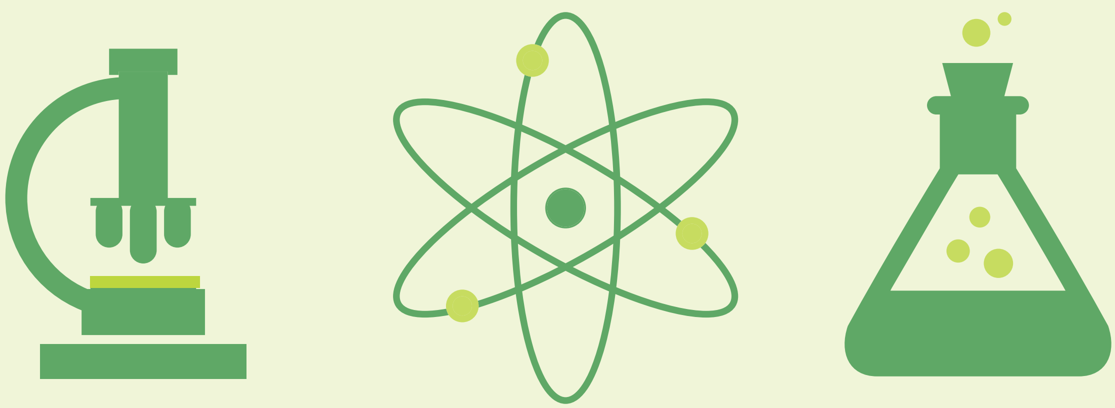
THE CUNY HSE CURRICULUM FRAMEWORK

SECTION 3

Science: Matter & Energy



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The CUNY HSE Curriculum Framework

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Science: Matter & Energy

Overview

CHALLENGES AND OPPORTUNITIES

There are a number of challenges for teachers of high school equivalency in teaching science. In many programs, teachers are responsible for all the basic subjects. This means that we all have to be generalists. Many of us don't have a science background to fall back on, and even if we do, we have limited time with students, so whatever we do has to serve more than one purpose. Other challenges include a general lack of resources for science education in adult classrooms. How many of us have microscopes, petri dishes, and sinks for clean up? There are many interesting demonstrations that can be done with household items, but logistics can be difficult when many HSE classes take place in borrowed classrooms, community centers, and church basements.

On the other hand, studying science with adults offers exciting opportunities for teachers who want to use students' own experiences to enrich the classroom. Students can use science literacy to make sense of pressures acting on their community, such as climate change, environmental health, nutrition, etc. Students have real world knowledge to use in their study of science. Starting with making observations, collecting data, and making conjectures, the class can be strengthened by the diversity of our students who are able to use knowledge from their lives. Science also offers unique opportunities for students to work together and develop teamwork since they will have to work in small groups to complete projects. A good science curriculum provides connections to math, reading, and writing, reinforcing achievement in all areas. The work students complete will help in their transition to college work in fields that require science. Recent achievements in technology provide amazing opportunities in the classroom, using smartphone apps, web-based simulations, interactive web sites, and instructional videos. The greatest benefit of studying science, though, is the opportunity to look at the world again and share "wonderful ideas" that allow students and teachers to explore together (Duckworth, 1996).

BUILDING CONTENT KNOWLEDGE

New versions of the HSE test place a greater emphasis on content knowledge in basic science concepts than previous versions of the GED. In order to do well, test-takers will have to use background knowledge in conjunction with strategic reading and test-taking skills. This science curriculum map is intended to help students develop foundational content knowledge in concepts in matter and energy that underlie all of the physical sciences.

Our intention with this curriculum is to help students learn basic science content knowledge while developing their reading, writing, and analytical skills. The curriculum is intended for use by teachers who don't have a background in science. We provide background information for each lesson and resources for more information. This curriculum may also be used as a separate introduction to science for students who are transitioning into college to study majors that require science: nursing, dental technician, engineering, radiology, etc.

Some of the big ideas we explore:

- How can science help explain recognizable phenomena in the world?
- How do we evaluate scientific responses to questions about the observable world? Examples include: What causes lightning? Why do helium balloons float? Where do the beads of water on the outside of a cold drink come from? Why is the ocean salty?
- What are our common misconceptions about how the world works and how can we straighten them out?

The subjects that make up and connect the daily lessons are rooted in essential questions. For example, students explore electric charge in an early lesson in order to understand a concept that is important in understanding atomic level interactions in chemistry, biological processes in the body, and large systems such as weather. In this curriculum, we try to link each lesson to previous lessons through embedded review, so that students build a network of ideas and knowledge. We also try to build in opportunities for students to reflect on how each lesson fits into previous understandings (or doesn't fit and requires a restructuring of understanding).

We believe that students learn best when they are active members in the classroom. As much as possible, we ask our students to observe, collect data and make conjectures before we deliver information. We believe that it is important to bring up misconceptions and create some controversy in the classroom, so that students see how new concepts don't always fit with the old. We try to leave room for classrooms to follow student inquiry about phenomena in the world. We are looking for depth rather than coverage, while teaching the high utility topics on the HSE science test.

STRUCTURE OF A SCIENCE LESSON PLAN

The general structure of our science lessons includes a review/quiz at the beginning of the lesson to give students an opportunity to reconnect to the content, check comprehension and cement their understanding. Most lessons start with a request for students to consider an observation of a particular natural phenomenon (water beading on a glass, a floating balloon, or a burning candle, for example), followed by an invitation to ask questions and make hypotheses about the scientific explanation of these events. We then explore the underlying science framed by student questions: Why does lightning happen? Where does the sound of thunder come from? What is the speed of lighting? How do we know lightning is five times hotter than sun? How do we know the temperature of the sun? Of course, we can't always answer students' questions, but we can point directions towards explanations, make suggestions for further learning through readings and videos and encourage their curiosity, since this engagement is what will help students get excited about learning science. We use students' curiosity to understand basic science concepts: scale of the universe, electric charge, chemical bonding, etc. Each lesson also highlights some of the important vocabulary for these essential ideas. For example, in the lesson on States of Matter, we focus on the words *evaporation, vaporization, sublimation,* and *condensation*, connecting them to the words students already know: *boiling, freezing, and melting*. Each lesson ends with a summary written by students, reinforcing their learning of the content.

