PISCATAWAY
TOWNSHIP SCHOOLS

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Content Area: Research in Molecular Biology and Bioinformatics (Honors)
Grade Span: 11-12
Revised by: Craig Lollin & Jessica Pritchard
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COURSE OVERVIEW

Description

This is a 5 credit full year Honors elective course for students in grades 11 & 12 who have successfully completed one year of Biology and Chemistry.This course consists of an introduction to molecular biology and an authentic research experience. This program has been developed in conjunction with the Waksman Institute of Microbiology at Rutgers University. Student research projects focus on the DNA sequence analysis of genes from an organism of interest, and how these genes compare to those found in other species. Currently Duckweed, a fresh-water aquatic plant, is of interest to the scientific community because of its use in bioremediation and its potential use as a biofuel. Students in the program will isolate and sequence genes from a cDNA library (a collection of mRNA sequences reverse transcribed into DNA). These sequences have never been determined before. If a student successfully analyzes a sequence, it will be published in GenBank, the international repository of all known DNA sequences, for other scientists to study. Each published sequence will bear the student's name and his/her teacher's name. In the course of their analyses, WSSP students will compare Landoltia sequences with those from other eukaryotes to determine the evolutionary relationship of Landoltia to other organisms. In addition, if their sequence codes for a protein from another organism and the three-dimensional structure of that protein has been solved, students may be able to use their sequence information to design a model of that protein and see how it differs from the same protein in Landoltia. Students will be expected to present their research findings in a poster format at the end of the school year. https://wssp.rutgers.edu/research

Goals

The goals of this course are to provide students with the tools needed for an academic and professional career using modern biological and laboratory techniques. The course operates under the simple premise that students learn science by doing. Students will participate in authentic collegiate level research. As their knowledge of these disciplines increases, students will become more independent in the application of various techniques in order to conduct novel research.

Scope and Sequence

Unit	Topic	Length
Unit 1	Biotechnology Industry	3 days
Unit 2	Laboratory Skill Development	5 days
Unit 3	Microbiology, Cell Culture and Polymerase Chain Reaction	7 days
Unit 4	DNA Structure, Analysis and Bacterial Transformation & Plasmid Purification	7 days
Unit 5	Protein Structure & Bioinformatics Analysis	9 days
Unit 6	Poster Presentation (WSSP) – Research Project	12 days

UNIT 1: Biotechnology Industry

Summary and Rationale

This unit will introduce and expose students to a general background of biotechnology, how it is used and regulated, and the types of careers available. What is Biotechnology? Our lives are already significantly affected by the Biotechnology industry and students should gain an understanding of how it affects them and what opportunities exist for employment within the field.

Recommended Pacing

3 days

State Standards

HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.	
Assessment Boundary	Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.
HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.	
Assessment Boundary	Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process
HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.	
Clarification Statement	Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- Develop Background Knowledge of Biotechnology Industry
- Conduct Independent Research of Historically Significant Scientists
- Understand a Research based project in Molecular Biology and Bioinformatics
- Formulate a timeline for a research project from inception to completion

Unit Essential Questions

- What are the historical uses of Biotechnology?
- How can I conduct an authentic research based problem in the field of Biotechnology?
- What are the details that I must be aware of in order to plan my research?
- How do I properly order the tasks involved in a research project?

Objectives

Students will know:

- The basic background of molecular biology and the biotechnology industry
- The importance of keeping accurate notes related to laboratory research
- How model organisms are used in conducting molecular biology research

Students will be able to:

- Keep accurate notes and records of their laboratory research
- Articulate the current WSSP research project and its purpose and goals
- Create and keep the timeline of their ongoing WSSP research project

UNIT 2: Laboratory Skill Development

Summary and Rationale

This unit presents an opportunity to discuss basic safety protocols for the laboratory and experimental procedures that students will be experiencing. This will include the safe handling of materials, the use of PPEs and the proper use of laboratory equipment. In this unit, students will also learn the importance of accurate measurements and how to use equipment to properly make accurate measurements of reagents.

