Group 7 (Nathan Butler, Matthew Cummings) Lesson Plan

Content Area: Biology

Grade level: 9th – 10th

Est. Time: ~1 hour

Topic: Bacterial genetics, mutation, and adaptation.
Adherence to New York State Science Standards

In this lesson's activities, students will use scientific inquiry, computer modeling, and graphical analysis in order to extend concepts from a specific lesson example to broader general trends and themes in biology. The following criteria are from The Living Environment Core Curriculum, from the University of the State of New York and the New York State Education Department:

STANDARD 1

Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Key Idea 1:

The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing and creative process.

> **PERFORMANCE INDICATOR 1.1:**
> **Elaborate on basic scientific and personal explanations of natural phenomena, and develop extended visual models and mathematical formulations to represent one's thinking.**
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> **PERFORMANCE INDICATOR 1.4:**
> **Coordinate explanations at different levels of scale, points of focus, and degrees of complexity and specificity, and recognize the need for such alternative representations of the natural world.**

Key Idea 2:

Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.

Key Idea 3:

The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into natural phenomena.

> **PERFORMANCE INDICATOR 3.1:**
> **Use various methods of representing and organizing observations (e.g., diagrams, tables, charts, graphs, equations, matrices) and insightfully interpret the organized data.**

Major Understandings:
3.1a Interpretation of data leads to development of additional hypotheses, the formulation of generalizations, or explanations of natural phenomena.

STANDARD 4

Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

Key Idea 1:
Living things are both similar to and different from each other and from nonliving things.

Living things are similar in that they rely on many of the same processes to stay alive, yet are different in the ways that these processes are carried out.

The components of living systems, from a single cell to an ecosystem, interact to maintain balance. Different organisms have different regulatory mechanisms that function to maintain the level of organization necessary for life. Diversity is evident and important at all levels of organization—from a single cell to a multicellular organism to an ecosystem.

PERFORMANCE INDICATOR 1.3:
Explain how a one-celled organism is able to function despite lacking the levels of organization present in more complex organisms.

Major Understandings
1.3a The structures present in some single-celled organisms act in a manner similar to the tissues and systems found in multicellular organisms, thus enabling them to perform all of the life processes needed to maintain homeostasis.

Key Idea 2:

Organisms inherit genetic information in a variety of ways that result in continuity of structure and function between parents and offspring.

Organisms from all kingdoms possess a set of instructions (genes) that determines their characteristics. These instructions are passed from parents to offspring during reproduction.

The inherited instructions that are passed from parent to offspring exist in the form of a code. This code is contained in DNA molecules. The DNA molecules must be accurately replicated before being passed on.

PERFORMANCE INDICATOR 2.1:
Explain how the structure and replication of genetic material result in offspring that resemble their parents.

Major Understandings
2.1a Genes are inherited, but their expression can be modified by interactions with the environment.
2.1b Every organism requires a set of coded instructions for specifying its traits. For offspring to resemble their parents, there must be a reliable way to transfer information from one generation to the next. Heredity is the passage of these instructions from one generation to another.
2.1c Hereditary information is contained in genes, located in the chromosomes of each cell. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes in its nucleus.

2.1d In asexually reproducing organisms, all the genes come from a single parent. Asexually produced offspring are normally genetically identical to the parent.
2.1e In sexually reproducing organisms, the new individual receives half of the genetic information from its mother (via the egg) and half from its father (via the sperm). Sexually produced offspring often resemble, but are not identical to, either of their parents.
2.1f In all organisms, the coded instructions for specifying the characteristics of the organism are carried in DNA, a large molecule formed from subunits arranged in a sequence with bases of four kinds (represented by A, G, C, and T). The chemical and structural properties of DNA are the basis for how the genetic information that underlies heredity is both encoded in genes (as a string of molecular bases) and replicated by means of a template.

Key Idea 3:
Individual organisms and species change over time.

PERFORMANCE INDICATOR 3.1:
Explain the mechanisms and patterns of evolution.

Major Understandings
3.1a The basic theory of biological evolution states that the Earth’s present-day species developed from earlier, distinctly different species.
3.1b New inheritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells.
3.1c Mutation and the sorting and recombining of genes during meiosis and fertilization result in a great variety of possible gene combinations.
3.1d Mutations occur as random chance events. Gene mutations can also be caused by such agents as radiation and chemicals. When they occur in sex cells, the mutations can be passed on to offspring; if they occur in other cells, they can be passed on to other body cells only.
3.1e Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life-forms, as well as for the molecular and structural similarities observed among the diverse species of living organisms.
3.1f Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring.
3.1g Some characteristics give individuals an advantage over others in surviving and reproducing, and the advantaged offspring, in turn, are more likely than others to survive and reproduce. The proportion of individuals that have advantageous characteristics will increase.
3.1h The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions.

Key Idea 4:
The continuity of life is sustained through reproduction and development.

