Creating a New Medication to Target Resistant Strains of Bacteria

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for the STEM Education Center at WPI's Summer 2022 Research Experience for Teachers program

Subject: Biology
Grade Level: 10-12
United Nations Sustainable Development Goal 3:
Ensure healthy lives and promote well-being for all at all ages

Overview

Antibiotic resistant pathogens are a global problem because antibiotics used to treat infections are becoming ineffective. Some diseases, like TB, disproportionately affect poorer nations than it does wealthy nations. Students are medical researchers developing a new antibiotic to combat antibiotic-resistant bacteria. Their antibiotic must block the transcription or translation of a resistance gene, or be an enzyme that breaks down the proteins produced by the resistance gene.

Standards & Learning Targets

HS-LS1-1. Construct a model of transcription and translation to explain the roles of DNA and RNA that code for proteins that regulate and carry out essential functions of life.
Clarification Statements:
• Proteins that regulate and carry out essential functions of life include enzymes (which speed up chemical reactions), structural proteins (which provide structure and enable movement), and hormones and receptors (which send and receive signals).
• The model should show the double-stranded structure of DNA, including genes as part of DNA's transcribed strand, with complementary bases on the non-transcribed strand.
State Assessment Boundaries:
• Specific names of proteins or specific steps of transcription and translation are not expected in state assessment.
• Cell structures included in transcription and translation will be limited to nucleus, nuclear membrane, and ribosomes for state assessment.

Vocabulary	**Tier 1**	**Tier 2**	**Tier 3**
	Life Functions Structural Movement Signals Model	Regulate Construct Essential	Transcription Translation DNA RNA Proteins Hormones Receptors Complementary Nucleus

			Nuclear membrane Ribosomes Gene Cell Enzymes Double-stranded
What do students need to **KNOW**?	1. Students will use the following vocabulary words in context: Transcription, translation, DNA, RNA, ribosomes, protein, complementary 2. Transcription of a gene is the process of creating a complementary RNA copy of a DNA sequence 3. Translation is the process of creating protein, using a ribosome, based on the genetic code in the RNA. 4. Proteins regulate and carry out essential functions of life. They include enzymes (which speed up chemical reactions), structural proteins (which provide structure and enable movement), and hormones and receptors (which send and receive signals).		
What do students need to **DO**?	1. Construct a model of transcription and translation 2. Explain the roles of DNA and RNA that code for proteins that regulate and carry out essential functions of life.		
What will students **CREATE**?	1. A model explaining how a current antibiotic targets cells and how the protein products from a resistance gene interferes with the antibiotic.		

HS-LS3-4(MA). Use scientific information to illustrate that many traits of individuals, and the presence of specific alleles in a population, are due to interactions of genetic factors and environmental factors.

Clarification Statements:

• Examples of genetic factors include the presence of multiple alleles for one gene and multiple genes influencing a trait.

• An example of the role of the environment in expressed traits in an individual can include the likelihood of developing inherited diseases (e.g., heart disease, cancer) in relation to exposure to environmental toxins and lifestyle; an example in populations can include the maintenance of the allele for sickle-cell anemia in high frequency in malaria-affected regions because it confers partial resistance to malaria.

State Assessment Boundary:

• Hardy-Weinberg calculations are not expected in state assessment.

Vocabulary	**Tier 1**	**Tier 2**	**Tier 3**
	Scientific Traits Environmental Influencing Disease	Illustrate Genetic Expressed Inherited Toxins Frequency Resistance	Alleles Gene Malaria Sickle-cell anemia Hardy-Weinberg

What do students need to **KNOW**?	1. Students will use the following vocabulary words in context: Expressed/expression, Gene, Environmental 2. Many traits of individuals are due to interactions of genetic factors and environmental factors.
What do students need to **DO**?	1. Describe how their new antibiotic in the environment inhibits the expression of resistance genes in the bacteria. 2. Demonstrate with their model how the new antibiotic works
What will students **CREATE**?	1. Create a model, demonstrating the expression of a gene for a protein relating to antibiotic resistance, and how their new antibiotic inhibits the expression of those genes

ELA Standard: 4. Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, vocabulary, substance, and style are appropriate to purpose, audience, and task.

Vocabulary	**Tier 1**	**Tier 2**	**Tier 3**
	Information Listeners Organization Development Findings	Evidence Vocabulary Purpose Audience Logically	Concisely Substance Style
What do students need to **KNOW**?	1. Students will use the following vocabulary words in context: Findings, Evidence, development 2. How to present to an appropriate audience		
What do students need to **DO**?	1. Explain the processes of transcription and translation to a group of peers 2. Explain the process of the control of gene expression to a group of peers 3. Use a visual aid to assist in their explanations 4. Present information clearly, concisely, and logically such that listeners can follow the line of reasoning 5. Present to an audience using appropriate style, vocabulary,organization, and development		
What will students **CREATE**?	1. A presentation explaining how the antibiotic works and demonstrating their models		

Prior Knowledge

Students will have already learned about evolution and antibiotic resistance. Students will have already learned about enzyme function. They will have already learned that enzymes speed up

chemical reactions and have a structure complementary to the substrate. Students will also already know the double-helix structure of DNA and the process of DNA replication. Students will also be able to explain the processes of transcription and translation. Students will also know cell organelles.

