

# Building Critical Thinking Skills in Microbiology

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## Problem:

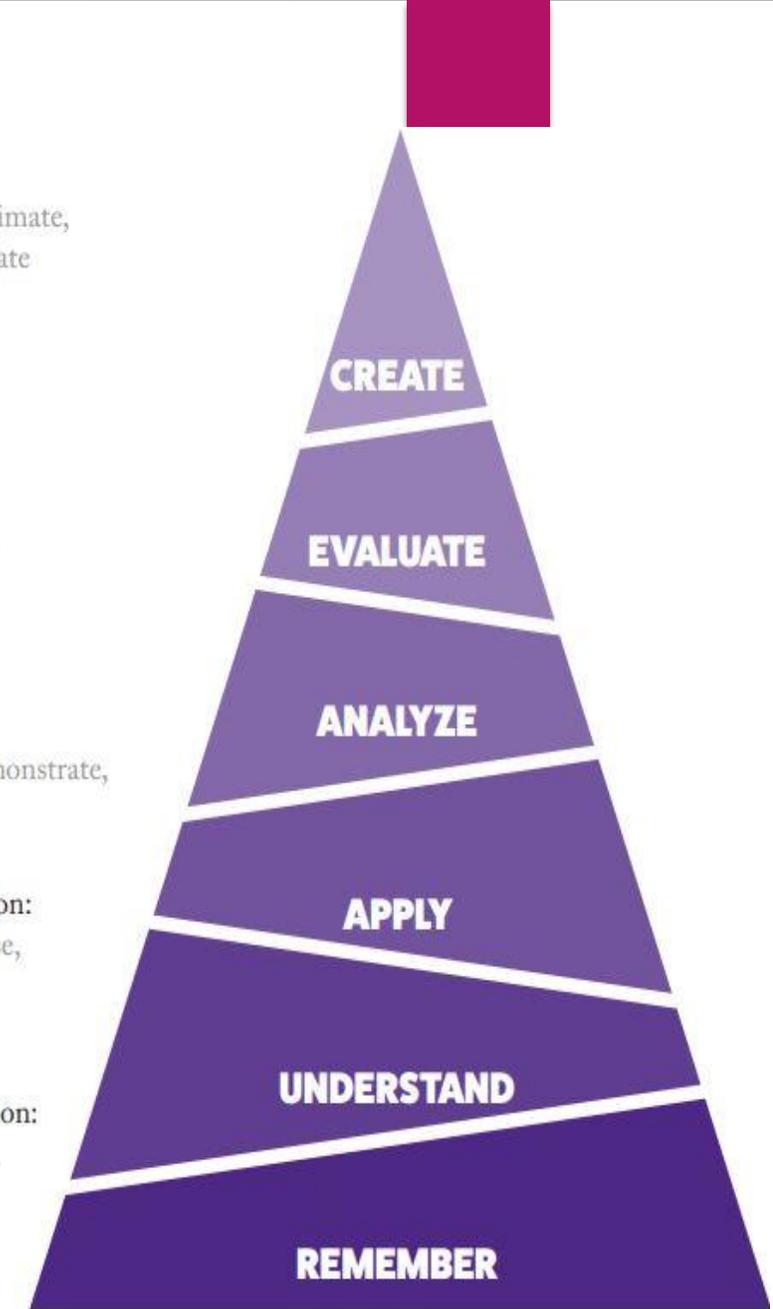
Students focus on memorization and simple understanding.

Students struggle to apply concepts, analyze situations, or evaluate/justify their reasoning.

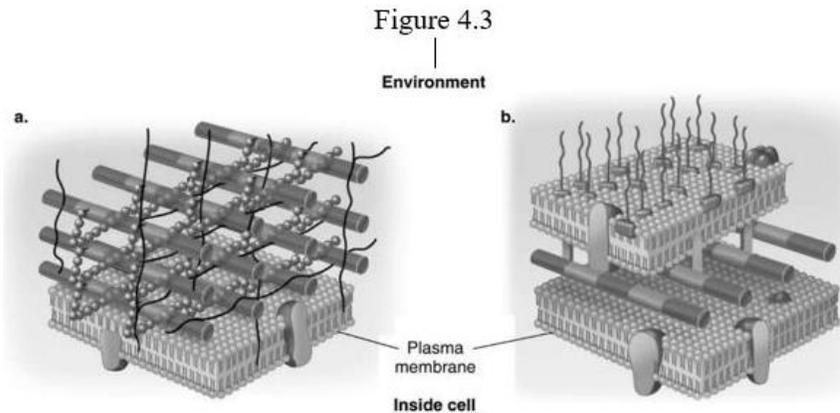
## Goal:

