# SCIENCE

Through a broad and deep range of course offerings, the Science Department seeks to address the needs and interests of all students. Laboratory experiments, hands-on activities, and computer simulations challenge students to problem solve, analyze, discover, and understand the fundamental principles of nature. This understanding empowers them to live in and contribute to an increasingly technological society while gaining confidence in their own abilities.

The department requires two years of laboratory science, one in the life sciences and one in the physical sciences. The majority of students, however, take additional courses of particular interest.

For information on courses designated *GESC*, please refer to pages 5–6.

**Biology I**
*freshmen and sophomores*
This introductory course is organized around four biological themes: change over time, communication, transfer of energy and matter, and homeostasis. Through the lens of these themes, students are able to more deeply understand and appreciate all biological systems. Topics studied include evolution, cell and molecular biology, and human anatomy and physiology. The use of hands-on modeling activities enhances student engagement and understanding. In the lab, students learn how to design well-controlled experiments and how to analyze collected data. Through this lab work, students gain hands-on experience with current techniques used in research laboratories.

**Advanced Biology I**
*sophomores, juniors, seniors*
This course is an introductory biology class for students who have had a full year of chemistry. It covers the same topics as Biology I but emphasizes the biochemical processes in greater depth and detail. As with Biology I, students learn to think critically about how living organisms evolve and survive and are encouraged to make connections to all biological processes within the natural world. The course makes frequent use of case studies to facilitate application of the course content to complex real-world problems. Students spend ample time in the laboratory practicing many of the techniques used in research laboratories today, collecting and analyzing data, and discussing current research topics. Prerequisites: Chemistry and permission of the department

**Chemistry I**
Students in this introductory class improve their scientific literacy by developing analytical and problem-solving skills through the lens of basic chemical principles such as atomic theory, chemical reactions and bonding, stoichiometry, energy, solutions, equilibrium, acids and bases and electrochemistry. Students engage in small-group and individual problem-solving, laboratory investigations, and exercises to hone written and graphical communication. Prerequisite: Algebra I; Co-requisite: Concurrent enrollment in Algebra II or permission of the department

**Advanced Chemistry I**
This course is designed for those students with strong quantitative ability and who also possess an avid interest and proven achievement in science. Through this rigorous and fast-paced course, students come to an understanding of the methods and principles of modern chemical theory. The development of scientific writing and analytical problem solving skills are emphasized. Topics draw from the basic principles of inorganic chemistry: electronic structure of the atom, periodicity of elements, stoichiometry, chemical bonding, molecular structure, gas laws and kinetic molecular theory, equilibrium, kinetics, acids and bases, oxidation-reduction and electrochemistry. Throughout the course, students are involved in an extensive laboratory curriculum. Advanced Chemistry I helps to prepare students for the SAT Subject Test in Chemistry. Prerequisite: permission of the department; Co-requisite: Advanced Algebra II or Algebra II with permission of the department

**Integrated Earth and Physical Sciences**
*juniors and seniors*
This course exposes students to an array of real-life, science-based situations from both the past and present and pushes students to read critically and think independently to improve their understanding of the world around them. The course focuses on developing a scientific worldview by examining the underpinnings of modern scientific thought and by encouraging the use of problem-solving and data analysis skills to analyze and interpret important scientific concepts. Students improve their scientific design and data analysis skills through a variety of laboratory exercises and projects. Topics include the history of scientific thought, astronomy, Newton's dynamics and kinematics, electricity and magnetism, light and optics, atomic structure, radioactivity and nuclear power, geology, meteorology and climate. Co-

requisite: Algebra II

**Physics I**
*sophomores, juniors, seniors*
This course introduces students to Newtonian physics and a variety of problem-solving techniques. Through laboratory investigation and class discussion, students explore mechanics, energy, waves, optics, electricity, and magnetism. This course emphasizes a practical approach to understanding physics concepts using familiar objects and everyday situations. Physics I is designed to assist students in developing a greater appreciation for real-world problem-solving situations. Co-requisite: Advanced Precalculus or Precalculus with permission of the department

