COURSE CATALOG

New Jersey Governor’s School in the Sciences at Drew University

2016
2016 NJGSS COURSE CATALOG

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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 neurobiology, biology, 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, biochemistry and physics 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 rocket science, cognitive illusions, learning of toxic metals from e-waste, olfactory learning and memory, modeling small molecule movement across a polymer membrane, 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 banquet 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 schools, as well as scientists from industrial and governmental laboratories.

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.
# 2015 Governor's School in the Sciences Course Schedule

## Core Courses (M, T, Th, F)

<table>
<thead>
<tr>
<th>Time</th>
<th>Course Name</th>
<th>Instructor</th>
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</thead>
<tbody>
<tr>
<td>9:00 am – 10:00 am</td>
<td>Neurobiology</td>
<td>Knowles</td>
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<td></td>
<td>Cell Biology and Cancer</td>
<td>Seanor</td>
</tr>
<tr>
<td>10:10 am – 11:10 am</td>
<td>Special Relativity</td>
<td>Supplee</td>
</tr>
<tr>
<td></td>
<td>Concepts of Chemical Bonding: An Introduction to Molecular Orbital Theory</td>
<td>Pearsall</td>
</tr>
<tr>
<td>11:20 am – 12:20 pm</td>
<td>Rulers, Compasses, and Famous Impossibilities</td>
<td>Surace</td>
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<tr>
<td></td>
<td>Human Evolution</td>
<td>Van Blerkom</td>
</tr>
</tbody>
</table>

## Laboratories (T, Th*) 1:30 pm – 4:15 pm (July 14, 16, 21, 23, 28, ***29)

<table>
<thead>
<tr>
<th>Time</th>
<th>Course Name</th>
<th>Instructor</th>
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<tbody>
<tr>
<td></td>
<td>Experiments in Biology</td>
<td>Scarano</td>
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<tr>
<td></td>
<td>Experiments in Organic Chemistry</td>
<td>Cincotta</td>
</tr>
<tr>
<td></td>
<td>Experiments in Computer Science</td>
<td>Mayans</td>
</tr>
<tr>
<td></td>
<td>Experiments in Biochemistry</td>
<td>Cassano</td>
</tr>
<tr>
<td></td>
<td>Experiments in Physics</td>
<td>Kaplan</td>
</tr>
</tbody>
</table>

## Team Projects (M, W*, F) 1:30 pm – 4:15 pm (July 13, 15, 17, 20, 22, 24, 27, ***30)

<table>
<thead>
<tr>
<th>Time</th>
<th>Course Name</th>
<th>Instructor</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Project in Mathematical Physics: Rocket Science</td>
<td>Murawski</td>
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<tr>
<td></td>
<td>Project in Chemistry: Leaching of Toxic Metals from E-Waste</td>
<td>Hinrichs</td>
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<tr>
<td></td>
<td>Project in Psychology and Neuroscience: Olfactory Learning and Memory</td>
<td>Cousens</td>
</tr>
<tr>
<td></td>
<td>Project in Chemistry: Controlled-Release Kinetics: Modeling Small Molecule Movement Across a Polymer Membrane</td>
<td>Cincotta</td>
</tr>
<tr>
<td></td>
<td>Project in Biology: Cloning and Functional Complementation of EF3</td>
<td>Dunaway</td>
</tr>
</tbody>
</table>

***Team Projects and Laboratories are switched in the last week with Labs meeting on Wed (July 29) and Projects meeting on Thurs (July 30).***
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.

C2  CELL BIOLOGY AND CANCER
INSTRUCTOR: Krista Seanor, Dover High School

Cancer has been observed since the beginning of recorded history. However, our understanding of the mechanisms by which cancer originates and develops has been greatly advanced by recent work in molecular and cellular biology. Cancer is caused by the breakdown in a series of carefully regulated events. In this course, we will explore these events at the molecular and cellular level. Topics will include mechanisms of cell growth control, transcriptional control, regulation of cell signaling pathways, and basic cancer immunology, as well as the variety of causes. In addition, we will examine how cancer is detected; how various treatments work to stop the spread of cancer; and how scientists develop drugs to combat cancer. Students will have the opportunity to work in small groups to investigate a topic of choice.