Recommended Pacing

5 days

State Standards

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HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Assessment Boundary	Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- Familiarity with Safety Data Sheets (SDS) documentation
- Observation of current safety requirements within the lab
- Proper and safe uses of the equipment
- Working knowledge of accurate measurements

Unit Essential Questions

- How can we attempt to conduct our experiment/research project and observe safety protocols?
- What do we want our waste disposal practices to be & can we properly implement them?
- Why is it important to document one's laboratory practices?

Objectives

Students will know:

- The proper equipment and uses of the equipment for our research project
- How to make measurements properly with regard to Numbers and Accuracy, Significant Figures, Scientific Notation, Making Solutions, Molar Solutions, Dilutions
- Current safety requirements within the lab and how to properly observe them at all times

Students will be able to (SEPs):

- Research & understand SDS documentation related to materials being used in our research project
- Perform a dilution and/or titration
- Understand and Write a Standard Operating Procedure (SOP)

UNIT 3: Microbiology, Cell Culture and Polymerase Chain Reaction

Summary and Rationale

This unit presents an opportunity to learn the details of prokaryotic and eukaryotic cell culture and their uses in molecular biology. Students will learn how to use a blue/white screening technique and select optimal colonies of bacteria from a cDNA library plate. They will perform an overnight culture for maximal cellular growth followed by both the PCR technique with gel electrophoresis analysis and the miniprep procedure of clone plasmid purification and isolation. Students conduct research and perform lab activities in class.

Recommended Pacing

7 days

State Standards

HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

Assessment Boundary	Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.

HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Assessment Boundary	Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- Microbiology, Cell Culture and Aseptic Technique to transfer Bacteria
- Plasmid cDNA Transformation and the blue/white screening technique
- Bacterial selection and Overnight bacterial growth
- PCR techniques and Gel electrophoresis analysis
- cDNA insert/Plasmid Miniprep isolation and purification

Unit Essential Questions

- What is the relevant history of microorganisms related to research in microbiology?
- What is a cell library? Vectors? Cell culture? An overnight? PCR? Gel electrophoresis?
- What is sterile technique and why is it important/essential to our research?
- How does one select a bacterial colony properly?
- How is a PCR performed?
- How is PCRG used to map the size of an insert?

Objectives

Students will know (DCIs):

- Why microorganisms are used in research
- Important vocabulary and concepts included within the scope of this research project

Students will be able to (SEPs):

- Use sterile technique in the performance of our research activities
- Explain how and why and select colonies from a cell plate library – blue/white screen
- Explain and perform an overnight bacterial culture
- Explain what a vector is and how we will use the pTripEx2 vector during this project
- Explain how the cell plate library was created and provided to us by WSSP
- Analyze a PCRG and properly map the size of the insert
- Complete the cDNA insert/plasmid miniprep isolation/purification

UNIT 4: DNA Structure, Analysis and Bacterial Transformation & Plasmid Purification

Summary and Rationale

This unit presents an opportunity to learn about the details of Nucleic acid structure and its role in the Central Dogma of Biology – a pillar upon which molecular biology was established. Students will learn through information presented in class about the portions of the research project that are performed by WSSP Rutgers scientists and provided to our students in a ready-made form. This includes mRNA purification and reverse transcription preparation of cDNA, plasmid ligations, E. coli transformations and cDNA Library preparation.

Recommended Pacing

7 days

State Standards

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Assessment Boundary	Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.

HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Assessment Boundary	Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- The Central Dogma of Biology
- mRNA purification techniques
- Reverse Transcription of cDNA inserts and plasmid ligation
- *E. coli* plasmid transformations
- cDNA insert/Plasmid Miniprep isolation and purification

Unit Essential Questions

- What is the central dogma of biology? And how does it relate to our project?
- How does the structure of DNA and RNA allow for manipulation in research?
- What are the ethical implications surrounding the new fields of personal genomics within medicine?
- What are practical applications to this kind of biotechnology?

