The NSTA Atlas of the Three Dimensions

NSTA Engage
Wherever you are 😊

November 15, 2020
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#3DAtlasChat

- A slow chat on twitter from November 15th to December 17th
- A different chapter of the Atlas every week
- A new question every weeknight
- Follow @NSTA_Atlas
- Follow #3DAtlasChat

- For more information: bit.ly/atlasFAQ
Andrew “Chick” Ahlgren

Many people deserve thanks for their roll in the development of the Atlas, but for so many reasons, I owe special thanks to Andrew “Chick” Ahlgren.

Among many other things, he:

• Co-Authored *Science for All Americans*

• Was Deputy Director at AAAS Project 2061

• Developed the idea of mapping standards

• Hired me to work on volume 2 of the *Atlas of Science Literacy*
Map from the Development of Benchmarks for Science Literacy

- Photosynthetic and cellular respiration in living systems, including photosynthesis and cellular respiration, the light cycle, and the dark cycle. (4.2.A)
- The energy from the sun is converted into chemical energy through photosynthesis, which is then used by living systems to power their biological processes. (4.2.B)
- The flow of energy and matter through ecosystems, including the transfer of energy between trophic levels and the cycling of nutrients. (4.2.C)
- The interdependence of living systems and their environment, including the impact of human activities on ecosystems. (4.2.D)

- The impact of human activities on energy and matter cycles, including the increase in greenhouse gases and the impact on global climate. (4.2.E)
- The role of energy and matter cycles in sustaining life on Earth, including the importance of biodiversity and the vulnerability of ecosystems to change. (4.2.F)
Access to Map 4.2

Which answer describes your current access to Map 4.2: Flow Matter and Energy in Living Systems

A. I have a **hard copy** of the Atlas (the book)
B. I have printed a **hard copy** of that map
C. I have a digital copy (PDF) of the entire Atlas
D. I have the digital copy (PDF) of that map that was included as a handout with the workshop
E. I have a digital copy (PDF) of the map from the Atlas sampler from the NSTA Press Website
F. I **don’t** have a copy of the map
The Need for Change
For Example...

Consider a Seed and a Log

- Under the right conditions, a maple seed can grow into a maple tree.

- But a maple tree is much bigger and more massive than a maple seed.

- How would your students explain where all of the extra material a maple tree has come from?
Let’s look at an example using a concept cartoon.

**Phenomenon:** This huge tree started as a little seed.

**Question:** What provided most of the mass that made the tree grow so large?
Phenomenon: This huge tree started as a little seed.

Question: What provided most of the mass that made the tree grow so large?

A. I think most of it came from nutrients in the soil that are taken up by the plant’s roots.
B. I think most of it came from the Sun’s energy.
C. I think most of it came from molecules in the air that came in through holes in the plant’s leaves.
D. I think most of it came from water taken up by the plant’s roots.
Put a letter “H” for “Helpful” next to the boxes that contain core idea elements that you think would be useful to help students answer the question about the seed and the log.
Plants acquire their material for growth chiefly from air and water. LS1.C-E2

The energy released [from] food was once energy from the Sun that was captured by plants in the chemical process that forms plant matter (from air and water). PS3.D-E2

Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases and water from the environment and release waste matter (gas, liquid, or solid) back into the environment. LS2.B-E1

Food provides animals with the materials they need for body repair and growth and the energy they need to maintain body warmth and for motion. LS1.C-E1

The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plant parts and animals) and therefore operate as “decomposers.” Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem. LS2.A-E1

Plants depend on water and light to grow. LS2.A-P1

All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow. LS1.C-P1

Plants acquire their material for growth chiefly from air and water. LS1.C-E2

Also on 4.3

The energy released [from] food was once energy from the Sun that was captured by plants in the chemical process that forms plant matter (from air and water). PS3.D-E2

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What So College Graduates Understand?

• While watching the film, think about what level of understanding did the students’ responses demonstrate.

Special thanks to the Science Media Group at the Harvard Smithsonian Center for Astrophysics
What So Elementary Students Understand?

Put a “G” (for “Graduate”) next to the boxes that contain core idea elements that there was evidence that the college graduates had some understanding of the ideas.
From light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.

Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. LS2.B-H1

The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. PS3.D-H2

The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. LS1.C-H1

As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. LS1.C-H4

The sugar molecules thus formed contain carbon, hydrogen, and oxygen; their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. LS1.C-H2

Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. PS3.D-M2

Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. LS1.C-M2

Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. LS2.B-H2

As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. LS1.C-H3

Food webs are models that demonstrate how matter and energy are transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil of the physical environment. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. LS2.B-M1

Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. LS1.C-M1

%PDF-1.5 %BoundingBox [58 0 684 989]
Three Dimensional Standards

July 2011
“Figuring Out” vs. “Learning About”

• **Disciplinary core ideas** are important so that students are figuring out phenomena and not just learning about facts and details.

• **Science and engineering practices** build explanatory ideas.