OUR LEARNING OBJECTIVES FOR OUR STUDENTS

In completing this unit, it is our hope that students will:

- Gain a solid understanding of matter, energy, and their interactions.
- Understand the cycles of matter and energy through our world.
- Become familiar with some big ideas in science.
- Develop facility with basic scientific practices: making observations, collecting, and comparing data, and making and testing hypotheses.
- Overcome fear of studying science.
- Improve ability to read, annotate, and understand science texts.
- Develop basic understandings in physical science that will prepare for further study in STEM-related fields.

The Structure of the Science Curriculum Framework

This Curriculum consists of the Overview, followed by five main sections: the Curriculum Map; Unit Descriptions; Lesson Plans for three units; Math/Science Connections; and Resources for Teaching Science. Each Unit Description provides foundational learning needed for students to grasp subsequent science topics. Each of the three Lesson Plans includes a note to the teacher, lesson steps (often with sidebar commentary), in-class activities, readings, handouts, homework assignments, and Internet links to more information.

- **SCIENCE CURRICULUM MAP**
- **23 UNIT DESCRIPTIONS**
- **3 LESSON PLANS with instructor notes and handouts**
- **SCIENCE/MATH CONNECTIONS**
- **RESOURCES FOR HSE SCIENCE**

HSE Science Curriculum Map/ Unit Descriptions

1) Introduction to Studying Science*
2) Matter*
3) Scale & the Atomic Theory*
4) Change of State
5) Electric Charge
6) The Atom
7) Chemical Bonding
8) Chemical Reactions
9) Macromolecules
10) Conservation of Matter
11) Motion
12) Energy
13) Transformation of Energy
14) Photosynthesis and Cellular Respiration
15) Ecosystems
16) The Atmosphere
17) The Oceans
18) Planet Earth
19) The Cell
20) DNA
21) Heredity
22) Evolution
23) The Human Body

** The full lesson plan, with instructor notes and handouts, is included in the subsequent section.*

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1 | Introduction to Studying Science

Key Questions:

- Why is questioning important in studying science?
- How do observations of phenomena in the world relate to studying science?
- What is an interaction?
- What are some questions we have about phenomena in the world?
- What are our past experiences in learning science?
- What are our goals for learning science?

These areas of concentration focus on a central theme of matter and how it interacts with other matter and with energy to explain what happens around us every day. Understanding matter is the basis for all sciences, and if students don't have this background, they are limited in what they can understand in biology, earth sciences, and space sciences. For example, a thorough understanding of photosynthesis is dependent on students' understanding atoms, molecules, elements, chemical formulas, and chemical reactions.

This first lesson focuses on interaction, which is the most accessible concept for students out of matter, energy, and interactions. They see that they can predict the outcome of many interactions in the world because of their past observations.

Students see that they can (and should) apply their own observations to what we discuss in class. It's also meant to connect the often abstract study of science with concrete, recognizable phenomena relevant to students' lives. All of science is built on observing things happening in the world, and asking questions about how or why those things happened the way that they did. Students should also begin the study of science with confidence that they already understand a few things and can predict based on past experience and prior knowledge.

The lesson is intended to set up future lessons on matter and energy.

2 | Matter

Key Questions:

- What is matter?
- What is mass?
- What is volume?
- How are mass and volume different?
- What is a particle and how is it related to matter?
- What are the phases of matter?

This sequence of science lessons focuses on matter and energy. We'll trace matter from atoms to molecules to cells to the human body. Along the way, we'll look at how plants capture and store the energy of the sun in the bonds of matter, and how animals like us release and use that energy from the bonds of matter. We'll also learn how matter codes information in the form of DNA. Before we do any of that, we need to understand what matter is—and what matter isn't.

The core concepts of this lesson are about identifying matter. Students should come away understanding that matter has mass and volume. They should also come away understanding what mass is and what volume is, and how they are different. Next, they should understand that matter is made up of very tiny particles. The next few lessons will focus on understanding the nature of these particles and how these particles behave. The nature and behavior of the particles will explain many "macro" phenomena such as melting, floating, density, rusting, bonding, etc.

Math connections: Measurement, unit conversions, calculating volume

The lesson is essential background knowledge for future lessons on:

- Heat & matter
- The atom
- Chemical bonding
- And many others

3 | Scale & the Atomic Theory

Key Questions:

- **What is the scale of things in the universe?**
- **How big is an atom?**
- **How big is a cell?**
- **What is atomic theory?**

This lesson focuses on volume (size) and introduces the huge scope of the size of matter. In looking at matter, we could be talking about the size of an atom, a cell, a human, an ocean, the atmosphere, the Earth, or the solar system. A key point here is to distinguish between the size of an atom and a cell. Both are microscopic, so many students think of them as being about the same size. But the size difference is enormous—in fact, there are about the same number of atoms in one cell as there are cells in the human body!

These units on matter start at a human scale and go down to the size of atoms in order to understand the nature of matter. Key to this understanding is the atomic theory, which states, "Everything is made up of atoms." The atomic theory is the foundation for biology, chemistry, physics, earth science, and astronomy. Without a clear understanding of this idea, students can't come to learn photosynthesis, genes and inheritance, climate, or pollution in an in-depth way.

The final message of this lesson is that the structure and behavior of these atoms (on the micro level) explains a lot of the visible (macro) phenomena in the world.

