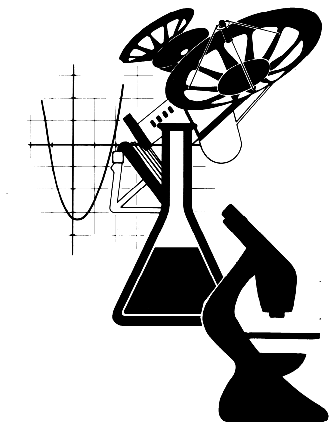
COURSE CATALOG



New Jersey Governor's School in the Sciences at Drew University 2011

2011 NJGSS 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 biological anthropology, biology, chemistry, mathematics, neurobiology, and physics. 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, chemistry, and computer science 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 cloning of DNA, computer modeling of physical systems, celestial mechanics, chemical synthesis, and sensation and perception. The final day of the school is devoted to a scientific meeting at which teams report their results to the entire group. Results are published in a Governor's School Journal. 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 Madison. Entertainment on campus includes films and the New Jersey Shakespeare Festival. Other special events include a College Fair and a Career Morning. Students can attend local religious services.

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.

2011 COURSE SCHEDULE

CORE COURSES (M, T, Th, F)			
9:00 am	C1	Neurobiology	Knowles
9:00 am	C2	Cell Biology and Cancer	Seanor
10:10 am	C3	Inside the Mind of Einstein: Understanding the Theory of Special Relativity	Quinn
10:10 am	C4	Concepts of Chemical Bonding: An Introduction to Molecular Orbital Theory*	Pearsall
11:20 am	C5	Rulers, Compasses, and Famous Impossibilities	Surace
11:20 am	C6	Biological Anthropology: Human Evolution	Van Blerkom
LABORATORIES (T, Th)			
1:30 - 4:15 pm	L1	Experiments in Biology	Koepf Csaszar, Scarano
	L2	Experiments in Organic Chemistry*	Avaltroni, Stanton
	L3	Experiments in Computer Science	Mayans
	L4	Experiments in Physics	Quinn
TEAM PROJECTS (M, W, F)			
1:30-4:15 pm	T1	Project in Chemistry: Investigating the Unobservable: The Effects of Molecular Structure on Chemical Reaction Mechanisms	Cassano
	T2	Project in Chemistry: Can We Develop the New Teflon? Developing Replacement Coatings for New Surfaces	Avaltroni
	T3	Project in Microbiology: Green Tea: A Household Cleanser	Sandler
	T4	Project in Psychology and Neuroscience: Olfactory Learning and Memory	Cousens
	T5	Project in Chemistry: Controlled-Release Kinetics: Modeling Small Molecule Movement across a Polymer Membrane	Cincotta
	T6	Project in Applied Mathematics and Computer Science: Googling 3D Shapes*	Rustamov
	T7	Project in Neuroscience: Computational Modeling of Neural Systems	Kouh
	T8	Project in Ecology: Effects of Climate Change on Competitive Interactions Between Native and Invasive Maple Trees	MacDonald-Beyers

* PREREQUISITE RECOMMENDED - See course description

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 INSIDE THE MIND OF EINSTEIN: UNDERSTANDING THE THEORY OF SPECIAL RELATIVITY

INSTRUCTOR: Paul Quinn, Kutztown University

In 1905, Albert Einstein published his Theory of Special Relativity. This theory was so important that it shaped the future work of all physicists forever. Relativity challenged the accepted ideas of classical physics, causing many physicists to create paradoxes to disprove Einstein's ideas. In the end, through various experiments, Einstein's theory has been shown to correctly predict, not only what is observed in classical physics, but observations made on the atomic and nuclear scale.

In this course, we will examine the Theory of Special Relativity in all its beauty. We will discuss the consequences of Einstein's work, as well as the various puzzles that were used to try and discredit Einstein. In the end, you will see how Special Relativity exists in perfect harmony with Classical Physics. We will look at how time, energy, momentum, and mass are all affected by Einstein's ideas. You will learn how we all change the rate at which we travel through time. This course will give you an extreme appreciation for how the simplicity of Special Relativity produces such earth shaking consequences for the rest of physics.

