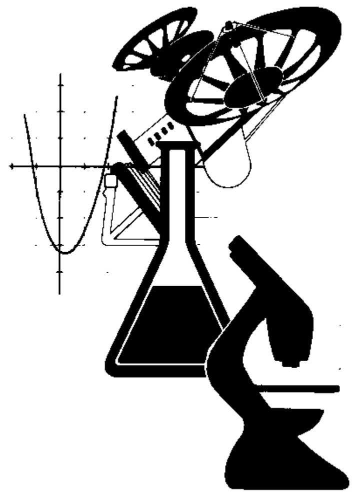
COURSE CATALOG



Governor's School
of
New Jersey Program
in the
Sciences
at
Drew University

2024

2024 GSNJS COURSE CATALOG

CONTENTS

PROGRAM DESCRIPTION

The Governor's School in the Sciences has several objectives. The first is to broaden the scholars' appreciation and knowledge of science through exposure to a range of scientific topics and scientists. The subject of career exploration and choice is woven throughout the program. The second objective is to introduce scientific research to the scholars via hands-on research experience in a student's area of interest. Resources from New Jersey's industrial, governmental, and academic science establishments are used.

The program at Drew consists of a number of components designed to accomplish the objectives.

1. There is a core curriculum of six courses in biochemistry, physics, chemistry, mathematics and biological anthropology. Offered four times a week, these courses address aspects of these fields not normally seen in either high school or first year college. *Students are required to select **three** courses from this core.* Homework is assigned, although no grades are given for the courses.

2. Biology, organic chemistry, computer science, physics and molecular biology laboratories are held two afternoons a week. Each offers innovative experiments. *Each student must select **one** lab course.*

3. Three afternoons a week are set aside for work on team projects. Students work in small teams under faculty guidance on mini-research topics. Recent topics have included olfactory learning and memory, modeling small molecule movement across a polymer membrane, machine learning in python, impact of air pollution on biogeochemical cycle, cloning and functional complementation of EF3. The final day of the school is devoted to a scientific meeting at which teams report their results to the entire group. Work on the research projects frequently takes place during free times on weekends.

4. Evening colloquium speakers discuss modern science from both industrial and academic viewpoints. This allows a glimpse into doing science and provides a discussion of real-world considerations related to work in science.

During free evenings and weekends, there is time for study, as well as for recreation, on the campus and in the town of Madison. Entertainment and special events on campus include films, Career Day and a Talent Show. Students can attend local religious services nearby.

Closing ceremonies are held at a farewell gathering for all scholars, faculty, counselors, and visiting dignitaries.

The faculty for the Governor's School in the Sciences includes science faculty from Drew and other local colleges and high schools.

Free of exams, grades, or any form of AP or college credit, the experience of scholars spending an intensive period of time working, learning, and living together always has proved to be productive, satisfying and memorable for all concerned.

2024 GOVERNOR'S SCHOOL IN THE SCIENCES COURSE SCHEDULE

CORE COURSES (M, T, Th, F)			
9:00 am – 10:00 am			
HS-4	C1	Neurobiology	Knowles/
HS-308	C14	Data Analytics	Liporace/
10:10 am – 11:10 am			
HS-308	C4	Molecular Orbital theory	Pearsall /
HS-4	C8	Human Evolution	Windfelder/
11:20 am – 12:20 pm			
HS-4	C11	Molecular Biology of Cancer	Dunaway/
HS-308	C7	Chemical Principles in Living Systems	Cassano/
LABORATORIES (T, Th*) 1:30 pm – 4:15 pm (July 9, 11, 16, 18, 23, ***24)			
HS-226	L2	Experiments in Organic Chemistry	Pearsall /
BC-1	L3	Experiments in Computer Science	Kass/
HS-229	L5	Experiments in Biochemistry	Barrabee & Bruno/
HS-106	L7	Experiments in Forensic Anthropology	Monetti/
TEAM PROJECTS (M, W*, F) 1:30 pm – 4:15 pm (July 8, 10, 12, 15, 17, 19, 22, ***25)			
HS-106	T6	Project in Archaeology and Material Science	Masucci/
HS-139	T12	Project in Psychology	Dolan/
HS-229	T18	Project in Chemistry	Cincotta/
HS-105	T20	Project in Environmental Biology	McQuigg/
HS-308	T21	Project in Mathematical Physics	Surace/