Help students build and improve their critical thinking skills

- ▲ **CREATE** - Build on the information: design, hypothesize, invent, develop, estimate, theorize, elaborate, test, improve, originate
- ▲ **EVALUATE** - Justify the information: judge, critique, justify, recommend, criticize, assess, disprove, rate, resolve
- ▲ **ANALYZE** - Question the information: analyze, categorize, separate, dissect, simplify, deduce, infer
- ▲ **APPLY** - Use the information: answer what if, use, compute, solve, demonstrate, apply, construct, build, experiment
- ▲ **UNDERSTAND** - Explain the information: answer why and how, explain, paraphrase, describe, illustrate, compare, contrast, interpret, outline, map, rephrase
- ▲ **REMEMBER** - Memorize the information: answer what, remember, list, label, state, define, choose, find, select, match



# Multiple Choice with Reasoning to Build Critical Thinking Skills



3. In Figure 4.3, which diagram of a cell wall has a structure that protects against osmotic lysis?

- a. a
- b. b
- c. both a and b
- d. neither a nor b
- e. The answer cannot be determined based on the information provided.

**Explain why the chosen answer is correct and why the other responses are incorrect.**

▶ Strategy implemented in one of two Fall 2022 BIOL 210 – Microbiology sections

▶ Scaffolded Approach

▶ Homework

▶ Introduced format

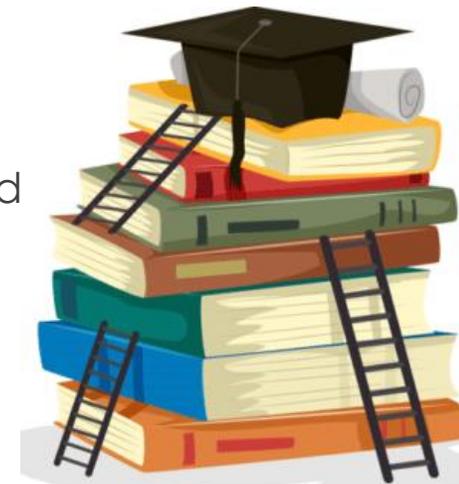
▶ Detailed feedback provided

▶ Low Stakes

▶ Assessment on Exams

▶ Reasoning is graded

▶ Detailed feedback provided



# Strategy Inspired by.....

- ▶ **Ginger Robinson's SET presentation "Critical Thinking in Criminal Justice: Multiple Choice or Multiple Points of Confusion?", January 2022**
- ▶ **Teaching Change – José Antonio Bowen**
  - ▶ CH 11 Designing Change (p387) – "Create structure and scaffolding. Higher numbered courses should require more difficult thinking, not just more difficult content. Increase cognitive complexity through a sequence of courses with more self directed work, increased ambiguity...."
- ▶ **Creating Wicked Students – Paul Handstedt**
  - ▶ Creating Authoritative Exams – Prompting Critical Thinking Through Multiple-Choice (p. 92) "if content testing is all we do, we're missing an opportunity to expose our students to the kind of complex situations that exist in many settings beyond the academy. (pg. 93) "...place questions with multiple reasonable solutions toward the end of an exam, followed by a short answer question....briefly justify the choice you made in the previous question....to get a sense of how students are thinking..." Used a combination of Variations 3 & 4 (p. 96)
- ▶ **The Miniature Guide to Critical Thinking Concepts & Tools – Richard Paul & Linda Elder**
  - ▶ A Checklist for Reasoning (pgs. 6-7)
- ▶ **Engaged Teaching by Elizabeth Barkley & Claire Howell Major**
  - ▶ Helping Students Acquire Effective Learning Strategies (p.46), "design assessment tasks to mirror and reward deep learning objectives" and "Design higher quality assessments – ones that require students to engage with problems and apply their learning rather than encouraging them to memorize facts".
  - ▶ Assessing Grading and Learning (p. 91) "Effective teachers understand that the greatest value they can contribute to a student's learning process may be the careful observation, analysis, and feedback that enables the learner to improve. Students who recognize what they do and do not know are better able to focus their learning."