C4 CONCEPTS OF CHEMICAL BONDING

INSTRUCTOR: Mary-Ann Pearsal, 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. In this course we will examine these interactions and obtain some insight into the beauty of molecules and the amazing ways that atoms can put themselves together.

We will begin with an overview of the conventional bonding theories of ionic and covalent bonds. We will then delve deeper into the chemistry of the elements. As we discover the tremendous variety of compounds formed, we will find our theories are no longer sufficient. For example, we will consider how molecules can defy the valence and octet rules, why compounds can behave like metals and the real truth about resonance. To understand these molecules and compounds we will learn about the more sophisticated approach provided by molecular orbital theory.

Some background in chemistry will be assumed - one year in high school will be fine.

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 BIOLOGICAL ANTHROPOLOGY

INSTRUCTOR: Linda M. Van Blerkom, Drew University

HUMAN EVOLUTION

What were our ancestors like? How and why did we evolve? What is our relationship to other animals? What can our genes tell us about prehistoric migrations? This core course in biological anthropology examines these and other questions as we explore the latest research on human origins and evolution.

There is now abundant fossil and genetic evidence suggesting that our lineage began with an assortment of ape-like ancestors 5 to 7 million years ago and, after a number of twists and turns, led to modern humans, *Homo sapiens*, 100 - 200,000 years ago. We are the only hominin species left on earth, but this was not the case during most of our past. In this course we will trace this complex evolutionary history and consider what may have happened to our extinct kin.

The course begins with an introduction to basic osteology (the study of bones) and how anthropologists make inferences from fossil and skeletal evidence. It continues 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 and learn more about our close cousins, the African apes, as models for early hominins. We'll examine the fossil evidence for human evolution and try to determine what earlier hominins were like. Finally, we'll 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*.

LABORATORY

L1 EXPERIMENTS IN BIOLOGY

INSTRUCTORS: Sara Koepf Csaszar, Drew University
Paris Scarano, Drew University

THE EVOLUTION, STRUCTURE, AND FUNCTION OF VERTEBRATES

One of the most successful organisms in terms of their diversity and ability to adapt has been the vertebrates. This laboratory will explore selected aspects of the evolutionary history, anatomy, and physiology of this fascinating group of animals by studying the microanatomy of mammalian organs, comparing the anatomy of different vertebrate fishes, doing a morphometric analysis of mammalian skeletons, and measuring auditory, cardiac, and other physiological responses using physiological sensors connected to a computer data acquisition and analysis system. This laboratory requires that students dissect preserved specimens (fish) in addition to serving as subjects of their physiological exercises.

L2 EXPERIMENTS IN ORGANIC CHEMISTRY

INSTRUCTORS: Michael Avaltroni, Fairleigh Dickinson University
Jeremy Stanton, McNair Academic 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, 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 PHYSICS

INSTRUCTOR: Paul Quinn, Kutztown University

HANDS-ON EXPLORATION OF MODERN PHYSICS

This is a laboratory physics course designed to help you explore some of the concepts and phenomena that are usually only taught as ideas and equations in a high school physics class. Physics involves not just theory, but also the testing of those theories by actual experiments. In this laboratory you will be repeating some of the experiments used by Einstein and others to explain and understand the world around them. Included in the experiments we will conduct are the photoelectric effect, electron diffraction, blackbody radiation, the Milikan oil drop experiment, and several other classic experiments that have shaped our understanding of the physical world. This lab will therefore give you a chance to see if the equations you have learned in class match the reality of what actually occurs in nature.

TEAM PROJECTS

T1 PROJECT IN CHEMISTRY

INSTRUCTOR: Adam Cassano, Drew University

INVESTIGATING THE UNOBSERVABLE: THE EFFECTS OF MOLECULAR STRUCTURE ON CHEMICAL REACTION MECHANISMS

Chemical reactions occur all around us, and inside us, but how do they occur? Individual steps generally happen too quickly to be able to observe, making a detailed picture of reaction mechanisms difficult. What factors control the paths reactants take to become products? Will there be intermediates? What do these intermediates look like? In this team project, we will use computational chemistry to investigate the reaction paths for models of RNA cleavage, a reaction critical in biological systems. The information about the reaction paths can be used to understand how enzymes can make these reactions proceed at rates required to support life.

