Activities for Understanding Gene Regulation

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Abstract

The purpose of these activities is to help students to understand the fundamental concepts of gene expression and structure of bacterial operons using as a model the organization and regulation of the lactose operon. Activities range from role-playing the workings of the lac operon to small group "think tanks" to discover and discuss aspects of regulation and control of the operon. In the first and third activities, student groups are assigned one aspect of lac operon regulation and are given the task of acting out the structure and function of the required components. In the other activities, students answer questions about regulation of gene expression through group discussion to promote understanding and application of the concepts. These activities provide visualization, require students to "do and think," and allow for flexible adaptation to many different classroom situations as well as extensions to situations requiring higher-order thinking. This activity was designed to help make the abstract concept of the structure and function of the lactose operon more concrete. Rather than merely memorizing the parts and functions of the operon, students actively participate in the process that they are studying. These activities can then be used to apply knowledge of gene expression in the *E. coli* lac operon to other operons and other species.

Activity

Invitation for User Feedback. If you have used the activity and would like to provide feedback, please send an e-mail to MicrobeLibrary@asmusa.org. Feedback can include ideas which complement the activity and new approaches for implementing the activity. Your comments will be added to the activity under a separate section labeled "Feedback." Comments may be edited.

Editor's Note (2008): This Curriculum Resource was published prior to establishment of current criteria of submission, and as such, does not contain all criteria required of current publications. However, the Editorial Committee felt that the activity itself remained worthwhile and relevant, and encourages potential users to contact the authors for clarification as needed. If you do update this activity for use with your students, and are interested in updating the resource for distribution in the library, please contact ASM at MicrobeLibrary@asmusa.org.

INTRODUCTION

Core Theme Addressed.
1. Microbial cell biology - regulation of cellular activities

Intended Audience.
Activity 1: Microbiology/biology majors, allied health majors, science education majors, non-majors
Activity 2: Microbiology/biology majors
Activity 3: Microbiology/biology majors
Activity 4: Microbiology/biology majors

Time Required. 30 to 45 minutes for each activity

Pedagogical Function.
This activity was designed to help make the abstract concept of the structure and function of the lactose operon more concrete. Rather than merely memorizing the parts and functions of the operon, students actively participate in the process that they are studying. These activities can then be used to apply knowledge of gene expression in the *E. coli* lac operon to other operons and other species.

PROCEDURE

Materials.
Activity 1 -- markers, light weight poster board or colored construction paper for signs or labels, tape.
Activity 2 -- index cards, markers or pens.
Activity 3 -- same as for activity 1, plus pictures of growth curves (see Figures 1 & 2).
Activity 4 -- index cards, markers or pens.

Background.
Prerequisite knowledge for all activities includes prokaryotic cell structure and function, cell growth, metabolism, and mechanisms of transcription and translation. An introductory lecture should cover a basic overview of an operon system and its components. Prior to activity 1 students should read about regulation of the lactose operon. Activity 2 should be done before a lecture on the lactose operon. Activity 3 should follow a discussion of (or reading about) inducible operons. Activity 4 should follow reading about or a lecture on the lactose operon. For Activity 4, students should also have an understanding of mutations and their effect on gene products.

It might be helpful to describe in general terms what the role play will look like. As an example for students to model, the movie, "Protein Synthesis: An Epic on the Cellular Level" (Harper and Row Media, 1971) can be shown.

Safety Issues. Not applicable.

Student Version.
Activity 1 - Lactose Operon Role Play.
Before doing this activity you should understand cell structure and function, cell growth, metabolism and the processes of transcription and translation. In addition you should read the section in your textbook on regulation of the lactose operon.

- Your instructor will assign your group a component of the lactose operon.
- Take 10-15 minutes to make a label for your component(s) and discuss how you will accurately act out your assigned process.
- Using the diagram of the operon in the front of the room as a guide, place your component(s) in the proper position to act out its function. Your instructor will describe the environmental conditions for functioning of the operon.
- As groups in the class act out their parts, decide whether their role play is correct, discussing why it is correct or why it is in error.

