# INTRODUCTION

In 2013, California adopted revised standards for education in the natural sciences based on the **Next Generation Science Standards**. These new standards were designed to move away from and exhaustive list of content to a greater focus on outcomes indicating a deeper understanding of the underlying scientific phenomena. This **Statement of Competencies in the Natural Sciences Expected of Entering Freshmen** is intended to update the 1988 **Statement on Natural Science Expected of Entering Freshmen** to reflect this shift in science education in California. The Intersegmental Committee of Academic Senates (ICAS) appointed faculty from the California Community Colleges, California State University, and the University of California to update the previous statement to reflect current practices in science education.

California only requires students to complete two years of science while in high school. With that in mind, there was considerable time spent looking at creating two sets of expectations, one for those students planning to pursue a degree in science, technology engineering, or mathematics (STEM) and one for students planning to pursue other degree options. High schools are encouraged to emphasize the value of taking more science. Taking more science courses will help students build important skills like analytic problem solving, organization, teamwork, and study skills and will not limit the possible majors available when students are applying for admission.

This document has been broken into two distinct sections. The first section describes the benefits of scientific literacy, beyond understanding the individual scientific discipline, and describes some common elements that are woven through all scientific disciplines. The second section is broken into four scientific disciplines with each discipline providing a summary of performance expectations, examples of how each of the common elements relate to those disciplines, and how the use of technology is integrated into each of these disciplines. The four disciplines are:

* **Chemistry**
* **Earth & Space Sciences**
* **Life Sciences**
* **Physics**

This document does not make any recommendations about how high schools should structure their science courses. Each school serves a unique student population, has different resources, and should create a course structure that maximizes those resources in serving their students. Every student graduating from high school, that plans to attend a college or university, is expected to achieve all of the performance expectations outlined in NGSS and this document.

How many years of science do high school students need? ACT has done some research that shows that students are more prepared for college when they take more science courses. ACT found that 13 % of students taking less than three years of high school science are prepared on the ACT Readiness Benchmark in Science. 45 percent of students taking a course in biology, chemistry, and physics were found to be prepared. Harvard tells hopeful applicants: “The natural sciences help to explain, to predict, and sometimes to control, the processes responsible for phenomena that we observe. They constitute a large and growing portion of human knowledge important to everyone. Even if you have no intention of becoming a scientist, an engineer, or a physician, you should study science throughout secondary school.” The University of California A-G subject requirements strongly encourage students to take three years of a laboratory science. Ultimately, the number of years that a student spends taking science courses will depend on the set up of the high school’s curriculum, but there are clear benefits to taking more science for all students.

To ensure that all entering freshman are prepared to complete their degree in a minimum number of units, this document is based upon the following recommendation:

*Proper preparation for baccalaureate level science coursework, necessitates that high schools encourage students to take a science classes during each year of high school. All students’ benefit from the knowledge acquired and skills developed through completion of additional science courses. These skills will be invaluable in assisting students with the completion of their degree, no matter what major they choose.*

Many students may consider taking an Advanced Placement (AP) science course while in high school. AP courses can help students build upon skills gained in a previous science courses, but taking a second course in one discipline should not replace a course in another. Students should be encouraged to take AP science courses only if they do not conflict with the completion of the all of the performance expectations listed in NGSS.

# SECTION 1

Humans are extremely curious. A child’s natural curiosity is the same curiosity that has driven many scientists to dedicate their lives to looking for answers to the questions of how everything in nature has come to be. When young students first come to school and are exposed to the wonders of science, they are amazed by possibilities. Science teachers see that excitement every day from students. As their understanding of the universe grows, so does their desire to explore other aspects of the world. Science education is an opportunity to help students explore their natural curiosity and build skills that will allow them to become productive members of society that critically analyze situations instead and determine the best course of action.

When you expose young children to scientific experiments, they are instantly fascinated and want to learn more. Bombarding students with an endless collection of facts they are expected to memorize can diminish the sense of wonder that students have during a demonstration or experiment. While covering facts cannot be eliminated, educators hope to give our students more than some answers to trivia questions. We want them to be able to collect information, assess the validity of that information, determine which facts are pertinent to a problem, and to try and formulate a solution. We want them to develop skills that will be useful in their education and their careers and that desire applies throughout the curriculum.

