**Beta-2 Version of Modeling Biology for a P-C-B Sequence**

This NGSS Modeling Biology course is designed for use in a high school science curriculum that begins with physics, followed by chemistry, and then biology. This course makes use of the students’ understanding of chemistry as they develop their understanding of biology. For example, students learn about DNA, transcription and translation early in the course and then use their understanding of basic molecular biology to enhance their understanding of subsequent topics such as the structure and function of cells, genetics, and evolution. Throughout the course, later models build on earlier models in a logical progression.

Table 1 outlines the **sequence of models** developed in this course. Table 2 provides additional information, including how the later models build on models that have been developed earlier in the course. Resources for teaching these models have been grouped in eight **topics**, which are listed in the last column of the table.

For each of the first five topics, we have developed one or two **instructional units** that are similar to the instructional units in AMTA chemistry and physics. For each topic we present a Teacher Notes document (which includes instructional suggestions and background biology). For the students, we have prepared readings, worksheets and lab activities. All of these learning activities engage students in scientific practices as they develop their understanding of the models and core concepts. The Teacher Notes explain how these units help students to meet the Next Generation Science Standards by learning Disciplinary Core Ideas, engaging in Science and Engineering Practices, and understanding Crosscutting Concepts (<https://www.nextgenscience.org/get-to-know>).

We plan to complete the adaptation of the remaining three topics by the end of the summer. Currently, we provide Student Handouts and Teacher Notes for multiple learning activities related to these topics. The Student Handouts combine the reading, worksheets and lab activities.

Earlier versions of this course have been pilot tested at Ridley High School, and individual learning activities have also been pilot tested by biology teachers in the greater Philadelphia area and beyond. This version of Modeling Biology for a P-C-B Sequence is still under development and will need revisions and additions in the coming years.

We present a beta-2 version at this time with two goals in mind. First, we hope that the resources presented will be useful for your teaching. Second, we hope that some of you will serve as “beta testers” and help us by providing feedback and suggestions for improvements and additions.   
To post your comments, please visit <https://forms.gle/yqtjL6vTR7w1KHJS7>

This document is available at [**https://tinyurl.com/NGSS-ModBio**](https://tinyurl.com/NGSS-ModBio). This folder also contains a Google Slides document, the five topic overviews and a Zoom recording of the webinar.

Thank you,

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**Table 1. Progression of Models in the Biology Modeling Course for a P-C-B Sequence**

|  |  |
| --- | --- |
| **Model** | **Description** |
| Characteristics of Life | Students learn about the constellation of characteristics that distinguish living things from non-living things. |
| Levels of  Organization | To provide a broad context for the models that follow, students are introduced to the levels of organization in biology from molecules to biosphere. Students also investigate the characteristics of life. |
| Biological Molecules | Building upon the chemistry students have already learned, the exploration starts at the molecular level. The structure and interaction of C, H, N, O, and P atoms result in various biological macromolecules which in turn have structures that contribute to the processes of life. The reactions which build and support life are often facilitated by enzymes which lower the activation energies of organism’s specific, essential reactions such as the digestion of food. |
| DNA Structure | Students learn about the double helix structure of DNA and base pairing; this provides a basis for understanding DNA function. |
| DNA  Replication | Students learn how base-pairing and the double helix structure of DNA provides the basis for semiconservative replication of DNA molecules. |
| Transcription  and  Translation | A gene is a segment of DNA that gives the instructions for making a protein. During transcription, the sequence of nucleotides in DNA determines the sequence of nucleotides in mRNA. During translation, the sequence of nucleotides in mRNA determines the sequence of amino acids in a protein. Thus, a different sequence of nucleotides in a gene can result in a different sequence of amino acids in a protein. This can alter the structure and function of the protein, which can result in different organism characteristics. |
| Cell Structure  and Function | Students learn about the most basic unit of life, the cell. Students learn how organelles cooperate to accomplish the multiple functions of a living cell, for example, the production and secretion of proteins. Students analyze multiple examples of the relationship between structure and function in diverse eukaryotic cells. |
| Cell membrane | Students investigate how phospholipids and proteins combine to form the selectively permeable cell membrane, which regulates what gets into and out of the cell. |
| Energy and  Biological  Processes | To understand how organisms use energy, students learn how the hydrolysis of ATP provides the energy for many biological processes, and students learn about cellular respiration (the coupled reactions in which the energy released when glucose is metabolized is used to produce ATP). Students also analyze how photosynthesis and biosynthesis create biological molecules which can be used for cellular respiration or growth and repair. |
| Mitosis | Students learn how the cell cycle produces genetically identical daughter cells. They use model chromosomes to understand how DNA replication and mitosis ensure that each new cell gets a complete set of chromosomes with a complete set of genes. |
| Meiosis and  Fertilization | Students use model chromosomes to understand how meiosis produces haploid gametes. Then, students model meiosis and fertilization in a format that mimics a Punnett square. Thus, students develop a basic understanding of how genetic information is passed from one generation to the next. |
| Genetics | The genetics model combines student understanding of (1) how genotype influences phenotype via the effects of genes on protein structure and function and (2) how genes are transmitted from parents to offspring through the processes of meiosis and fertilization. The probabilistic patterns of inheritance and Punnett square predictions are explored. Additional concepts covered include polygenic inheritance, incomplete dominance, and how a new mutation can result in a genetic condition that was not inherited. Finally, students learn more about molecular biology and are introduced to genetic engineering. |
| Organism | Students learn how the structure of organs and organ systems is related to their functions. (Structure includes shape, constituent components, and relationships between components.) Students also learn how body systems interact to accomplish important functions. Finally, students learn how negative feedback helps to maintain homeostasis. |
| Population  Growth | Students learn how processes at the organism level result in exponential and logistic population growth. Then, students analyze examples where the trends in population size do not match the predictions of the exponential or logistic population growth models. They learn that models are based on simplifying assumptions and a model’s predictions are only accurate when the simplifying assumptions are true for the population studied. |
| Evolution | Students use their understanding of inheritance and population growth to develop a basic understanding of natural selection. Then, students use their understanding of natural selection, genetic drift, and gene flow to understand several examples of evolution (changes in mouse fur color in new environments and the evolution of eyes). |
| Food Webs | Students learn about food webs and how interactions in food webs can influence trends in population size. Students use their understanding of trophic relationships in food webs, photosynthesis, and cellular respiration to understand energy flow through ecosystems, carbon cycles, and trophic pyramids. Thus, students use their understanding of processes at the cellular-molecular and organismal levels to understand several ecological phenomena. |

