**Roanoke Valley Governor’s School for Science and Technology  
Computational Biology and Bioinformatics  
Competency List, 2020-2021**

(Last updated: March 2020)

This course explores the interdisciplinary analysis of biological data, with a focus on bioinformatics and genomics. Students will learn to use existing software, along with developing their own code, to employ gene expression databases in pursuit of research objectives. Major topics include molecular biology, comparative sequence analysis, ‘big data’ resources, human health, and evolutionary biology. Students will gain direct experience with database searches, sequence alignments, visualization of gene expression profiles, and coding in Biopython.

This course is taught using best practices in gifted education. Each competency is aligned with Hockett’s five principles of gifted education:

**Gifted Education Principles:**( Hockett, J.A. (2009) “Curriculum for Highly Able Learners That Conforms to General Education and Gifted Education Quality Indicators.” *Journal of Education for the Gifted***. Vol. 32, No. 3, p. 394-440)**

1. High-quality curriculum for gifted learners uses a conceptual approach to organize or explore content that is discipline based and integrative.
2. High-quality curriculum for gifted learners pursues advanced levels of understanding beyond the general education curriculum through abstraction, depth, breadth, and complexity.
3. High-quality curriculum for gifted learners asks students to use processes and materials that approximate those of an expert, disciplinarian, or practicing professional.
4. High-quality curriculum for gifted learners emphasizes problems, products, and performances that are true to life, and outcomes that are transformational.
5. High-quality curriculum for gifted learners is flexible enough to accommodate self-directed learning fueled by student interests, adjustments for pacing, and variety.

COMPETENCY I

**Conduct analytical and computational investigations using accepted principles of experimental design or engineering goal and analysis.**

*Enabling Objectives:*

* 1. Apply the definition to identify the major concepts of experimental design or engineering goal within the scenario of an experiment including: hypothesis, dependent variable independent variable, constants, control, repeated trials or problem identification, creating alternate solutions, prototyping, testing, and redesigning. Appropriate accommodations will be made to the standard scientific method process in the context of data analysis and programming focus of bioinformatics research.
  2. Apply concepts learned in science and math classes to analyze experiments with respect to the major concepts of experimental or engineering design, design strengths and weaknesses, and develop improved designs.
  3. Write a clear and precise set of procedures.
  4. Apply information learned in science and math courses and use technology available at the school to construct appropriate data tables and graphs for various types of scientific data.
  5. Describe the relationship between variables depicted on a graph as appropriate in the context of the course.
  6. Develop and discuss ethical guidelines for research projects.

COMPETENCY II

**Gather and analyze relevant background information.**

*Enabling Objectives:*

1. Identify relevant library, database, and web resources for specific research problems.
2. Effectively use relevant library, database, and web resources for research and information.
   1. Use search engines to find information on various topics.
   2. Explain strengths and weaknesses of various search engines.
   3. Demonstrate proficiency using advanced search engines.
   4. Properly use and cite information taken from a variety of sources.
   5. Recognize and distinguish between different types of websites.
3. Use professionals in industry or academia as resource people for research project information as necessary and document these contacts.
4. Obtain the most relevant articles and books found in library and internet searches.
5. Analyze articles and books for information relevant to a specific research problem and take notes from them, using proper documentation.

COMPETENCY III

**Complete the steps necessary to design, implement, and analyze a complex experiment or engineering goal.**

*Enabling Objectives:*

1. Design a complex experiment which includes one or more independent variables, and correlation of variables (as relevant for bioinformatics).
2. Successfully meet the established time lines for the performance objectives.
3. Maintain a current, organized, and accurate laboratory logbook.
4. Construct appropriate data tables and graphs for data derived from your experiment.
5. Apply concepts of inferential and descriptive statistics to support conclusions from the experiment.
6. Participate in the RVGS Project Forum and, if appropriate, in the district, regional, state, and international science fairs, and the annual VJAS meeting.

