Fairfield Public Schools
Science Curriculum

The Chemistry of Medicines

CROSS CUTTING CONCEPTS

Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Scale, proportion, and quantity. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

Systems and system models. Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

Structure and function. The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

Stability and change. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Course: Description

Students in high school continue to develop their understanding of physical science, specifically chemistry. The high school performance expectations in Chemistry build on the middle school ideas and skills and allow high school students to explain more in-depth phenomena. There are three disciplinary core ideas in high school chemistry: 1) Structure and Property of Matter 2) Energy 3) Chemical Reactions. These performance expectations blend the core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge to explain ideas across the science disciplines. In the medicinal chemistry performance expectations at the high school level, there is a focus on several scientific practices. These include understanding of covalent bonding, molecular shapes and polarity and how this effects intermolecular interaction; the basis of disease pathways and how pharmaceuticals are developed: and how energy is used in diagnostic imaging to diagnose disease.

Standards for this course are taken from the *Next Generation Science Standards* and are of three types:

Disciplinary Core Ideas: Shown as content objectives, these standards define what students should know about the most essential ideas in the major science disciplines. The focus is on a limited number of core ideas in science and engineering both within and across the disciplines to avoid the shallow coverage of a large number of topics and to allow more time for teachers and students to explore each idea in greater depth. Reduction of the sheer sum of details to be mastered is intended to give time for students to engage in scientific investigations and argumentation and to achieve depth of understanding of the core ideas presented.

Science and Engineering Practices: These standards enable students to apply the content in the DCI's and the skills of practicing scientists and engineers to explain phenomena and solve real world problems. Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. Engaging in the practices of engineering likewise helps students understand the work of engineers, as well as the links between engineering and science.

Cross-cutting Concepts: These standards provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas. These broad concepts tie together the influence of engineering, technology, and science on society and the natural world.

http://www.nextgenscience.org/next-generation-science-standards

The Chemistry of Drug Design: Overview

Course Essential Questions
• How does molecular structure affect how pharmaceuticals interact in the body? • How is energy used to diagnosis disease?

Course: Year-at-a Glance

Unit	Title	Unit Essential Questions
1	Molecular Structure	-HS-PS1-1: How can the periodic table be used as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms? -HS-PS 1-2: How can the outcome of simple chemical reactions be explained based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties? -HS-PS 2-6: How do scientists communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials?

2	Disease Pathways	-HS-LS1-3: How can investigations be planned and conducted to provide evidence that feedback mechanisms maintain homeostasis? -HS-PS1-5: How are scientific principles and evidence applied to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs? HS-LS3-2: How do scientists make and defend a claims based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors?
3	Applications for Medical Diagnoses	-HS-PS3-1: How are computational model created to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known? HS-PS3-5: How can scientists develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction? HS-PS1-8. How can models be used to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

1. Molecular Structure

Overview

In structure and properties of matter, students are expected to develop understanding of how atoms bond in molecules, intermolecular forces, and to provide an understanding of the mechanisms of pharmaceuticals. Further explore the role of electromagnetic radiation in medicinal diagnosis of disease.

Unit Content Objectives

At the conclusion of this unit, students will be able to:

- Understanding of how electronic structure determines bonding, shapes, and properties in organic compounds.
- Explain how chemical bonding be predicted using the periodic table and experiment with chemical synthesis.
- Communicate scientific and technical information on how the molecular structure of molecules effect their function with macromolecules involved in disease

Unit Essential Questions

- How does structure of molecules effect their function?

NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):

- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-4),(HS-PS1-5)
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (HS-PS1-6)
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7)
- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)

- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1)
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),*(secondary to HS-PS2-6)*
- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. *(secondary to HS-PS1-1),(secondary to HS-PS1-3),*(HS-PS2-6)

SCIENCE AND ENGINEERING PRACTICES (SEP):

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3)

Corresponding CT Core Standards:
ELA/Literacy -
WHST.9-12.7; WHST.9-12.9

2. Disease Pathways

Overview

Students are able to understand basics of disease pathways, historically how diseases were targeted, and modern medicinal design.

Unit Content Objectives

At the conclusion of this unit, students will be able to:

- Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.
- Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

Unit Essential Questions

- How has modern science advanced our understanding of medicine?

NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):

- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-2),(HS-LS3-3)
- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-4),(HS-PS1-5)
- Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1)

SCIENCE AND ENGINEERING PRACTICES (SEP):

- Constructing Explanations and Designing Solutions
  Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-1)

- Engaging in Argument from Evidence
  Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
  Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2)
- Developing and Using Models
  Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
  Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4)

Corresponding CT Core Standards:
ELA/Literacy -
RST.11-12.1; WHST.9-12.5; SL.11-12.5; MP.2

3. Applications for Medical Diagnoses

Overview

Students will be able to understand how electromagnetic radiation and nuclear medicine is used to diagnose diseases.

Unit Content Objectives

At the conclusion of this unit, students will be able to:

- Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
- Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Unit Essential Questions

- How is energy used to understand the status of the human body?

NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):

- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) (HS-PS3-3)
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to HS-PS3-3)*

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)
- Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)

SCIENCE AND ENGINEERING PRACTICES (SEP):

- Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
  Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2),(HS-PS3-5)
- Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
  Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8)
  Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)

Corresponding CT Core Standards:

ELA/Literacy -

RST.9-10.7; WHST.11-12.8; HSN-Q.A.2