• **Crosscutting concepts** are used by students to organize and connect thinking.
“To develop a thorough understanding of scientific explanations of the world, students need sustained opportunities to work with and develop the underlying ideas and to appreciate those ideas’ interconnections over a period of years rather than weeks or months. This sense of development has been conceptualized in the idea of learning progressions. If mastery of a core idea in a science discipline is the ultimate educational destination, then well-designed learning progressions provide a map of the routes that can be taken to reach that destination.”

-pg. 26 of the Framework
How to Read a Map
Maps organize all of the elements from standards on a particular topic (e.g. Models, Patterns, or Definitions of Energy) on a single page. The elements from grades K-2 are at the bottom of the page and elements from grades 9-12 are at the top.
Arrows connect elements to indicate how competency in one element can be useful in learning another. Thus, the map is a useful tool to help educators think about what each element means and how elements build on one another over time in order to plan curriculum, instruction, and assessment. This Map Key provides further details about all of the features on a map.
Title
The name of the map (topic) that is featured at the top of the page.
Map Key

Topic Code
One (or more) codes in parentheses next to the title that identifies the topic of the map. For example, the Topic ID for Developing and Using Models is “MOD”. For the Disciplinary Core Ideas, the Topic ID is the identifier for the component ideas (e.g. PS1.A, LS1.C & LS2.B, and ESS2.C).
### Science and Engineering Practices

**AQDP:** Asking Questions and Defining Problems  
**MOD:** Developing and Using Models  
**INV:** Planning and Carrying Out Investigations  
**DATA:** Analyzing and Interpreting Data  
**MATH:** Using Mathematics and Computational Thinking  
**CEDS:** Constructing Explanations and Designing Solutions  
**ARG:** Engaging in Argument From Evidence  
**INFO:** Obtaining, Evaluating, and Communicating Information  

### Crosscutting Concepts

**PAT:** Patterns  
**CE:** Cause and Effect: Mechanism and Explanation  
**SPQ:** Scale, Proportion, and Quantity  
**SYS:** Systems and System Models  
**EM:** Energy and Matter: Flows, Cycles, and Conservation  
**SF:** Structure and Function  
**SC:** Stability and Change  

### Disciplinary Core Ideas in Physical Science

**PS1:** Matter and Its Interactions  
**PS1.A:** Structure and Properties of Matter  
**PS1.B:** Chemical Reactions  
**PS1.C:** Nuclear Processes  
**PS2:** Motion and Stability: Forces and Interactions  
**PS2.A:** Forces and Motion  
**PS2.B:** Types of Interactions  
**PS2.C:** Stability and Instability in Physical Systems  
**PS3:** Energy  
**PS3.A:** Definitions of Energy  
**PS3.B:** Conservation of Energy and Energy Transfer  
**PS3.C:** Relationship Between Energy and Forces  
**PS3.D:** Energy in Chemical Processes and Everyday Life  
**PS4:** Waves and Their Applications in Technologies for Information Transfer  
**PS4.A:** Wave Properties  
**PS4.B:** Electromagnetic Radiation  
**PS4.C:** Information Technologies and Instrumentation  

### Disciplinary Core Ideas in Life Science

**LS1:** From Molecules to Organisms: Structures and Processes  
**LS1.A:** Structure and Function  
**LS1.B:** Growth and Development of Organisms  
**LS1.C:** Organization for Matter and Energy Flow in Organisms  
**LS1.D:** Information Processing  
**LS2:** Ecosystems: Interactions, Energy, and Dynamics  
**LS2.A:** Interdependent Relationships in Ecosystems  
**LS2.B:** Cycles of Matter and Energy Transfer in Ecosystems  
**LS2.C:** Ecosystem Dynamics, Functioning, and Resilience  
**LS2.D:** Social Interactions and Group Behavior  
**LS3:** Heredity: Inheritance and Variation of Traits  
**LS3.A:** Inheritance of Traits  
**LS3.B:** Variation of Traits  
**LS4:** Biological Evolution: Unity and Diversity  
**LS4.A:** Evidence of Common Ancestry and Diversity  
**LS4.B:** Natural Selection  
**LS4.C:** Adaptation  
**LS4.D:** Biodiversity and Humans  

### Disciplinary Core Ideas in Earth and Space Science

**ESS1:** Earth’s Place in the Universe  
**ESS1.A:** The Universe and Its Stars  
**ESS1.B:** Earth and the Solar System  
**ESS1.C:** The History of Planet Earth  
**ESS2:** Earth’s Systems  
**ESS2.A:** Earth Materials and Systems  
**ESS2.B:** Plate Tectonics and Large-Scale System Interactions  
**ESS2.C:** The Roles of Water in Earth’s Surface Processes  
**ESS2.D:** Weather and Climate  
**ESS2.E:** Biogeology  
**ESS3:** Earth and Human Activity  
**ESS3.A:** Natural Resources  
**ESS3.B:** Natural Hazards  
**ESS3.C:** Human Impacts on Earth Systems  
**ESS3.D:** Global Climate Change  