**Advanced Physics I**
*sophomores, juniors, and seniors*
Challenging laboratory explorations, engaging classroom derivations and demonstrations, and intimate small group investigations form the core learning experience in Advanced Physics I. Students work together to develop the conceptual understanding, analytical skills, and self-confidence needed to master a wide array of physics topics. The major area of emphasis in the fall term is Newtonian mechanics. In the winter term, students explore electrostatics and circuits. In the spring, the focus shifts to studies of magnetism, optics, and wave interactions for sound and light. The course stresses problem solving with a heavy emphasis on graphical interpretation and vector mathematics. It is appropriate for students with good aptitude and proven achievement in both science and mathematics. With extra preparation, students are prepared for the SAT Subject Test in Physics. Prerequisite: one previous science course and permission of the department; Co-requisite: Advanced Precalculus with Differential Calculus or Advanced Precalculus with permission of department

**CL Chemistry II**
This course continues the study of chemical principles and theory at a level consistent with that of a first year college offering. It covers all of the topics of the first level course, but at a deeper level and at a faster pace. Inquiry-based laboratory experiments follow the suggestions of the AP curriculum and support the concepts studied in class. Lab work helps students develop proficiency with basic analytical laboratory techniques, and they are frequently asked to design their own protocols to solve problems. This course prepares students for the Advanced Placement examination. Prerequisite: Advanced Chemistry I and/or permission of the department

**CL Physics II**
This problem-solving intensive course pushes students to consider more deeply the topics introduced in Advanced Physics I and to investigate challenging questions incorporating calculus techniques. Dynamic classroom discussions and developments, extensive small group investigations, and laboratory work centered on experimental design enable students to develop confidence and a strong conceptual mastery. The first half of the course focuses on mechanics — covering Newton's laws, conservation of energy and momentum, rotational dynamics, simple harmonic motion, and universal gravitation. The second half explores electricity and magnetism — delving deeply into Coulomb's Law, Gauss's Law, Ampere's Law, Faraday's Law, and circuits involving capacitors and inductors. This course fully prepares students for Advanced Placement examinations in both Mechanics and Electricity & Magnetism. Prerequisite: Advanced Physics I; Co-requisite: CL Calculus BC or CL Calculus AB with permission of department

**CL Modern Physics**
*half course*
Modern Physics discusses the topics of physics that have shaped modern scientific thought and inquiry. Students learn about topics such as special relativity, quantum mechanics, nuclear physics, and the Standard Model of physics and they study how these topics are explored experimentally. Although these concepts are not studied in CL Physics II, the basic physical principles from CL Physics II are essential in understanding these more advanced ideas. Concepts of differentiation and integration learned in CL Calculus BC are likewise essential to being able to solve the problems presented in this course. Not only do students build a quantitative and qualitative knowledge of modern physics, but they also think critically about how these ideas have dramatically shaped and altered the world we live in. Pre-/co-requisites: CL Calculus BC and CL Physics II; departmental permission required

**CL Environmental Science** *(GESC)*
This course provides students with the scientific concepts and methodologies to understand the interrelationships within the natural world. Through on-campus field trips and hands-on activities, students will come to a solid understanding of the core ecological principles. In addition, they will learn to identify and analyze environmental problems within the natural world; relative risks will be evaluated and alternative solutions to problems will be examined. Topics covered include ecological foundations and principles, introduction to plant science, energy, climate

change, human population and demographics, toxicology, pollution and pandemics, fresh water resources, water quality, and global water issues. Students learn to observe environmental systems critically and to develop and conduct well-designed experiments with the goal of making positive changes to the local Loomis Chaffee campus and surrounding ecosystem and in the spirit of environmental stewardship and sustainability. This course covers the majority, but not the entirety, of the AP Environmental Science curriculum; those students interested in sitting for the AP Environmental Science exam in May will need to complete some independent work to prepare for that exam and should consult with the instructor to identify those additional topics. Prerequisites: biology, chemistry, and permission of the department