T2 PROJECT IN CHEMISTRY

INSTRUCTOR: Michael Avaltroni, Fairleigh Dickinson University

CAN WE DEVELOP THE NEW TEFLON? DEVELOPING REPLACEMENT COATINGS FOR NEW SURFACES

Water resistant coatings are widely used in everyday application, from Teflon to Rain-X, and materials of this type have been extensively studied. In the past several years, a new procedure was developed within the area of water repellant coatings to dramatically reduce the time necessary to form surfaces which permanently alter the surface of a material in this way. Using microwave irradiation, phosphonic acids were observed to irreversibly bond to the surfaces of oxides (including titanium, aluminum, stainless steel and glass), in a matter of minutes. The importance of this development provides a means for covalent attachment of many new substrates, including all types of glasses, ceramics and polymers. Students will learn the technique for applying phosphonic acid coatings to glass to develop non-stick, lubricating coatings and will test the efficiency of this coating as a possible non-toxic alternative to current coatings such as Rain-X.

T3 PROJECT IN MICROBIOLOGY

INSTRUCTOR: Rachel Sandler, Edison High School

GREEN TEA: A HOUSEHOLD CLEANSER

Can drinking tea prevent tooth decay and gum disease? Imagine if after eating a sugary snack you could drink a cup of tea and prevent disease and cavity-causing bacteria from growing in your mouth. There are hundreds of bacteria living in your mouth. While many of them are harmless and even beneficial, some are destructive. Some of these microbes include *Porphyromonas gingivalis*, the primary cause of gum disease, and *Streptococcus mutans*, the bacteria responsible for cavities. Previous research has demonstrated that antioxidants found in both green and black tea are capable of inhibiting the growth of bacteria.

Green tea and black tea are made by the infusion of leaves from the plant *Camellia sinensis* in boiling water. While green tea leaves have been minimally processed, black tea leaves have been fully fermented. When infused, various types of polyphenols, particularly flavonoids such as epigallocatechin gallate (EGCg), gallocatechin gallate (GCg). These flavonoids have demonstrated health benefits and even antimicrobial activity.

In this research project, we will use basic microbiology techniques to test the effect of green and black teas on *Streptococcus mutans* and compare them to conventional mouthwashes, both in-vitro and in-vivo.

Since this project includes taking mouth swabs, students and their parents will be asked to sign an Institutional Review Board (IRB) consent form as per IRB guidelines.

T4 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 non-invasive behavioral experiment to examine features of olfactory memory as a part of ongoing research in our laboratory.

T5 PROJECT IN CHEMISTRY

INSTRUCTOR: David Cincotta, Drew University

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 first 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).

T6 PROJECT IN APPLIED MATHEMATICS AND COMPUTER SCIENCE

INSTRUCTOR: Raif Rasamov, Drew University

GOOGLING 3D SHAPES

Just like Google searches online text documents, emerging systems now search repositories of three-dimensional (3D) models with queries describing geometric properties. For example, a biochemist might use such a geometric search engine to find an enzyme that has similar molecular structure as the molecule they are working with; a mechanical engineer might use it to find a particular CAD model in a parts catalog based on its 3D shape characteristics; a doctor might use shape analysis to aid diagnosis of a disease from the shapes of afflicted organs.

In this project, students will begin learning mathematical and computational approaches to 3D shape analysis and search. We will discover methods for pose normalization (the problem of putting all shapes into a reference pose), shape retrieval (searching for a shape similar to an input shape), and shape correspondence (given a set of points on one shape, find similarly located points on the second). Notions from linear algebra (matrices, projection), differential geometry (surface normal, curvature, isometry), and statistics (covariance, histogram) will be introduced as needed. Students will be challenged to discover their own solutions to the problems above. Next, the proposed approaches will be implemented and tested for effectiveness.

It is recommended that students selecting this project have some experience with programming.

