HILLSBOROUGH TOWNSHIP SCHOOL DISTRICT

SCIENCE CURRICULUM

RESEARCH IN MOLECULAR BIOLOGY HONORS

AUGUST 2022

Research in Molecular Biology Honors

Course Overview

Research in Molecular Biology Honors is a semester-long course designed to give students a comprehensive introduction to DNA structure & function, protein structure & function, gene expression and regulation, microbiology, and an exploration of biotechnology. It is a rigorous course where students will develop the laboratory, critical thinking, and communication skills currently used in the biotechnology industry. Furthermore, students will participate in the Waksman Student Scholar Program at Rutgers to study the genomics of organisms, such as *Landoltia punctata*, and how the genes in this organism compare to other species. After their analysis of a duckweed gene using modern molecular biology laboratory techniques, such as restriction enzyme digests, PCR, and agarose gel electrophoresis, students will compare their gene sequences using online bioinformatics tools. At the end of the semester, students will present their research findings in a poster session highlighting the structure and function of their protein. The project will conclude with the publication of their gene sequence in databases at the National Center for Biotechnology Information (NCBI) (http://www.ncbi.nlm.nih.gov/) for scientists throughout the world to use.

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Unit Title	**Time Frame/Pacing**
DNA and The Role of Molecular Biology Techniques in Society	45 days

Phenomena/Anchoring Activity/Anchoring Question/Essential Questions

Phenomena:

- iHub Biology Genetics- A brief video that depicts boys who have Duchenne Muscular Dystrophy (DMD). The video depicts them in their everyday lives, enjoying the company of others, but needing support to move and, in some instances, to breathe.
- History of diabetes treatments: Before insulin was discovered in 1921, people with diabetes didn't live for long. Insulin from cattle and pigs was used for many years to treat diabetes and saved millions of lives, but it wasn't perfect, as it caused allergic reactions in many patients. The first genetically engineered, synthetic "human" insulin was produced in 1978 using E. coli bacteria to produce the insulin. Eli Lilly went on in 1982 to sell the first commercially available biosynthetic human insulin under the brand name Humulin.
- Genetically modified crops video

Essential Question:

- How can science be used to make our lives better?
- What bioethical debates surround the use of genetic engineering technologies?

Enduring Understandings

- All cells contain DNA.
- DNA contains regions called genes which code for proteins.
- Mutations in the genetic code can alter protein structure and therefore organism functioning.
- Scientists have developed technologies that can read, interpret, and alter gene sequences in various species.

NJ Standards/NGSS Performance Expectations Taught and Assessed
Students who demonstrate understanding can:

- 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.
- 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.
- HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
- HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

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3-Dimensional Learning Components		
Science and Engineering Practices	**Disciplinary Core Ideas (DCI)**	**Crosscutting Concepts**
Asking Questions and Defining Problems • Ask questions that arise from examining models or a theory to clarify relationships. **Analyzing and Interpreting Data** • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. **Constructing Explanations and Designing Solutions** • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. **Engaging in Argument from Evidence** • Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.	**LS1.A: Structure and Function** • Systems of specialized cells within organisms help them perform the essential functions of life. ○ All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. **LS3.A: Inheritance of Traits** • Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. **LS3.B: Variation of Traits** • In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating	**Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **Scale, Proportion, and Quantity** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another

	new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.	

Interdisciplinary Connections: Math, ELA, and Computer Science and Design Thinking

Math

- MP.2 Reason abstractly and quantitatively. (HS-LS3-2), (HS-LS3-3)

ELA

- RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS1-1)
- WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-1)
- WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-1)

Computer Science and Design Thinking

- 8.2.12.EC.1 Analyze controversial technological issues and determine the degree to which individuals, businesses, and governments have an ethical role in decisions that are made.
- 8.2.12.EC.2 Assess the positive and negative impacts of emerging technologies on developing countries and evaluate how individuals, non-profit organizations, and governments have responded.
- 8.2.12.EC.3 Synthesize data, analyze trends, and draw conclusions regarding the effect of a technology on the individual, culture, society, and environment and share this information with the appropriate audience.

Career Readiness, Life Literacies, and Key Skills

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- 9.4.12.CI.1 Demonstrate the ability to reflect, analyze, and use creative skills and ideas.
- 9.4.12.CT.1 Identify problem-solving strategies used in the development of an innovative product or practice.
- 9.4.12.CT.2 Explain the potential benefits of collaborating to enhance critical thinking and problem solving.

Social-Emotional Learning Competencies

- **Social Awareness**: Demonstrate an awareness of the differences among individuals, groups, and others' cultures.
- **Relationship Skills**: Establish and maintain healthy relationships, Utilize positive communication and social skills to interact effectively with others.

