

DNA & Genetics Syllabus – VAMPY

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Course description: Dive into the fascinating world of genetics, where science meets real-world innovation. In this engaging course, you'll explore the building blocks of life, uncovering the mysteries of DNA, genes, and inheritance. Starting with the basics of DNA structure and Mendelian genetics, you'll advance to tackle real-world genetic challenges, from understanding genetic disorders to exploring cutting-edge applications in medicine and biotechnology. This course will provide a scaffolded learning experience accessible to all students, starting with foundational genetics concepts and advancing to college-level studies in genetics. This course involves mixed methods of inquiry and explicit instruction, where minds-on learning takes center stage with daily lab experiments and interactive demonstrations that bring genetics to life. Whether you're passionate about biology or curious about how genetics shapes the world around us, this class offers an exciting journey into one of the most rapidly advancing fields in science. A full list of course objectives is included at the end of this document.

Course philosophy: *VAMPY is one of my favorite places to teach, and I hope it becomes a favorite place to learn for my students.*

This course is accessible to all students and will begin with the basics of DNA and genetics, as all students will not have experienced a high school biology course. However, we will quickly advance past these concepts, exploring more rigorous (and exciting!) levels of study that will include college-level genetics concepts and biotechnology. Expect an active classroom with many different things happening throughout the day, including labs, activities, and lecture/discussion.

Expectations:

- Be ready to learn by being on time with your materials ready.
- Be responsible for your learning by actively participating in discussions, activities, and labs.
- Be respectful by listening to others, helping others, and taking care of our classroom.

Assessments: students will not receive standard grades during this course, but they will be informally quizzed and have their work reviewed and discussed regularly. A pre-test and post-test will be given to measure major learning outcomes.

Laboratory notes:

- Students must have a pair of *closed-toe shoes* available for the lab each day, as labs will take place each day.
- There will be hazardous chemicals we use, so students *must be willing* to follow laboratory procedures and expectations regarding handling and disposal. I will always explicitly discuss safety concerns and actions students should take prior to beginning the lab.

Required Items:

- All learning materials, including textbooks, lab materials, paper, etc., will be provided by the Center For Gifted Studies.

One Lunch (1 hour) and 2 breaks per day:

A 15-minute break is given once in the morning session and once in the afternoon session.

- This time allows for restroom use and water refills.
- Students often go outdoors during this time and play four square, ultimate frisbee, card games, and others!

Study Hall:

Each night students will have a 1 hour study hall including a designated time of independent study for content of the day. Subsequent tasks will vary and could include finishing classroom assignments, studying with one another, and introducing new topics.

Topics, Lab, and Activities during class:

The timeline and order are subject to change based on pacing and student needs and interests, but these are the expected experiences for students. Not all activities or topics are detailed; listed below are those significant in time and content.

Week 1	Week 2	Week 3
<p>Monday: Introductions and team building *Genetics Pre-Test* Lab Safety & Experimental Design Introduction to Genetics and Personalized Genetics Lab: Plant DNA Extraction Set-up lab: Wisconsin Fast Plants</p> <p>Tuesday: Lab: Extracting Human DNA Atoms, bonds, and macromolecules DNA Structure & Replication & Activity Protein Synthesis & Activity</p> <p>Wednesday: Enzymes Activity: Modeling Enzymes Lab: Macromolecules and Enzymes Types of Mutations Lab: Fruit Fly Mutants</p> <p>Thursday: Meiosis and Meiosis Activity Chromosomal Mutations Investigation Single-Gene Inheritance Lab: Wisconsin Fast Plants</p> <p>Friday: Mini-microscopes lesson Beyond Mendel's Laws Lab: Self-blood typing Lab: Synthetic Blood Typing</p>	<p>Monday: Pedigrees Case Study Pedigree Presentation of Chromosomal Mutations Activity: Modeling Protein Synthesis with Sickle Cell Disease Lab: Corn Genetics Chi-squared Analysis</p> <p>Tuesday: Multifactorial Traits Activity: Exploring Multifactorial Traits Sex Chromosomes Case Study: Royal Disease</p> <p>Wednesday: Eukaryotic & Prokaryotic Gene Expression Activity: Modeling Gene Expression in Stickleback Fish Stem Cells</p> <p>Thursday: Population Genetics Activity: Genetic Drift Lab: Genetics of Taste Digest, PCR, & Gel Electrophoresis</p> <p>Friday: Cell Cycle Genetics of Cancer DNA Technology Lab: Gel Electrophoresis #1 Lab: pGLO Bacterial Transformation.</p>	<p>Monday: Lab: pGLO Bacterial Transformation continued. DNA Sequencing Techniques Activity: <i>Genes and Consequences</i> Reproductive Technology</p> <p>Tuesday: Genetically Modified Organisms & Genetic Modification Techniques Lab: pGLO Bacterial Transformation continued. CRISPR-Cas9 and CRISPR Modeling Lab: CRISPR</p> <p>Wednesday: Lab: CRISPR continued Ethics</p> <p>Thursday: <i>Reserved for on-campus experiences that do not have a confirmed time scheduled, but that are in the process of being scheduled.</i></p> <p>Friday: <i>Time Reserved for topics of student interest that were left unaddressed and topics of which students show particular interest.</i></p> <p>*Genetics Post-Test*</p>

DNA & Genetics (VAMPY)	Course Objectives	Collings
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Objectives modified from the [Genetics Society of America's \(GSA\) framework for modern genetics](#); it is my goal for students to learn most of this, though day-to-day pacing and student interests may steer our studies.