T7 PROJECT IN NEUROSCIENCE

INSTRUCTOR: Minjoon Kouh, Drew University

COMPUTATIONAL MODELING OF NEUROSYSTEMS

This year's team project in neuroscience will focus on one of the most critical trends in neuroscience: the increasing usage of computational tools and ideas in investigating the information-processing mechanisms of the brain. NJGSS Scholars pursuing this project will (1) learn the basics of computer programming and scientific computing software; (2) be introduced to neural network theory; and (3) build and simulate simple neural network models for pattern classification and memory storage. Through this project, the students will gain a valuable working knowledge of how different ideas and approaches from multiple disciplines, such as math, computer science, and physics, can come together to provide a deeper understanding of a complex biological process like visual perception and memory. The students will also develop computer-programming and problem-solving skills that can be transferred and applied to other fields.

T8 PROJECT IN ECOLOGY

INSTRUCTOR: Kristi MacDonald-Beyers, Hudsonia, Ltd., Science Park High School

EFFECTS OF CLIMATE CHANGE ON COMPETITIVE INTERACTIONS BETWEEN NATIVE AND INVASIVE MAPLE TREES

Climate change is a major focus of present studies in evolution and ecology because understanding how species and ecosystems will react to these changes has major implications for human health, food production, and biodiversity. While change is an inherent part of Earth's natural history, specific types of rapid and widespread change are now largely due to humans. We will study the potential effects of two types of human-caused change, introduction of invasive plant species and climate change, on shaping the future forests of New Jersey.

Global climate change models predict that in the next 100 years, average temperature and rainfall will be higher. It is also predicted that the frequency and intensity of severe weather events will increase. Since plants are greatly affected by climate, it is anticipated that there will be major changes in the distribution of vegetation types (biomes) in North America and throughout the world. Because of the principle of competitive exclusion, plants with better growth characteristics under these new climatic conditions are expected to out-compete and eliminate plants with less favorable growth characteristics. One explanation for why exotic invasive plants are so successful is the fact that their growth characteristics out-compete native plant species in an ecosystem. Exotic invasive plants are those species that have been introduced into the United States, "escaped" from landscaped areas, and have become established in ecosystems at the expense of native plant species. The Norway maple (*Acer platanoides*), is an invasive shade tree that was first introduced to North America from Europe in 1756, and is often more successful than native tree species causing large-scale changes in the composition of many forests in the northeastern United States. Millions of dollars are spent annually on research and eradication programs for Norway maple, yet many questions remain about why Norway maple is so successful in our forests, what effects it is having on ecosystems, and how these anticipated climate changes will affect its spread.

Our study will determine the ability of native sugar maple (*Acer saccharum*) and invasive Norway maple seedlings to maintain and/or recover baseline photosynthetic rates after being exposed to high temperatures and drought-like conditions similar to those predicted by various climate change models. Small differences in the ability to photosynthesize under these new climate conditions could give plants the competitive edge that would enable them to out-compete other plants. The data that we will collect will then be used in the tree simulator model SORTIE-ND (http://www.sortie-nd.org/) to model what might happen to these forests in next 150 years.

2011 SCHEDULE - NEW JERSEY GOVERNOR'S SCHOOL IN THE SCIENCES

	SUN	MON	TUE	WED	THUR	FRI	SAT
9:00 am	Free Time	Core Course C1-Neurobiology C2 - Biology	Core Course C1 C2	Free Time	Core Course C1 C2	Core Course C1 C2	Career Day 7/16 (10 am -12 pm)
10:10 am		C3 - Physics C4 - Chemistry	C3 C4		C3 C4	C3 C4	
11:00 am – 1:00 pm	Brunch						Brunch
11:10 am		C5 - Math C6 - Anthropology	C5 C6		C5 C6	C5 C6	
12:30 pm - 1:15 pm		Lunch	Lunch	Lunch	Lunch	Lunch	
1:30 pm – 4:15 pm Team/Lab		Team Project	Laboratory	Team Project	Laboratory	Team Project	
5:00 pm	Picnic Dinner	Dinner	Dinner	Dinner	Dinner	Dinner	Dinner
7:00 pm			Speaker		Speaker College Info Session (7 pm – 9 pm) College Fair 7/21 (7 pm - 9 pm)	Movies	
Evenings	Events				Events	Dance	Movies