How do we help teachers and students develop the skills used in scientific inquiry and not become tied to covering an endless list of topics? The Next Generation Science Standards (NGSS) were designed to focus on what students should be able to do instead of a list of things that students should know. NGSS was created through broad collaboration between K-12 teachers, university professors, and practicing scientists. These new standards are designed to help students develop the skills that scientists and engineers use every day. The new standards outline performance expectations in the following areas:

* Physical Sciences
* Life Science
* Earth and Space Sciences
* Engineering

The inclusion of engineering at the high school level is something knew, but the skills that engineers use are exactly those that we hope all of our students will have when they complete their education. Engineering is about analyzing a particular problem and formulating a possible solution. At the university level, engineering majors will be exposed to techniques that are useful for a particular field like circuit design, designing a jet engine, or creating the next miracle drug. Students will not be exposed to specific fields of engineering, but they will be exposed to new types of problems and different types of data and data analysis techniques. By incorporating different perspectives on problems solving, students will begin to develop the skills necessary to study engineering. Ultimately, students entering a college or university should be able to analyze a problem and attempt to formulate a solution. This skill isn’t limited to engineering; it is used in mathematics, the natural sciences, the social sciences, and the humanities. Engineering is also about looking at a complex problem, breaking that problem into different pieces, and bringing all of those pieces back together to complete the project. For example, the design of a jet is a complex task that involves many different pieces and looking at the overall design can be overwhelming. Engineers learn how to take a problem like this apart and break it into manageable projects. Each of those projects must come together to complete the original design. These same skills will be used during the science courses that students take during high school. They will learn to work in teams and to split the work among different team members. The teamwork skills developed during the laboratory portion of science courses helps build the foundation for the collaborative efforts that engineers use in industry.

NGSS also includes the integration of technology into scientific inquiry. Technology is all around us and the only constant is that the technology we are using today will be obsolete very soon. Students need to be able to use technology and adapt to new technology every day of their lives. Science laboratory courses require students to use various different pieces of technology. Technology can be used to simulate experiments, collect data, and analyze it. One of the unique benefits that science courses offer is the exposure to different types of technology with each different type of experiment. Working with unfamiliar technology helps students develop important skills that they will use throughout their education and employment. The ability to use today’s technology is important, but being able to adapt to any technology that is developed will assist students throughout their lives.

Science instruction is typically broken up into disciplines like biology, chemistry, and physics. This structure might give the impression that scientific disciplines are not related, but the NGSS includes crosscutting concepts that illustrate the connections that exist between different scientific disciplines. The mastery of these concepts help students view the sciences as a unified field of study and it helps them develop an understanding of looking at the same idea from different perspectives. Many ideas have several different facets and students need to develop the skills to meld those different facets together to complete their understanding of each concept. The skills developed through the mastery of the crosscutting concepts will help students succeed in any environment that requires them to assimilate differing perspectives to reach evidence based conclusions.

Scientific instruction assists students with the development and strengthening skills that they will use throughout their studies. All science courses require students to apply skills that they acquired in math courses. Skills like graphing, error analysis, finding solutions to algebraic equations, and extracting pertinent information from word problems.

Science courses are often the first time that students see that the concepts they learned in math classes will be applied in other areas. Students also continue to develop and enhance skills that can be used throughout their high school and university studies. These skills include improved study habits, the ability to read and extract information from technical textbooks, and organizational skills from problem solving to managing a heavy course load. These skills are not exclusive to science courses, but all of them will help students complete their baccalaureate degrees.

This revised competency statement summarizes the performance expectations, cross cutting concepts, and technological integration for the four scientific disciplines. As with NGSS, students are expected to complete all of the expectations listed in this document. Section 2 is broken into four scientific disciplines:

1. Chemistry
2. Earth and Space Sciences
3. Life Sciences
4. Physics

Each one of these scientific disciplines includes a summary of the performance expectations, a set of nine cross cutting concepts, and how technology has been integrated into the study of that area. The nine crosscutting concepts included for each discipline area are:

1. Uncertainty and weighing evidence
2. Systems and system modeling
3. Structure and function
4. Stability and change
5. Energy and matter
6. Scale and proportionality
7. Synthesis of information and how it contributes to the “big picture”
8. Visualization of data
9. Human and global impact

Completion of all of the required performance expectations will require students to master the crosscutting concepts, develop problem-solving skills, and be able to adapt to various types of technology. These skills combined with the scientific knowledge gained will prepare students to be successful in any major.