## Elective Term Courses

**Astronomy I: Introduction to Astronomy and the Solar System**
*term course/juniors and seniors*
The fall term course introduces students to observational astronomy and methods for measuring distances in the solar system and universe. Students gain an understanding of the foundations of astronomical evidence for our place in the universe by studying the historical development of astronomy from the ancient Greeks to Kepler and Newton as well as modern techniques for studying planets and stars. The course also provides an overview of our solar system. Students will have the opportunity to view the night sky with the school's telescope and make use of the O'Brien Planetarium. Prerequisite: Chemistry or Physics

**Astronomy II: Observing the Universe**
*two-term course/juniors and seniors/winter and spring*
This course focuses on stars, galaxies, and cosmology. Major topics include the structure and evolution of stars; stellar explosions and the formation of neutron stars and black holes; the creation of galaxies; relativity and theories about the origin and fate of the universe, with emphasis on the Big Bang; and current questions about the role of dark matter and dark energy. Students will also explore astrobiology, recent space missions, and the possibility of locating habitable planets outside our own solar system. Prerequisite: Chemistry or Physics

**Comparative Anatomy**
*term course/juniors and seniors*
This course investigates the anatomy of several different vertebrate organisms including humans. Systems such as the muscular system, nervous system, digestive system and skeletal system are compared between a variety of organisms. The class includes many hands-on activities with a heavy emphasis on dissection; potential organisms for dissection include fetal pig, snake, rat, mink, and fish as examples. These lab activities, as well as lectures, focus on comparing anatomical structure and function and lead to a greater understanding of evolution and common ancestry among vertebrates. Students interested in this course do not need a deep background in the field of biology but should be interested in animal body systems and function and not afraid to take part in dissections. Prerequisites: Biology and Chemistry

**Genetics**
*term course/juniors and seniors*
This course explores some of the most recent advances in the study of genetics. A review of Mendelian genetics, the structure and function of DNA, and the central dogma of biology enables students to gain deeper understandings of these basic genetic concepts before further investigating the more complex aspects of cancer, evolution, and genetic diseases. Lab work and hands-on activities include exploration of gene expression, genetic engineering, and gene therapy. Prerequisites: Biology and Chemistry

**Forensic Science**
*term course/juniors and seniors*
This course focuses on the application of various science techniques used to solve crimes including fingerprinting, blood typing, blood spatter analysis, and DNA profiling. Students combine their knowledge of biology and chemistry in order to solve multiple crime scenes. Students will also learn the basics of the American criminal justice system and discuss its structure, intentions, and shortcomings. The course emphasizes forensic science as a discipline that provides strong, but not infallible, evidence for criminal proceedings. Care is always taken to note the reliability of all techniques studied. Prerequisite: Biology and Chemistry

**Ecology** *(GESC)*
*fall term/juniors and seniors*
This course focuses on ecological principles and natural history and introduces laboratory skills to help students

understand the interactions among organisms and between organisms and their environments. Students begin to explore the key ecosystem services provided by natural ecosystems and learn about energy flow, biotic and abiotic factors, and cycling of matter (water, nutrients, etc.) in the ecosystem. Prerequisite: Biology and Chemistry are strongly recommended.

**Human Populations and Impact** *(GESC)*
*winter term/juniors and seniors*
This course explores our human population: how and why it grows, and its impact on the earth. Utilizing current events, students explore how education, food security, public health, energy use, and climate change have a reciprocal relationship with local and global population growth and demographics. Throughout the term, research-based projects and laboratory studies will enable students to more fully understand these concepts. Prerequisite: Ecology

**Sustainability: Soil, Water, and Agriculture** *(GESC)*
*spring term/juniors and seniors*
This hands-on, project-based course investigates both local and global sustainable agricultural practices with a focus on water use in those practices. Current water issues, including water pollution, drinking water concerns, and the question of access to clean water will be addressed. Further studies will investigate the specific impact of both traditional and sustainable agriculture on soil health, the hydrologic cycle, and the availability of fresh water for human use. As a culmination of previous work done in environmental science, students use the Loomis Chaffee campus as a microcosm for learning how to use sustainable practices to improve their local environments. Prerequisite: Ecology