# Early Homework Examples

## Feedback

### Building critical thinking skills

10. Which type of stain is most helpful in helping clinicians to decide which antibiotic to prescribe for a bacterial infection?
- a. negative stain
  - b. simple stain
  - c. Gram stain
  - d. endospore stain
  - e. flagella stain

**Explain why the chosen answer is correct and why the other responses are incorrect.**

Gram stains are the most useful in helping clinicians decide which antibiotic to prescribe because they can help diagnose the presence of bacteria in an infection. It will be helpful for doctors to diagnose the illness soon so that they can administer medication. The other stains will not be fast enough to be used to find if bacteria is present.

Excellent start! All of the answers are correct!! Some of the explanations are stronger than others. Q3 - outlines evidence for each answer nicely.

Providing solid evidence both for an answer and against other answers is essential when I ask these types of questions. More detail could be provided for some questions - see below.

In Q4 & 5 - tell me why the other answers are wrong, in other words, what did the other scientists prove or accomplish? Q7 - Scanning EM uses electrons, why isn't it the correct answer? Q10 - use the textbook to find more evidence - CH3 & 4. List what type of evidence these other stains provide. Tell me what the Gram stain is staining and why that helps doctors

### Strong critical thinking skills

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  - e. flagella stain

**Explain why the chosen answer is correct and why the other responses are incorrect.**

Negative staining is used for viewing of bacterial cell morphology and size. Simple staining can be used for all types of bacterial cells, highlights the entire microorganism to visualize cell shapes and structures. It's a simple technique because only one dye is used, direct because the actual cell is stained and a mordant may be used to hold the stain or coat the specimen to enlarge it. **A gram stain is most often used to find if someone has a bacterial infection, the test will show if the infection is gram-positive (thick peptidoglycan cell wall) or gram-negative (thin peptidoglycan cell wall with layer of lipopolysaccharides). Gram-positive bacteria tend to be killed more easily by penicillin, lysozyme and detergents.** Endospores are resistant, dormant structures inside some cells that cannot be stained by ordinary methods. An endospore stain is used to demonstrate endospores forming within vegetative cells and make free spores easy to detect. Flagella are structures of locomotion. A flagella stain uses a mordant and carbolfuchsin to thicken appearance of flagella, making them visible under the light microscope.

## Feedback

Outstanding job! Your explanations provide evidence that demonstrate a strong command of the information. Keep this up and you will be well prepared for the exam!

# Early Exam Examples

30. Imagine that you are Gram staining a mixed culture of both gram-positive and gram-negative bacteria and you accidentally omitted the iodine (mordant) step. What colors would the bacteria on your slide appear to be?

- A. The gram-positive bacteria would be purple and gram-negative bacteria would be pink
- B. All of the bacteria would look purple
- C. All of the bacteria would look pink
- D. The bacteria would not be stained at all (clear)

0/3

Explain your reasoning for choosing this response.

The bacteria would not be stained because....? Where is the rest of your answer? Did you forget to come back? Remember the mordant is the "cement". If it is missing the crystal violet won't be trapped in the G<sup>+</sup> cell wall. Therefore all cells will be decolorized and then stained pink by safranin.

31. If a cell is starved for ATP, which of the following pathways would be most likely to shut down?

Building critical thinking skills

Strong critical thinking skills

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3/3

Explain your reasoning for choosing this response.

Iodine in gram staining ensures that the crystal violet gets absorbed into & trapped in the peptidoglycan cell wall, in gram positive cells. Without this step all stained cells will wash off in the decolorization process & everything will stain pink.

If steps done accurately gram (+) → purple, gram (-) → pink.

