The Operon Concept Inventory

Measuring Targeted Learning Gains in Microbiology

Jared Taylor, Elizabeth Imrie, George Spiegelman

(CWSEI and the Department of Microbiology and Immunology)

Carl Wieman Science Education Initiative

UBC Life Sciences

The Operon Concept

- The concept of operons is an essential component of many microbiology-based courses, and is encountered by biology students a number of times.

- For example, many UBC biology students first encounter operons in Biology 112, and again in later courses such as Microbiology 325.

The Operon Concept

- An “operon” is any group of genes within bacteria that are controlled by common regulatory features.
- Operons are taught as a way of introducing and teaching the concept of gene regulation within bacteria, and there are many examples of operons that are controlled by different mechanisms and conditions.

Understanding Operons

- Understanding operons requires students to understand various other topics such as:
  - Transcription (mRNA production).
  - Translation (protein production).
  - Chemical intermolecular interactions between:
    - Proteins and other proteins
    - Proteins and DNA
    - Proteins and small molecules
  - Equilibria.
  - Membrane transport.

The Operon Concept Inventory

- Students typically have a hard time understanding operons and as a result may benefit from activities designed to increase their learning with operons.

- In order to measure the effectiveness of these activities, we developed a series of questions aimed at measuring how well students understand operons, called the Operon Concept Inventory.

Operon Misconceptions

- The OCI was developed by analysing a large number of student responses to operon-related quiz questions (to identify misconceptions).

- Multiple choice questions were developed to target these misconceptions, and each distracter was carefully developed in order to highlight what type of misconception each student has.