*****Team Projects and Laboratories are switched in the last week with Labs meeting on Wed (July 24) and Projects meeting on Thurs (July 25)*****

CORE COURSES

C1 NEUROBIOLOGY

INSTRUCTOR: Roger Knowles, Drew University

In this course, students explore the biological basis for the mental processes by which we think, perceive, learn and remember. First, students study how neurons in the brain communicate with each other, with an emphasis placed on molecular mechanisms of synaptic transmission. Next, students examine how sets of neurons are organized into functional anatomical regions and how signaling among these regions give rise to discrete cognitive systems. Using tools gained from these cellular and anatomical lessons, students then debate two major questions in neurobiology: 1) how does the brain store memories, and 2) what happens to the brain when Alzheimer's disease robs patients of their memories. Throughout this course, students are challenged to consider how ongoing and future research can further our understanding of how the brain functions.

C4 AN INTRODUCTION TO MOLECULAR ORBITAL THEORY

INSTRUCTOR: Mary-Ann Pearsall, Drew University

Chemistry is centered around the study of atoms and their interactions with each other to form chemical bonds. You may have noticed that many of the principles of chemistry require you to accept "exceptions" and things that do not quite fit. In this course, we will examine a more sophisticated electron-wave based approach to chemical bonding which is known as molecular orbital theory. We will use this approach to describe the bonding in a variety of systems to obtain some clarity of understanding into the sometimes rather contradictory guiding principles of conventional bonding theories

We will begin with a description of electron waves in atoms, and then review the conventional bonding theories of ionic and covalent bonds. As we do, we will highlight some of the problems with these approaches, and acknowledge places where our conventional theories are no longer sufficient, even for simple molecules such as oxygen and hydrogen sulfide. We will then apply our understanding of electron waves in atoms to chemical bonding to develop a cohesive and elegant understanding of bonding. Then, with stunning simplicity, we will resolve the puzzles posed by those annoying exceptions, and unsatisfying descriptions such as resonance and metallic bonding. In doing so, we will gain insight into the beauty of molecules and the amazing ways that atoms can put themselves together.

A solid background in chemistry will be assumed. One year in high school will be fine. This material does not repeat AP chemistry and is appropriate whether or not you have completed an AP chemistry course.

C7 CHEMICAL PRINCIPLES IN LIVING SYSTEMS

INSTRUCTOR: Adam Cassano, Drew University

The complex networks of interacting molecules which give rise to life must follow basic chemical principles. In this course, we will apply chemical principles related to intermolecular forces, thermodynamics, equilibrium, and kinetics to explore biochemical phenomena, including binding affinity, specificity, and enzyme catalysis. This course will quickly introduce (or review!) these basic chemical principles, derive the equations describing the phenomena, and apply them to biological processes such as signal transduction, transcriptional regulation, and metabolism.

C8 HUMAN EVOLUTION

INSTRUCTOR: Tammy Windfelder, Drew University

This course approaches human evolution from a theoretical point of view, combining both biological and cultural processes into a cohesive bio-cultural model. It begins by tracing the development of modern evolutionary theory and then turns to the many lines of evidence used to explore and explain human evolution. These lines of evidence include studies of our primate relatives, discoveries from the fossil record, patterns of modern day genetic variation, and archaeological evidence. Modern human variation can only be explained as the end result of evolutionary forces acting on the complex interplay of biology and culture over millions of years. We continue to be affected by these forces, and this course not only provides information about where we came from, it also provides the scientific background to help us understand where we might be going as our species continues to evolve.