Learning Targets	Investigations/Resources	Formative Assessment
Analyze the basic structure of DNA and how its code will affect the structure of the protein built.	POGIL: Protein Synthesis the Central Dogma of Biology CK-12 PLIX Series- Protein Synthesis Learn Genetics Basic Genetics Module Resources. Ex. Transcribe and Translate a Gene Interactive Explore, Types of Proteins Interactive Explore, Test A Protein's Activity Interactive Explore.	Progress demonstrated in POGIL key concept responses Progress demonstrated in PLIX Open Discussion Question responses Progress demonstrated in Exit ticket responses
Develop skills in performing biotechnology techniques- restriction enzyme digests, bacterial transformation, DNA sequencing, gel electrophoresis, polymerase chain reaction, CRISPR.	Investigation- Gene Colony Transformation Investigation- Restriction Mapping of a Plasmid DNA Investigation- PCR Forensics Simulation Learn Genetics All About PCR-Beta Virtual Lab TeachEngineering Introduction to Genetic Engineering and Its Applications	Progress demonstrated in Lab analysis responses Model a mathematically accurate plasmid map from gel electrophoresis data of the digested recombinant plasmid Summative: After performing lab analysis and conducting research of technology use in society, explain a specific example of how the introduction of a gene into a bacterium can change the phenotype of the bacterium. Also explain the

	iHub Biology Genetics Bend 2 CRISPR How can Science Make our Lives Better?	specific role of the protein expressed by the gene in changing the bacterium's phenotype. Summative: iHub Biology Genetics Lesson 15 Student Activity Sheet- What have we figured out so far about CRISPR?
Research the significance of biotechnology in pharmaceutical development, agriculture, forensics, genetic testing, industrial products, and scientific research.	Evaluating GMO Perspectives	Progress demonstrated in Do Now and Exit ticket responses Summative: Critically Thinking in Pairs Activity- students use evidence to develop an argument to support a specific position on the use of GMOs in society then evaluate arguments from opposing positions to and reach consensus to develop a new position addressing needs and wants of both sides.
Analyze the role of biotechnology in society, including the risks and benefits.	Evaluating GMO Perspectives	See above assessment

Instructional Modifications and/or Accommodations (ELL, Special Education, Gifted, At-Risk of Failure, 504)

- Individual accommodations and modifications in students' IEP and 504's will be followed and adhered to. Along with this: Group work and projects in this unit will be designed to allow the struggling learners to scaffold their learning and develop skills for working on larger projects by breaking down tasks. All students will be given opportunities to use different learning modalities to advance their understanding using varied strategies that accentuate their own learning style. Gifted learners will have the opportunity to challenge their problem solving skills by asking more complex questions and exploring concepts in greater depth.

Summative Assessment(s)	**Assessment Modifications and/or Accommodations (ELL, Special Education, Gifted, At-Risk of Failure, 504)**
• DNA and The Role of Molecular Biology Techniques in Society Unit Test	• All assessments will be modified in accordance with specifications from CST as enumerated in each student's educational plan. This may include, but is not limited to, extra time, clarification of questions, reading questions aloud, word banks, and alternate testing sites.

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Unit Title	**Time Frame/Pacing**
Gene Sequencing and Bioinformatics Analysis	45 days

Phenomena/Anchoring Activity/Anchoring Question/Essential Questions

Phenomena:

- 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.
- A video overview of the Waksman Student Scholar Program and the research project

Essential Question:

- Which genes are expressed in *Landoltia punctata* (duckweed)?
- How do they compare with expressed genes from other species?
- What is the protein's function and where is it localized?
- What is the evolutionary relationship of *Landoltia punctata* to other organisms?

Enduring Understandings

- All cells contain DNA.
- DNA contains regions called genes which code for proteins.
- Mutations in the genetic code can alter protein structure and therefore organism functioning.
- Scientists have developed technologies that can read, interpret, and alter gene sequences in various species.

NJ Standards/NGSS Performance Expectations Taught and Assessed
Students who demonstrate understanding can:

- 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.
- HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.
- 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.
- HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
- HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

3-Dimensional Learning Components

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Science and Engineering Practices	Disciplinary Core Ideas (DCI)	Crosscutting Concepts
Developing and Using Models • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. **Planning and Carrying Out Investigations** • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. **Scientific Investigations Use a Variety of Methods** • Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. **Asking Questions and Defining Problems** • Ask questions that arise from examining models or a theory to clarify relationships. **Analyzing and Interpreting Data** • Apply concepts of statistics and probability (including determining function fits to data,	**LS1.A: Structure and Function** • Systems of specialized cells within organisms help them perform the essential functions of life. ○ All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. **LS3.A: Inheritance of Traits** • Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. **LS3.B: Variation of Traits** • In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and	**Structure and Function** • Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. **Scale, Proportion, and Quantity** • Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another **Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable. **Nature of Science** • Science is a Human Endeavor ○ Technological advances have influenced the progress of science and science has influenced advances in technology.

slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. **Constructing Explanations and Designing Solutions** • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. **Engaging in Argument from Evidence** • Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence.	result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. **LS4.A: Evidence of Common Ancestry and Diversity** • Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.	