The lesson is essential background knowledge for future lessons on:

- Heat and matter
- The atom
- Photosynthesis
- Genes and inheritance
- Climate
- And many others

4 | Change of State

Key Questions:

- **What is heat? (Is it matter?)**
- **What does heat do to particles?**
- **What are the different phases of matter?**
- **How and why does matter change from phase to phase?**
- **What is the relationship between heat and motion?**

This lesson begins by reviewing what matter is. This is a good time to challenge students to recall what the previous lesson was about, and to review and check for misunderstandings.

The previous lesson stated that the behavior of particles explain many important phenomena. This lesson examines one very important aspect of the behavior of particles: What effect does heat have on particles? The central concept of this lesson is that heat, which is a form of energy, makes particles move. Lots of heat makes particles move quickly and expand. Removing heat makes particles slow down. The particles never stop moving entirely, but at a cold temperature they might just vibrate in place. This is not the only time we'll connect energy and motion in this lesson set.

The impact of heat on matter explains how and why there are different phases of matter: solid, liquid, gas, and plasma. This lesson reviews the important vocabulary of changing phases of matter, such as condensation. This lesson is essential material in order to understand the water cycle in ecosystems.

Math connections: Reading a thermometer, conversion between Fahrenheit and Celsius

The lesson is essential background knowledge for future lessons on:

- The conservation of matter (the water cycle)
- Ecosystems
- The atmosphere and the greenhouse effect
- The oceans
- Climate change

5 | Electric Charge

Key Questions:

- **What is a physical property?**
- **What is electric charge?**
- **What are the types of electric charge?**
- **What does electric charge do to particles?**

We start to look closely at the particles that make up matter in this lesson. We've learned already about how heat impacts them. Now, we look at what other properties they have. This lesson introduces the concept of physical properties. Then, we look at a very important and unusual property: electric charge. Electric charge is essential for understanding the behavior of particles, the structure of the atom, and chemical bonding. (It's also a foundational concept for many science concepts that we won't have time to review in this lesson set: electricity, batteries, magnetism, solubility, hydrogen bonding, how neurons work, and how the heart beats.)

The takeaway of this lesson is that there are two varieties of charged particles, positive and negative, that exert forces on each other. Like particles repel each other and opposites attract. There is also a neutral particle. These three particles make up all of matter. Learning about these three charged particles prepares students to learn about the structure of the atom in the next lesson.

Math connection: Addition/subtraction of signed numbers

The lesson is essential background knowledge for future lessons on:

- The atom
- Chemical bonding & molecules
- Chemical reactions
- The cell

To see the classroom video, **Electric Charge: How Does Lightning Form?,** visit the CUNY HSE Curriculum Framework web site at http://literacy.cuny.edu/hseframework.

6 | The Atom

Key Questions:

- **What is matter made up of?**
- **What is the atomic theory?**
- **What are atoms?**
- **How does electric charge relate to atoms?**
- **What is an element?**
- **Elements and atoms sound like the same thing to me. What's the difference?**
- **How many elements are there?**
- **What are all these numbers on the periodic table?**

As Richard Feynman said, if there is one piece of essential science knowledge, it is that everything is made up of atoms. The atomic theory might be the single most important concept for students to walk away from the class with. First, there is the idea that all of matter can be built out of these very tiny building blocks. Next, students should learn that an atom has a nucleus, and is made up out of three particles: protons, neutrons, and electrons. The attraction between the charged particles holds the atom together.

Elements are specific types of atoms, determined by the number of protons. The number of protons determines what element an atom is. If you change the number of protons, you change the identity. In contrast, if you change the number of neutrons or electrons, you don't change the identity, but you change some of the properties of that atom. The elements are listed on the periodic table. Students should learn how to read and interpret atomic mass and atomic number on the periodic table. To simplify it, tell them that the identity of the element is listed on the periodic table three times: the name (hydrogen), the abbreviation (H), and the atomic number (1). These three things all tell you the identity. The atomic mass will tell you the number of neutrons, if you subtract the number of protons from it.

Math connections: Rounding numbers, solving for x (finding missing value)

The lesson is essential background knowledge for future lessons on:

- Chemical bonding
- Chemical reactions
- Matter is conserved
- Photosynthesis and cellular respiration
- The atmosphere
- Planet Earth

7 | Chemical Bonding

Key Questions:

- **If atoms are so tiny, but they make up everything in the world, how do they link together to make larger things?**
- **What is a chemical bond?**
- **What is a molecule?**

Atoms form molecules by bonding to each other. Bonding is all about electrons. The basic model of an atom allows space for two electrons in the first electron shell, and eight electrons in the second electron shell. Atoms really want to have full electron shells, and this drives bonding. For example, hydrogen has only one electron, but it has two electron "seats" in its electron shell. So it will form a bond as soon as possible in order to fill that empty seat. The number of empty electron "seats" an atom has is the number of bonds that is can make. Oxygen has six electrons in its second electron shell, and since this second shell can accommodate eight electrons, this means that an oxygen atom has two empty seats. So an atom of oxygen can form two bonds with those two empty seats.

When two hydrogen atoms bond, the electron of the first atom half-occupies both its original seat and the empty seat on the other hydrogen atom. The electron on the second atom does the same—it half-occupies both its original seat and the empty seat in the other atom. What's really driving this is an attraction between the electron of one atom to the positively-charged nucleus of the other hydrogen atom.

There is some terminology to introduce related to bonding. Once two or more atoms bond, the total thing is now called a molecule. So anytime someone says "molecule," you know that more than one atom and a chemical bond are involved. Another terminology distinction: a compound is a molecule that contains more than one type of element. H_2O is a compound because it contains both hydrogen and oxygen. But H_2 is not a compound, since it contains only one type of element.

This lesson ends by introducing molecular formulas. This is a tricky concept that rears itself again when teaching chemical reactions and photosynthesis. Right now, just introduce the "shorthand" way to write a molecule: H_2O, H_2, and how to notate TWO of these molecules: $2H_2O$, $2H_2$.