C3  SPECIAL RELATIVITY
INSTRUCTOR: Jim Supplee, Drew University

This course is an introduction to special relativity. It begins with relativistic kinematics — the study of motion. A course in classical physics might also begin with kinematics, but relativity involves some subtleties that require careful thought about motion. It turns out that the space coordinates and the time coordinate of an event are related in a way that was essentially unforeseen by classical physics. Topics will include length contraction, time dilation, space-time coordinate transformations, and the light cone. The course will also cover relativistic dynamics, including relativistic energy and momentum.

In classical physics, three-component vectors are very useful, because position, velocity, acceleration, force, and many other physical quantities are three-component vectors. In relativity, however, it is often preferable to note position \((x, y, z)\) and time \((t)\) in a way that reveals the mathematics of how space and time are related. We will therefore sometimes use four-vectors, such as \((t, x, y, z)\).

Some ideas of relativity seem contrary to common sense or even paradoxical. This is because common sense is based on experience with things moving at familiar speeds, but the laws of physics are quite different for objects moving near the speed of light. Relativistic physics is quite different from classical physics; it was a fundamental breakthrough in scientific thought.

This course uses a few ideas from high school physics, but should, nonetheless, be generally accessible to students with no previous physics course.
C4  CONCEPTS OF CHEMICAL BONDING
INSTRUCTOR: Mary-Ann Pearsall, Drew University

AN INTRODUCTION TO MOLECULAR ORBITAL THEORY

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.

C5  RULERS, COMPASSES, AND FAMOUS IMPOSSIBILITIES
INSTRUCTOR: Steve Surace, Drew University

In high school geometry we quickly learn how to make many constructions with a ruler and compass. We learn how to bisect angles but we are told that it is impossible to trisect angles with a ruler and compass. We can construct a line segment whose length is the fourth root of two, but it is impossible to construct other lengths like the cube root of two. Constructing a regular 17-gon is possible, but the construction of a regular 7-gon is impossible.

In this course we will see how making a construction with a ruler and compass is equivalent to solving certain polynomial equations. The degree of these polynomials is crucial in determining when a construction is impossible. When the construction is possible, the polynomial will help us make the construction.

The Theory of Equations that we will study has many far-reaching consequences which will be explored during this course.
C6  HUMAN EVOLUTION
INSTRUCTOR: Linda M. Van Blerkom, Drew University

How and why did we evolve as we did? What is our relationship to other animals? What can our genes tell us about our evolutionary history? How has it affected our health today? This course examines these and other questions as we explore the latest research on human origins and our continuing evolution.

The course begins with a review of evolutionary theory and some popular misconceptions about it. We'll look at our species' place in nature as a member of the order Primates, specifically as bipedal apes, and learn what that means. We are more than 98% similar to chimpanzees genetically; how and why are we different? What does that miniscule genetic difference do? What does the fossil record tell us about the earliest members of the human lineage? Is the missing link still missing? What conditions led to the evolution of genus Homo? We'll also consider the origins of modern humans, the enigma of the Neandertals, and what genetics can tell us about the evolution and diversification of anatomically modern Homo sapiens, including evidence for interbreeding with archaic humans and how humans have continued to evolve recently. Finally, we'll look toward the human future and consider what it may hold in terms of human evolution and our possible extinction.
LABORATORY

L1  EXPERIMENTS IN BIOLOGY
INSTRUCTOR: Paris Scarano, Drew University

THE STRUCTURE AND FUNCTION OF VERTEBRATES

In terms of their diversity and ability to adapt, the vertebrates have been some of the most successful organisms. This laboratory will explore selected aspects of the anatomy and physiology of this fascinating group of animals by measuring auditory, cardiac, muscular, and other physiological responses using physiological sensors and a computer data acquisition system, and by comparing the anatomy of different vertebrate fishes. This laboratory requires that students dissect preserved specimens (fish) in addition to serving as subjects for several physiological exercises.

L2  EXPERIMENTS IN ORGANIC CHEMISTRY
INSTRUCTOR: David Cincotta, High Tech High School

Organic chemistry deals with the chemistry of carbon-containing compounds. The experiments in this lab will illustrate how chemical structure affects the properties and reactivities of organic compounds. We will investigate several classes of organic compounds from alcohols to polymers. Some structural features are easily identified by spectroscopy, a valuable tool for organic chemistry.

*For those who have had a high school chemistry course.

