2021 Course Catalog

New Jersey Governor's School in the Sciences
at Drew University
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 astronomy, biology, biochemistry, chemistry, neuroscience, 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. There are four Book Clubs, which meet two times a week. These book clubs offer opportunities to read a carefully selected book on a scientific topic and to have in-depth discussions around various themes. Each student must select one book club.

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. This year’s topics include machine learning, cognitive illusions, quantum computing, computational chemistry, and drug docking studies. Each student must select one team research project. 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 weekdays and weekends.

4. 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 evenings and weekends, there will be special events such as a Career Day and a Talent Show.

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 three-week intensive period of NJGSS is focused on learning and working together.
# COURSE SCHEDULE

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

<table>
<thead>
<tr>
<th>Time</th>
<th>Course</th>
<th>Instructor</th>
<th>TBA</th>
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</thead>
<tbody>
<tr>
<td>9:00 AM - 10:00 AM</td>
<td>Neurobiology</td>
<td>Knowles</td>
<td>TBA</td>
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<tr>
<td></td>
<td>Special Relativity</td>
<td>Supplee</td>
<td>TBA</td>
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<tr>
<td>10:10 AM - 11:10 AM</td>
<td>Concepts of Chemical Bonding: An Introduction to Molecular Orbital Theory</td>
<td>Pearsall</td>
<td>TBA</td>
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<td></td>
<td>Human Evolution</td>
<td>Windfelder</td>
<td>TBA</td>
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<tr>
<td>11:20 AM - 12:20 PM</td>
<td>Molecular Biology of Cancer</td>
<td>Dunaway</td>
<td>TBA</td>
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<tr>
<td></td>
<td>Astronomy: A Journey Across the Universe</td>
<td>Murawski</td>
<td>TBA</td>
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## Book Clubs (T, Th) 1:30 PM - 2:30 PM or 2:40 PM - 3:40 PM

<table>
<thead>
<tr>
<th>Time</th>
<th>Course</th>
<th>Instructor</th>
<th>TBA</th>
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<tbody>
<tr>
<td>1:30 PM - 2:30 PM</td>
<td>The Power of Light: “Eating the Sun”</td>
<td>Larson</td>
<td>TBA</td>
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<tr>
<td>2:40 PM - 3:40 PM</td>
<td>Genetics and the (Re)Evolution of Cancer Medicine: “The Emperor of All Maladies“</td>
<td>Dunaway</td>
<td>TBA</td>
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<td>The Big Bang</td>
<td>Kaplan</td>
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<td></td>
<td>The Case of Patient H.M.: An Exploration of Neuroscience, Medical History and Ethics</td>
<td>McKittrick</td>
<td>TBA</td>
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## Team Projects (M, W, F) 1:30 PM - 4:15 PM

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<th>Time</th>
<th>Course</th>
<th>Instructor</th>
<th>TBA</th>
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<tbody>
<tr>
<td>1:30 PM - 4:15 PM</td>
<td>Project in Computer Science: Machine Learning</td>
<td>Kouh</td>
<td>TBA</td>
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<tr>
<td></td>
<td>Project in Psychology: Cognitive Illusions</td>
<td>Dolan</td>
<td>TBA</td>
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<tr>
<td></td>
<td>Project in Physics: Quantum Computing</td>
<td>Kaplan</td>
<td>TBA</td>
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<td></td>
<td>Computational Chemistry</td>
<td>Cassano</td>
<td>TBA</td>
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<td></td>
<td>Using Computational Drug Docking to Identify Possible Therapeutics and Lead Compounds</td>
<td>Cincotta</td>
<td>TBA</td>
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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.

C3 SPECIAL RELATIVITY
INSTRUCTOR: Jim Supplee, Drew University

This course primarily addresses relativistic kinematics — the study of relativistic motion. Courses in classical physics typically begin with kinematics, but relativistic kinematics involves some subtleties that require careful thought about motion, space, and time. Such careful thought reveals that distance and time are concepts that become mixed in a curious way.

