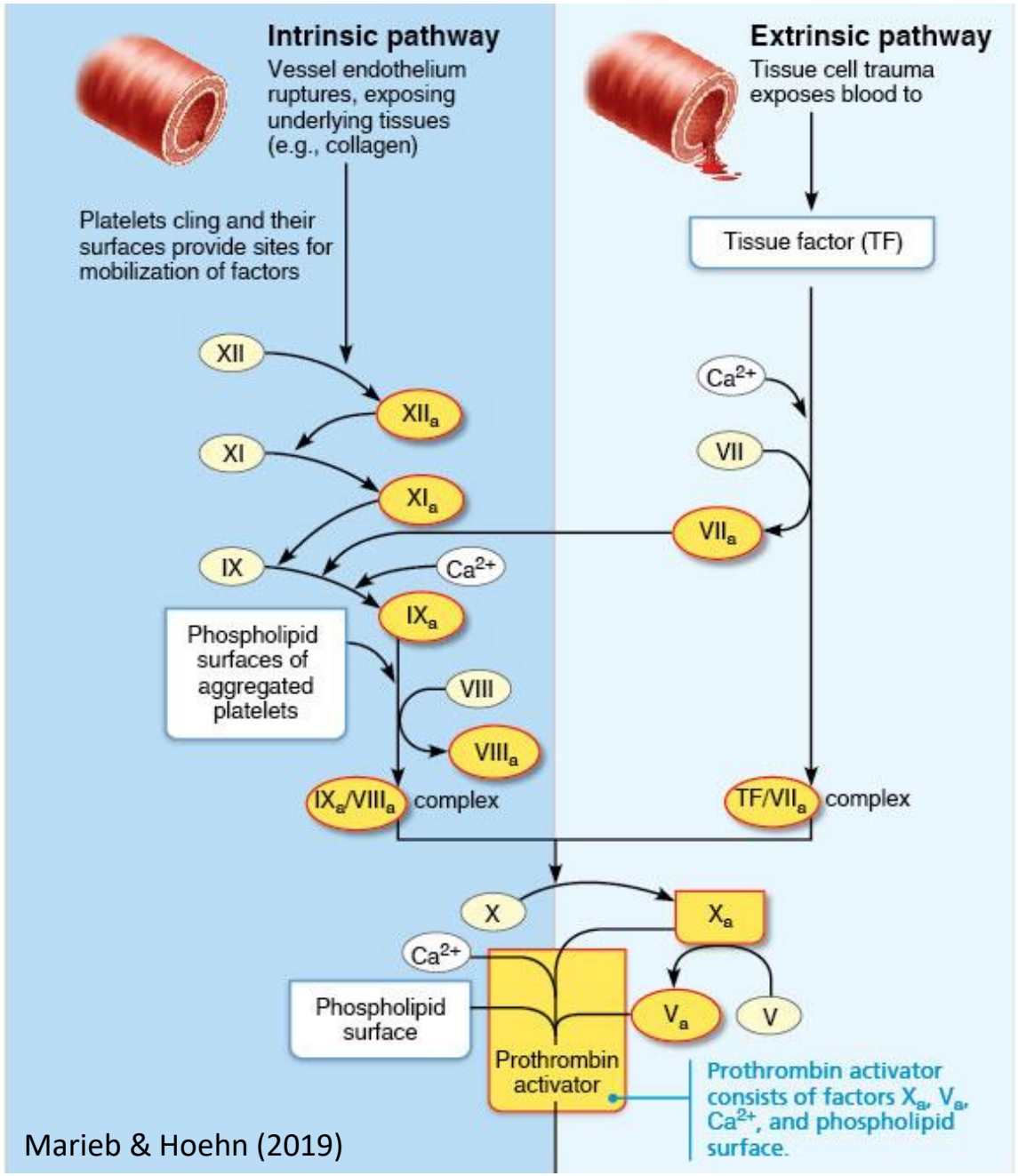
TQT 12.2. Given a picture or description of damage to a specific area of the spinal cord or a spinal nerve, predict the symptoms.



TQT 24.3. Given a biochemical pathway, classify it as anabolic or catabolic.