# SECTION 2

## Chemistry

**Guiding Principles Leading to Performance Expectations**

Students will develop an understanding of the common elements of the sciences as well as those pertaining to chemistry. Chemistry involves the identification of the substances that matter is composed of, the examination of their properties, and the way these properties can change or be manipulated to form new substances. Chemistry can be explored on four basic levels: organic, inorganic, analytical, and physical; where this paper redefines and organizes the following nine common elements with special attention to the four basic levels of chemistry.

Examples given have been divided into the basic levels of chemistry to adequately cover the breadth and depth of experience for high school students. These levels include the chemistry of carbon and its reactions/interactions (organic); descriptive chemistry of the main group and transition metal elements (inorganic); quantitative laboratory methods applied to main group and transition metal chemistry (analytical); and periodicity, atomic/molecular structure, and mathematical relationships of physical properties pertaining to various molecules and atoms (physical).

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Chemistry** | **Scope and Application**  **Students should demonstrate the ability to:** | **Specific examples – These represent topical examples at four chemistry levels. Not all examples are expected but serve to typify depth and breadth of the elements at four chemical levels.** |
| Uncertainty and weighing evidence | * Distinguish between science and pseudoscience e.g. research journals versus news and commercial websites * Identify reputable sources * Differentiate between scientific information and political platforms or social beliefs | **Organic –** combustion of fossil fuels and the production of CO2 from human activities  **Inorganic –** mercury and lead toxicity in oceanic and drinking water  **Analytical –** laboratory practices for identifying and quantifying chemical reactions based on the scientific method  **Physical –** the role of molecular properties in their manifestation as green house gases |
| Systems and system modeling | * Apply the periodic table to the description of atoms and molecules * Differentiate chemical reactions based on periodicity and reactivity * Use mathematical modeling in experimental investigations * Use mathematical modeling in theoretical investigations | **Organic –** using molecular models to visualize organic molecules  **Inorganic –** describing the observed oxidation states of main group elements and transition metals based on periodicity  **Analytical –** Beer’s Law analysis on the absorption of light by colored solutions  **Physical –** ideal gas laws |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Chemistry** | **Scope and Application**  **Students should demonstrate the ability to:** | **Specific examples – These represent topical examples at four chemistry levels. Not all examples are expected but serve to typify depth and breadth of the elements at four chemical levels.** |
| Structure and function | * Characterize the relationship between structure and function * Discuss how the arrangements of atoms leads to observed bulk scale crystal/lattice structures * Discuss how the arrangements of atoms leads to different phases of matter | **Organic –** putting together larger structures of organic molecules based on simple structures such as methane or water  **Inorganic –** extrapolating the molecular structure of salts/minerals from the atomic scale to the bulk scale (i.e. crystal/lattice structure)  **Analytical –** measured observations of reactivity based on molecular structure  **Physical –** the description of solids, liquids, and gases based on structural details of the arrangement of atoms |