L3  EXPERIMENTS IN COMPUTER SCIENCE
INSTRUCTOR: Robert Mayans, Fairleigh Dickinson University

CELLULAR AUTOMATA

Cellular automata are abstract computer models that can produce visual displays of dazzling complexity and variety. Each cell has a set of rules on how it changes, and the same rule holds for all cells in the space. We will examine a number of cellular automata and determine the patterns inherent in each of them. By means of very simple programming, we can create cellular models of all sorts. We will see how different rules for cellular automata can model the motion of gasses, the skin markings on mammals, reforestation after a fire, the growth of a snowflake, and patterns of evolutionary competition and cooperation. In our computer laboratory work, we will build these cellular models and invent new ones, and track their evolution over time. No previous programming experience is assumed.
L4 EXPERIMENTS IN BIOCHEMISTRY
INSTRUCTOR: Adam Cassano, Drew University

One mantra biochemists live by is "never waste pure thoughts on an impure protein." In this laboratory, we will go through a procedure to purify the enzyme alcohol dehydrogenase from yeast cells. Once we have procured our protein, we will assay its purity, as well as characterize it by size and enzymatic activity. Along the way, we will learn various aspects of protein structure and enzymatic activity. Techniques will include column chromatography, gel electrophoresis, and enzyme kinetic analysis using UV-Vis spectrophotometry.

L5 EXPERIMENTS IN PHYSICS
INSTRUCTOR: Daniel Kaplan, Matawan Regional High School

THE ROLE OF PHASE RELATIONSHIPS IN WAVE PHENOMENA

What do designing a concert hall, building invisibility coatings for stealth bombers, detecting underwater submarines, analyzing electronic circuits, studying the signatures left from the Big Bang, and explaining the variety of colors on butterfly wings have in common? They are all based on an understanding of the role of phase relationships in wave interactions. In this lab we will explore wave properties in detail for a variety of wave phenomena including mechanical waves, sound waves, visible-light, electronic signals, and microwaves. We will strive to gain an understanding of the similarities and differences of wave phenomena cutting across many different types of waves and media.
TEAM PROJECTS

T1 PROJECT IN MATHEMATICAL PHYSICS
INSTRUCTOR: Robert Murawski, Drew University

ROCKET SCIENCE
In this project we will investigate rocketry both theoretically and experimentally. Starting from Newton’s Laws, we will develop the Rocket Equation and the laws of motion that govern a rocket in-flight. We will use computers to make simulations based on these laws and to make predictions. Then we will build model rockets and launch them. We will test how the rocket performs with various payloads and with different surface coatings (e.g. plain cardboard, glossy paint, wax, glue, etc). We will collect real data and compare it to our computer models. We will discover the nature of the drag law at work on a rocket in-flight. Buckle up!

T2 PROJECT IN CHEMISTRY
INSTRUCTOR: Ryan Hinrichs, Drew University

LEACHING OF TOXIC METALS FROM E-WASTE
E-waste is defined as the disposal of computers, cell phones and other electronic devices. Due to the high costs of recycling E-waste in safe and efficient facilities, the majority of E-waste either ends up in landfills or is shipped to developing countries where recycling is done using primitive techniques (i.e., low temperature fires) with little regard for environmental and worker safety. Electronic components and display screens contain high levels of heavy metals such as lead (Pb), mercury (Hg), cadmium (Cd) and antimony (Sb), which can leach into drinking water supplies. In this team project, we will analyze E-waste to determine their total concentration of heavy metals as well as leaching rates into several aqueous solutions modelling fresh water, salt water and landfill conditions. Laboratory measurements will be conducted by participants using Drew’s state-of-the-art ICP-OES (Inductively coupled plasma optical emission spectrometer).

T3 PROJECT IN PSYCHOLOGY AND NEUROSCIENCE
INSTRUCTOR: Graham Cousens, Drew University

OLFACTORY LEARNING AND MEMORY
Although common experience tells us that memory is a unitary process, a large body of research in the biological and behavioral sciences has revealed that the brain supports multiple memory systems. These systems exhibit distinct functional properties with respect to duration, capacity, and the sort of information stored, and they appear to be supported by distinct brain circuits.