Classical physics, notably mechanics, can be modified to incorporate insights from relativity; this leads to more broadly applicable physical laws, often called “relativistic” laws of physics. To facilitate the advancement from classical physics to relativistic physics, it helps to note that in classical physics, three-component vectors such as position (x, y, z), velocity, acceleration, force, etc. are used. But in relativity, it can be advantageous to write time and position as a single four-component vector (t, x, y, z), to help reveal the mathematics of how space and time are related.

Relativity is strikingly different from classical physics; it was a fundamental and pivotal breakthrough in scientific thought. Some of the most basic and foundational ideas from relativity can seem odd or even paradoxical. These unexpected ideas and their consequences are experimentally confirmed to great accuracy; they just seem odd because common sense is based on experience with things moving at familiar speeds, not at nearly the speed of light.
Topics in this course include length contraction, time dilation, space-time coordinate transformations, and the light cone. The course emphasizes relativistic kinematics, but also briefly addresses relativistic dynamics, including relativistic energy and momentum. The course uses a few ideas from high school physics, but should, nonetheless, be generally accessible to students with no previous physics course.

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 for the invention of material culture from the simplest stone tools to the
complex cultural world that we live in today. 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.

C12 ASTRONOMY: A JOURNEY ACROSS THE UNIVERSE
INSTRUCTOR: Robert Murawski, Drew University

Did you ever wonder why we are here on this planet?

This course will begin with a cosmic trip through the universe. We will describe the overall structure of the universe and various celestial objects using, for example, recent Hubble Space Telescope images, LIGO measurements and the Event Horizon Telescope.

We will then discuss the origins of modern astronomy. In particular, we will describe how people throughout history have viewed the Solar System leading up to the scientific revolution and the scientific method. The course will then focus on the mathematics and the celestial mechanics that govern the motion of the heavenly spheres in our Solar system.

Finally, we will discuss recent results by the Kepler space mission on its search for exoplanets. We will discuss the conditions necessary for a planet to support life and estimate the number of advanced civilizations in the Milky Way Galaxy by using the Drake equation. In this course you will have the opportunity to analyze data from the Kepler mission and perhaps discover the next Earth 2.0.
BOOK CLUB

B1  THE POWER OF LIGHT
INSTRUCTOR: Bjorg Larson, Drew University
BOOK: “Eating the Sun: Small Musings on a Vast Universe” by Ella Frances Sanders, plus supplemental readings.

Light as a physical entity is enigmatic and pervasive. It is the major source of energy for life on our planet, and also a powerful tool for exploring both our own world and the universe beyond. It can be described as a particle and a wave, it carries energy and momentum, but has no mass. We can trap small particles. We can shine it through human tissues to discover a broken bone or cancerous tumor. We can split it into its spectrum and discover the origins of the universe. We can enjoy the colors of a sunset or the pigments of a renaissance artist. We will use the book “Eating the Sun: Small Musings on a Vast Universe” as a template to explore some of these ideas and how they connect to our own experiences.

B2  GENETIC AND THE (RE)EVOLUTION OF CANCER MEDICINE
INSTRUCTOR: Stephan Dunaway, Drew University
BOOK: “The Emperor of All Maladies” by Siddhartha Mukherjee

It has been over a decade since the sequencing of the human genome was spelled out for the world. What followed was the birth of the post genomic era of molecular biology. Instead of classifying diseases by a list of symptoms, scientists and doctors will be able to trace the causes of human disease to the very source, the gene. From an individual’s genetic information, geneticists and doctors will be able to predict, diagnose, and treat disease with greater success than ever before. As a result, the face of modern medicine has been changed forever. Using the book “The Emperor of All Maladies,” we will use cancer as a case study, examining and comparing treatments from both before and after this genetic revolution to illustrate modern medicine’s promise and pitfalls.
B3  THE BIG BANG
INSTRUCTOR: Daniel Kaplan, Montclair High School
BOOK: “The Big Bang” by Simon Singh

The concept of the Big Bang is at the core of all modern cosmology. This book offers a fascinating account of how the scientific community slowly, over centuries, evolved a perspective about most areas of Physics ending with the final acceptance of the Big Bang Theory. The book starts with Pythagoras in around 500 BCE and extends up to 1992, when the book was written. In each era it delves into the lives and challenges of the different scientists, covering not only the scientific breakthroughs, but also the politics within the scientific community and the impacts of society on the evolution of scientific thought. The reader gains an appreciation for the evolution of both scientific method and of scientific paradigms. At the same time the reader will obtain an understanding of the key areas of Physics including Gravitation, Quantum Physics, Special and General Relativity, Atomic Physics, Nuclear Physics, and many of the key areas of Astrophysics.