### Disciplinary Core Ideas in Engineering, Technology, and Applications of Science

**ETS1:** Engineering Design  
**ETS1.A:** Defining and Delimiting Engineering Problems  
**ETS1.B:** Developing Possible Solutions  
**ETS1.C:** Optimizing the Design Solution  

### Connections to Nature of Science

**VOM:** Scientific Investigations Use a Variety of Methods  
**BEE:** Science Knowledge Is Based on Empirical Evidence  
**OTR:** Scientific Knowledge Is Open to Revision in Light of New Evidence  
**ENP:** Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena  
**WOK:** Science Is a Way of Knowing  
**AOC:** Scientific Knowledge Assumes an Order and Consistency in Natural Systems  
**HE:** Science Is a Human Endeavor  
**AQAW:** Science Addresses Questions About the Natural and Material World  

### Connections to Engineering, Technology, and Applications of Science

**INFLU:** Influence of Science, Engineering, and Technology on Society and the Natural World  
**INTER:** Independence of Science, Engineering, and Technology
Map Key

Map Code:
A unique identifier for the map that appears in the top right hand corner of the map. The number before the period identifies which chapter the map comes from and the number after the period identifies which map it is in that chapter.
Map Key

Element Box

A rectangle on a map that contains the text of one of the bulleted statements (called “elements”) from the foundation boxes and the NGSS appendices.
Students who demonstrate understanding can:

**K-PS3-1. Make observations to determine the effect of sunlight on Earth’s surface.**

*Clarification Statement: Examples of Earth’s surface could include sand, soil, rocks, and water.*

*Assessment Boundary: Assessment of temperature is limited to relative measures such as warmer/cooler.*

<table>
<thead>
<tr>
<th>Science and Engineering Practices</th>
<th>Disciplinary Core Ideas</th>
<th>Crosscutting Concepts</th>
</tr>
</thead>
</table>
| Planning and Carrying Out Investigations | **PS3.B: Conservation of Energy and Energy Transfer**  
- Sunlight warms Earth’s surface. (K-PS3-1) | **Cause and Effect**  
- Events have causes that generate observable patterns. (K-PS3-1) |
| Connections to Nature of Science | Scientific Investigations Use a Variety of Methods  
- Scientists use different ways to study the world. (K-PS3-1). | }
Map Key

Element Box
The color of a box indicates what type of element it is.

Science and Engineering Practices
Crosscutting Concepts
Disciplinary Core Ideas
Connections to Nature of Science
Connections to Engineering
Performance Expectations
Map Key

Element Code
A unique identifier for an element. The first part of the code (before the dash) is the Topic Code. After the dash, there is a letter and a number. The letter indicates the elements grade level:
- P for Primary (Grades K-2)
- E for Elementary (3-5)
- M for Middle School (6-8)
- H for High School (9-12)
Element Codes

- **Element Codes**

  **Topic Code**

  **Grade Band**
  - P = Primary (K–2)
  - E = Elementary (3–5)
  - M = Middle School (6–8)
  - H = High School (9–12)

  **Element Number**
  Indicates whether it is the 1st, 2nd, 3rd, etc. element for the topic in that grade band

- Example: PS1.A-M1
Map Key

Arrow

A connection between two element boxes indicates that competency in one element is useful in learning to achieve the other element. Arrows always point at least somewhat upwards.
An arrow from Box A to Box B means that competency with what is described in Box A can be helpful in students’ progression to competency with what is described in Box B.
What Does an Arrow Mean?

There are many possible meanings for such a connection, more than can be easily categorized. However, here are several examples of what an arrow from A to B (A → B) could imply:

• A is an essential prerequisite to B
• A defines a term or concept that is useful in learning B
• B is a more complex version of A
• B encompasses A along with an additional expectation
• Being able to do A is useful in learning to do B
• Doing A helps to understand B
• B is a generalization and A is a specific example of that generalization
• A is a generalization and B is an exception or special case of that generalization
Studying an Arrow

Pick one arrow from map 4.2 Flow of Matter and Energy in Living Systems discuss what you think the relationship is between the two elements that it connects.
Map Key

Strand
A chain of connected elements that run up the map and share a theme or involve the development of the same idea. The simplest strands are aligned in a vertical column connected by arrows, but sometimes a strand may fork and/or converge if it doesn’t make sense to stack the elements in one straight line.
Grade Bands

The map is broken up into four grade bands. Grades K-2 (primary) is at the bottom of the map with grades 3-5 (elementary), grades 6-8 (middle school), and grades 9-12 (high school) stacked up in order. How high or low an element appears within a grade band is not an indicator of what grade it belongs in or whether learning it should proceed or follow other ideas in that grade band.
Map Key

Also On Connection

This phrase followed by one or more map codes indicates that the connected element boxes also appears on those other maps.
### Off-Map Element

An element code in a very small box on the map. It represents an element that can be found on other maps that is somewhat relevant to the topic of the map, but not so much so that the element needs to be on the map. Due to design constraints, an Off-Map Element may appear more than once on a map and some connections to it may not be shown. The full text of can be found on the page opposite the map.
**Map Key**

**Element Code**

The number that appears after the letter indicates the bullet position of the element in that particular grade level (1st, 2nd, 3rd, etc.). The code for an element appears in every box after the text for that element.