C11 MOLECULAR BIOLOGY OF CANCER

INSTRUCTOR: Stephen Dunaway, Drew University

As a disease of the DNA, cancer can arise from disruption of multiple cellular pathways, particularly those that control cell cycle progression. The course will focus on the initial observations of the molecular basis for this group of diseases at the outset. Then we will expand our coverage of the topic by focusing on various oncogenes and tumor suppressor genes that play prominent roles in cancer development. We will spend time investigating how cells monitor and protect genomic stability and the roles these pathways play in preventing cancer. We will also investigate how cancer cells progress to a metastatic state which allows them to freely circulate throughout the body. Finally, we will spend time discussing various clinically relevant cancer treatments.

C14 DATA ANALYTICS

INSTRUCTOR: Diane Liporace, Drew University

Although the statistical analysis of data has existed for a long time, some say thousands of years, modern data analytics is something altogether unique to our time and is changing the world we live in.

This course will begin with a discussion of the 4 V's of big data: Volume, Velocity, Variety, and Veracity and by identifying real use cases. Then, students will install Anaconda with Python and Jupyter Notebook, the popular software development environment used by data scientists. They will explore the Python data science libraries NumPy for scientific computing and statistics, Pandas for data manipulation and analysis, and Matplotlib and Seaborn for visualization. Students will read a CSV file containing real world data from an open data repository and use general programming concepts and techniques to perform data analysis.

All software distributions are free and downloadable via the internet.

LABORATORY

L2 EXPERIMENTS IN ORGANIC CHEMISTRY

INSTRUCTOR: Marry-Ann Pearsall, Drew University

Organic chemistry is the chemistry of carbon-containing compounds. In this laboratory you will learn some of the experimental techniques used in organic chemistry and explore how structure affects properties and reactivity. In the experiments that you will do, you will extract some organic molecules from natural sources, and synthesize (make) others. You will characterize these molecules using a variety of methods. This laboratory requires a background of high school chemistry.

L3 EXPERIMENTS IN COMPUTER SCIENCE

INSTRUCTOR: Steven Kass, Drew University

CELLULAR AUTOMATA

Cellular automata are dynamical systems based on simple rules that can produce surprisingly complex patterns and behavior. A cellular automaton is a "world" made up of discrete cells, each of which evolves over time according to a simple set of rules. Cellular automata can model a vast variety of phenomena, including the motion of gasses, patterns seen in nature (think leopard spots or butterfly wings), the spread of epidemics, crystal growth, and patterns of evolution and even human-like behavior. In this computing laboratory course, we will build and study both known and new cellular automata. No previous programming experience is assumed.

L5 EXPERIMENTS IN BIOCHEMISTRY

INSTRUCTOR: Ellen Barrabee & JoAnne Bruno,

YADH-a, YADH-a, YADH-a! Protein Purification and Enzyme Activity of Yeast Alcohol Dehydrogenase

Proteins are large biomolecules made of smaller building blocks called amino acids that are organized into chains to form intricate three-dimensional structures. In the laboratory, proteins are purified from complex mixtures, such as cells or tissues, through a series of processes that are selected based on the properties of the protein of interest. Once isolated, the protein function, structure, and interactions can be characterized and studied.

In this hands-on laboratory course, participants will isolate the protein, Alcohol Dehydrogenase (ADH), from yeast. Yeast alcohol dehydrogenase (YADH) is a special type of protein, called an enzyme, responsible for catalyzing the conversion of an aldehyde to ethanol (alcohol) during the fermentation of glucose. Classical protein purification techniques will be employed, including cell disruption, protein precipitation, affinity chromatography, dialysis, and centrifugation. Once protein purity has been established using gel electrophoresis, and protein concentration has been calculated using a Bradford colorimetric assay, participants will measure the enzymatic activity and specificity of the isolated YADH protein using absorption spectroscopy.

