



BACTERIAL HOMEOSTASIS AND TOOTH DECAY

NEW YORK STATE

THE LIVING ENVIRONMENT CORE CURRICULUM

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 1.3

Work toward reconciling competing explanations; clarify points of agreement and disagreement.

Major Understandings

- 1.3a Scientific explanations are accepted when they are consistent with experimental and observational evidence and when they lead to accurate predictions.

Scientific papers are accepted by the scientific community through a review process. This review process involves other scientists who read the paper, analyze the data that is shown in the paper and concur with the authors' conclusions. The experiments performed in this paper were done multiple times with similar results.

- 1.3b All scientific explanations are tentative and subject to change or improvement. Each new bit of evidence can create more questions than it answers. This leads to increasingly better understanding of how things work in the living world.

*The results illustrated in this interactive paper suggest that *S. mutans* increases transcription of the *F-ATPase* gene in response to changes in environmental pH, but does not suggest how that might happen. Understanding the molecular mechanism behind the change would allow scientists to design drugs that could inhibit that mechanism. Additional studies must be undertaken.*

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.

Performance Indicator 2.1

Devise ways of making observations to test proposed explanations.

The scientists who did the work described in this interactive paper designed their experiments with the appropriate variables and controls in order to test their hypothesis

Performance Indicator 2.2

Refine research ideas through library investigations, including electronic information retrieval and reviews of the literature, and through peer feedback obtained from review and discussion.

Major Understandings

- 2.2a Development of a research plan involves researching background information and understanding the major concepts in the area being investigated. Recommendations for methodologies, use of technologies, proper equipment, and safety precautions should also be included.

The experiments described in this interactive paper were done using existing methodologies (slot blotting). Without these methodologies, the experiments may not have been possible

Performance Indicator 2.3

Develop and present proposals including formal hypotheses to test explanations; i.e., predict what should be observed under specific conditions if the explanation is true.

Major Understandings

- 2.3a Hypotheses are predictions based upon both research and observation.
2.3b Hypotheses are widely used in science for determining what data to collect and as a guide for interpreting the data.
2.3c Development of a research plan for testing a hypothesis requires planning to avoid bias (e.g., repeated trials, large sample size, and objective data-collection techniques).

The study described in this interactive paper is an illustration of all these steps of scientific inquiry

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.

*The results illustrated in this interactive paper suggest that *S. mutans* increases transcription of the *F-ATPase* gene in response to changes in environmental pH, but does not suggest how that might happen. Much is known about how gene transcription is regulated, which leads to hypotheses about the specific mechanism of *S. mutans*.*

Performance Indicator 3.5

Develop a written report for public scrutiny that describes the proposed explanation, including a literature review, the research carried out, its result, and suggestions for further research.

Major Understandings

- 3.5a One assumption of science is that other individuals could arrive at the same explanation if they had access to similar evidence. Scientists make the results of their investigations public; they should describe the investigations in ways that enable others to repeat the investigations.
3.5b Scientists use peer review to evaluate the results of scientific investigations and the explanations proposed by other scientists. They analyze the experimental procedures, examine the evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations for the same observations.

This interactive paper describes work that has undergone peer review

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.

Performance Indicator 1.2

Describe and explain the structures and functions of the human body at different organizational levels (e.g., systems, tissues, cells, organelles).

Major Understandings

- 1.2f Cells have particular structures that perform specific jobs. These structures perform the actual work of the cell. Just as systems are coordinated and work together, cell parts must also be coordinated and work together.

The S. mutans bacteria has many proteins that perform functions in the cell (enzymes of respiration), transporters that allow sugar to enter or remove lactic acid. If any one of these proteins fails to function, the cell can not survive in its environment.

- 1.2g Each cell is covered by a membrane that performs a number of important functions for the cell. These include: separation from its outside environment, controlling which molecules enter and leave the cell, and recognition of chemical signals. The processes of diffusion and active transport are important in the movement of materials in and out of cells.

S. mutans uses a passive transporter to allow sugars through its cell membrane, and an active transporter to remove lactic acid.

- 1.2h Many organic and inorganic substances dissolved in cells allow necessary chemical reactions to take place in order to maintain life. Large organic food molecules such as proteins and starches must initially be broken down (digested to amino acids and simple sugars respectively), in order to enter cells. Once nutrients enter a cell, the cell will use them as building blocks in the synthesis of compounds necessary for life.

S. mutans is found in the mouth and utilizes glucose. Enzymes in the mouth can break down large organic food molecules into glucose

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.

S. mutans is a single cell organism, yet it maintains homeostasis in a changing environment.

Key Idea 2

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

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.

All bacteria have the F-ATPase gene, but the amount of the gene can change in response to the acidity of the environment.

- 2.1g Cells store and use coded information. The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires.

The interactive paper illustrates the process of transcription and translation

- 2.1h Genes are segments of DNA molecules. Any alteration of the DNA sequence is a mutation. Usually, an altered gene will be passed on to every cell that develops from it.

- 2.1i The work of the cell is carried out by the many different types of molecules it assembles, mostly proteins. Protein molecules are long, usually folded chains made from 20 different kinds of amino acids in a specific sequence. This sequence influences the shape of the protein. The shape of the protein, in turn, determines its function.

The interactive paper describes how proper protein structure is required for proper function

Key Idea 3:

Individual organisms and species change over time.

Performance Indicator 3.1

Explain the mechanisms and patterns of evolution.

Major Understandings

- 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.

*Although this is not described directly in the interactive paper, *S. mutans* competes with other oral bacteria for space. If *S. mutans* lives next to a bacteria that can not survive a low pH, and both bacteria are given an infinite amount of sugar to metabolize, the ability of *S. mutans* to continue to produce acid at low pH will result in the death of the other bacteria. It has been observed that children who consume refined sugars in large quantities when their teeth are erupting tend to have more *S. mutans* on their teeth. This initial colonization of *S. mutans* makes it difficult for other, non-cavity causing, bacteria to establish themselves, and can lead to increased risk of tooth decay.*

Key Idea 5:

Organisms maintain a dynamic equilibrium that sustains life.

Performance Indicator 5.1

Explain the basic biochemical processes in living organisms and their importance in maintaining dynamic equilibrium.

Major Understandings

- 5.1c In all organisms, organic compounds can be used to assemble other molecules such as proteins, DNA, starch, and fats. The chemical energy stored in bonds can be used as a source of energy for life processes.

The interactive paper describes how sugar is broken down in the bacteria to produce energy in the form of ATP.

- 5.1e The energy from ATP is used by the organism to obtain, transform, and transport materials, and to eliminate wastes.

The interactive paper illustrates how ATP is used to power the active transporter

Performance Indicator 5.2

Explain disease as failure of homeostasis.

Major Understandings

- 5.2a Homeostasis in an organism is constantly threatened. Failure to respond effectively can result in disease or death.

The interactive paper takes the viewpoint of the bacteria – failure of the bacteria to respond to changing environmental pH can result in death.

- 5.2b Viruses, bacteria, fungi, and other parasites may infect plants and animals and interfere with normal life functions.

Performance Indicator 5.3

Relate processes at the system level to the cellular level in order to explain dynamic equilibrium in multicelled organisms.

Major Understandings

- 5.3a Dynamic equilibrium results from detection of and response to stimuli. Organisms detect and respond to change in a variety of ways both at the cellular level and at the organismal level.

S. mutans responds to changing pH by altering the number of H⁺ transporters it has.