31. If a cell is starved for ATP, which of the following pathways would be most likely to shut down?

# Examples of Improved HW Critical Thinking

Q9  
HW 6

9. Antibiotics can lead to septic shock if used to treat
- Viral infections
  - Gram-negative bacterial infections
  - Helminth infections
  - Gram-positive bacterial infections
  - Protozoan infections

**Explain why the chosen answer is correct and why the other responses are incorrect.**

Antibiotics can treat bacterial infections but are ineffective against most gram-negative bacteria. When Antibiotics are used to treat gram-negative bacteria, they can also kill off the beneficial bacteria that normally live in the body. This can lead to an overgrowth of gram-negative bacteria and an increase in endotoxins. These endotoxins can trigger an immune system response that can lead to septic shock. Septic shock is the last stage and the most fatal. Antibiotics are also ineffective against viruses and that can cause sepsis. Sepsis is an early stage and is not as fatal as septic shock. Helminth infection is caused by a parasitic worm and doesn't lead to septic shock. Gram positives can be treated with some antibiotics. Some protozoan infections can be treated with antibiotics.

Q16  
HW 6

16. What type of immunity results from vaccination?
- Innate immunity
  - Naturally acquired active immunity
  - Naturally acquired passive immunity
  - Artificially acquired active immunity
  - Artificially acquired passive immunity

**Explain why the chosen answer is correct and why the other responses are incorrect.** Vaccines and injections can provide artificially acquired active immunity, which involves the introduction of a foreign substance into the body. As a result of exposure to a pathogen, such as a virus or bacteria, the body produces antibodies. Immune system antibodies attach to pathogens and destroy them, keeping the body safe from disease. People tend to use this type of immunity to protect themselves against dangerous diseases and try to achieve herd immunity.

Feedback

Q9 - the response doesn't get to the root of WHY gram negative bacteria release endotoxins. Make a connection with the fact that the endotoxin is part of their cell wall structure.

Feedback

Q13 - Nice! It would be a good idea to mention the outcomes of the complement cascade and the fact that C3 activation leads to cytolysis, inflammation, and opsonization.

Q16 - Nice. Consider telling me how passive immunity is different from active immunity.

Q17 - Nice!

# Late Semester Exam Examples

37. Which of the following is an example of a poor antigen?

- a. glycoproteins
- b. whole fungal cells
- c. glycogen
- d. enzymes

Explain your reasoning

0/3 Antigens are most of the times, proteins. Fungal cells as a whole cannot be categorized as one and they are too large to be an effective antigen because it would make them a target. Whole cells have many epitopes making them a good antigen. Glycogen is repeating chain of glucose molecules - no variation + carbs are not very antigenic alone.

## Weak vs Strong Examples

35. Cholera toxin polypeptide A binds to surface gangliosides on target cells. If the gangliosides were removed,

- a. polypeptide A would bind to target cells
- b. polypeptide A would enter the cells
- c. polypeptide B would not be able to enter the cells
- d. *Vibrio cholera* would not produce cholera toxin

Explain your reasoning

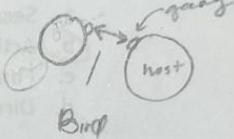
3/3 AB binding requires <sup>polypeptide</sup> A to be able to bind to the target cell before injecting polypeptide B into the host. Without the presence of gangliosides, polypeptide A would not have a receptor to bind to, and therefore polypeptide B cannot enter the target cell.

35. Cholera toxin polypeptide A binds to surface gangliosides on target cells. If the gangliosides were removed,

- a. polypeptide A would bind to target cells
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- c. polypeptide B would not be able to enter the cells
- d. *Vibrio cholera* would not produce cholera toxin

Explain your reasoning

2.5/3 If the host cell does not have the necessary target for binding then the toxin won't be able to bind since the site is not present. - link this to B gaining access + action.



Progress  
Example

# Assessment



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- **COMPARED FINAL GRADES**
- **EVALUATED INDIVIDUAL STUDENT PROGRESS**

## ***Average Qualitative Reasoning Scores (QRS) for each HW and Exam***

0 = no reasoning provided

1 = limited reasoning, such as restating the chosen answer

2 = moderate reasoning, such as evidence of why 1-2 other options are incorrect

3 = strong reasoning, such as evidence to support correct response and eliminate other responses.