PERFORMANCE INDICATOR 4.1:
Explain how organisms, including humans, reproduce their own kind.

Major Understandings
4.1a Reproduction and development are necessary for the continuation of any species.
4.1b Some organisms reproduce asexually with all the genetic information coming from one parent. Other organisms reproduce sexually with half the genetic information typically contributed by each parent. Cloning is the production of identical genetic copies.

Broad Objectives: Students will investigate the basic structure and function of bacterial DNA and how mutations affect bacterial populations. After the activities, students should be able to explain the ways mutations can be both harmful and beneficial. The expected product in this lesson objective is a computer-simulated bacterial culture and a graph of the population growth curves. The condition for demonstrating success at this task is activity in student-pairs and small groups. The criterion for success is an example of adaptations in other organisms and an explanation of how the environment determines the efficacy and value of the adaptation. Students are expected to extend and apply the concepts of mutation and adaptation to all organisms in general.

Learning Outcomes/Specific Objectives: Students will be able to draw the basic structure of DNA, use computer modeling to show how mutation can result in both adaptation and maladaptation, and graph the population growth curves of simulated bacterial populations. Students will submit a 1 page written summary of the lesson and activities, including the drawing of DNA and the growth curve graph, in order to demonstrate their proficiency.

Set Induction and Content: Bacterial population growth.

Activities: For these activities, each student will pair with another, review the text section on bacterial genetics, and apply their knowledge to this and later activities. First, students will discuss the textbook section and then answer the following questions. Each student-pair will then join another pair for the simulation activity.

Questions:

1. Define point mutation.

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2. What are the two ways in which bacteria can be adaptable?

____.

3. What are two major differences between bacterial DNA and the DNA of eukaryotes?

____.

4. What life history trait of bacteria allows relatively rapid proliferation of novel mutations in bacterial populations?

____.

5. While mutations occur in all organisms, what produces the most genetic diversity in sexually reproducing organisms, like humans?

____.

Four-person group computer simulation activity: In the new groups, students will discuss the ways that certain substances and environments can cause mutations in DNA. Then, the groups will discuss the possible outcomes (i.e., make predictions) of UV irradiation of the bacterial populations in the culture simulation. Students may use the class computer internet access as a supplement to the text to search for examples. Finally, students will run the culture simulation. The data from the simulation will be analyzed in excel, wherein students will create graphs of bacterial growth curves.

Resources and Materials: Biology text book, biology websites, Microsoft excel, and a computer simulation program.

Literacy Strategy: This proposed lesson utilizes computer modeling and small group discussion. Computer modeling allows the visualization and prediction of the behavior of complex systems. Predictions of the behavior of these systems are contingent upon the maximization of parameters as the behaviors are determined by often numerous factors. For example, in order to most accurately predict a complex behavior such as population growth of a sexually-reproducing organism, one must account for such factors as initial population size, number of reproducing individuals, age at first reproduction, length of fecund period, birth rate, death rate, resource availability, and competition, among others. Multiple parameters can be introduced to provide a more realistic model of complex behaviors, or the model may be simplified to fit the scope of the lesson objectives.

When incorporated in lessons, computer modeling and simulation reduces the cognitive demands on the learner. Whether few or many parameters are used, the learner does not have to process as much semantic information to understand the information. This is one of the reasons computer modeling is such a powerful stratagem for students with language-based learning disabilities. In this lesson involving bacterial populations (asexual), we simplified the model to include only three parameters: replication rate, mutation rate, and death rate. The graphic depiction of the concepts and relationships among them used in this lesson conveys the most important point of the lesson: mutation and genetic change can be advantageous or detrimental, depending on the organism's full genetic make-up and its environment, and both sexual and asexual reproduction propagates genetic changes in future generations, a fact which is evident across the entire Tree of Life.

Small group discussions can facilitate and stimulate student learning because students will likely become actively engaged when their peers are involved. Small group discussions are particularly likely to stimulate student interest and engage them with the material. While many students seem unwilling to engage actively in discussions in a large lecture classroom because of discomfort and feelings of "stage-fright," the smaller group size can put the students at ease. This would be particularly helpful in facilitating participation by students of different racial and ethnic backgrounds who may feel isolated if they are on their own and represent a relative minority demographic in the class. With topics involving complex concepts and higher-order thinking—as in this lesson in bacterial genetics and adaptation—small group discussions will broaden and enrich the educational experiences of all students.

Closure, Evaluation, and Assignment: After having engaged in classroom activities, students will provide examples of adaptations in other organisms in their write up. In the class discussion, students will talk about why mutations are important in the fields and subfields of biology, especially medicine. The class will discuss how the principles and processes represented in the simulation are explored through laboratory activities, including real-time bacterial culture plate incubation. For the next lesson on bacterial genetics, students can use the textbook chapters and biology websites to investigate the topic of antibiotic resistance and how genetic recombination produces new bacterial strains.