Math connection: Proportional reasoning

The lesson is essential background knowledge for future lessons on:

- Chemical reactions
- Matter is conserved
- The atmosphere
- Photosynthesis and cellular respiration
- Planet Earth

8 | Reactions

Key Questions:

- Why did the Hindenburg explode?
- What's a chemical reaction?
- What's a chemical equation?
- What is a balanced and unbalanced chemical equation?
- What can speed up a chemical reaction?
- What is the impact of heat on a chemical reaction?
- Some ice melted into water. Why isn't this a chemical reaction?

The main idea of this lesson is that chemical reactions are what allow tiny molecules like carbon dioxide and water to react to build larger and larger things, like sugar molecules, proteins, membranes, cells, plants and animals. This lesson prepares students to encounter reactions again later during lessons on photosynthesis and respiration. The most important thing to learn is that a chemical reaction means that molecular bonds were broken or formed. Therefore, something new was produced.

There are two other learning points here about chemical reactions. We represent a reaction with a chemical "equation," which has some similarities to mathematical equations. You have to determine whether a chemical equation is balanced or not by counting the number of each type of atoms on each side of the equation. They should be equal to each other. In other words, if 6 oxygen atoms go into a chemical reaction, you need to have 6 oxygen atoms come out the other side. Atoms do not disappear and they are not created, which we will come back to in a future lesson on the conservation of matter.

Finally, molecules must crash into each other with enough energy in order to react with each other. Return to the topic of heat, and how it makes small particles like atoms and molecules move faster. If they are moving faster, they are crashing into each other with more energy. Therefore, heat makes chemical reactions more likely. The Hindenburg is a good example of this. Without heat, hydrogen gas and oxygen gas do not react readily. But at high temperatures, they are crashing into each other with a lot of energy, which can cause reactions to take place.

Math connections: Equal sign, equations

The lesson is essential background knowledge for future lessons on:

- Matter is conserved
- Photosynthesis and cellular respiration
- The atmosphere
- Planet Earth

9 | Macromolecules

Key Questions:

- What are macromolecules?
- What are the four main kinds of macromolecules?
- What's the main role of carbohydrates?
- What do lipids/fats do?
- What do proteins do?
- What do nucleic acids do?

Chemical reactions produce molecules, and through many chemical reaction, the molecules can get bigger and bigger and bigger. There are four important macromolecules that make up human bodies. They are carbohydrates, lipids (fats), proteins, and nucleic acids. Students should be familiar with carbohydrates, fats, and proteins in terms of food content, and that's a good connection to make.

The main content of this lesson is these four macromolecules and what their roles are. All of these macromolecules do several things, but they all have one especially important role. Carbohydrates and lipids/fats provide energy. Carbohydrates can do other things in the body, such as labeling cells, and fats also do other things, like building the walls of cells. But the most important thing for students to understand is that we get our energy from carbohydrates and fats.

Proteins and nucleic acids are different. They do not provide energy stores. Proteins are the "doers" of the body. Proteins move around cells doing things such as breaking things down, building things up, moving, making repairs, sending messages, receiving messages, and a million other tasks. If the body is a city, proteins are the people.

Proteins also determine eyes color and hair texture. Certain proteins produce green eyes, and different proteins produce brown eyes. Certain proteins produce curly hair, and different proteins produce straight hair.

Nucleic acids store information. (They can do a few other things, too, but this is the most important association for students should have.) We will get into this in detail when discussing DNA. For now, students should be able to connect each macromolecule with its most important task.

Math connections: Reading labels of nutritional facts, percentages, proportional reasoning

The lesson is essential background knowledge for future lessons on:

- Matter is conserved
- Photosynthesis and cellular respiration
- The cell
- DNA
- Heredity

10 | Conservation of Matter

Key Questions:

- **Can I make an atom? Can I destroy an atom?**
- **So where do atoms come from?**
- **How old are the atoms in my body?**
- **How is matter conserved?**
- **What is the water cycle?**
- **Are there other cycles?**

This lesson introduces a few new ideas, but it also encompasses a review of many of the concepts previously covered in this lesson set. The fact that carbon atoms have been around for millions of years is bizarre but true, and it seems funny to me that science classes didn't make a bigger deal out of this idea that you could have a carbon atom in your hand that used to be part of a dinosaur, or Miles Davis, or the Titanic. This conservation of matter also sets up the idea of conservation, which will return in future lessons about energy. Both matter and energy are conserved.

This lesson also introduced the idea of cycles. Cycles of matter, energy, and information (in the form of DNA) are central to how our world operates. This is the first lesson that begins to broaden out to ecosystems.

The lesson is essential background knowledge for future lessons on:

- Photosynthesis and cellular respiration
- Energy being conserved
- Ecosystems

11 | Motion

Key Questions:

- **What is speed? What is velocity? What's the difference?**
- **What's acceleration?**
- **Who was Newton?**
- **What is Newton's first law of motion?**
- **What is Newton's second law of motion?**

The lessons up until this point have focused on matter—what it is, how it is structured, and important types of matter. Here, we look at matter in motion. Motion has vast consequences for matter. Try to imagine a world that is totally still—it would be a dead world.

The content of this lesson is speed, velocity, acceleration, and Newton's laws. These are taught in two chunks. The first chunk is about speed, velocity, and acceleration. Velocity differs from speed in that velocity also includes direction. So 55 mph is a speed, and 55 mph to the north is a velocity. Acceleration is the change in velocity. So if something is completely still and starts moving, it has accelerated.

Newton's laws are about motion. The first and second laws are the most important and relevant here, and they are both about how to change motion. The first law says that you can't change something's motion unless you apply a force to it. A force is a push or pull. So, if something is still, you can't put it into motion unless you apply a force to it. If something is moving, you can't change its motion unless you apply a force to it. Forces include gravity and the push/pull felt by electric charges. In other words, everything stays the same (inertia) unless you apply a force.

The second law says what happens if you DO apply a force. If you apply a force to an object, you will changes its motion, and this law gives you a little equation to calculate exactly how much you changed its motion. $F = ma$, or *force = mass x acceleration*.