Nature of Genetics

How is DNA organized?

- Describe the types of DNA regions that do not encode proteins: the general organization, possible function, and frequency of genes and non-gene DNA sequences in a typical eukaryotic genome.
- Explain what is meant by single-nucleotide polymorphism (SNP) and short tandem repeat (STR), and explain how SNPs and STRs can be used as genetic markers even if they do not cause phenotypic changes.
- Discuss how DNA is packaged in the chromosomes in terms of histones, nucleosomes, and chromatin
- Explain the meaning of ploidy (haploid, diploid, aneuploid etc.) and how it relates to the number of homologues of each chromosome.
- Describe how the positions of individual genes on a given chromosome are related to their positions on the homolog of that chromosome.
- Differentiate between a gene and an allele, including the recognition that genes may have many alleles.
- Explain the functional significance of packaging DNA into chromosomes and the lack of correlation between chromosome size and genetic information content.

What are the molecular components and mechanisms necessary to preserve and duplicate an organism's genome?

- Draw a simple line diagram showing a segment of DNA from a gene and its RNA transcript, indicating which DNA strand is the template, the direction of transcription and the polarities of all DNA and RNA strands.
- Describe the process of mitosis, transcription, and translation. How are mistakes in these processes identified and corrected?

Transmission & Patterns of Inheritance

What are the mechanisms by which an organism's genome is passed on to the next generation?

- Distinguish between somatic and germline cells; listing similarities and differences.
- Compare and explain the inheritance of germline and somatic mutations.
- Describe, using diagrams, the sequence of events involving DNA in meiosis from chromosome duplication through chromosome segregation.
- Explain how meiosis is different from mitosis.
- Explain how independent assortment of alleles during meiosis can lead to new combinations of alleles of unlinked genes.
- Describe the difference between meiosis in mammalian males and females.
- Distinguish between sister chromatids and homologous chromosomes.
- Discuss how errors in chromosome number can arise during meiosis, and why such alterations can be detrimental

- Calculate the probability of a particular gamete being produced from an individual assuming independent segregation.
- Calculate the probability of a particular genotype, given independent segregation and random union of gametes between two individuals.
- Contrast the mechanisms of inheritance of nuclear and organellar genetic information

How can one deduce information about genes, alleles, and gene functions from analysis of genetic crosses and patterns of inheritance?

- Interpret pedigree information to determine the suitability of a DNA marker for tracking a disease trait in a family.
- Draw a pedigree based on information in a story problem.
- Using pedigrees, distinguish between dominant, recessive, autosomal, X-linked, and cytoplasmic modes of inheritance.
- Predict the transmission of phenotypes associated with maternal effect genes.
- Explain why the terms “dominant” and “recessive” are context dependent and may differ at the cellular level or at the level of a pedigree.
- Calculate the probability that an individual in a pedigree has a particular genotype (using Bayesian inference if appropriate for course).
- Design genetic crosses to provide information about genes, alleles, and gene functions.
- Interpret the results of experiments comparing the phenotypes that result from single mutations in two different genes with the phenotype of the double mutant, contrasting epistatic and additive interactions.
- Explain how continuous traits are the result of many different gene combinations that can each contribute a varying amount to a phenotype.
- Evaluate how genes and the environment can interact to produce a phenotype.

How does the phenomenon of linkage affect the assortment of alleles during meiosis?

- Use statistical analysis to determine how well data from a genetic cross or human pedigree analysis fits theoretical predictions including an explanation of the appropriate statistical test.
- Explain the meaning of a LOD score.
- Diagram the process of homologous recombination during meiosis and explain how it can lead to new combinations of linked alleles.
- Explain the role of homologous recombination in ensuring proper segregation of homologs in meiosis I.
- Explain how a specific combination of linked alleles (haplotype) can persist through many generations (linkage disequilibrium).
- Calculate gene linkage and genetic map distances and interference from the frequencies of progeny with recombinant phenotypes from genetic crosses.
- Explain how genetic distance is different from physical distance.
- Calculate the probability of a particular gamete being produced from an individual, provided map distance.

Molecular Biology of Gene Function

How is genetic information expressed so it affects an organism’s structure and function?

