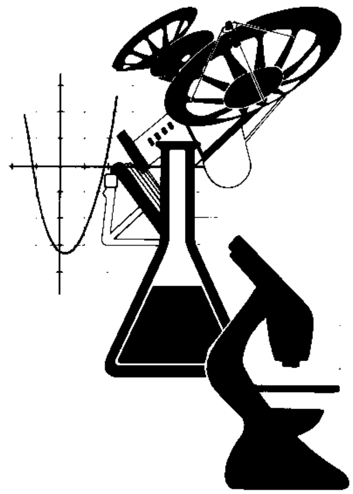
COURSE CATALOG



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

2025

2025 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.

2025 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/ Brenna
HS-308	C14	Data Analytics	Liporace/ Harris
10:10 am – 11:10 am			
HS-308	C4	Molecular Orbital theory	Pearsall / Ece
HS-4	C8	Human Evolution	Windfelder/ Katelyn
11:20 am – 12:20 pm			
HS-4	C11	Molecular Biology of Cancer	Dunaway/ Chrissy
HS-308	C3	Special Relativity: Concepts, Consequences, and Applications	Gonzalez Silva/ David
LABORATORIES (T, Th*) 1:30 pm – 4:15 pm (July 8, 10, 15, 17, 22, ***23)			
HS-226	L2	Experiments in Organic Chemistry	Pearsall / Chrissy
HS-229	L5	Experiments in Biochemistry	Barrabee, Bruno & Salituro/ David
HS-203	L6	Experiments in Physics	Murawski/ Harris
HS-133	L13	Experiments in Cell Biology	Dorrity/ Brenna
TEAM PROJECTS (M, W*, F) 1:30 pm – 4:15 pm (July 7, 9, 11, 14, 16, 18, 21, ***24)			
HS-3A	T4	Project in Neuroscience	Cousens/ Harris
HS-106	T6	Project in Archaeology and Material Science	Masucci/ Katelyn & Ece
HS-139	T12	Project in Psychology: Cognitive Illusions	Dolan/ Brenna
HS-208	T	Project in Computer Science: AI-assisted Discovery of Physics Laws	Kouh/ David & Ece
HS-133	T	Project in Molecular Biology	Dorrity/ Chrissy

*****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.

C3 SPECIAL RELATIVITY: CONCEPT, CONSEQUENCES, AND APPLICATIONS

INSTRUCTOR: David Gonzalez Silva, Colts Neck High School / Rutgers University

This course explores Einstein's Theory of Special Relativity, a groundbreaking framework that reshaped our understanding of space, time, and motion. Beginning with Einstein's two postulates, the course builds toward a conceptual and mathematical understanding of relativistic kinematics and the surprising implications of the theory, including simultaneity, and the relativistic effects of time dilation, and length contraction. To help students visualize and analyze these phenomena, the course introduces spacetime diagrams and light cones, along with transformations between different reference frames, inertial and noninertial. Students will also examine relativistic momentum and energy, as well as the Doppler effect for electromagnetic waves. The course will also touch on foundational ideas from General Relativity with an emphasis placed on developing a strong conceptual grasp and connecting theoretical insights to real-world applications such as the Global Positioning Systems, satellite communications, and stellar spectroscopy. The course is accessible to students with minimal previous backgrounds in physics and aims to challenge common conceptions shaped by experiences at everyday speeds, offering an exciting window into the counterintuitive yet experimentally confirmed nature of relativistic phenomena.

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.

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.

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.

L6 EXPERIMENTS IN PHYSICS

INSTRUCTOR: Robert Murawski, Drew University

ELECTRONICS LABORATORY

Electronic devices are pervasive in every aspect of today's world. From emails to EVs, from solar panels to cell phones, and from batteries to Bitcoins, almost all modern conveniences are thanks to electronics. Therefore, a solid understanding of electronics is a key to understanding the way the modern world operates. In this series of labs, we will take a look at what is under the hood of electronic devices. The fundamentals of DC and AC circuits will be taught and the labs will coincide with the lectures. Starting from the basics of Ohm's law and working towards small signal amplification, the focus of the labs will always be a learn by doing approach. Students will leave with a deeper appreciation of electronics and hopefully start to see the invisible world behind the plug.

L13 EXPERIMENTS IN CELL BIOLOGY

INSTRUCTOR: Tyler Dorrity, The College of New Jersey

In this lab course, we will use microscopes to examine and manipulate cells. Microscopy is delicate work, requiring careful handling and preparation of cellular samples, and patience. Using diverse types of microscopes (light microscopes, confocal, immunofluorescent), we will observe both bacterial and human cells. Beyond microscope operation and image analysis, you will learn how to count and dilute cells, immunofluorescent staining, blood diagnostics, and bacterial staining protocols. These techniques are broadly applicable both in biological research, and in clinical settings.