## ***Compared QRS scores on unit HW to unit Exams***

## ***Compared average QRS HW/Exam scores from the first half of the semester to the second half.***

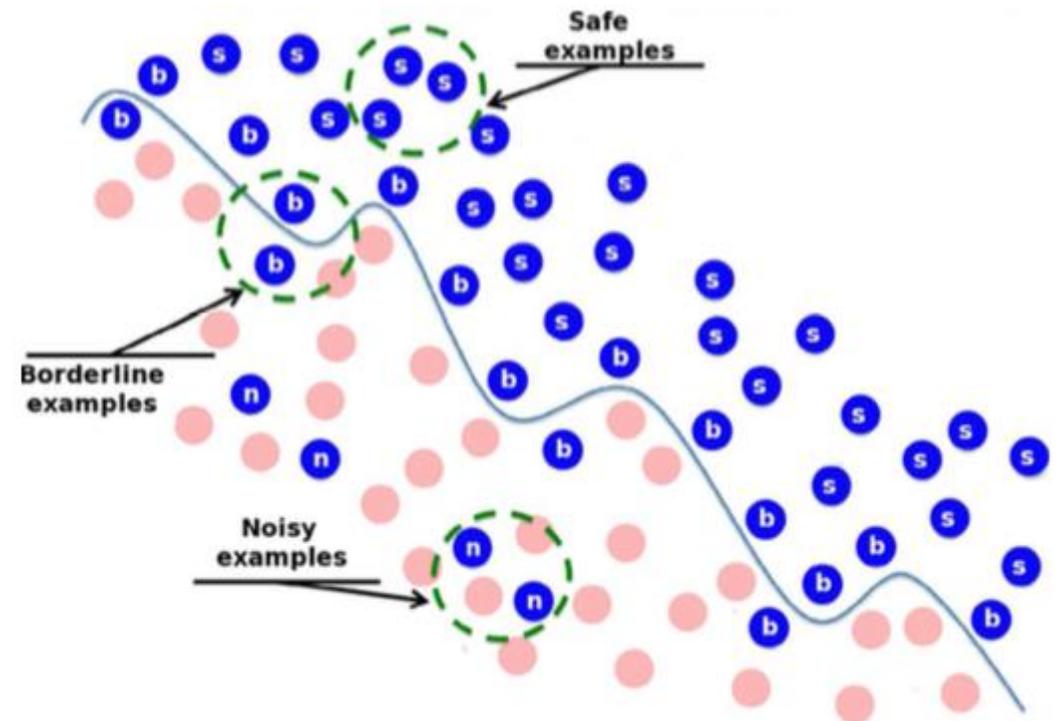
- **SURVEY**

# Outcomes – Grades/Individual Progress

	F21 Control	SP22 Control	F22 Control	F22 Experimental
AVG Grades	81.3	70.2	72.9	69.6

## Individual Progress - Qualitative Reasoning Scores

- ▶ No overall class trends comparing first/second half of the semester QRS scores.
- ▶ Individually, QRS scores were fairly predictive of success level on exams.
  - ▶ Opportunity for early intervention
  - ▶ Good tool for teaching positive learning strategies
  - ▶ Helpful in identifying misconceptions