---

**PS1.A-M1**

**Element Number**

Whether it the 1st, 2nd, 3rd, etc. element for the topic in that grade span
Map Key

Note for Chapter 9

This chapter contains maps of Performance Expectations (PEs). The boxes in these maps contain PEs instead of elements and use the PE code instead of an element code. In addition, these maps do not have a Topic ID.
Chapter 4 • Disciplinary Core Ideas—Life Science

4.2: Flow of Matter and Energy in Living Systems
LS1: From Molecules to Organisms: Structures and Processes
LS2: Ecosystems: Interactions, Energy, and Dynamics

How do organisms obtain and use the matter and energy they need to live and grow?

LS1.C: All living things require a source of ready-to-use energy to carry out their needs. The source of energy also determines the type of organism. Carbon-based life depends on organisms that can use the energy from the sun. Other organisms can use the energy in the chemical bonds of organic molecules.

LS2.A: Cycles of Matter and Energy Transfer in Ecosystems
How do matter and energy move through ecosystems?

The cycling of matter and the flow of energy in ecosystems occur through interactions among different organisms and their physical environment. All living systems need matter and energy to survive and grow. Energy comes from the sun, and matter comes from the food they eat. Through photosynthesis, the sun's energy is captured and stored in plant cells. Animals obtain energy from plants by eating them. Energy is transferred from one trophic level to the next in a food chain. As matter transverses through the various levels of the pyramid, energy is lost to the environment.

LS2.B: Interactions among Organisms
How do interactions among organisms influence the transfer of energy and matter in ecosystems?

Interactions among organisms influence the distribution of matter and energy within ecosystems. Organisms interact with each other and their physical environment in many ways, including competition, predation, and cooperation. These interactions can affect the survival and distribution of species within an ecosystem. For example, the presence of a predator can influence the population size of prey species. In turn, the availability of prey can affect the population size of predators. These interactions can lead to changes in the structure and function of ecosystems over time.
Chapter 9 • Performance Expectations—Life Science

9.6: Matter and Energy in Organisms and Ecosystems

In fifth grade, the performance expectations in fifth grade tests students for multiple elements of the NGSS. These elements include understanding and explaining the structure of matter, the behavior of energy, and the interactions between the two. The performance expectations in fifth grade focus on the following:

1. Understanding the structure of matter and its role in the environment.
2. Understanding the behavior of energy and how it interacts with matter.
3. Understanding the interactions between structure and behavior of matter and energy.

These elements are integrated into the Performance Expectations and can be found in the map on page 9-6. The map is titled "Matter and Energy in Organisms and Ecosystems."
How the NSTA Atlas is Organized
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Chapter 7: Connections to Nature of Science
Chapter 8: Connections to Engineering, Technology, and Applications of Science
Chapter 9: Performance Expectations

Appendices
Appendices

A. List of All Elements
B. List of All Performance Expectations with their Clarification Statement and Assessment Boundaries
C. The Connections Box
D. Cross Reference between Performance Expectations and Disciplinary Core Idea Elements
E. Text of the Off-Map Elements for Selected Maps
Appendixes and Other Back Matter

APPENDIX C: THE CONNECTIONS BOX

On the standards page, these connection boxes are located below the foundation boxes. The information in these boxes has been used to develop the list below. The list is designed to support a coherent vision of the standards by showing how the disciplinary core ideas (DCIs) related to a performance expectation connect to other DCIs and how the performance expectations in science connect to the Common Core State Standards (CCSS). The connections are grouped into three sections:

Connections to other DCIs in this grade level

This section lists the DCIs that connect to a given performance expectation at the same grade level, but outside the present set of performance expectations. For example, physical science and life science performance expectations contain concepts related to photosynthesis, and could be taught in relation to one another. Ideas within the same main DCI as the performance expectation (e.g., PSL.C for HS-PS.C-1) are included in the connection box, but are ideas within the same topic arrangement as a performance expectation (e.g., HS-PS.II.2 for HS-PS.II).

Connections to other DCIs across grade levels

This column lists the DCIs that connect to the core ideas in a given performance expectation (usually at prior grade levels or at 1) build on the foundation provided by the core ideas in this performance expectation (usually at subsequent grade levels).

Connections to the CCSS

The final two columns list pre-requisite or connected CCSS in English language arts and mathematics that align to given performance expectations. For example, performance expectations that require student use of experimental notation will align with the corresponding CCSS for mathematics. An effort has been made to ensure that the mathematical skills that students need for science were taught in a previous year where possible. Some appearing in tables are not pre-requisite to the successful accomplishment of a given performance expectation but are otherwise connected to it.