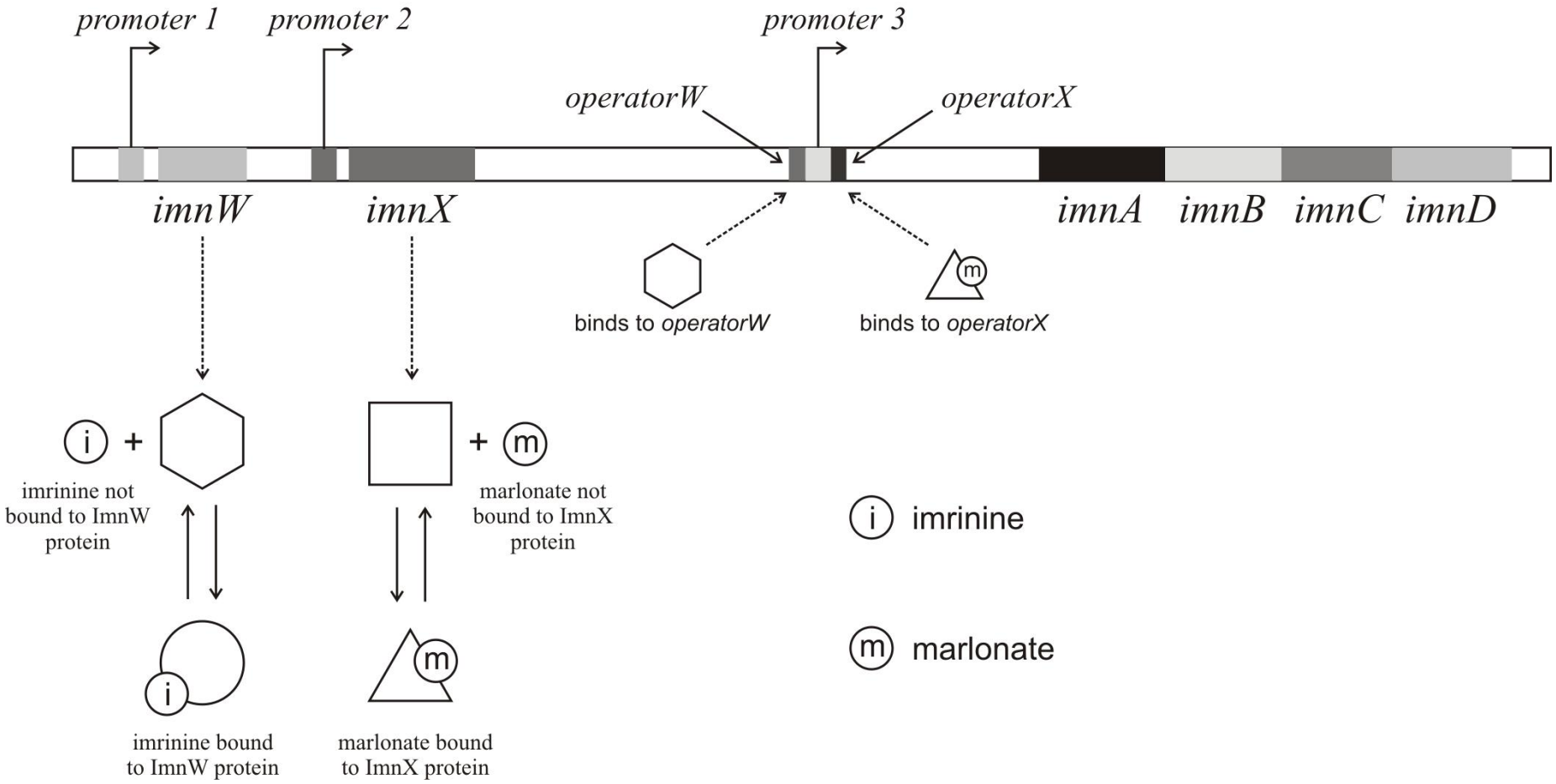
The Imrinine (*imn*) Operon

- The OCI presents students with a fictitious operon that has realistic features but is unlike any operon they have encountered.
- In order to answer the questions, the students must analyse the information and determine how the regulatory features interact with each other.
- Students cannot answer the questions by recalling information. Instead they must transfer and apply previously learned information.

The following questions are based on the diagram shown below. The diagram shows the region of a bacterial genome containing the imrinine (*imn)* operon and regulatory proteins. The genes *imnW* and *imnX* encode two regulatory proteins that affect transcription of the *imn* operon. The imrinine operon encodes proteins that allow bacterial cells to break down a carbon/energy source called **imrinine**. All of the genes are indicated by a solid coloured box and gene name in the diagram. The locations of the promoters are indicated by bent arrows.

The transcription of the *imn* operon is controlled by the presence of imrinine and another food molecule known as **marlonate**. When both marlonate and imrinine are available, bacteria cells will use marlonate as a carbon/energy source instead of imrinine. For each of the questions assume all other essential nutrients are always present.

NOTE: this operon may not be regulated in a similar way to any operons you have seen before.