| Stability and change | * Describe a chemical reaction as a re-arrangement of atoms in a molecule * Understand the role of structural stability or instability leading to a chemical reaction * Have a general understanding of the time sequence of a chemical reactions (i.e. molecules must first collide before reacting) | **Organic –** reactions with carbon  **Inorganic –** reactions with main group elements and transition metals (i.e. Qualitative Analysis)  **Analytical –** using laboratory techniques to quantify the total change of a reaction (i.e. Titrations)  **Physical –** understanding rates of chemical reactions using the collision model |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Chemistry** | **Scope and Application**  **Students should demonstrate the ability to:** | **Specific examples – These represent topical examples at four chemistry levels. Not all examples are expected but serve to typify depth and breadth of the elements at four chemical levels.** |
| Energy and matter | * Have an understanding that mass is conserved in chemical reactions * Have an understanding of heat, energy, and work and their conservation * A view of heat and work as processes that are direction specific (i.e. system vs. surroundings) | **Organic –** the notion of exothermic and endothermic reactions of carbon containing molecules  **Inorganic –** the notion of exothermic and endothermic reactions of main group elements and transition metals  **Analytical –** calorimetry experiments  **Physical –** the laws of thermodynamics and conservation of mass |
| Scale and proportionality | * Assess the magnitude and effect of size from the atomic scale and manifestations on the bulk scale * Compare the size of atoms based on periodicity * Compare the size of larger, biologically relevant molecules such as proteins to smaller molecules such as water | **Organic –** the size of proteins, DNA, etc. in relation to the size of a cell or larger biological entities  **Inorganic –** lattice constants  **Analytical –** solution concentrations, pH scale, equilibrium constants, etc.  **Physical –** atomic and ionic trends in size |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Chemistry** | **Scope and Application**  **Students should demonstrate the ability to:** | **Specific examples – These represent topical examples at four chemistry levels. Not all examples are expected but serve to typify depth and breadth of the elements at four chemical levels.** |
| Synthesis of information and how it contributes to the “big picture” | * Debate topics dealing with ethics of chemistry, such as pharmaceuticals * Analyze economic and sociopolitical situations * Communicate science clearly | **Organic –** synthesis of pharmaceuticals using organic molecules  **Inorganic –** synthesis of pharmaceuticals using main group and transition metal elements  **Analytical –** cost of laboratory procedures, job market for chemists, etc.  **Physical –** energy requirements for large scale production of pharmaceuticals |
| Visualization of data | * Convert and display data collected into graphs and tables * Comprehend and use tables and graphs to draw conclusions * Interpretation of images of macroscopic and microscopic structure * Employ mathematical modeling to solve problems | **Organic –** observe 3D images of organic molecules converted into data streams  **Inorganic –** observe 3D images of in-organic molecules converted into data streams  **Analytical –** converting experimental observations into graphs, tables, charts, etc.  **Physical –** analyze experimental data with respect to fundamental laws and relationships |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Chemistry** | **Scope and Application**  **Students should demonstrate the ability to:** | **Specific examples – These represent topical examples at four chemistry levels. Not all examples are expected but serve to typify depth and breadth of the elements at four chemical levels.** |
| Human and global impact | * Develop confidence in formulating questions and providing supporting evidence * Weigh costs and benefits of chemical interventions and solutions * Demonstrating and understanding of probability in human and global applications * Analyze and create solutions to long-term sustainability of life on earth | **Organic –** understanding the difference between “organic food” and pesticides being organic molecules  **Inorganic –** metal contamination from industrial processes  **Analytical –** conducting measurements on the global scale, such as ocean pH monitoring or atmospheric CO2 monitoring  **Physical –** using fundamental relationships scaled up to predict global affects. |