**Robotics**
*term course/sophomores, juniors, and seniors*
This hands-on, experiential term course teaches students about advances in technology and collaboration skills, both of which are critical for innovation in the evolving 21st century workplace. Students are exposed to three ways in which robotics functions in today's society: manufacturing, human-assistance, and autonomous control. Students work in small groups to explore the field of robotics through the completion of two major projects over the course of the term. First, students build kit-style unmanned aquatic vehicles (UAVs), modify them as needed, and learn how to successfully control the vehicles to perform tasks underwater. Second, students will design and build small "mouse-like" robots to autonomously navigate a maze, find a piece of "cheese," and return it to the mouse hole. Both projects require students to become familiar with the Loomis Chaffee design process and the tools and resources in the Pearse Hub for Innovation. In addition to fabricating their own robots, and in order to better understand their use in industry, students have the opportunity to visit a local manufacturing company that uses robots.

**Science of Engineering and Design**
*term course/juniors and seniors*
Students learn about and gain experience in the engineering design and manufacturing process. Students learn the design thinking approach to problem identification, the process of creating prototypes using the tools and resources of the Pearse Hub for Innovation (3-D Printer, laser engraver, CNC router, etc.), and computer aided design (CAD). Students frequently present projects of their own designs throughout the term.

**CL Biology II: Genetics**
*fall term/juniors and seniors*
This rigorous course studies the profound implications of recent advances in genetics. Topics include the discovery, structure, and function of DNA, Mendelian and non-Mendelian patterns of inheritance as well as the control of gene expression and epigenetics. The course has a significant laboratory component that emphasizes the use of modern techniques such as the isolation of DNA, polymerase chain reaction (PCR), and DNA sequencing in order to conduct a research project in molecular genetics. Examples of such projects include those focused on genetic engineering and the creation of genetic knockouts, as well as the construction of a genetic pedigree by tracking the intergenerational inheritance of physical traits combined with analysis of specific DNA sequences controlling these traits. Prerequisites: Biology, Chemistry, and permission of the department

**CL Biology II: Cell Biology I** *(winter)*
**CL Biology II: Cell Biology II** *(spring)*
*One- or two-term course/juniors and seniors/winter only or winter and spring*
Cells are the smallest living things that can perform the functions of life and understanding how cells work is fundamental to all biological science. In this course, students study cells from the outside in, beginning with an investigation of membranes and transport followed by explorations of how a cell responds to its environment (cell signaling). Particular emphasis is placed on the study of enzymes and their control of cells, eukaryotic organelles, cell interaction with the environment (cell signaling), cell division (understanding cancer), and programmed cell death (apoptosis). Students spend a great deal of time in the lab exploring cell culture and the staining of mammalian

cells. Other lab investigations include the study of intracellular trafficking mechanisms, the movement of proteins, and fluorescent microscopy. Prerequisites: Biology, Chemistry, and permission of the department *Note: The spring term of Cell Biology may only be taken when following the winter term of Cell Biology.*

**CL Biology II: Microbiology**
*fall term/juniors and seniors*
Though bacteria have only a single cell (as opposed to trillions in the human body), they perform many of the same cellular functions that humans do — consuming nutrients, generating energy, and eliminating wastes. This laboratory-intensive class allows students to closely examine bacterial metabolism, morphology, and genetics. After experiments are run, there is a heavy emphasis placed on analyzing lab results and discussing the conclusions that can (and cannot) be drawn from them. A flipped-classroom model where students watch video lectures outside of class maximizes the amount of in-class time dedicated to hands-on lab work and problem solving. Prerequisites: Biology, Chemistry, and permission of the department