L7 FORENSIC ANTHROPOLOGY

INSTRUCTOR: Lisa Monetti, Drew University

Forensic anthropology is the scientific field that provides expert analysis of the skeleton in medico-legal contexts. Forensic anthropologists rely on an understanding of skeletal biology, archaeology, and forensic science to identify skeletal remains and interpret the circumstances of death, decomposition, and the body's interaction with the environment. This lab course will introduce students to the scientific methodology used by forensic anthropologists to analyze the skeleton, estimate the biological sex, age at death, and stature of an individual from skeletal remains, interpret skeletal trauma, and see how those data can be used towards the personal identification of the individual.

Students will have access to replica skeletal remains and will have an opportunity to observe real human skeletal remains only if they wish to and after discussions about ethical study of human remains. This course will encounter topics related to death, interpersonal violence, and the criminal justice system and will prioritize the ethical analysis and treatment of human remains.

TEAM PROJECTS

T6 PROJECT IN ARCHAEOLOGY

INSTRUCTOR: Maria Masucci, Drew University

ARCHAEOLOGY AND MATERIALS SCIENCE: DECODING THE SECRETS OF ANCIENT ECUADORIAN POTTERY ENGINEERS

Archaeologists have come to recognize that the technological choices of ancient crafts persons are sensitive data for understanding past cultures and industries. These are also the most enduring cultural traits and the best indicators for cultural relationships as communities of practice form around common training and the passing down of technology across generations. This is the basis of the "chaîne opératoire" approach to ancient technology and the investigation of ancient societies where we have only stone tools and ceramic artifacts - the two most enduring and common artifact types found on archaeological sites – to give a glimpse into the lives and knowledge of ancient peoples. In this project our goal is the reconstruction of the "chaîne opératoire" for an ancient Ecuadorian community of potters from ca. 200 BC – 600 AD. The project will provide new contributions to the understanding of this ancient culture which is often overlooked due to the focus on better known societies of Mexico and Peru. We will employ multiple types of analysis including thin section analysis with **optical petrography** (polarizing light microscope), macroscopic analysis using **3D scanning** with an IPad Pro for cross-section analysis of the ancient pottery sherds and **experimental archaeology** by making and firing our own experimental ceramics to provide test comparisons and controls for our analysis of the archaeological ceramics.

T12 PROJECT IN PSYCHOLOGY

INSTRUCTOR: Patrick Dolan, Drew University

COGNITIVE ILLUSIONS

Illusions fascinate us because they trick us into believing something that is quite different from reality (*illudere* - to mock). Far from just a curiosity, illusions provide a window into our thought processes and how the brain works when it is not being tricked. Equipped with the ability to process only a limited amount of information, the brain develops "shortcuts" in order to handle the enormous amount of information received from our five senses. While these shortcuts often serve us well, they occasionally fail us, leading to cognitive illusions. This team project will research some facet of cognitive illusions related to our perception, memory, or reasoning.

T18 PROJECT IN CHEMISTRY

INSTRUCTOR: David Cincotta, High Tech High School

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING TO IDENTIFY NEW THERAPEUTICS AND LEAD COMPOUNDS

Traditionally, molecular docking has been used to predict the ability of drug candidates to bind with disease proteins. This structure-based approach makes computational docking calculations of the binding confirmations and free energies of binding of small-molecule ligands to large disease molecules thus inactivating the disease process. Until recently, this required brute force calculations to identify potential binding sites on a protein followed by free-energy calculations of binding affinities with a ligand. Now, artificial intelligence and machine learning have accelerated the identification of binding sites and simplified the calculations. A crucial remaining question is whether AI and ML make better predictions (leading to better pharmaceuticals and more effective treatments) than do the traditional methods. This summer, Scholars will make ML and traditional calculations of binding affinity on protein-ligand pairs with experimentally known affinities to demonstrate the relative effectiveness of both methods. They will utilize public databases of small-molecule pharmaceuticals to identify candidates for re-purposing against significant diseases that have not yet been cured or are difficult to treat. Scholars will predict ligand position and orientation in binding sites and calculate binding affinities to help identify promising small molecules for future investigation.