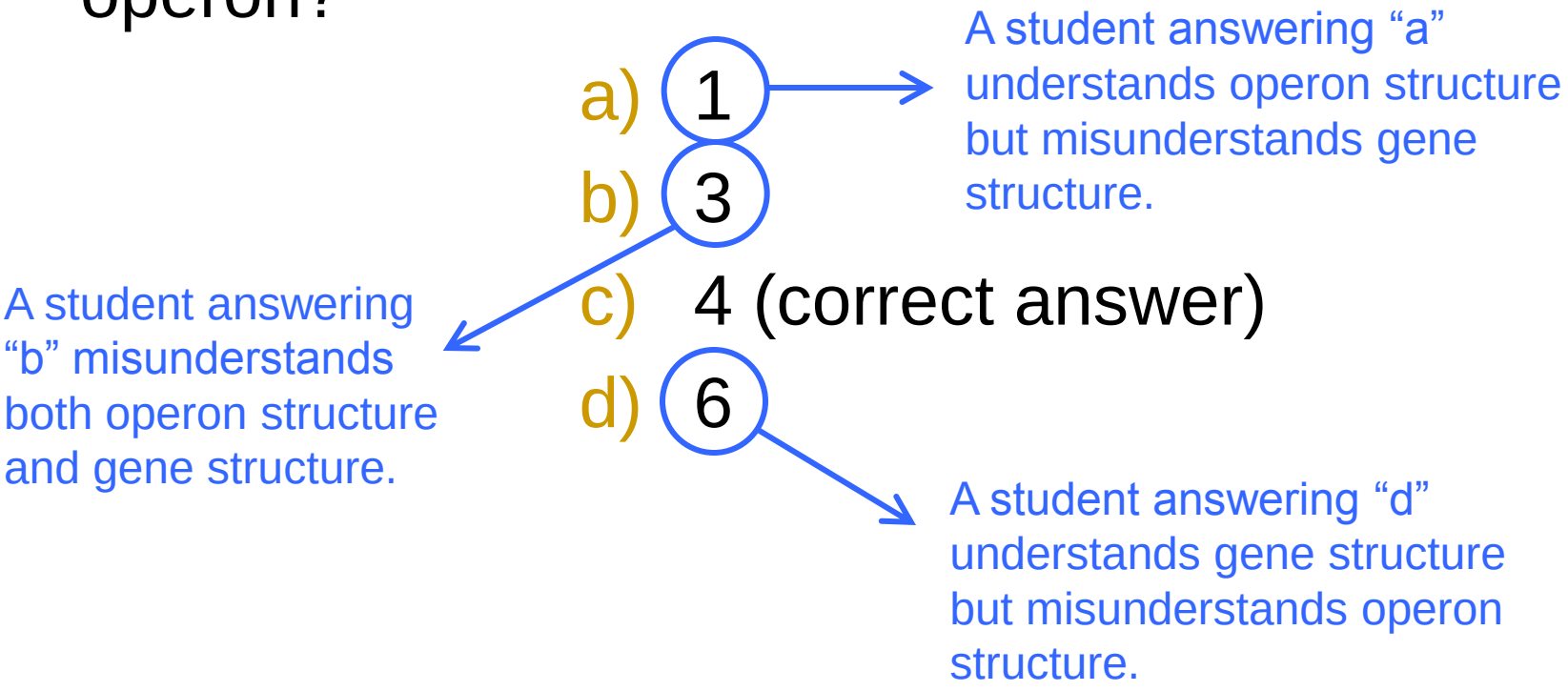

promoter 1
promoter 2
promoter 3
operatorW
operatorX
imnW
imnX
imnA
imnB
imnC
imnD
binds to operatorW
binds to operatorX
i
+
imrinine not bound to ImnW protein
+
m
marlonate not bound to ImnX protein
imrinine bound to ImnW protein
marlonate bound to ImnX protein
i imrinine
m marlonate

The OCI Questions

- The OCI uses two groups of related questions that target student understanding of:
  - Operon structure
    - Five questions probe student understanding about basic operon structure and related elements. How the students answer these questions reveals which misconceptions they have about operon and gene structure, bacterial transcription, and bacterial translation.
  - Operon regulation
    - The remaining 17 questions probes the ability of the students to transfer their understanding of operons in order to determine how the OCI operon is regulated. Students need to understand the “logic” of operons to answer these questions.

Operon Structure Example Question

- How many start codons are there in the *imn* operon?



Operon Regulation Example Question

Suppose a deletion mutation removes *operatorW* in some cells. Assume that only marlonate is available to these cells. Which of the choices makes the following statement accurate?

The cells will have _____ transcription of the *imn* operon due to the_____.

A student answering “b” understands the logic of operon regulation, but misunderstands which factors are important for regulation.

a) …a very low (basal) level of….presence of marlonate. (correct answer)

b) …a very low (basal) level of ….lack of *operatorW*.

c) …zero….presence of marlonate.

A student answering “c” understands the logic of operon regulation but does not understand equilibrium effects.

d) …a high level of….lack of imrinine.

e) …a high level of….lack of *operatorW.*

A student answering “d” or “e” misunderstands the logic of operon regulation and how the factors affect regulation of the operon.

Validating the OCI Questions

- The OCI questions were “validated” using a series of individual think-aloud interviews with students from Biology 112.
- Validation helps to ensure that student correctly interpret both the questions and possible answers.
- This minimizes the possibility of students getting a question incorrect due to misreading or misunderstanding the question text.

Validating the OCI Questions

- An initial nine validation interviews were carried out while iteratively rewriting the original 25 questions in between interviews.
- This was followed by trial test runs with sample students from Biology 112 (see next slide) and Microbiology 325.
- This data was used to redesign the OCI figure and text (and to remove certain questions), after which an additional seven validation interviews were carried out.

Sample Trial-Run Results

- Sixteen volunteers from Biology 112 tried the OCI as a pre and post test.
- Average pre-test score (25 max): 9.75
- Average post-test score (25 max): 13.25
- Average learning gain: 23%

Learning gain = (post-pre)/(25-pre)

The Next Stage

- The next stage is to have a series of experts try the OCI and provide feedback to ensure there are no content problems with any of the questions.

- Full class trials with the OCI will also be required to collect sufficient data on how well the OCI can measure changes in student learning and understanding of operons and gene regulation.