—Adapted from “How to teach the next generation science standards” (pp. 1-47), NSTA (2016)

APPENDIX D: CROSS-REFERENCES BETWEEN PERFORMANCE EXPECTATIONS AND DISCIPLINARY CORE IDEA ELEMENTS

This list of disciplinary core idea (DCI) elements indicates which performance expectations (PEs) make use of the DCI element in question. If a PE is listed in blue, that means the DCI element is considered a primary element in the PE, which simply means that the DCI element is shown in bold with a different DCI than the PE. For example, the DCI element PSL.A-HS.3 is a secondary element in the PI HS-PS.6-8 because the DCI element is considered part of PSL. Matter and its interactions but the PE is contained as part of PS2. Motion and stability: Forces and interactions. DCI elements that are secondary to a particular PE are just as important as any other DCI elements of the PE.

—Adapted from “How to teach the next generation science standards” (pp. 48-109), NSTA (2016)
Excerpts of the Framework in the Atlas
PS1 and PS1.A from the Framework
PS1 and PS1.A in the Atlas (pgs. 36-39)
Dimension 3

DISCIPLINARY CORE IDEAS—PHYSICAL SCIENCES

Most systems or processes depend at some level on physical and chemical subprocesses that occur within it, whether the system in question is a star, Earth’s atmosphere, a river, a bicycle, the human brain, or a living cell. Large-scale systems often have emergent properties that cannot be explained on the basis of atomic-scale processes; nevertheless, to understand the physical and chemical basis of a system, one must ultimately consider the structure of matter at the atomic and subatomic scales to discover how it influences the system’s larger scale structures, properties, and functions. Similarly, understanding a process at any scale requires awareness of the interactions occurring—be it the flow between objects, the related energy transfers, and their consequences. In this way, the physical sciences—physics and chemistry—underlie all natural and human-created phenomena, although other kinds of information transfers, such as those facilitated by the genetic code or communicated between organisms, may also be critical to understanding their behavior. An overarching goal for learning in the physical sciences, therefore, is to help students see that there are mechanisms of cause and effect in all systems and processes that can be understood through a common set of physical and chemical principles.

The committee developed four core ideas in the physical sciences—three of which parallel those identified in previous documents, including the National Science Education Standards and Benchmarks for Science Literacy [1, 2]. The three core ideas are PS1: Matter and Its Interactions, PS2: Motion and Stability: Forces and Interactions, and PS3: Energy.

(from A Framework for K-12 Science Education, p. 103)
Description of Core Idea PS1

**Core Idea PS1**

**Matter and its interactions**

(How can one explain the structure, properties, and interactions of matter?)

The existence of atoms, now supported by evidence from modern instruments, was first postulated as a model that could explain both qualitative and quantitative observations about matter (e.g., Brownian motion, rates of reactions and products in chemical reactions). Matter can be understood in terms of the types of atoms present and the interactions both between and within them. The states of solid, liquid, gas, or plasma, properties (e.g., hardness, conductivity), and reactions (both physical and the interactions of matter) can be described and predicted based on the types, interactions, and motions of the atoms within it. Chemical reactions, which underlie so many observed phenomena in living and nonliving systems alike, conserve the number of atoms of each type but change their arrangement into molecules. Nuclear reactions involve changes in the types of atomic nuclei present and are key to the energy release from the sun and the fusion of isotopes in matter.

**PS1A: Structure and Properties of Matter**

How do particles combine to form the variety of matter one observes?

While too small to be seen with visible light, atoms have substructures of their own. They have a small central region or nucleus—containing protons and neutrons—surrounded by a larger region containing electrons. The number of protons in the atomic nucleus (atomic number) is the defining characteristic of each element; different isotopes of the same element differ in the number of neutrons only. Despite the immense variation and number of substances, there are only some 100 different stable elements.

Each element has characteristic chemical properties. The periodic table, a systematic representation of known elements, is organized horizontally by increasing atomic number and vertically by families of elements with related chemical properties. The development of the periodic table (which occurred well before atomic structure was understood) was a major advance, as its patterns suggested and led to the identification of additional elements with particular properties. Moreover, the table’s patterns are now recognized as related to the atom’s outermost electron patterns, which play an important role in explaining chemical reactivity and bond formation, and the periodic table continues to be a useful way to organize this information.

**Disciplinary Core Ideas**

**Physical Science**

**Core Idea PS1: Matter and Its Interactions**

*How can one explain the structure, properties, and interactions of matter?*

The existence of atoms, now supported by evidence from modern instruments, was first postulated as a model that could explain both qualitative and quantitative observations about matter (e.g., Brownian motion, rates of reactions and products in chemical reactions). Matter can be understood in terms of the types of atoms present and the interactions both between and within them. The states of solid, liquid, gas, or plasma, properties (e.g., hardness, conductivity), and reactions (both physical and the interactions of matter) can be described and predicted based on the types, interactions, and motions of the atoms within it. Chemical reactions, which underlie so many observed phenomena in living and nonliving systems alike, conserve the number of atoms of each type but change their arrangement into molecules. Nuclear reactions involve changes in the types of atomic nuclei present and are key to the energy release from the sun and the fusion of isotopes in matter.