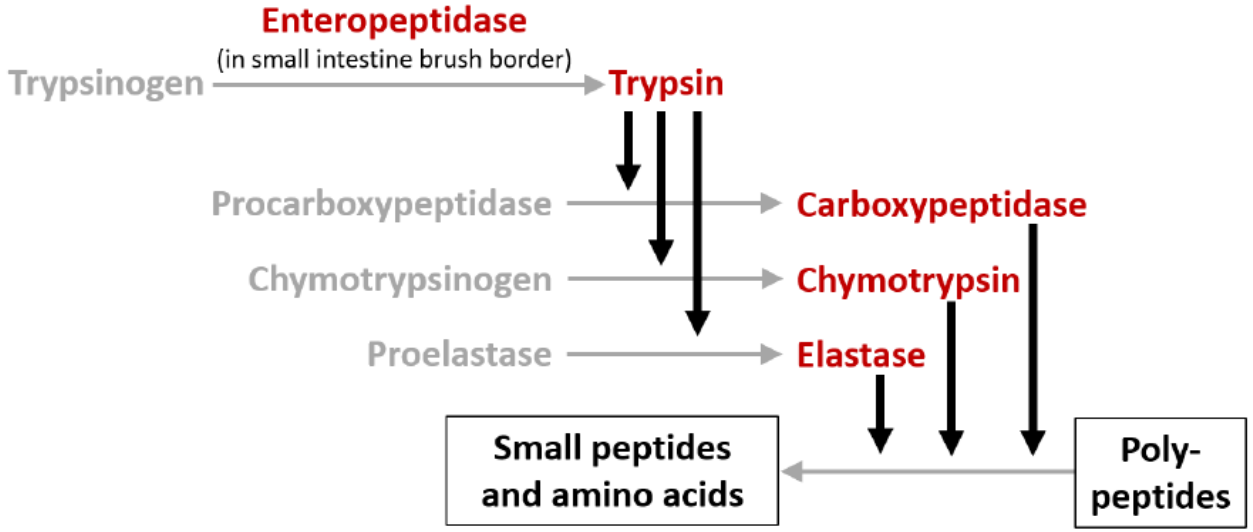


Activity/Study Guide (ca. 2018):



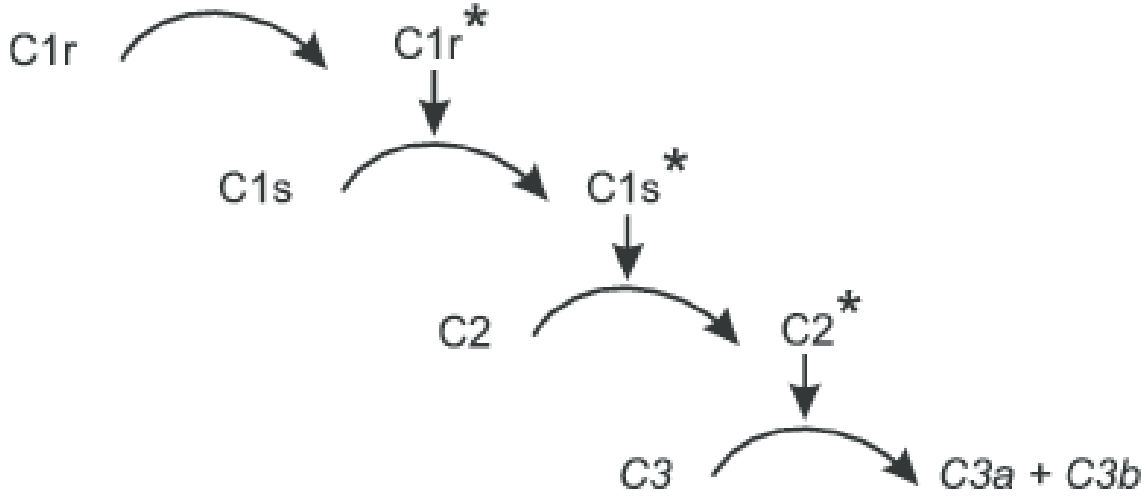
Marieb & Hoehn (2019)

Test (ca. 2018):

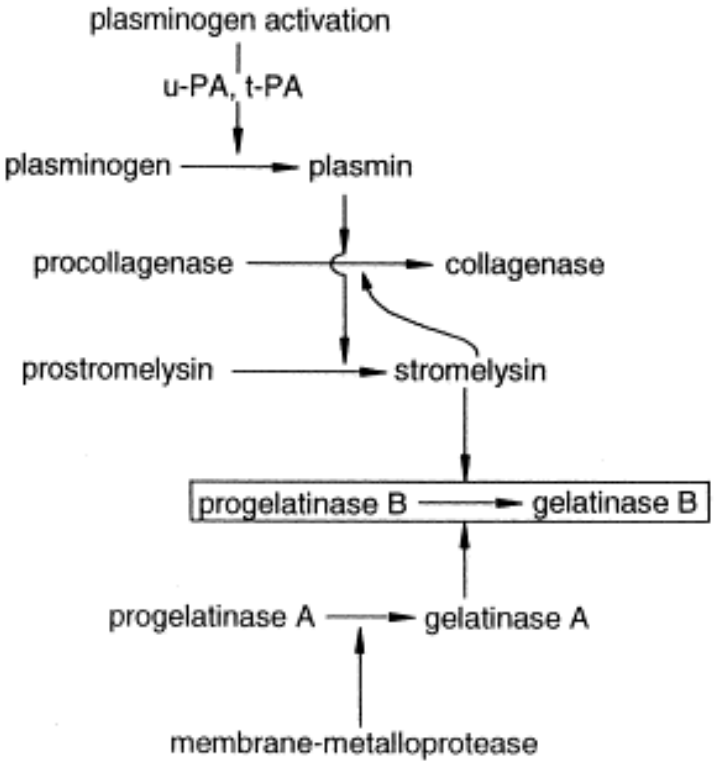


TQT 23.3. Given a diagram of a new-to-you protease cascade, answer questions about it, based on your experience with previous protease cascades (blood clotting, digestive proteases).