Activity 2 - Cell Growth in the Presence of Two Sugar Sources.
Before doing this activity you should understand cell structure and function, cell growth, metabolism, transcription and translation.

- Working in a group, study the two growth curves shown in Figure 1 and Figure 2. One shows *E. coli* growing in a broth containing both glucose and lactose; the other shows the organism growing in a broth containing glucose only or lactose only.
- Suggest one or more hypotheses to explain the difference between the curves. Take about 15 minutes to study the graphs and formulate your hypotheses.
- Have a reporter for your group tell the class what your group discussed.
- Decide whether you agree or disagree with the other groups' hypotheses. List your reasons.

Activity 3 - Design a Repressor System.
You will complete this activity in a group as determined by your instructor. Before doing this exercise you should understand the organization of an operon and how an inducible operon system works.

- With the other members of your group, take about 10 minutes to discuss what happens to gene expression in the presence of a repressor. One member of your group should take notes on your discussion. Another group member will be a reporter who will describe to the class one component of a repressor system.
- Based on the class discussion and what you know about inducible operons, the class will design and play the roles of components of a repressor system.
- Your instructor will assign each group one of the components of the system you have designed.
- Take 15 minutes to decide how your group will portray its assigned component. Make any signs or labels that are necessary to identify your role in the system.
- Perform the repressor system role play.

Activity 4 - Alterations of Operon Function through Mutation.
Before beginning this exercise you should understand induction and repression of gene expression and the organization of an operon. You should also understand the effect of mutations on the expression of gene products.

- Think about ways that the lactose operon can be altered or mutated so that the result would be constitutive expression of the structural genes of the system. List three possible mechanisms. Spend about 10 minutes working individually.
- Discuss your list with one other person, or with a small group of 3 to 4, depending on the size of your class. Your instructor will tell you which is appropriate.
- Share one of your proposed mechanisms with the class.
- Think about ways that the lactose operon can be altered or mutated so that the result would be complete repression of the structural genes of the operon.
- Discuss and share the mechanisms you proposed as you did before.

Safety Issues. Not applicable.

ASSESSMENT and OUTCOMES

Suggestions for Assessment.

- Peer oral assessment is incorporated into the activities through whole class discussion and feedback.

- A follow-up take-home assignment to design and manipulate a prokaryotic cell operon that regulates a biosynthetic pathway.
- Concepts included on a test.
- Written report on the group process for designing role plays or coming to other conclusions as a result of the group work.

Problems and Caveats.

Activity 1.

Divide the class into groups, with group size dependent on the detail desired and the room size. For example, lactose could be played by two students that are "cleaved" by b-galactosidase. Alternatively, with fewer students, the lactose and the monosaccharide products could be represented by signs. The groups should represent one of the following:

- operon: promoter, operator, 3 structural genes
- regulatory molecules: cAMP, CAP, lactose repressor, lactose/inducer
- transcription: enzyme, mRNA
- translation: ribosomes, gene product (and its function)

A diagrammatic representation of the operon should be visible on the wall and the role play should go on around this diagram (e.g. The student portraying the "repressor" should stand in front of the operator position until the student playing lactose comes and removes the repressor from its position.)

- Each group is given a task, materials to use to identify their components, and 10 to 15 minutes to discuss how they will act out their assigned process.
- Members of each group will come to the front of the class to act out their role. The instructor will guide the groups through a given environmental condition (e.g., The cell is in media containing lactose.). The groups will interact to simulate the cell's response to its environment.
- As the response is acted out, the class is asked to verify that the correct response was made and to evaluate if any steps are missing.
- The instructor guides the review discussion.

Activity 2.