Objectives

Students will know:

- The structure of DNA and RNA
- How the structure of DNA allows for Bioinformatics analysis and laboratory molecular biological manipulation

Students will be able to:

- Discuss the relevance of the central dogma of biology to our research effort
- Explain the process of casting and performing Electrophoresis gels, as well as the significance, common errors of and analysis of PCR and RDG
- Discuss the ethics of personal genomics
- Discuss the methods of completing the cDNA insert/plasmid miniprep isolation/purification

UNIT 5: Protein Structure & Bioinformatics Analysis

Summary and Rationale

This unit presents an opportunity to learn about the details of Protein Structure. Students will gain a deep appreciation for the redundancy of the genetic code as well as the diversity of amino acid sequences that continue to perform similar structural or enzymatic processes within living organisms. Revealed during this type of Bioinformatics analysis are the evolutionary relationships between organisms. Students explore the relationship between the concepts of structure determines function and evolutionary conservation amongst related species (as well as the implications of conservation amongst distantly related species). Students will learn about the 3 dimensional nature of protein folding and use computer modeling programs to visualize and manipulate proteins for display. Students will become familiar with the proteomics databases and how to access this information for analysis.

Recommended Pacing

9 days

State Standards

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Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

Protein Structure – Primary, Secondary, Tertiary and Quaternary
Protein functions – Structural, Enzymatic, Binding, Transport, etc.
Evolutionary implications of sequenced homology
Conducting independent analysis of clone data
Close reading of scientific journals to extract relevant information for research purposes

Unit Essential Questions

- How does the structure of proteins allow for analysis using bioinformatics?
- What can we learn by studying protein sequences from different organisms?
- How does one use DNA/RNA/AA sequence data to draw meaningful conclusions?
- What sources exist to aid in bioinformatics analysis?
- How can current information be used to make predictions about the past/future?

Objectives

Students will know:

- How to effectively use Jmol, DSAP, FinchTv, Cn3D, CDD, NCBI BLAST suite, Toolbox, PDB, The Arabidopsis Information Resource (TAIR) database, Arabidopsis Interactome database, Transcriptome Shotgun Assembly (TSA) database, http://bar.utoronto.ca/cell_efp/cgi-bin/cell_efp.cgi

- Create 'electronic fluorescent pictographic' representations of your gene of interest's subcellular protein product localization

Students will be able to:

- Detail the structure of proteins
- Analyze cDNA/protein sequences and make determinations about evolutionary relationships based on data
- Use DSAP to analyze their Practice clones as well as their unknown clones
- Run BLASTn, BLASTx, BLASTp, BLAST 2 alignment searches
- Use FinchTv to analyze their nucleotide sequence waveforms
- Use Jmol and/or Cn3D to manipulate and display their protein sequences for modeling purposes
- Use NCBI database in order to research and use relevant information about their proteins

UNIT 6: Poster Presentation (WSSP) – Research Project

Summary and Rationale

This unit presents an opportunity for students to develop the culmination project of the course. Students create a poster presentation of their research work throughout the year. The successful students will present their published clone submission and its analysis. Through their presentations, students experience firsthand how scientific information is shared with colleagues and to take ownership over the work that they have completed.

Recommended Pacing

12 days

State Standards

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HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- Public engagement with science describes intentional, meaningful interactions that provide opportunities for mutual learning between scientists and members of the public. Mutual learning refers not just to the acquisition of knowledge, but also to increased familiarity with a breadth of perspectives, frames, and worldviews. https://www.aaas.org/pes/what-public-engagement

Unit Essential Questions

- How does one effectively communicate their research findings to a large audience?

Objectives

Students will know:

- How to use NCBI database in order to research and use relevant information about their proteins
- How to create a poster outlining their relevant research and the data that they collected and analyzed

Students will be able to:

- Present their posters and discuss research projects within molecular biology