**Core Idea PS2: Motion and Stability: Forces and Interactions**

*How can one explain and predict interactions between objects and within systems of objects?*

Interactions between two objects can cause changes in one or both of them. An understood set of forces between objects is important for describing how the interactions change, as well as for predicting stability or instability in systems. Nuclei are subject to forces between unlike charges from a new type of interaction: gravity, electromagnetism, and the strong and weak nuclear interactions.

**Core Idea PS3: Energy**

*How is energy transferred and conserved?*

Interactions of objects can be explained, and predicted using the concept of the transfer of energy from one object to another, leading to the idea that energy can be transferred in a variety of ways. An understanding of the transfer of energy from one object to another can also help in understanding the transfer of energy into or out of the system.

**Core Idea PS4: Waves and Their Applications in Technologies for Information Transfer**

*How are waves used to transfer energy and information?*

Waves are a repeating motion of energy that transfers energy from one place to another without movement of matter itself and sound are waves. Observations and models of sound waves can explain phenomena such as undershoot and overshoot, and the interactions of electromagnetic radiation with matter. Scientific and engineers can design systems for transferring information across long distances, storing information, and investigating events in real-time, without them being limited by human perception.

**CHAPTER 3**

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Structure and Properties of Matter

**3.2 • PSL.B & PSL.C • p. 40**

Chemical Reactions and Nuclear Processes

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Forces and Motion

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Types of Interactions

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Definitions of Energy

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Conservation of Energy and Energy Transfer

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Energy in Chemical Processes and Everyday Life

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Wave Properties

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Electromagnetic Radiation and Information Technologies

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A Framework for K-12 Science Education

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Core Idea PS1: Matter and its Interactions

How can you explain the structure, properties, and interactions of matter?

The existence of atoms, now supported by evidence from modern instruments, was first postulated as a model that could explain both qualitative and quantitative observations about matter (e.g., Brownian motion, rates of reactions and products in chemical reactions). Matter can be understood in terms of the types of atoms present and the interactions between and within them. The states (solid, liquid, gas, or plasma) properties (e.g., hardness, conductivity, and heat capacity) of both physical and chemical properties of matter can be described and predicted based on the types, interactions, and motions of the atoms within it. Chemical reactions, which undergo so many observed phenomena in living and nonliving systems alike, conserve the number of atoms of each type but change their arrangement into molecules. Nuclear reactions involve changes in the types of atomic nuclei present and are key to the energy release from the sun and the formation of isotopes in nature.


How do particles combine to form the variety of matter one observes?

While too small to be seen with visible light, atoms have substructures of their own. They have a central region or nucleus—containing protons and neutrons—surrounded by a larger region containing electrons. The number of protons in the atomic nucleus (atomic number) is the defining characteristic of each element and differs in the number of neutrons only. Despite the immense variation and number of substances, there are only 100 different stable elements.

Each element has characteristic chemical properties. The periodic table, a systematic representation of known elements, is organized horizontally by increasing atomic number and vertically by families of elements with similar chemical properties. The development of the periodic table helped astronomers understand the elements of the universe. Over time, new elements are identified, and the table is continually updated to include new elements.

The substructure of atoms determines how they can combine and exchange forms of energy to form all of the world's substances. Electrical attractions and repulsions between charged particles (e.g., atomic nuclei and electrons) in matter explain the structure of atoms and the forces between atoms that cause them to form molecules (the chemical bonds), which in turn form the thousands of substances (e.g., biological molecules, rocks, metals, plastics) that are part of our world. The properties of matter (e.g., mass, hardness, conductivity, and heat capacity) are determined by the structure of matter and the interactions between its component parts.

The periodic table of the elements is a valuable tool for organizing and understanding the vast array of substances in our world. It helps scientists predict the properties of new elements and understand the behavior of known substances. The periodic table is a fundamental concept in chemistry and physics, and it is used in many fields, including materials science, medicine, and engineering.
Description of Component Idea PS1.A

Chapter 3 • Disciplinary Core Ideas—Physical Science

3.1: Structure and Properties of Matter

PS1-A: Structure and Properties of Matter

How do particles combine to form the variety of matter we observe?

While there is a consensus on the nature of light, atoms have subatomic particles of their own. There are subatomic particles in everything—solids, liquids, and gases. One of those subatomic particles is the electron. Each electron has a specific charge, which is different from the charge of all other subatomic particles. The arrangement and motion of subatomic particles determine the properties of matter.

The arrangement of subatomic particles in a material determines its properties. For example, the arrangement of subatomic particles in a crystal determines its hardness. The arrangement of subatomic particles in a gas determines its density.

Matter can be characterized by its measurable properties. Different materials with different properties are suited to different uses. The ability to image and manipulate individual atoms in tiny structures allows for the design of new types of materials with particular desired functionality (e.g., supercapacitors, transistors).