- How is genetic information expressed so it affects an organism’s structure and function?
- Explain how the genetic code relates transcription to translation
- Describe how expansion or retraction of triplet repeats can alter gene function and create a phenotype

- Discuss how various factors might influence the relationship between genotype and phenotype (e.g. incomplete penetrance, variable expressivity, and sex-limited phenotype)
- Explain how abnormalities in gene dosage can affect phenotype.

Expression and Regulation

How can gene activity be altered in the absence of DNA changes?

- Discuss the roles of types of RNA other than mRNA in expressing genetic information
- Defend how most cells can have the same genetic content and yet have different functions in the body.
- Contrast the packaging of DNA into euchromatin versus heterochromatin in the context of histone modification, and DNA modification (where applicable).
- Discuss the potential roles of DNA modification, histone modification, and non-coding RNA in epigenetic inheritance, both somatic and germline.
- Discuss environmental impacts on epigenetic systems.
- Gene Regulatory Networks: Model how transcription factors, enhancers, and repressors interact to form networks controlling development.

How do genes and genomes control changes in an organism's structure and function throughout its life cycle?

- Describe how differential histone modification modulates gene activity and is utilized in developmental progression
- Use a model systems to describe investigations of evo-devo
- Describe genetic cascades; use the sex-determination cascade to explain how differential gene expression can result in the development of different sexes.
- Explain how polarity is established in a developing embryo using gene expression gradients.

Genetic Variation

- How do different types of mutations affect genes and the corresponding mRNAs and proteins?
- Describe how duplications, deletions, inversions, and translocations can affect gene function, gene expression, and genetic recombination. Describe the same for transposable elements.
- Describe how mutations arise and how environmental factors can increase mutation rate.
- Cite examples of mutations that can be beneficial to organisms.
- Interpret results from experiments to distinguish between different types of DNA rearrangements.
- Distinguish between loss of function and gain of function mutations and their potential phenotypic consequences.
- Predict the most likely effects on protein structure and function of null, reduction-of-function, overexpression, dominant-negative and gain-of-function mutations.
- Compare the role of both loss and gain of function mutations in the origin of tumors

Evolution and Population Genetics

What are the processes that can affect the frequency of genotypes and phenotypes in a population over time?

- Describe the mechanisms by which variation arises and is fixed (or lost) in a population over time.
- Calculate allele frequencies based on phenotypic or genotypic data for a population, and be able to explain the assumptions that make such a calculation possible.

- Model how random mating yields predicted genotype frequencies in Hardy-Weinberg Equilibrium (HWE), and how non-random mating affects allele and genotype frequencies.
- Test whether HWE has been reached in a population.
- Explain how inbreeding increases the number of homozygotes (and possibly disease) in comparison to HWE.
- Explain how natural selection and genetic drift can affect the elimination, maintenance or increase in frequency of various types of alleles (e.g. dominant, recessive, deleterious, beneficial) in a population.
- Interpret experiments to determine the relative influences of genes and the environment on a given phenotype.
- Describe how variation can be measured, and what can be done to distinguish genetic and environmental sources of variation.
- Interpret bioinformatics data to compare homologous genes in different species and infer relative degrees of evolutionary relatedness.
- Use comparative data from multiple species to identify which regions of a protein, pathway, regulatory system etc. are critical for function.

Genetics of Model Organisms

How do the results of molecular genetic studies in model organisms help us understand aspects of human genetics and genetic diseases?

- Justify why information on functions of human genes can often be acquired through studies of simple model organisms such as yeast, nematode worms, and fruit flies.
- Compare the benefits and limitations of using model organisms to study human genes and human genetic diseases. Identify specific cases where insights from model organisms have provided crucial insights into human disease.
- Defend the assertion that genetic testing will play a central role in the diagnosis and treatment of cancer in the future.

Methods and Tool in Genetics

What experimental methods are commonly used to analyze gene structure, gene expression, gene function, and genetic variants?

- Explain reverse genetics and compare methods for generating specific mutations in the genome vs. generating phenocopies using techniques such as RNAi or morpholinos.
- Explain the method of SNP/STR mapping and interpret SNP/STR mapping data to pinpoint the chromosomal location of a human disease gene.
- Interpret complementation tests, including an assessment of the molecular interactions that might yield the results observed.
- Genome Editing and CRISPR Technology:
- Explain how tools like CRISPR-Cas9 and base editors can be used to alter DNA sequences and study gene function.
- (Next Generation Sequencing) Explain the principles and applications of high-throughput sequencing for detecting mutations, expression, and genome assembly.
- Single-Cell Technologies: Introduce single-cell sequencing and its role in resolving cell heterogeneity.
- Use online tools (e.g., BLAST, Ensembl, UCSC Genome Browser) to analyze genes and variants.
- Interpret sequencing data (FASTQ, BAM, VCF) and gene expression matrices.