Materials/Resources

Computers, Art supplies, Slides with instructions and examples, prepared plates with the glowing bacteria

Timeline of Activities

Each lesson takes one, 45-50 minute class period.

Duration	Activity	Instructions	Product
Day 1			
5 mins	Warm up	Think of a time you had a bacterial infection. How did you treat it? How long did it take to treat it? Students who are willing share their experiences.	Student responses
15 mins	Research	Students working in groups of 3 choose an antibiotic resistant strain of bacteria they are most interested in learning more about. Students research statistics and symptoms about the bacterium.	Students notes
15 mins	Elevator pitches and posters	Students create a poster and short elevator pitches arguing to the class why their bacterium is dangerous and why there is an impetus to develop a new treatment for the bacterium	Student posters
15 mins	Presentations	Students orally present to their classmates about their resistant bacterial strains	Presentations
Day 2			
10 mins	Introduction	Students watch the video https://www.youtube.com/watch?v=znnp-lvj2ek about antibiotic resistance. Students write down what they notice and wonder about the video.	Students notice and wonder
15 mins	Research	Students research the antibiotic used to treat the resistant strain of bacteria. Students learn how the antibiotic kills the bacteria. Students are given guiding questions such as:	Notes on how the antibiotic kills the bacteria

		"What molecule/organelle does the antibiotic target in the bacterial cell?" *"Why is this organelle/molecule important?"* *"Why can't the cell reproduce without this organelle/ molecule?"*	
15 mins	Model-building	Show students an example of a model I created. Students create a model to support them in explanation of how the antibiotic kills the bacteria. Their model may be a 3D model, a drawing, or a video	Models
10 mins	Feedback and revision	Students share their models with classmates and explain how their antibiotic kills bacteria. Students offer feedback to make their models more clear. Students then revise their models.	Revised models
Day 3			
10 mins	Introduction	Elicit prior knowledge of the central dogma of biology. Review of transcription and translation	
15 mins	Research	Students research the proteins that result from antibiotic resistance genes. Students research how the protein interferes with the antibiotic.	Student notes from the research
15 mins	Model-expansion	Show students exemplar model and how it Students expand on their models from the previous day. Their model demonstrates transcription and translation of the antibiotic resistance gene and shows how the protein interferes with the antibiotic.	Models
10 mins	Feedback and revision	Students share their models with classmates and explain how their antibiotic kills bacteria. Students offer feedback to make their models more clear	Revised models
Day 4 & Day 5			
5 mins	Introduction	Ask students, *"In what ways does the environment contribute to what we look like?"* Show students pre-made plates of pGLO plates one plate containing arabinose and another without arabinose.	Student responses
15 mins	Exploration	Students work in groups of 3-4 to explore this site https://learn.genetics.utah.edu/content/epigenetics/ Groups then share out 3-5 things they learned about how the environment affects the expression of their genes	Group responses

15 mins	Direct-instruction	Explain to students that the bacteria contain the same genes, but genes can be turned on or off depending on what is present in the environment. In this case, the arabinose turns on the expression of GFP. Show students some slides explaining how arabinose turns on GFP expression and show an example of a repressor.	
10 mins	Brainstorm	Instruct students that they are going to be working as pharmaceutical reps advertising a new medication that specifically targets an antibiotic strain of bacteria. Their new medication must inhibit either: 1)Transcription of the antibiotic resistance gene 2)Translation of the mRNA 3) The proteins that result from antibiotic resistance genes.	Student brainstorming
15 mins	Model-expansion	Students build on their models and add on their models to show how their medication interferes with the gene expression	Models
10 mins	Feedback and revision	Students share their models with classmates and explain how their antibiotic kills bacteria. Students offer feedback to make their models more clear	Revised models
15 mins	Final Presentations	Students need to advertise their new medication to a pharmaceutical company to the class. Students demonstrate how their new medication works at the molecular level	Presentations
5 mins	Reflection	Students give feedback about what they liked and did not like about the project to be used to plan future lessons	Student feedback

Culturally Responsive Teaching Strategies

Differentiation	Students have multiple ways of presenting material to each other and different ways of obtaining the information. Direct instruction includes verbal, written, and visual information
Scaffolding	Lessons are broken down so that students build on their projects, incorporating information. Guiding questions provide scaffolding

	to help students focus their research.
Modeling	Students are given exemplars of models to give inspiration and assist them with developing theirs

Career Connections

Students need to act as pharmaceutical representatives explaining how their new antibiotic targets resistance genes in bacteria.

Can connect with members of the WPI Shell lab to discuss the actual lab experience

Assessment

Performance Assessment Rubric