**Integration of Technology- techniques**

Technology in the chemical sciences is ever changing. It is expected that students should have exposure to modern techniques; however, more importantly the ability to adapt to new technologies is paramount. Therefore, an understanding of how to troubleshoot and acquire new information should be emphasized when specific technologies/techniques are not available.

## Earth and Space Sciences

**Guiding Principles Leading to Performance Expectations**

The fields of earth and space sciences were not included in the 1986 Competencies reports, and the multidisciplinary that characterizes these fields was underemphasized in this document. Public interest in earth science in particular has gained momentum as pressing problems of climate change; pollution and natural resource availability become increasingly urgent. The study of earth and space sciences allows students the opportunity to integrate information and practices from physics, chemistry, and biology.

Earth and space science encompasses the study of earth and planetary systems, earth’s place in the universe, and interactions between humans and earth systems. This area of study includes, but is not limited to, the sub disciplines of geology, astronomy, atmospheric science, oceanography, hydrology, and civil and environmental engineering. In the earth and space sciences, scientists interrogate how the earth, solar system, and universe formed; evolved over time; and continue to change. Scientists examine the complex processes through which change occurs on varied temporal and spatial scales to elucidate the mechanisms that govern the systems function and to predict outcomes to perturbations to these systems. Engineering related to earth and space sciences includes designing solutions to environmental problems and creation of technology to observe, explore, and analyze earth and space.

The NGSS includes three standards in Earth and Space Sciences. These focus on 1) Earth’s place in the universe, including Big Bang, formation of celestial bodies, and working of solar systems; 2) the components, interactions, and feedbacks in earth systems; and 3) connections between earth systems and human activities.