**CL Biology II: Molecular Biology I** *(winter)*
**CL Biology II: Molecular Biology II** *(spring)*
*one or two-term course/juniors and seniors/winter only or winter and spring*
The functions of our bodies are carried out by a variety of biological molecules, two of the most important of which are proteins and DNA. Proteins provide structure within the cell and catalyze essential cellular reactions, while DNA carries the genetic blueprint for the cell. The winter term of this laboratory-intensive course focuses on proteins, with a culminating project of isolating and purifying one specific protein from a mixture of thousands. To develop an effective purification scheme, students learn the basic biochemistry of buffers, amino acids, and proteins as well as protein separation and quantification methods. The spring term explores the topic of DNA and culminates in cloning a gene from one species of bacteria into another. To accomplish this task, students learn the basics of modern genetic engineering by focusing on techniques such as plasmid isolation, creation of recombinant DNA, and transformation of recombinant DNA into host cells. A flipped-classroom model where students watch video lectures outside of class maximizes the amount of in-class time dedicated to hands-on lab work and problem solving. Prerequisites: Biology, Chemistry, and permission of the department *Note: The spring term of Molecular Biology may only be taken when following the winter term of Molecular Biology.*

**CL Organic Chemistry I**
*term course/juniors and seniors*
The goal of this course is to give students an introduction to and strong foundation in organic chemistry. Topics covered include chemical structure and bonding, molecular representations, nomenclature, and physical and chemical properties of alkanes, alkenes, alkynes, alkyl halides, alcohols, ketones, and carboxylic acids. This course also introduces students to drawing resonance structures, curved arrows, and reaction mechanisms such as SN1, SN2, E1, and E2. Students have the opportunity to hone their laboratory skills through practical work that involves investigations such as determining the boiling point and melting point of organic substances, extraction of caffeine, simple and fractional distillation, and the classical synthesis of esters. Prerequisites: Chemistry Advanced or CL Chemistry; co-requisite of Physics or permission of the department

**CL Organic Chemistry II**
*term course/juniors and seniors*
This term course is a continuation of the first term of CL Organic Chemistry with an emphasis on instrumental analyses such as infrared (IR) spectroscopy and proton nuclear magnetic resonance (NMR) spectroscopy. More complex organic reactions such as nucleophilic substitution of the carbonyl group, esterification reactions, formation of enols and enolates, multistep synthesis reactions and finally, retrosynthesis are explored in this second term of organic chemistry. Students conclude the spring term by executing a project in which they come up with a novel way to synthesize an organic molecule of their choice. This class involves significant lab work and use of peer-reviewed scientific journals. Students must take the winter term of Organic Chemistry to be eligible for enrollment in the spring term course. Prerequisite: CL Organic Chemistry I

**CL Guided Research Projects in Molecular Biology**
*half course/seniors*
Guided Research Projects are yearlong, half courses in the science department that allow students who have completed the graduation requirements for science, and those with an interest in the biological and biomedical sciences, to engage in sustained, significant, mentored scientific research. In this capstone class, students conduct authentic research in molecular biology, and with guidance, design their own research question using an established model system for that experimental work (one that matches the expertise of a Loomis Chaffee science faculty member). Projects involve sustained skill acquisition and the development of rigorous scientific methodology; they also require the student to master experimental techniques that go beyond the traditional science department curriculum. Students maintain a

research quality notebook and document their results in either extended lab report or scientific poster format, and they present their research findings to an audience at the end of the school year. Acceptance into the GRP is a competitive process and interested students are required to complete a written application. Prerequisites: fulfillment of or co-enrollment in CL Biology electives and permission of the department

**CL Guided Research Projects in Environmental Sustainability** *(GESC)*
*half course/seniors*
This Guided Research Project is a hands on/experiential learning approach to environmental stewardship and sustainability using Loomis Chaffee as a location of study and action. Students learn about all the facets of campus sustainability including waste management, energy conservation, water demands, and agriculture. While investigating these themes students are required to research and organize an action plan and proposal for a specific sustainability project, with the expectation of having the project carried out in the spring term. Prerequisite: Biology, Chemistry; pre/co-requisite CL Environmental Science or Ecology and permission of the department

**Independent Studies in Science**
*term course*
A student who has completed the two-year laboratory science requirement may undertake an Independent Study Project in Science. Projects may involve either in-depth research of previously encountered topics or an independent study of material not presently offered. The student must arrange for a project advisor from within the department, **submit a written proposal**, and obtain approval from the project advisor, academic advisor, department head, and dean of faculty for any independent study project. Prerequisites: fulfillment of departmental requirements and permission of the department