Before the lecture on the lactose operon, students are divided into groups to study two growth curves. One shows *E. coli* growing in a broth containing glucose and lactose (Figure 1), and the other shows the organism growing in glucose only or in lactose only (Figure 2). Note that the slopes of the curves in Figure 2 are different for growth on glucose and on lactose. It would be beneficial to emphasize that such curves are not unique to *E. coli*. After the groups have made observations and have suggested hypotheses to explain the differences in the curves, the instructor should ask a reporter for one group to tell the class what was discussed in that group. The instructor then asks other groups to give reasons that they agree or disagree with the first group's assessment. The activity ends with a lecture or discussion on the concepts of diauxy and catabolite repression as they apply to the lactose operon.

Activity 3.

After a lecture on an inducible operon system, students will design a repressor system. First, the students will discuss in small groups what occurs in the presence of a repressor. A reporter from each group will describe to the class one component of the system. The instructor will record these on an overhead or chalkboard. When the list is complete, the instructor should assign each component to a different group. The group members will decide how to act out the action of the component. They will need to be provided with markers, and paper or small poster boards to make labels for their components. If the size of the class is too large, a small group of students could be chosen to perform assigned roles for the entire class. It might be helpful to show the students an example of a role play such as the film, "Protein Synthesis: An Epic on the Cellular Level." You might want to have students apply this activity to an inducible and/or repressible operon other than the lactose operon. An example might be the *Mer* operon, the *trp* operon, or a fictitious operon designed to practice the general principles of operon function.

Activity 4.

For this activity the students need markers or pens and note cards. It would follow a lecture, discussion or reading on the lactose operon. Students use the "Think-Pair-Share" method (or a modification that uses discussion in groups of 3 to 4 instead of a pair) to brainstorm ways that the lactose operon could be mutated that would result in constitutive expression of the operon. Then the students should think of changes that will result in full repression of the operon. One member of a group will share an example with the class and the other students will assess whether or not this change would give the desired expression phenotype. The discussion continues until all of the ideas that were generated have been reported. Alternatively, students may write a report (individually or in small groups) that is turned in for assessment.

SUPPLEMENTARY MATERIALS

References.

1. Mulnix, Amy. 1994. Lactose Operon: An Active Learning Approach. Bioscene **20**(1): 11-13. PDF file found at http://papa.indstate.edu/amcbt/volume_20/v20-1p11-14.pdf
2. "Protein Synthesis: An Epic on the Cellular Level." 1971. Harper and Row Media. 16mm film. Senses Bureau, producer.

Appendices.

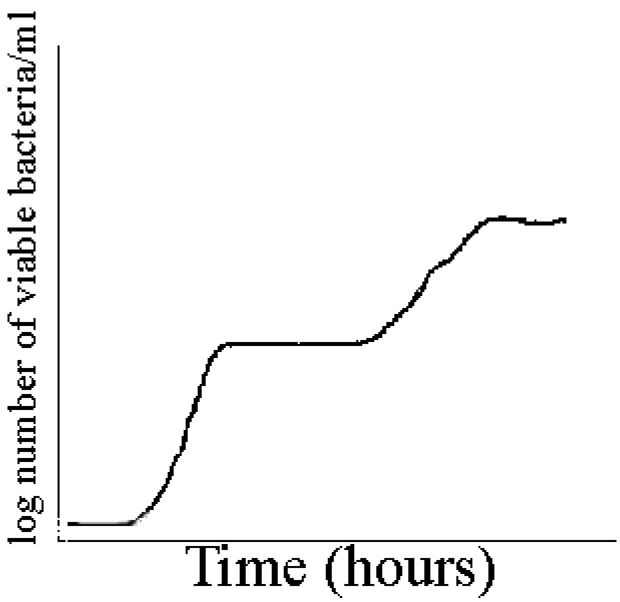
Figure 1

Figure 2

Curriculum Resources

Appendix.

Figure 1. Bacterial Growth in Media Containing Equal Concentrations of Glucose and Lactose



Curriculum Resources

Appendix.

Figure 2. Bacterial Growth in Media Containing Glucose OR Lactose only