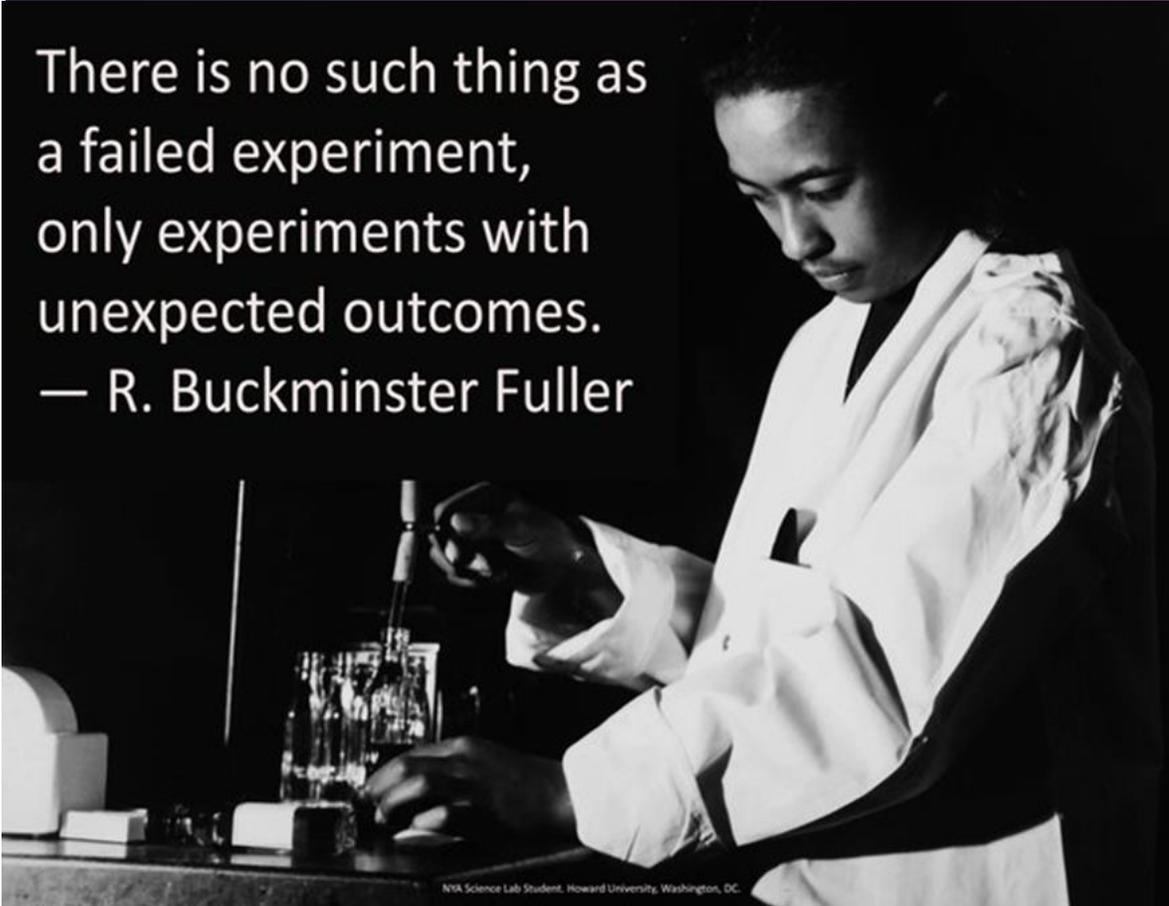


# Survey Results

Questions – Completed by 10/16 students	Average Score
Helpful in checking my knowledge of concepts.	4.2/5
Helped be to better understand the concepts.	3.6/5
Helped prepare me for exams.	4.1/5
I found the feedback improved my understanding of the concepts.	4.1/5
I found the feedback helped prepare me for exams.	4.3/5
I feel my critical thinking skills improved.	3.3/5
I evaluate MC options and apply reasoning more than I did before using this approach.	3.3/5

# Unexpected Outcomes

There is no such thing as  
a failed experiment,  
only experiments with  
unexpected outcomes.  
— R. Buckminster Fuller



## LACK OF PARTICIPATION IN REASONING ON HW AND EXAMS

### Skipping reasoning on HW

Time?

Focus on points vs learning?

Didn't understand the value of the  
exercise?

### Skipping reasoning on exams

Time?

Level of preparation?

Lacked knowledge to answer the question?

# Future Directions



- ▶ Encourage time management
- ▶ Discuss the value of this exercise
- ▶ Incentivize completion of reasoning
- ▶ Share Qualitative Reasoning Score rubric and scores to encourage growth
- ▶ Share the *Miniature Guide to Critical Thinking*
- ▶ Define critical thinking & connect to employer expectations
- ▶ Survey student perceptions/understanding of critical thinking



# Final Thoughts

- ▶ Grateful for:
  - ▶ My SET colleagues
  - ▶ Community that SET creates
  - ▶ The opportunity for exploration & reflection
  - ▶ Joan's leadership, guidance, and support!