Interdisciplinary Connections: Math, ELA, and Computer Science and Design Thinking

Math
- MP.2 Reason abstractly and quantitatively. (HS-LS3-2), (HS-LS3-3)
- HSS-IC.B.6 Evaluate reports based on data. (HS-LS2-6)

ELA
- RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-LS1-1)
- RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-LS4-5)

- RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-LS3-1)
- WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS1-1)
- WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-LS4-6)
- WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HSLS1-3)
- WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-LS1-3)
- WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS1-1)
- SL.11-12.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (HS-LS4-1), (HS-LS4-2)
- SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-LS1-2), (HS-LS1-4), (HS-LS1-5), (HS-LS1-7)

Computer Science and Design Thinking

- 8.2.12.EC.1 Analyze controversial technological issues and determine the degree to which individuals, businesses, and governments have an ethical role in decisions that are made.
- 8.2.12.EC.2 Assess the positive and negative impacts of emerging technologies on developing countries and evaluate how individuals, non-profit organizations, and governments have responded.
- 8.2.12.EC.3 Synthesize data, analyze trends, and draw conclusions regarding the effect of a technology on the individual, culture, society, and environment and share this information with the appropriate audience.

Career Readiness, Life Literacies, and Key Skills

- 9.4.12.CI.1 Demonstrate the ability to reflect, analyze, and use creative skills and ideas.
- 9.4.12.CT.1 Identify problem-solving strategies used in the development of an innovative product or practice.
- 9.4.12.CT.2 Explain the potential benefits of collaborating to enhance critical thinking and problem solving.
- 9.4.12.IML.3 Analyze data using tools and models to make valid and reliable claims, or to determine optimal design solutions.

Social-Emotional Learning Competencies

- **Social Awareness**: Demonstrate an awareness of the differences among individuals, groups, and others' cultures.

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• **Relationship Skills**: Establish and maintain healthy relationships, Utilize positive communication and social skills to interact effectively with others.		
Learning Targets	**Investigations/Resources**	**Formative Assessment**
Analyze the DNA waveform of a gene and determine its open reading frame.	Geospiza's FinchTV: DNA sequence viewer and analyzer Interpretation and correction of DNA waveform	Progress demonstrated in providing the key components of a sequenced gene: 3-UTR, ORF, and 5-UTR Progress demonstrated in Exit ticket responses Accurately complete an edit of a DNA waveform
Isolate and sequence a gene sequence by performing biotechnology techniques- restriction enzyme digests, gel electrophoresis, polymerase chain reaction, plasmid miniprep.	Bacterial Inoculation PCR of Gene Insert Plasmid DNA Miniprep and Restriction Digest of Insert Electrophoresis of Digest and PCR Products	Progress demonstrated in the ability to analyze if there is enough DNA in the miniprep to complete sequencing Progress demonstrated in the ability to analyze the gene sequence length using two forms of evidence– PCR and restriction digest. Accurately model a mocked up gel of a restriction digest and PCR products
Analyze and determine if the gene sequence is similar to genes from other organisms using bioinformatic programs and accessing databases that are used daily by practicing research scientists.	Basic Local Alignment Search Tool (BLAST) DNA Sequence Analysis Program (DSAP) Waksman Student Scholar Program Translator Toolbox	Progress demonstrated in the ability to analyze and compare BLASTX vs BLASTP data Evaluate a PDB Search for Homologous Proteins Progress demonstrated in the ability to perform Expression and Localization Analysis
Using the gene sequence information for a protein from another organism and the three-dimensional structure of that protein, design a model of that protein and see how it differs from the same protein in *Landoltia punctata.*	3-D Protein modeling using Jmol Protein poster presentation	Progress demonstrated in the ability to perform a BLAST2 sequence alignment between the predicted protein sequence from the Wolffia clone and the protein sequence of the *Landoltia punctata* protein to be modeled.

		Summative: Poster session
Instructional Modifications and/or Accommodations (ELL, Special Education, Gifted, At-Risk of Failure, 504)		
• Individual accommodations and modifications in students' IEP and 504's will be followed and adhered to. Along with this: Group work and projects in this unit will be designed to allow the struggling learners to scaffold their learning and develop skills for working on larger projects by breaking down tasks. All students will be given opportunities to use different learning modalities to advance their understanding using varied strategies that accentuate their own learning style. Gifted learners will have the opportunity to challenge their problem solving skills by asking more complex questions and exploring concepts in greater depth.		
Summative Assessment(s)	**Assessment Modifications and/or Accommodations (ELL, Special Education, Gifted, At-Risk of Failure, 504)**	
• Gene Sequencing and Bioinformatics Analysis Unit Test	• All assessments will be modified in accordance with specifications from CST as enumerated in each student's educational plan. This may include, but is not limited to, extra time, clarification of questions, reading questions aloud, word banks, and alternate testing sites.	