**Table 2. Major Concepts, Sequential Development of Models, and Teaching Resources**

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| --- | --- | --- | --- |
| **Model** | **Major Concepts** | **Previous Models Used as Students Develop This Model** | **Topic with Resources for Teaching This Model\*** |
| Characteristics of Life | Characteristics that distinguish living things from non-living things |  | Introduction to Biology |
| Levels of Organization | Levels of organization from molecules to the biosphere | Characteristics of Life | Introduction to Biology |
| Biological Molecules | Intermolecular attractions; structure and behavior of functional groups, macromolecules and enzymes |  | Biological Molecules |
| DNA Structure | Nucleotides; complementary pairing | Molecules | DNA, Transcription and Translation (see also Inheritance) |
| DNA Replication | Information for the next generation of cells; semiconservative; enzyme function | DNA structure; Molecules | DNA, Transcription and Translation (see also Inheritance) |
| Transcription | Introductory overview: DNA → protein → phenotypic characteristic  Using the information in DNA to produce RNA; enzyme function | DNA structure; Molecules | DNA, Transcription and Translation (see also Inheritance) |
| Translation | Using the information in RNA to produce proteins; interaction between mRNA, tRNA and rRNA; | Transcription; DNA structure; Molecules | DNA, Transcription and Translation (see also Inheritance) |
| Cell Structure and Function | Smallest unit that exhibits all the characteristics of life; organized and compartmentalized chemical reaction systems (e.g. transcription and translation) | Characteristics of Life; DNA structure; Transcription; Translation | Cell Structure and Function |
| Cell Membrane | Regulate what gets into and out of the cell | Molecules; Cell structure and function | Cell Structure and Function |
| Energy and Biological Processes | Conservation of energy; cellular respiration and hydrolysis of ATP; photosynthesis; bioenergetics and biosynthesis | Molecules | Energy and Biological Processes |
| Mitosis | Cell self-replication; continuity of information to the next generation of cells | DNA replication; Cell structure and function | Inheritance |
| Meiosis and Fertilization | Continuity of information to next generation of sexual reproducers; variation of information passed to the next generation | DNA replication; Cell structure and function | Inheritance |
| Genetics | Gene expression (DNA → proteins → characteristics of organism); gene transmission (meiosis and fertilization); mutations; genetic engineering | DNA structure and replication; Transcription; Translation; Meiosis and fertilization | Inheritance |
| Organism | Organisms are composed of one or more cells; cells often organized in tissues, organs and organ systems; homeostasis and negative feedback | Levels of organization; Cell structure and function | Organism |
| Population Growth | Exponential and logistic models, and their limitations | Levels of organization | Ecology and Evolution |
| Evolution | Changes in a population over time (natural selection, genetic drift, gene flow)  Speciation; the history of life on earth | Genetics; Population growth; DNA structure and replication | Ecology and Evolution |
| Food Webs | Energy transfer between organisms in a community | Energy and biological processes; Population growth | Ecology and Evolution |

\*For each topic, we have prepared a separate record with the same name; each record presents resources teachers can use to help their students develop, understand, and apply the models included in that topic.