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Earth and Space Sciences** | **Scope and Application** | **Specific Example** |
| Uncertainty and weighing evidence | * Involves timescales and spatial scales that exceed human experience with potentially limited sample sizes resulting in high levels of uncertainty that obscures causes and effects * Depends on the unpredictable human behaviors that create uncertainty in outcomes * Requires the ability to distinguish scientific evidence from opinion and to determine credibility of various sources of information | * Climate models produce projections of future climate with inherent uncertainty due to differences in how inputs, interactions and feedbacks are quantified and the uncertainty in future human actions. * Records of Earth’s past and models of Earth’s structure are constructed based on proxies and other analytic techniques such as isotopic and elemental composition and seismic waves. Multiple approaches are used to decrease uncertainty in reconstructions |
| Systems and system modeling | * Identifies the main components of earth and space systems * Uses numerical and physical models to simulate and predict interactions between components of earth and space systems, including feedbacks | * Global climate models are used to simulate atmosphere-ocean interactions that affect potential changes in global temperature. * Models of interactions between planetary bodies in the solar system are used to plot trajectories of objects in space, including space vehicles. |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Earth and Space Sciences** | **Scope and Application** | **Specific Example** |
| Structure and function | * Characterizes geological and hydrological formations and their behavior over time that determines their use in human activities * Characterizes how much energy is absorbed, reflected and reemitted from the Earth and sun. | * Some areas are more susceptible to seismic activity due to their location on tectonic plates and their ground stability * The large heat capacity of water allows the oceans to fluctuate less in temperature on diurnal and seasonal cycles, and mitigate temperature change on longer timescales. * Construction of large water projects such as dams on the Sacramento and American rivers change the deposition of silt in the Sacramento Delta, influencing diversion of freshwater to Southern California. |
| Stability and change | * + Follows long term changes including universe expansion and orbital cycles   + Describes equilibrium and perturbed carbon and hydrologic cycling | * + Earth’s position and distance in relation to the sun affects the intensity and distribution of radiation reaching the Earth, causing both seasonal changes and changes in climate on larger timescales.   + The equilibrium carbon cycle is currently being perturbed on short timescales by human activities including burning of fossil fuels and deforestation. |
| Energy and matter | * Tracks transfer and conservation of energy, carbon and water throughout earth systems * Calculates the energy budget of earth system, including radiative forcings | * Decay of radioactive isotopes in the Earth’s mantle generates thermal energy, driving tectonic movement * Movement and changes in the phase of water are connected to movement of energy and mass throughout the earth system. |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Earth and Space Sciences** | **Scope and Application** | **Specific Example** |
| Scale and proportionality | * Details the multiple mechanisms that affect equilibrium across time-scales * Resolves processes at different levels and identifies different mechanisms are dominant at different scales * Explains non-linear systems in which small changes can have amplified effects and large changes may have negligible effects | * Weather involves changes in meteorological parameters on short timescales, whereas climate involves averaged change over decadal or longer timescales. * Geologic processes occur through rapid and slow processes such as erosion, volcanic eruptions, earthquakes and seafloor spreading. * Storms can form in a particular location due to subtle changes in conditions. * Changes in temperature can cause feedbacks in sea ice extent and other ice surfaces that amplify or mitigate temperature changes, resulting in a seemingly disproportional response. |
| Synthesis of information and how it contributes to the “big picture” | * Integrates physics, chemistry, and biology into multiple subdisciplines including atmospheric science, geology, hydrology, astronomy and civil & environmental engineering | * Determining precipitation, like the drought in CA, requires connecting many variables, including atmospheric water content, snowpack and human activities * Integrating satellite measurements including radar, lidar, sea level and images increase the reliability of weather predictions. |
| Visualization of data | * Presents time-series and spatial representations * Represents 3-dimensional processes in 2 dimensions | * Plots of atmospheric Greenhouse gas concentrations allow for analysis of trends and patterns. * Geographic Information Systems (GIS) is used to look at relationships between human activities, land cover and topography. |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Earth and Space Sciences** | **Scope and Application** | **Specific Example** |
| Human and global impact | * Elucidates that humans influence environmental systems through pollution, land use change, resource extraction, and geochemical cycling | * Land use policies such as deforestation influence the atmospheric chemical composition, energy balance and rainfall patterns. * Release of ozone depleting substances increases UV penetration in the atmosphere and affects cancer rates in some areas. * Improved and sustainable agricultural practices can increase food production efficiency and decrease global hunger. |

**Integration of Technology**

Technology is an integral component of the collection and analysis of scientific evidence in the earth & space sciences. The instrumentation and tools available inform the character, quantity, and quality of evidence, which in turn informs scientific understandings. As technology advances and computational capacity increases, our ability to address more complex problems increases (e.g. increasing spatial and temporal resolution). Technologies necessary for studies in the earth and space sciences include: a) Sensors and sensor networks at multiple scales (e.g. Hubble telescope, water and air quality, satellites), b) Sample collection technology (e.g. geologic corers, planetary explorers), and c) Spatial and temporal analysis tools (e.g. GIS).