Materials can be characterized by their intensive measurable properties. Different materials with different properties are suited to different uses. The ability to image and manipulate individual atoms in tiny structures allows for the design of new types of materials with particular desired functionality (e.g., supercapacitors, transistors)."
Grade Band Endpoints for PS1.A

By the end of grade 2, different kinds of matter exist (e.g., wood, metal, water), and many of them can be either solid or liquid, depending on temperature. Matter can be described and classified by its observable properties (e.g., visual, aural, textural), by its uses, and by whether it occurs naturally or is manufactured. Different properties are suited to different purposes. A great variety of objects can be built up from a small set of pieces (e.g., blocks, construction sets). Objects or samples of a substance can be weighed, and their size can be described and measured. (Boundary: volume is introduced only for liquid measure.)

By the end of grade 5, matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means (e.g., by weighing or by its effects on other objects). For example, a model showing that gases are made from matter: particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon; the effects of air on larger particles or objects (e.g., leaves in wind, dust suspended in air); and the appearance of visible scale water droplets in condensation fog, and, by extension, also in clouds or the contrails of a jet. The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish (e.g., sugar in solution, evaporation in a cloud container). Measurements of a variety of properties (e.g., hardness, reflectivity) can be used to identify particular materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.)

By the end of grade 8, all substances are made from some 100 different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Pure substances are made from a single type of atom or molecule; each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with each other; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and vibrate in position but do not
change relative locations. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (Boundary: Predictions here are qualitative, not quantitative.)

By the end of grade 12. Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. 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. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.
PS1 and PS1.A from the Framework
How to Use the NSTA Atlas
How to Use the NSTA Atlas

Introduction

are nearly identical to the NGSS, whereas others have standards that are quite different. But all of these standards share at least some of the themes that are common across them. This book will help you understand these themes and how they can be applied in your classroom.

Another common feature is that some states added, deleted, or modified several of the DCI elements that are not present in the NSTA Atlas. These states included in their own way of depicting some of the themes that are common across them. This book will do its best to address these themes and how they can be applied in your classroom.

Some states have standards that include the NGSS model developed by the Framework. This book will help you understand how the standards are applied in your classroom.

Even educators in the few remaining states that have not adopted the NGSS must develop standards based on the Framework. This book will help you understand how the standards are applied in your classroom.

National Science Teaching Association

The NSTA Atlas of the Three Dimensions

National Science Teaching Association

Examples of Using the Maps

The rest of this section illustrates some ways in which teachers can use a map to enhance their teaching. For example, an educator reading the K-2 element ESS1.A.1 in Figure 13 might find it useful to review the relevant sections in the National Science Teachers Association’s (NSTA) Atlas. This book will help you understand how the standards are applied in your classroom.

Guiding Questions for Unpacking the Practices

- What do the maps in ESS1.A.1 entail?
- What are the key aspects of this practice?
- What are the steps involved in this practice?
- What are the steps involved in this practice?
- What are the steps involved in this practice?
- What are the steps involved in this practice?

Figure 13: Excerpt from Map 5.2

In addition, sometimes the map can help educators understand how the standards are applied in their classroom. For example, an educator reading the K-2 element ESS1.A.1 in Figure 13 might find it useful to review the relevant sections in the National Science Teachers Association’s (NSTA) Atlas. This book will help you understand how the standards are applied in your classroom.

National Science Teaching Association

The NSTA Atlas of the Three Dimensions

National Science Teaching Association

Guiding Questions for Unpacking the Concepts

- What are the key aspects of this concept?
- What are the key aspects of this concept?
- What are the key aspects of this concept?
- What are the key aspects of this concept?
- What are the key aspects of this concept?

Figure 14: Excerpt from Map 3.4

One possibility would be to take the idea in ESS1.A.2 that some organisms cannot survive in all of their habitats. How do you think this idea in ESS1.A.2 might be applied in your classroom? This book will help you understand how the standards are applied in your classroom.

National Science Teaching Association

The NSTA Atlas of the Three Dimensions

National Science Teaching Association
How to Use the Atlas

The maps and other features of the Atlas are a powerful tool for understanding the meaning of individual elements to:

• Develop curricula
• Plan and conduct professional learning
• Develop assessment
• Provide instruction

In addition, the Atlas is particularly useful for educators when they plan curriculum sequences.
Using Arrows to Think About Instruction

What has worked best for educators is to use the maps to stimulate thinking and discussion about the relationships between different ideas. Any instance of $A \rightarrow B$ can stimulate thinking and discussion about the following questions:

1. What do each of these elements mean?
2. How would students’ competency with element A be useful in learning element B?
3. How might students learning element B deepen their learning of element A?
4. How should the relationship between elements A and B affect the sequencing of instruction?
5. How should the answers to the above questions influence instructional decisions?