B4  THE CASE OF PATIENT H.M.: AN EXPLORATION OF NEUROSCIENCE, MEDICAL HISTORY AND ETHICS.
INSTRUCTOR: Christina McKittrick, Drew University

We spend our entire lives forming memories of the things we’ve done, the places we’ve been, the information we have learned: these memories shape the core of our identities. But how do we create these memories? Where do we create these memories? Understanding the mechanisms underlying the processes of learning and memory is one of the great challenges facing neuroscientists today. This course will focus on the key role that Henry Molaison, aka Patient H.M., played in helping us understand the importance of a structure called the hippocampus in the formation of new memories. Patients like H.M. have provided us with invaluable information about how the brain works, but at what cost? H.M.’s story takes us back to the early days of modern neurosurgery, when physicians and researchers pushed boundaries in their quest to understand the mysterious workings of the brain. We will explore the tensions between the pursuit of knowledge and the ethical limitations on research, as we move from the hopelessness of the insane asylums of the early 20th century, to the revolutionary work of pioneering neurosurgeons in the 1930’s, to the technological wonderlands of the laboratories of MIT and UCSD.
TEAM PROJECTS

T9  PROJECT IN COMPUTER SCIENCE: MACHINE LEARNING
INSTRUCTOR: Minjoon Kouh, Drew University

In this project, we will explore the field of machine learning, where computer algorithms are used to discover underlying patterns in data and make predictions. For example, we will use a supervised learning algorithm to recognize an object in an image, or we may employ an unsupervised learning algorithm to cluster data into meaningful groups. Scholars will be exposed to the whole workflow of collecting and exploring data, as well as choosing and running algorithms. Prior computer programming experience is recommended.

T12  PROJECT IN PSYCHOLOGY: COGNITIVE ILLUSIONS
INSTRUCTOR: Patrick Dolan, Drew University

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.

T16  PROJECT IN PHYSICS: QUANTUM COMPUTING
INSTRUCTOR: Daniel Kaplan, Montclair High School

Quantum computers offer the possibility to solve some previously impossible problems and lead to some major breakthroughs. Currently quantum computers are being developed in a few places such as IBM, Google, and MIT. This course explores quantum computing and gives students an opportunity to learn the concepts and then develop quantum computer algorithms which they will apply using the IBM quantum computing facility. By the end of the project, students will be developing their own unique algorithms and presenting the results.
T17  PROJECT IN CHEMISTRY: COMPUTATIONAL CHEMISTRY

INSTRUCTOR:  Adam Cassano, Drew University

Transition states represent the maximum energy structure of reactants as they proceed to products in a chemical reaction. Therefore, knowledge of the structure and energy of a reaction’s transition state is critical to making predictions about the reaction rate and possible mechanisms of catalysis. However, transition states are also inherently unstable, with bonds in the process of breaking and/or forming, making direct experimental study impossible in most cases. In this team project, we will explore some of the methods we can use to study transition states with a focus on phosphoryl transfer. This family of chemical reactions plays an enormous role in biological systems, including ATP hydrolysis, the creation and breakdown of DNA and RNA, regulating protein function, and processing environmental toxins. We will build on previous studies to better understand how the myriad of chemical structures and the environment involved in phosphoryl transfer reactions affects transition state structure, and therefore the reaction itself.

T18  PROJECT IN CHEMISTRY: USING COMPUTATIONAL DRUG DOCKING TO IDENTIFY POSSIBLE THERAPEUTICS AND LEAD COMPOUNDS

INSTRUCTOR:  David Cincotta, High Tech High School

Molecular docking can be 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. While we will not be designing novel drugs this summer, we will utilize public databases of small-molecule ligands to identify potential candidates for re-purposing against significant diseases that have not yet been cured or are difficult to treat. Using docking computational software, scholars will predict ligand position and orientation in binding sites and calculate binding affinities to help identify promising small molecules for future investigation.