## Life Sciences

**Guiding Principles Leading to Performance Expectations**

Students should have developed understanding of the common elements of the sciences pertaining to biology. Biology involves the study of living things and will be explored on three levels; population, organismal, and cellular/molecular.

Biology is a rapidly growing and expanding field. For example, since the previous paper, the advancement of applications of recombinant DNA and the other emerging technologies. There is also growing evidence of the importance of microbial communities on our planet and in our bodies. Areas of novel and innovative development in the field of biology and the merging of engineering, computer science and biology have given rise to new directions such as bioinformatics and nanotechnology.

Examples given have been divided into levels of biological information to adequately cover the breadth and depth of experience for high school students. These biological levels include; the chemistry of life typically referred to as cellular and molecular biology, the energetics of physiology, behavior and homeostasis of individual organisms referred to as organismal biology; and the complex interactions between and among living things, populations and the inanimate world typically referred to as an ecosystem. Since math, chemistry and physics are all integral to biology, it is suggested that the high school biology course be taken after these courses.

**Common Elements of Science Pertaining to Biology**

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Biology** | **Scope and Application**  **Students should demonstrate the ability to:** | **Specific examples – These represent topical examples, which may themselves be quickly outdated, at three biological levels and do not include all examples expected but serve to typify depth and breadth of the element at three biological levels.** |
| Uncertainty and weighing evidence | * Distinguish between science and pseudoscience e.g. research journals versus news and commercial websites * Identify reputable sources * Differentiate between scientific information and political platforms or social beliefs | **Cell and molecular level** - identifying common supportable data e.g. stem cells and cloning.  **Organismal level** - accessing and evaluating controversial information related to individual organisms e.g. the use of vaccines and claims of autism or dietary supplements and health.  **Ecosystems & populations** - describing verifiable information about human impact on ecosystems e.g. global warming |
| Systems and system modeling | * Describe the organization and classification of biomolecules * Distinguish between eukaryotic and prokaryotic cells * Differentiate cell types and major tissues types * Identify the main components and levels of biological systems * Describe the complex interactions and adaptations. * Use mathematical modeling | **Cell and molecular level** - describing the organization and classification of biomolecules, cells and tissues  **Organismal level** – identifying the metabolic processes and hierarchy fundamental to basic physiology of organisms e.g. health and the role of nutrition and exercise  **Ecosystems & populations** – delineating the basic model of an ecosystem e.g. food webs and recycling of matter and energy |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Biology** | **Scope and Application**  **Students should demonstrate the ability to:** | **Specific examples – These represent topical examples, which may themselves be quickly outdated, at three biological levels and do not include all examples expected but serve to typify depth and breadth of the element at three biological levels.** |
| Structure and function | * Characterize the relationship between structure and function * Describe components of inheritance, growth and development | **Cell and molecular level**- describing how the molecular shape of DNA, RNA and proteins relate to the function of these biomolecules. e.g. immunoglobulins  **Organismal level** - comparing and contrasting the relationship between anatomy and physiology  **Ecosystems & populations** – exploring and describing ecosystems and communities e.g. Biofilms, Quorums and ecological succession |
| Stability and change | * Construct classical inheritance trait patterns * Differentiate factors associated with variation of traits, adaptation and mutation * Provide examples of diversity and natural selection * Describe mechanisms of evolution | **Cell and molecular level** – describing the role of mutation in molecular change and evolution e.g. development of bacterial antibiotic resistance  **Organismal level** – Examining homeostasis and osmoregulation  **Ecosystems & populations** – Describing key factors in regulating ecosystem balance, natural selection, population growth and decline. |
| Energy and matter | * Explain the role of conservation and recycling * Describe factors affecting energy flow at various biological levels | **Cell and molecular level**– explaining the flow of energy through respiration and photosynthesis  **Organismal level** –characterizing energy metabolism in organisms and imbalances e.g. diabetes  **Ecosystems & populations** –Describing biological dependence upon natural resources, energy flow through ecosystems, and natural cycles e.g. carbon, nitrogen and water cycles |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Biology** | **Scope and Application**  **Students should demonstrate the ability to:** | **Specific examples – These represent topical examples, which may themselves be quickly outdated, at three biological levels and do not include all examples expected but serve to typify depth and breadth of the element at three biological levels.** |
| Scale and proportionality | * Assess the magnitude and effect of size from molecular to population levels * Describe the impact of small molecular changes on the characteristics of an organism * Evaluate organismal actions on the characteristics of populations * Use mathematical modeling to understand comparative or proportional effects | **Cell and molecular level** –Comparing and contrasting surface area, volume and size of components of various biological elements sperm, egg  **Organismal level** – Evaluating differences of magnitude in size ranging from prokaryotic and eukaryotic e.g. trillions of microbes present on the human body  **Ecosystems & populations** – Modeling specific examples of biomagnification, extinction and threatened species e.g. effects of DDT |
| Synthesis of information and how it contributes to the “big picture” | * Debate bioethical topics * Analyze economic and sociopolitical situations * Communicate science clearly | **Cell and molecular level** –exploring genomics and gene therapy e.g. gene therapy for primary immunodeficiency  **Organismal level** – investigating regenerative medicine and stem cell biology e.g. bone marrow transplants  **Ecosystems & populations** – studying preservation and global warming e.g. limited resources, sanctuaries and parks, vaccinations, population control |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Biology** | **Scope and Application**  **Students should demonstrate the ability to:** | **Specific examples – These represent topical examples, which may themselves be quickly outdated, at three biological levels and do not include all examples expected but serve to typify depth and breadth of the element at three biological levels.** |
| Visualization of data | * Convert and display data collected into graphs and tables * Comprehend and use tables and graphs to draw conclusions * Interpretation of images of macroscopic and microscopic structure * Employ mathematical modeling to solve problems | **Cell and molecular level** – observing 3D images of biomolecules  **Organismal level** – interpreting graphs and images of physiological function present on the human body  **Ecosystems & populations** – Modeling population growth curves incorporating variables e.g. disease, competition, food supply |
| Human and global impact | * Develop confidence in formulating questions and providing supporting evidence * Weigh costs and benefits of biological interventions * Demonstrating and understanding of probability in human and global applications * Analyze and create solutions to long-term sustainability of life on earth | **Cell and molecular level** – Understanding probability and its role in interpretation of sequenced genomes  **Organismal level** - Analyzing the effects of bioengineering on the food supply e.g. GMOs  **Ecosystems & populations** – Modeling population growth and exploring eugenics |