In addition, each of these questions could be considered reversing the arrow and trading A for B in the questions above.
Unpacking an Element (Introduction, pg xviii)

1. Scan the **strand** the element is in and see how the expectations for student learning progress from one grade band to the next.

2. Examine all of **the arrows** that connect the element to other elements on the map. Consider what the arrows indicate as a relationship between the elements.

3. Study any **off-map elements** that feed into or out of the element you are unpacking. You can find the full text of the off-map elements on the page facing a given map.

4. Read the **excerpts from the Framework** that appear on the facing page. The *Framework* excerpts in the chapter opener may also be helpful.

5. Look for an **Also on… Connection** to see if the element appears on other maps, and see what you can learn about the element by studying those maps.

6. Check the **index** to see if the element appears as an off-map element on any other maps and review those maps.

7. **Examine the PEs**, as well as their clarification statements and assessment boundaries, that make use of the element. This step is particularly important when unpacking DCIs. You can find the list of PEs in Appendix B, and you can use Appendix D to identify the PE(s) that go with a particular DCI element.
Unpacking NGSS

Identify Performance Expectations

Unpack Practices
- Describe the practice and its components
- Identify the requisite knowledge and skills
- Specify evidence of high level performance

Unpack DCIs
- Elaborate major ideas
- Define boundary conditions
- Describe prior knowledge
- Identify student challenges
- Brainstorm phenomena

Unpack CCCs
- Describe essential features
- Identify substantive intersections with science practices and disciplinary core ideas
Unpacking a Practice

1. Describe the practice and its components
   • What does it mean to “do” the practice?
   • What are the essential components of this practice?
   • What possible intersection might there be with other practices?

2. Identify the requisite knowledge and skills
   • What knowledge and skills do students need to use in order to show that they can perform the practice?

3. Specify evidence of high-level performance
   • What evidence would you expect to see for each component?
   • What are the different levels of performance for each component?
Unpacking a Crosscutting Concept

1. Describe essential features
   • What are the key aspects of this crosscutting concept?
   • What explanatory value does this crosscutting concept have?
   • How might a students’ understanding of this crosscutting concept grow over time?

2. Identify substantive intersections with science practices and disciplinary core ideas
   • Which practices provide unforced and meaningful connections with this crosscutting concept?
   • What are some concepts and/or contexts in life, earth, and physical science that would provide good opportunities for students to explore this crosscutting concept?
Unpacking Core Ideas (1 of 2)

1. Elaborate major ideas.
   • What is the intended meaning of the element of the core idea?
   • Is there one idea or are there several separate ones in the statement?
   • What terminology is explicitly used in the core idea?

2. Define boundary conditions.
   • What peripheral ideas or terms are not essential for understanding the core idea?

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Life Science
LS1: From Molecules to Organisms: Structures and Processes
LS2: Ecosystems: Interactions, Energy, and Dynamics
LS3: Heredity: Inheritance and Variation of Traits
LS4: Biological Evolution: Unity and Diversity

Physical Science
PS1: Matter and Its Interactions
PS2: Motion and Stability: Forces and Interactions
PS3: Energy
PS4: Waves and Their Applications in Technologies for Information Transfer

Earth & Space Science
ESS1: Earth’s Place in the Universe
ESS2: Earth’s Systems
ESS3: Earth and Human Activity

Engineering & Technology
ETS1: Engineering Design
3. Describe prior knowledge.
   • What other knowledge and skills (both from this topic and from other topics) do students need to achieve an understanding of this core idea?

4. Identify student challenges.
   • Are there any commonly held ideas that differ in important ways from the scientifically accepted understanding?
   • What methods can be used to determine students’ current understandings?
   • In what ways can instruction directly address or leverage students’ current understandings?

5. Brainstorm phenomena.
   • What phenomena would provide an example of this core idea?
Examples of Using the Maps
Example 1: Interpreting an Element

The orbits of Earth around the Sun and of the Moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the Sun, Moon, and stars at different times of the day, month, and year. ESS1.B-E1

Patterns of the motion of the Sun, Moon, and stars in the sky can be observed, described, and predicted. ESS1.A-P1
Example 2: Ideas about Instruction

For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all. LS4.C-E1

Some kinds of plants and animals that once lived on Earth are no longer found anywhere. LS4.A-E1

Fossils provide evidence about the types of organisms that lived long ago and also about the nature of their environments. LS4.A-E2
Example 3: Interdisciplinary Connections

Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. PS1.C-H2

Also on 3.2

The radioactive decay of unstable isotopes continually generates new energy within Earth’s crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. ESS2.B-H1

All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the Sun and Earth’s hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth’s materials and living organisms. ESS2.A-M1
The NSTA Atlas of the Three Dimensions

NSTA Engage
Wherever you are 😊
November 15, 2020
#3DAtlasChat

- A slow chat on twitter from November 15th to December 17th
- A different chapter of the Atlas every week
- A new question every weeknight
- Follow @NSTA_Atlas
- Follow #3DAtlasChat

- For more information: bit.ly/atlasFAQ
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