Math connection: Using formulas to solve for missing variables

The lesson is essential background knowledge for future lessons on:

- Energy: kinetic vs. potential

12 | Energy

Key Questions:

- **What is energy?**
- **What are the different types of energy?**
- **Is energy a type of matter?**
- **What impact does energy have on matter?**
- **What is kinetic energy?**
- **What is potential energy?**
- **What is the difference?**
- **Can you create energy out of nothing?**
- **Can you use energy up?**

What is energy? This is a question that even scientists have a difficult time answering. Energy is not matter, first of all, although it can be stored in matter. Energy is something that causes "work" to be done, or causes a change in the world. Forms of energy that students should learn about include heat, light, sound, the energy of motion (kinetic energy), chemical energy (the energy stored in food), electric energy.

Crash! One reason that motion is important is that it can do damage. In other words, it can make a change in the world. Objects in motion have kinetic energy. This kinetic energy can do things in the world. For example, a moving car can crash into a mailbox and destroy it. The moving car made a significant change to the mailbox. We use kinetic energy every day. When you walk to the subway station, you change your own location. You are using kinetic energy to change your position. If you clean your kitchen, you use kinetic energy to make changes in the kitchen. After being cleaned, the kitchen is different. You've made a change in the world.

Potential energy is "stored" energy. It has the potential to change into kinetic energy, often. A bowling ball on the top shelf has the potential to fall off and acquire kinetic energy by falling through the air. Chemical energy in an apple has the potential to be unlocked by your body and used to move.

Like matter, energy is conserved. It just changes form. This is an elusive and strange concept to illustrate, so it's important to connect this conservation law with the similar conservation law for matter.

The lesson is essential background knowledge for future lessons on:

- Transformation of energy
- Where matter and energy come from
- Photosynthesis and Cellular Respiration
- Ecosystems

13 | Transformation of Energy

Key Questions:

- **What does it mean when you say that energy is transformed?**
- **What is energy transformed into?**
- **How does this relate to the conservation of energy?**
- **What are some examples of energy being transformed?**
- **Why is this important to know about?**

The core concept here is that energy is conserved by being transformed. That means that the types of energy learned in the last lesson—heat, sound, light, chemical, electric, kinetic—can be converted from one to another. This feature of energy allows us to eat an apple and walk around, or plug a lamp into a socket and have light, or for plants to absorb sunlight and create fruit. Students need lots of examples of this and an opportunity to work with these transformations in order to grasp this idea.

This concept is important because all energy on Earth originates from the sun. Plants capture this energy of sunlight and package it into carbohydrates during photosynthesis. Animals eat these plants and release the energy stored in carbohydrates and transform it to heat, kinetic energy, or other types of energy.

The lesson is essential background knowledge for future lessons on:

- Where matter and energy come from
- Photosynthesis and cellular respiration
- Ecosystems

14 | Photosynthesis and Cellular Respiration

Key Questions:

- **Where does energy come from?**
- **How does energy move from the sun through our world?**
- **How is the sun's energy captured and used by plants and animals?**
- **Could animals survive without plants?**
- **How do animals like humans release the energy in glucose?**
- **How are photosynthesis and cellular respiration related?**

This lesson is closely related to several previous lessons, including the transformation of energy. In this lesson, we track the movement of energy from the sun, to green plants, to animals. The two key and opposite reactions are photosynthesis and cellular respiration.

In photosynthesis, the energy of the sun kicks off a chemical reaction inside of chloroplasts in green plants. The results of this chemical reaction are molecules of glucose (or sugar). This lesson also draws closely on the previous lesson on chemical reactions and on macromolecules. Glucose is a carbohydrate, which is one of the macromolecules that all living things are built out of. Plants are able to use the carbon from carbon dioxide in the air to built glucose. Animals are not able to use the carbon in carbon dioxide—they must take glucose in to get carbon to build structures in their bodies.

Glucose "holds" energy in its chemical bonds. The energy can be released by another reaction called cellular respiration. This is the chemical reaction that occurs in the cells of human bodies. Specifically, it occurs in the mitochondria, which is one of the key organelles that will be reviewed in the upcoming lesson on the cell.

The lesson is essential background knowledge for future lessons on:

- The cell
- Evolution
- The human body

15 | Ecosystems

Key Questions:

- **What is an ecosystem?**
- **What are the nonliving things in an ecosystem?**
- **How do nonliving things in an ecosystem affect the living things?**
- **What are some examples of ecosystems?**
- **How is matter conserved in an ecosystem?**
- **How is energy transformed in an ecosystem?**
- **How do producers, consumers, and decomposers work together in an ecosystem?**
- **What are fossil fuels and how are they formed?**

The water cycle was taught in a previous lesson, and this lesson builds on this idea of cycles to look at how other things move throughout an ecosystem. An ecosystem is made up of all living and nonliving things in a specific area. For example, a jungle is an ecosystem that's different from the ecosystem of a Florida beach. The key thing here is that nonliving things are also important and included in an ecosystem. So, the sand on the beach determines what kind of plants can grow there. Other nonliving elements that are important to ecosystems are soil, air, oxygen, sunlight, temperature, and water. How do these nonliving aspects affect and determine which living things thrive in this ecosystem? This lesson introduces the relationship between living things and the environment, and also introduces the idea that living things must adapt to their environment.

In this lesson, there's a return to the ideas of the conservation of matter and energy. Living things can be producers, consumers, or decomposers. This lesson ties these roles directly to how matter is conserved and energy is transformed. Food chains, predator-prey relationships, and populations are also reviewed.