TEAM PROJECTS

T4 PROJECT IN PSYCHOLOGY AND NEUROSCIENCE

INSTRUCTOR: Graham Cousens, Drew University

OLFACTORY OSCILLATIONS

The mammalian olfactory system supports a remarkable ability to detect, distinguish, and remember the perceptual profiles of a huge array of complex odorant mixtures. Olfactory processing is dependent on the flow of vaporized odorants across the olfactory epithelium, and both orthonasal olfaction (associated with sniffing) and retronasal olfaction (associated with swallowing) involve rhythmic oscillatory patterns that reflect the coordinated activity of diverse neuronal populations across olfactory regions. This project will investigate the characteristics of oscillatory activity in the mouse olfactory system using extracellular electrophysiological recordings to monitor local field potentials (LFPs) and single-unit activity. Some programming experience is beneficial but not required.

T6 PROJECT IN ARCHAEOLOGY

INSTRUCTOR: Maria Masucci, Drew University

ARCHAEOLOGY AND MATERIALS SCIENCE: SACRED STONE OR CLEVER FAKES?

Extensive evidence exists from accounts of the first meetings between Europeans and the original peoples of Latin America of the value placed on “green stone” as a sacred material. The ancient societies of coastal Ecuador participated in these beliefs and placed green stone beads and ornaments in the burials of their highest status members. Based on these historic accounts archaeologists have “assumed” that the ancient societies of Ecuador were trading for “precious” stones for their high status ornaments and burials. Archaeologists have referred to these “green stone” objects with a range of labels such as turquoise, jade, serpentine or even emeralds, without any analytical evidence of what stone was actually present and used. These labels carry great significance for interpreting and understanding these objects and the societies since the types of stones listed would have to come from as far away as modern day Colombia, Mexico or Peru. “Exotic” materials or ones which must be brought or traded over long distances do confer greater value and status and also would indicate contact between ancient societies. Have the archaeologists been accurate in their descriptions without ever analyzing the actual stone material? We now have a range of analytical tools from Materials Analysis which can settle this question and correct past assumptions and inaccurate labels. Was jade or emeralds actually present in the ornaments used in ancient Ecuador or were they using locally and easily available green “tuff” which can look like precious green stone? To answer this question and correct past inaccuracies our Team Project 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 and **geochemical** analysis of stone samples and artifacts from archaeological sites in Ecuador from ca. 200 B.C.E. – 600 C.E. With these multiple lines of data our goal is to correct the record and determine if the ancient Ecuadorians actually used or traded for “precious” green stones or were creating what looked like precious ornaments with locally and easily available “green stones.” It is possible that the Ecuadorians may even have “sold” their “fake” green stone ornaments to other unsuspecting neighbors!

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.

T20 PROJECT IN COMPUTER SCIENCE
INSTRUCTOR: Minjoon Kouh, Schmidt Sciences

AI-ASSISTED DISCOVERY OF PHYSICS LAWS
In this Team Project, we will replicate a simplified version of "AI Feynman" (by Udrescu and Tegmark, 2020), an algorithm for finding a mathematical expression that matches data from an unknown function. We will then examine its capabilities and limitations by challenging its performance under various conditions, such as data availability and complexity of the underlying function. Through this project, we will gain insight into how the recent advances in AI and computing can help scientists and serve as a co-pilot of scientific discovery.

T23 PROJECT IN MOLECULAR BIOLOGY
INSTRUCTOR: Tyler Dorrity, The College of New Jersey

HOST-PATHOGEN INTERACTIONS: USING VIRUSES TO DISCOVER NEW ASPECTS OF HUMAN IMMUNITY
In this Team Project, we will study the complex set of interactions that occurs when a pathogen infects a host. The immune system employs multi-layered defenses in order to prevent dangerous infections, and we are constantly uncovering new ways that the immune system protects its host. Here, we will explore immunity that occurs immediately after infection; recent studies have suggested that host cells will modify their mRNA to increase the strength of immune response. To confirm the validity of this finding, it is necessary to determine if any pathogens are capable of antagonizing this new immune pathway. We will explore the ability of vesicular stomatitis virus to alter mRNA in human cells to evade immunity. In this project, you will learn skills involving aseptic technique, culturing of human cells, viral safety protocols, gene cloning, RNA biology, and immune activation assays.

2025 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
C14</td><td rowspan="3">Free Time</td><td colspan="2"><u>Core Course</u>
C1
C14</td><td>Career Day
7/12
10:00 am –
12:15 pm</td></tr>
<tr><td>10:10 am</td><td colspan="2">C4
C8</td><td colspan="2">C4
C8</td><td></td></tr>
<tr><td>11:20 am</td><td colspan="2">C7
C11</td><td colspan="2">C7
C11</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></td><td>Speaker
7/22 Cheswick</td><td>Speaker
7/9 Bowman
7/16 Kouh</td><td></td><td></td><td></td></tr>
<tr><td>Evenings</td><td>Events
7/20
Talent
Show</td><td></td><td></td><td></td><td></td><td>Events
7/25
Conferences
Dance
7/11
7/25</td><td></td></tr>
</table>