COMPETENCY IV

**Create a project display board or poster to depict the work done on the project for use at Project Forum.**

*Enabling Objectives:*

* 1. All content should be easily read on the board and free of spelling and grammatical errors.
  2. All components of the board should be clearly labeled with appropriate headings (Introduction, Purpose, etc.).
  3. All graphs and photographs should be clearly labeled with appropriate annotations and citations when necessary.
  4. The name of the student should not appear anywhere on the display.
  5. Size specifications for project display board (ISEF regulations) are followed.

COMPETENCY V

**Construct a formal research paper following the format approved by the Virginia Junior Academy of Science.**

*Enabling Objectives:*

1. Create an integrated document.
2. Use information obtained from research to write an introduction and bibliography for the paper.
3. Write a methods and materials section that outlines the procedures followed in the project.
4. Write a results section that includes appropriate tables, graphs, statistics and diagrams. Include a narrative of the results obtained.
5. Analyze the results obtained in the discussion and conclusions section. Relate the project’s work to already published work.
6. Submit the research paper, in VJAS format, to the elective teacher.

COMPETENCY VI

**Create a presentation of the research project and present the research to classmates or at a scientific meeting.**

*Enabling Objectives:*

* 1. Incorporate text and graphics into a presentation.
  2. Add appropriate transitions between elements in a slide and transitions between slides.
  3. Effectively use color for backgrounds and text to add visual value.
  4. Organize key points so that the presentation flows logically and is easy to follow.
  5. Use proper enunciation, pronunciation, pace, and volume in communicating the research to one’s peers.

COMPETENCY VII

**Understand the basic concepts of cell biology, molecular biology, gene expression, and genomics.**

*Enabling Objectives:*

1. Describe the central dogma.
2. Describe the structure of DNA and larger constructs such as chromosomes, plasmids, cosmids, YACs, scaffolds, and other artificial DNA constructs.
3. Describe the structure and modification of various forms of RNA.
4. Describe the structure, modification, and activity of proteins.
5. Describe nucleotide-protein interactions, protein-protein interactions, and nucleotide-nucleotide interactions (including RNAi).
6. Describe gene structure and the role of promoters and epigenetics in gene activation.
7. Describe and contrast genome, transcriptomes, proteomes, and epigenomics.
8. Describe SNPs and their importance in genetic variation.
9. Interpret the significance of molecular biology sequences in the context of human health, including an understanding of disease markers, gene signatures, and hallmarks of cancer.

COMPETENCY VIII

**Understand the key concepts in the analysis of molecular biology sequences at single sequence and –omics levels.**

*Enabling Objectives:*

1. Describe the basics principles of computational biology and bioinformatics as an interdisciplinary science.
2. Describe and contrast nucleotide and protein sequences and interpret the IUPAC/IUB alphabet.
3. Describe nextgen sequencing approaches and their applications, such as GWAS and RNA-seq.
4. Interpret standard sequence nomenclatures and sequence formats, including accession numbers, HGNC, RefSeq, and FASTA.
5. Interpret and employ major molecular biology databases such as those hosted by NCBI.
6. Discuss the connections between homologous sequences and interpret the role of mutation and duplication in phylogeny and evolution.
7. Describe the conserved sequence motifs and interpret sequence logos.
8. Explain the rationale and general methodology of sequence alignments, including scoring and substitution matrices.
9. Contrast types of sequence alignments and explain the terms local, global, pairwise and multiple in the context of sequence alignments.

COMPETENCY IX

**Demonstrate ability to employ and innovate computational biology and bioinformatics software.**

*Enabling Objectives:*

1. Employ standard sequence analysis and database search tools, such as BLAST.
2. Conduct sequence alignments of various types with a range of molecular biology sequences.
3. Demonstrate an understanding of Python and Biopython coding and syntax.
4. Develop workflow diagrams and pseudocode to conceptualize software development.
5. Design and write novel code for processing and analyzing molecular biology sequences.
6. Design and write novel code for automation of computational biology/bioinformatics tasks.