The lesson is essential background knowledge for future lessons on:

- The atmosphere: atmospheric gases, CO_2 and global warming
- The oceans: glaciers, global warming, rising sea levels
- Planet Earth
- Humans and the ecosystems

16 | The Atmosphere

Key Questions:

- **What elements make up air?**
- **What is the atmosphere?**
- **What is the greenhouse effect?**
- **How does heat affect ecosystems?**

At this point, students have a strong background in basic science concepts, and they are prepared to understand climate change. Start by discussing what elements are found in air, in the gaseous state, of course. Move on to look at the atmosphere and its role in mediating the Sun's energy on its path to Earth. Carbon dioxide, so important for plants in photosynthesis, retains heat in its bonds differently than molecules of nitrogen and oxygen. This contributes to the greenhouse effect.

Have students consider what impact higher temperatures might have on specific ecosystems. Connect this to the phrase "global warming," if a student doesn't bring it up first.

Math connection: Reading graphs of atmospheric carbon dioxide

The lesson is essential background knowledge for future lessons on:

- The oceans
- Planet Earth
- Humans and the ecosystems

17 | The Oceans

Key Questions:

- **Why is the ocean salty?**
- **What else dissolves in oceans?**
- **Why do glaciers float?**
- **How much of the earth is covered in ocean?**
- **How is global warming affecting oceans?**
- **How do oceans participate in the water cycle?**

A key idea here is that increasing temperatures lead to the melting of glaciers, which cause rising sea levels. To make this more concrete, use maps of coastal cities to show how a rise in sea levels would wipe out large areas. The shift in water temperature also affects the growth of plants, coral, and fish species. Offer students practice in reading graphs and charts in this lesson by looking at comparisons in population and temperature.

This is also an opportunity to discuss solubility and other special properties of water, such as the unusual feature that it's less dense when solid than when liquid.

The lesson is essential background knowledge for future lessons on:

- Planet Earth
- Humans and the ecosystems

18 | Planet Earth

Key Questions:

- **How was the earth formed?**
- **What elements make up the earth?**
- **What is the structure of the earth?**
- **What is the theory of plate tectonics?**
- **How do plate tectonics relate to earthquakes and volcanoes?**
- **What is climate change?**

This is another lesson that picks up on the conservation of matter. Atoms formed in the Big Bang formed the earth, the atmosphere, and the oceans. Having looked at the atmosphere and the oceans, now focus on the earth and its structure.

Beyond the earth's structure, this lesson focuses on plate tectonics and how they explain earthquakes and volcanoes.

19 | The Cell

Key Questions:

- **What is the difference between living things and non-living things?**
- **How are living and non-living things the same?**
- **What's alive?**
- **What is a cell?**
- **What's made of cells?**
- **What is the nucleus?**
- **What is mitochondria?**
- **Do chemical reactions happen inside the cell?**
- **How are the macromolecules related to the cell?**

Second only to the lesson on the atom, this lesson on the cell is essential science content. Draw comparisons between the two, such as "all matter is made of atoms" and "all living things are made of cells… and cells are made of atoms." Students may confuse atoms and cells, for good reason, since both are referred to as "building blocks" and both have nuclei. It's a good time for a short discussion about scale, since each cell is made up of about 100 trillion atoms, and each human body is made up of about 100 trillion cells.

The key content here is that cells are the smallest functioning unit of a living thing. Plants, animals, bacteria, mushrooms—all living things are constructed of cells. Not all cells in a body are the same—they are differentiated. But the basic model of a cell is a membrane built out of lipids (fats), which contains some liquid which has some small organelles in it. The membrane is like the skin or "bag" of the cell. Focus on two organelles: mitochondria and the nucleus. The goal of the lesson it to have students associating mitochondria with energy and associating nucleus with control center. By discussing these two organelles, you can go back to what students already know about energy and cellular respiration, and you can also prepare students to learn more about DNA, which is housed in the nucleus.

The lesson is essential background knowledge for future lessons on:

- DNA
- Heredity
- The human body

20 | DNA

Key Questions:

- What is DNA?
- How is DNA related to nucleic acids?
- How is DNA related to proteins?
- How is DNA related to chromosomes and genes?
- What is the human genome?
- How much does human DNA overlap with the DNA of chimpanzees?
- How much does your DNA overlap with a person you aren't related to? How much does it overlap with a person you are related to?
- What is DNA testing?
- How are your traits related to your DNA?

Understanding DNA is background knowledge for many newspaper articles on the human genome, genes that increase your risk for cancers like BRCA, and DNA crime testing. Recently, it was discovered that all cells in the body shed fragments of DNA, which can make their way into the bloodstream. This is true of fetuses in the womb also, so a pregnant woman can have a blood test to find out if her baby is a boy or girl very early on in the pregnancy.

What is DNA? It's a molecule that codes for proteins. DNA is the code or recipe for every protein in your body. DNA is like a long book that explains how to build an army. The proteins are the soldiers.

Proteins are responsible for building everything in your body. They are also responsible for eye color, hair color and texture, height, and almost everything else about you. Your physical traits are a result of protein action in your body. And your DNA is what dictated those particular proteins (as opposed to different proteins), so your DNA is what ultimately defines what you look like.

The lesson is essential background knowledge for future lessons on:

- Heredity
- Evolution
- The human body

21 | Heredity

- **Recessive and dominant**
- **Punnett Squares**

We've talked about cycles of matter and energy already. Now we'll talk about cycles of information. DNA holds information—specifically, the information necessary to build proteins to create a human (or a plant or an animal). This information is passed on from parent to child. In other words: heredity.

How much DNA do we have? We get one set of 23 pieces of DNA from our mother and one set of 23 pieces of DNA from our father. In a sense, this is "double" DNA, because these pieces of DNA mostly code for the same things. But there are little differences. For example, if your father has red hair, the set of DNA you have from him will code for proteins that make red hair. But you also have a set of DNA from your mother. If she has black hair, the set of DNA from her will code for proteins that make black hair. You often have DNA that codes for two different physical traits. So how come you don't have both red and black hair? That's what this lesson is about.

Dominant vs. recessive traits and Punnett Squares seem to appear on every science test. This is a simplification of how things actually work. The classic example is blue vs. brown eyes. It used to be taught that there was exactly one area on DNA that coded for eye color, and that blue was totally recessive to brown. Now we know that it's much more complicated than that. Nonetheless, it's still important to know the basics of these ideas for the HSE test.