**Integration of Technology- techniques**

Biology is a field that employs many technologies and where possible, through hands-on labs and field trips, it is desirable that students are exposed a variety of technologies. These should include: molecular techniques, microscopy, metrics and measurement (i.e. micropipettes, scales, etc.). The explosion of information in the field of biology necessitates that students learn to access a wide variety of sources and evaluate their validity e.g. websites, journals, magazines, and news media. The use of virtual tools computational and information technologies to understand and model biological systems is also valuable.

## Physics

**Guiding Principles Leading to Performance Expectations**

Physics is an experimental science that provides a systematic understanding of the fundamental laws that govern physical, chemical, biological, terrestrial and astronomical processes. Because physics is a foundational science, it bears on wide variety fields, including engineering and technology.

Physics may be presented using algebra, trigonometry, or calculus, but students should all understand the fundamental principles of motion, forces and interactions, conservation laws, and fundamental forces like gravity and electrostatic attraction and repulsion. Through the investigation of these topics, students will explore scales from atomic to galactic, the structure of matter from atoms to planets, and how energy is converted from one for to another. The table below provides the scope and application along with specific examples, which are based on five main physics classifications: mechanics, thermodynamics, electricity and magnetism, light and optics, and modern physics.

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Physics** | **Scope and Application -**  **Students should demonstrate the ability to:** | **Examples –** |
| Uncertainty and weighing evidence | * Distinguish between science, pseudoscience, political platforms, and social beliefs (e.g., research journals versus news versus public opinion) * Measure and distinguish between precision and accuracy * Objectively apply the process of scientific inquiry; distinguish between hypothesis, theory and law * Experimental replication pertaining to the validation of evidence | * Develop experimental strategies for measuring and quantifying data.   + Accuracy of different measurement devices.   + How does uncertainty in multiple measurements affect the certainty of a calculated result? * Plan and conduct an experiment to produce data that can be assessed for reliability and accuracy.   + Data collection through experiments can be accomplished in the classroom and at home. * Analyze claims to determine their validity based on an analysis of the evidence cited.   + Evaluate news stories to determine if the conclusions presented are supported by evidence. |
| Systems and system modeling | * Evaluate consistency between physical reality and theoretical predictions. * Explain how models can be used to simulate physical systems and interactions, including energy, matter and information transfer, within and between systems at different spatial and temporal scales | * Explain the effect that separation distance has on various forces and how these forces lead to the structure of atoms, objects, solar systems, and galaxies.   + Gravitational Forces     - Attraction between atoms to form stars and planets.     - Attraction between planets to form solar systems   + Electric Forces     - Attraction between protons and electrons to form atoms. * Differences between direct and indirect observations of objects and structure.   + A solid can be seen with our eyes. The solid is composed of molecules |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Physics** | **Scope and Application -**  **Students should demonstrate the ability to:** | **Examples –** |
| Structure and function | * Characterize the relationship between structure and function of matter and physical systems * Predict the interactions between objects and within systems of objects | * Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles * Conduct experiments to show how forces acting on systems relate to cause and effect |
| Stability and change | * Explain how positive and negative feedbacks can stabilize or destabilize a system * Quantify using models how change and rates of change operate of short and long periods of time and over small to large spatial scales * Explain the relationship between a perturbation to a system and the system’s response in terms of stability or instability | * Use mathematical modeling to understand comparative or proportional effects * Design experiments that demonstrate how forces acting on a system can affects stability and change over different space and time scales |
| Energy and matter | * Explain the principles of energy conservation and energy transformation * Explain how energy drives the cycling of matter within and between systems | * Make observations to provide evidence that sound, light, heat, and electric currents can transfer energy from place to place. * Show that energy is conserved using experiments like calorimetry, Hooke’s Law, or linear motion on an inclined plane. * Apply scientific ideas to design, test, and refine a device that converts energy from one form to another |

|  |  |  |
| --- | --- | --- |
| **Common Elements Of the Sciences Pertaining to Physics** | **Scope and Application -**  **Students should demonstrate the ability to:** | **Examples –** |
| Scale and proportionality | * Assess the magnitude and effect of different sizes of matter and systems, ranging from the from molecular to bulk scales * Use mathematical modeling to understand comparative or proportional effects | * Comparison of varying size objects to compare the difference in size between very small objects (electrons, protons, atoms), everyday objects (people, cars, buildings) and large-scale objects (planets, stars, galaxies). |
| Synthesis of information and how it contributes to the “big picture” | * Clearly communicate physical principles and technical information in multiple formats, including orally, graphically, textually and mathematically * Construct explanations based on physical laws and reliable evidence obtained from models, theories, and experiments | * Communicate technical information, such as how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy (e.g., solar cells absorbing light to convert to electricity) |
| Visualization of data | * Convert and display data collected into graphs and tables * Comprehend and use tables and graphs to draw conclusions * Employ mathematical modeling to solve problems | * Graphing of experimental data including linear, parabolic, exponential, and logarithmic functions that include proper titles and labels that explain the experiment performed to produce it. * Creating best-fit lines and curves and use those graphs to compare results to theoretical predictions. |
| Human and global impact | * Develop skills and confidence in formulating questions and providing evidence to support conclusions | * Demonstrate how waves interacting with matter are used in everyday applications (e.g., medical imaging, communications, scanners etc.) |

**Integration of Technology- techniques**

Technology has been a part of physics since the beginning. From the invention of the telescope to view other planets, using your pulse to measure time, to incorporating computers and tablets into laboratory experiments. The technology that students use is constantly evolving, but the specific pieces of technology are less important than being able to adapt to new and unfamiliar technologies. Where students once used stopwatches to measure time, many experimental apparatuses now take the data automatically and transfer it into a program for analysis. Students should be exposed to many different types of technology to measure and analyze data. The use of various types of technology will provide students with the skills necessary to adapt to emerging technologies, a vital skill in the modern workforce.