- Example A: Based on your knowledge of protease cascades, what do the asterisks (*) mean in the protease pathway below at left? Explain your reasoning.
- Example B: Based on your knowledge of protease cascades, explain the role of gelatinase A in the protease pathway below at right. How is it generated, and what does it do?
- Example C: Make up an example (go a Google Images search for "protease cascade"?) and ask your classmates!

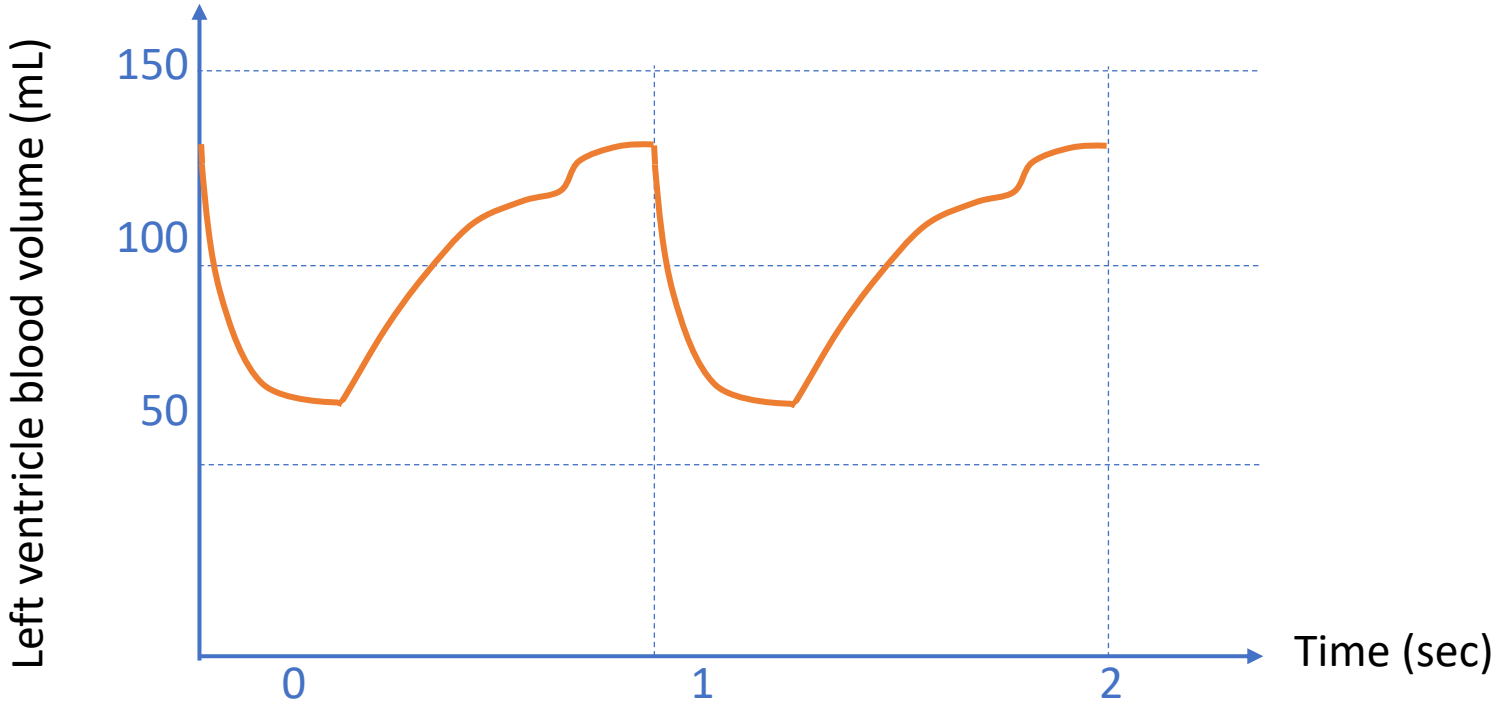


J.M. Dzik (2010), *Acta Biochimica Polonia* 57: 443-466;
P.E. Van den Steen et al. (2001), *Biochimica et Biophysica Acta* 1528: 61-73



TQT 18.7. Given information on left ventricular blood volume versus time, calculate cardiac output.

- Example A: See the graph below. What is the cardiac output? Explain your answer, including correct units.
- Example B: See the table at right. What is the cardiac output? Explain your answer, including correct units.
- Example C: make up an example and ask your classmates!



Time (sec)	LV blood volume (mL)
4.0	50
4.1	75
4.2	80
4.3	45
4.4	40
4.5	50
4.6	75
4.7	80
4.8	45
4.9	40
5.0	50
5.1	75
5.2	80
5.3	45