Math connection: Probability, percentages, fractions

The lesson is essential background knowledge for future lessons on:

- Evolution
- The human body

22 | Evolution

Key Questions:

- **What is evolution?**
- **What is natural selection?**
- **What's the difference between evolution and natural selection?**
- **How do species form?**
- **How is DNA involved in this?**
- **What is antibiotic resistance, and how is it an example of evolution?**

Animals evolve in response to their environment. Evolution refers to the change over time. This change is a change in traits AND a change in DNA. Since it is a change in the DNA, it will be passed on to children.

Why do these changes happen? The change is something that helped that animal live and thrive and reproduce in that environment. Say a salmon lays hundreds of eggs. One of the eggs has a mutation in its DNA that makes it grow a curved tail. This curved tail gives this fish an advantage—it can swim faster than all its sisters and brothers. Because it can swim faster, it escapes predators more easily, and enjoys a nice long time. During its long life, it is able to reproduce many, many times. All of the baby fish also have curved tails, and have a similar advantage. Now these baby fish reproduce more than non-curved tailed fish. A few years pass, and suddenly 50% of the salmon population in a certain place have curved tails.

Natural selection means that nature "selects" certain individuals—in other words, some traits of these individuals have given them an advantage over other individuals, and so they have survived longer and reproduced more.

This is how new species form—as a result of a specific environment. If you take one species of fish, and put them in three different environments, they will probably evolve over the years so that they can take advantage of these different environments. They might look different, but you will be able to find the commonalities that show that they are all related. You can find commonalities both in body structure and in their DNA.

23 | The Human Body

Key Questions:

- **What is the relationship between cells, tissues, and organs?**
- **What are the organs of the circulatory system?**
- **What does the circulatory system do in the body?**
- **What does blood do? Why do we have blood?**
- **What are common problems and diseases of the circulatory system?**
- **What is hypertension?**

The first point of this lesson is to talk about how cells build together to create a human. Similar cells form a certain tissue, and then different tissues built an organ. Organs that do related work are grouped into systems.

The circulatory system is the roads and highways of the body. Blood carries and transports products from many other systems—glucose from the digestive system, immune cells from the immune system, and hormones from the endocrine system. The circulatory system is comprised of the heart, arteries, veins, and the blood.

Hypertension, or high blood pressure, might not be on the HSE test, but it's such a common problem that I think it's worth discussing it in class.

Math connection: Reading graphs and charts, how much blood does your heart pump in a day?

> "I would rather have questions that can't be answered than answers which can't be questioned."
>
> —Richard Feynman

UNIT 1 Introduction to Studying Science

Lesson Plan

NOTE TO THE TEACHER

My experience studying science in school was that thousands of seemingly unrelated topics were taught to me, one after the other, with very little discussion of how they were connected or how they formed a coherent explanation of how the world works. One of my goals in this curriculum is to focus on a central theme of matter and how it interacts with other matter and with energy to explain what happens around us every day.

Understanding matter is the basis for all sciences, and if students don't have this background, they are limited in what they can understand in biology, earth sciences, and space sciences. These 10 lessons offer a strong foundation for all other science learning. For example, a thorough understanding of photosynthesis is dependent on students' understanding atoms, molecules, elements, chemical formulas, and chemical reactions.

This first lesson focuses on interaction, which is the most accessible concept for students out of matter, energy, and interactions. They see that they can predict the outcome of many interactions in the world because of their past observations. I hope that this serves two goals.

The first goal is that students see that they can (and should) apply their own observations to what we discuss in class. It's also meant to connect the often abstract study of science with concrete, recognizable phenomena relevant to students' lives. All of science is built on observing things happening in the world, and asking questions about how or why those things happened the way that they did. The Richard Feynman reading, "The Making of a Scientist," addresses this in a charming way.

The second, less direct goal is that students begin the study of science with confidence that they already understand a few things. Science strikes me as a field that presents itself as all-knowing, dropping a 40-pound textbook in your lap and expecting you to just memorize what the geniuses have figured out. This has made a lot of us feel pretty dumb in the past. In this curriculum, I want the students' first activity in science to be something that they could do with some confidence.

Connected to this, I hope that this curriculum offers a more humane view of the field—that science is just the (often flawed and limited) current understanding of how things work in our world. It's unfinished, it's often wrong, and it's ongoing. At some point, it's worth mentioning a few things that have been revised, like the belief that the Earth was the center of the universe or that smoking was good for your health. The revision to these beliefs is not to imply that "we've got it all figured out now," but rather to ask the question, "What will we revise and understand better 100 years from now?"

OBJECTIVES

- ✔ **Students will understand that "matter, energy, and interactions" is the main theme in this class.**
- ✔ **Students will understand what an interaction is.**
- ✔ **Students will understand that they can connect their observations to scientific discussions in class.**
- ✔ **Students will understand that making observations and asking questions is key to the practice of science.**

MATERIALS

- **Handout: What would happen if…?**
- **Reading: *The Making of a Scientist***
- **Handout: Notes on Today's Lesson**
- **Homework Assignment**

LESSON STEPS

Review the fields of science, and the methodology of this curriculum.

1 Introduce this unit on science by asking students what the different fields of science are. Start them off with one as an example and elicit the rest of them.

a. Chemistry
b. Biology
c. Earth Science
d. Astronomy
e. Physics

The HSE test expects students to know all five of these fields, but it's impossible to cover all of these fields in one class. Instead, this class will focus on core ideas that are essential and common to all five fields.

1

In our experience, once the conversation warms up, students will suggest many different fields of study: Astronomy, anatomy, oceanography, geography, psychology, etc. Write all these fields of study on the board and then circling the general fields. You might also star Life Science, Earth Science and Astronomy since these are the high emphasis areas on the HSE Science test. An understanding of matter, energy and interactions supports learning in all of these fields.