T20 PROJECT IN ENVIRONMENTAL BIOLOGY

INSTRUCTOR: Jessica McQuigg, Drew University

EVALUATION THE ROLE OF ZOOPLANKTON AND AQUATIC MACROINVERTEBRATES IN AN AMPHIBIAN DISEASE SYSTEM

The description of the project is: Wildlife disease outbreaks are increasing in frequency and severity around the globe. Disease dynamics are governed by complex interactions between hosts, pathogens, and the environment in which they interact. The amphibian chytrid fungus, *Batrachochytrium dendrobatidis (Bd)*, is one of the most devastating wildlife pathogens to date. Interestingly, while *Bd* devastates frog populations in some regions around the globe, it has less dramatic effects on the amphibians of the United States Midwest and east coast. Understanding why disease dynamics vary among species and populations affected by this pathogen is critical to mounting a management response to disease outbreaks. This project strives to determine if community interactions between *Bd* and aquatic macroinvertebrates and zooplankton may be moderating disease dynamics in this system.

T21 PROJECT IN MATHEMATICAL PHYSICS

INSTRUCTOR: Steve Surace, Drew University

CELESTIAL MECHANICS

Every trigonometry student learns how to completely determine the angles and sides of a planar triangle given certain pieces of information such as two sides of a triangle and the included angle. The Law of Sines and the Law of Cosines are two important results which allow us to make these calculations.

Since the sky appears to be a giant sphere with the Earth as its center, it important to study the properties of Spherical Triangles, i.e. triangles on a sphere. We will discover the analog of the Law of Sines and the Law of Cosines for these triangles. These laws will allow us to completely determine the measure of the sides and angles of a spherical triangle if we are given sufficient information (such as two sides and the included angle).

Kepler's Laws of planetary motion will be derived and we will combine them with the laws of spherical trigonometry, ellipse geometry, and Newton's Law of gravity to chart the positions of the planets for any day and time. We will use our results to write a computer program which will serve as a model of the Solar System.

Prerequisites: Parts of this project will involve sophisticated calculations using Calculus. Other parts will involve trigonometry and geometry. While calculus is not required for everyone in the project, a strong background and facility with high school mathematics is required to do even the non-calculus part of the project.

2024 SCHEDULE - NEW JERSEY GOVERNOR'S SCHOOL IN THE SCIENCES

<table>
<tr><th></th><th>SUN</th><th>MON</th><th>TUE</th><th>WED</th><th>THUR</th><th>FRI</th><th>SAT</th></tr>
<tr><td>7:45 am – 8:45 am</td><td colspan="7">Breakfast</td></tr>
<tr><td>9:00 am</td><td rowspan="3"></td><td colspan="2"><u>Core Course</u>
C1
C2</td><td rowspan="3">Free Time</td><td colspan="2"><u>Core Course</u>
C1
C2</td><td>Career Day
7/13
10:00 am –
12:15 pm</td></tr>
<tr><td>10:10 am</td><td colspan="2">C2
C3</td><td colspan="2">C2
C3</td><td></td></tr>
<tr><td>11:20 am</td><td colspan="2">C5
C7</td><td colspan="2">C5
C7</td><td></td></tr>
<tr><td>12:30 pm – 1:15 pm</td><td colspan="7">Lunch</td></tr>
<tr><td>1:30 pm –
4:15 pm Team/Lab</td><td></td><td>Team Project</td><td>Laboratory</td><td>Team Project</td><td>Laboratory</td><td>Team Project</td><td></td></tr>
<tr><td>5:00 pm</td><td colspan="7">Dinner</td></tr>
<tr><td>7:00 pm</td><td></td><td>Speaker
7/15</td><td>Speaker</td><td></td><td>Speaker
7/11
7/18</td><td>Movies</td><td></td></tr>
<tr><td>Evenings</td><td>Events</td><td></td><td></td><td></td><td></td><td>Events</td><td>Movies</td></tr>
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