Research on memory systems and their brain substrates has been aided by studies on olfactory learning and memory in rodents. For example, some forms of olfactory learning are critically dependent on the hippocampal formation, while others are dependent on the amygdaloid complex. Rodents are particularly adept at odor-guided learning tasks due to their dependence on their sense of smell and the strong connections between olfactory related areas of the brain and these memory-related areas. In this team project, students will design and execute a behavioral experiment to examine features of olfactory memory as a part of ongoing research in our laboratory.
T4 PROJECT IN CHEMISTRY
INSTRUCTOR: David Cincotta, High Tech High School

CONTROLLED-RELEASE KINETICS: MODELING SMALL MOLECULE MOVEMENT ACROSS A POLYMER MEMBRANE
Polymer matrices are often used to deliver controlled amounts of small molecules in objects as varied as nicotine patches, air fresheners, and deer repellents. How quickly substances are released is affected by the chemistry, size, and mass of the molecules being released (the mobile phase) as well as the chemistry and morphology of the containing polymer matrix (the stationary phase). The ideal case would be to have the rate of release be constant and independent of the concentration of the mobile phase (zero-order kinetics). In practice, the release of molecules is a function of the concentration of the mobile phase (first-order release). The objective of this project will be to develop a mathematical model to predict rates of diffusion of organic molecules through a typical polymer matrix. We will then use this information to construct a prototype passive device capable of releasing small molecules at a rate that comes close to being independent of its concentration (pseudo-zero-order kinetics).

T5 PROJECT IN BIOLOGY
INSTRUCTOR: Stephen Dunaway, Drew University

CLONING AND FUNCTIONAL COMPLEMENTATION OF EF3
Invasive fungal infections have been estimated to kill over one and a half million people per year and the incidence of this type of infection is increasing. The majority of invasive fungal infections occur in individuals with compromised immune systems due to immunosuppressive diseases or treatments such as HIV/AIDS, hematological cancers, chemotherapy and organ transplantation. Despite the availability of anti-fungal drugs, the mortality rate associated with invasive fungal infections remains high and the treatments available suffer from many shortfalls including toxicity and resistance. Thus, safer and more effective drugs are needed. Protein synthesis in fungi requires a unique factor, eukaryotic elongation factor 3 (eEF3), which is present in fungi but absent in mammals making it an excellent drug target. However, development of eEF3 as a drug target would be facilitated by a better understanding of its function in translation elongation which is currently unclear. While eEF3 was originally thought to be specific to fungi, analysis of recent genome sequencing projects led us to predict that eEF3 is also present in other lower, non-fungal eukaryotes. The presence of eEF3 in a wider range of organisms may help identify the conserved functions of eEF3; however, it must be shown that these eEF3-like proteins from other organisms possess the same functions as fungal eEF3. In this session, we will clone the potential eEF3 gene from Phytophthora infestans, also known as potato blight. This gene will then be transformed into Saccharomyces cerevisiae (baker’s yeast) to determine whether it can provide the essential functions of eEF3. Topics and techniques will include drug development, cloning via the Gibson assembly method, DNA sequencing, bioinformatics software and yeast culture and transformation.
# 2016 Schedule - New Jersey Governor's School in the Sciences

<table>
<thead>
<tr>
<th>Time</th>
<th>SUN</th>
<th>MON</th>
<th>TUE</th>
<th>WED</th>
<th>THUR</th>
<th>FRI</th>
<th>SAT</th>
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<tbody>
<tr>
<td>7:45 am – 8:45 am</td>
<td>Breakfast</td>
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<tr>
<td>9:00 am</td>
<td>Free Time</td>
<td>Core Course C1-Neurobiology</td>
<td>Core Course C1-Neurobiology</td>
<td>Free Time</td>
<td>Core Course C1-Neurobiology</td>
<td>Core Course C1-Neurobiology</td>
<td>Career Day 7/16</td>
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<td>C2 - Biology</td>
<td>C2 - Biology</td>
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<td>10:00 am – 12:15 pm</td>
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<tr>
<td>10:10 am</td>
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<td>C3 - Physics C4 - Chemistry</td>
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<td>C3 - Physics C4 - Chemistry</td>
<td>C3 - Physics C4 - Chemistry</td>
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<tr>
<td>11:20 am</td>
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<td>C5 - Math C6 – Anthropology</td>
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<td>C5 - Math C6 – Anthropology</td>
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<tr>
<td>12:30 pm – 1:15 pm</td>
<td>Lunch</td>
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<tr>
<td>1:30 pm – 4:15 pm Team/Lab</td>
<td>Team Project</td>
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<tr>
<td>5:00 pm</td>
<td>Dinner</td>
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<td>7:00 pm</td>
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<td>Speaker</td>
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