Introduce our central idea: Matter, Energy, and Interactions.

2 What are the core ideas? MATTER, ENERGY, and how they INTERACT in any combination. It's fine if this seems confusing right now because we will return to this central idea every lesson. Let's start with INTERACTIONS. What is an interaction? Elicit a few ideas and write a definition on the board.

Offer a few examples, such as:

- Two people fall in love
- Lightning strikes a tree
- Two cars crash
- You take a pill and your headache goes away.

3 Ask students to work with a partner and think of three examples of interactions and write them down. Give them 2-3 minutes to do this and then ask several groups to share. Makes a list on the board as students share their ideas.

4 Check off a few of the interactions that you will discuss in the coming science lessons, such as lightning hitting a tree.

Introduce observations and questioning as central practices of science.

5 Introduce the idea that science is based on OBSERVATIONS and QUESTIONS. Write these two terms on the board. Explain that everything we know about science comes from scientists making observations of the world and asking questions based on those observations. Say that everyone in the room has already made many observations, and that we will use those observations in our discussions of science.

6 For example, what would happen if you dropped a spoonful of sugar into water? Ask the students what happens. Point out that they already know what happens, but the next step is to ask questions about this. The first question is *Why does the sugar dissolve in water? Why doesn't it fall to the bottom like pieces of metal would?* Ask a few more questions, like *Can I mix an infinite amount of sugar into the water? Why not? Why does it dissolve at the beginning but not at the end? Why can't you see the sugar after it dissolves? Can you get the sugar back out? Would sugar dissolve in any liquid or only water?*

VOCABULARY

• Interaction •

Two or more things come together and have an effect on each other

5

Be explicit and make the point that observations include things we can see in the world with the naked eye, microscopes, telescopes, microphones, etc. and information we collect in experiments.

7

Observing, asking questions and answering WHY is science. Many students will think that science is about memorizing information, rather than seeking explanations that make sense. We want to make it clear to our students that we want them to understand the "Why" behind the content.

9

Richard Feynman was an American theoretical physicist who lectured and wrote books about physics for the general public. As a young man, he worked on the development of the atom bomb. He later won the Nobel Prize for Physics for creating a model of how light and matter interact. As an older man, he was part of a panel that investigated the Space Shuttle Challenger disaster. He's actually the one who figured out what happened. There was a very dramatic moment during the hearing where he describes putting an O-Ring under pressure in a glass of ice water. There are a number of Feynman recordings on YouTube that would be interesting for teachers' background knowledge. Feynman's lectures on physics are accessible and available for free online. (This BBC interview contains the original recollections that became the reading for this class: http://www.feynmanphysicslectures.com/bbc-horizon-interview/)

7 Distribute What Would Happen If...?. Ask students to work with a partner to use their previous experience to make notes on what would happen in each interaction. In the third column, students should write two questions about the interaction. Do one more example to get them started.

8 Stop students when the first few groups finish or when you think they've got the idea. Have two pairs of students to come together to compare answers. Address the whole class with any outstanding questions.

In-class reading.

9 (This can also be done as homework.) Distribute The Making of a Scientist. Ask students to select a passage (or section) that stands out to them for any reason. They might select a passage they agree or disagree with, or a passage that they like or dislike. They should make a few notes in the margin about why they chose that passage. A passage might be one sentence, a few sentences, or a paragraph or two.

10 When most of the class is finished, have students share their passage with a partner. After a few minutes of discussion, come together as a whole class and hear a few examples. If it doesn't come out naturally in the discussion, ask why Feynman was making a distinction between knowing the name of something versus observing/noticing things.

Review the structure of the class: Quiz, Lesson, Summary.

11 Congratulate the students on their good work on the first day of science, and tell them when their next science lesson will be. Review how you will be teaching science:

a. At the beginning of each lesson, there will be a cumulative quiz on the previous lesson. This is to help students review and reinforce the ideas. Explain that students who take tests or quizzes more frequently tend to remember the material better and also do better on future tests.

b. After the quiz, there will be a new lesson. Students will need to take notes during the lessons. Group and pair work is central to all lessons.

c. At the end of every lesson, you or the students will summarize the main ideas of the lesson.

Summarize today's lesson.

12 The first summary isn't going to be a formal summary—it's going to be notes. Ask students to work in pairs to make notes on what you talked about and did during today's lesson. Their list of notes doesn't have to be in complete sentences. It can include definitions of words, a note about an activity of question that was discussed, or anything else. It doesn't have to be in order. The idea is just to get down the most important ideas and concepts that were discussed in class today.

13 Collect ideas and record them on the board after they have had enough time to work on this.

14 Distribute your own version of notes. You can use "Notes on Today's Lesson" as a model for your own teacher's version of class notes. Point out how similar they are (even if they aren't that similar).

HOMEWORK

Distribute the homework assignment. Students should write a letter to you about their past experiences learning science. Ask students if their past experiences learning about science are mostly good, bad, or neutral. And ask them to think of at least one specific teacher or situation that they remember and describe it to you in the letter.

Offer an example of your own to model how to do this. (For example, the only thing I remember from my physics class in high school was being out in the hallways throwing balls around. I had no idea why we were doing that. A few years later, I enrolled in a physics class in college and I had a very hard time in that class. I had never heard of the words or concepts they were talking about, even though I supposedly had taken physics in high school.)

Encourage students to be honest in their letters. Students who may have it in their heads that they are just bad science students should have opportunities to re-examine that "truth." This assignment gives students and teachers an opportunity to start an individual conversation about past experiences in education and future goals in education and work.

VOCABULARY

Interactions • Observations • Summarize

11

Psychologists have shown that students learn more when they are given a series of brief quizzes that they do if they are just given one big exam at the end. Every time a memory is retrieved, it becomes stronger by being connected to new sensations and contexts. This has ramifications for how students should study. Students should test themselves as they read, looking away from the page to see what they remember or understand. One place to learn more is the American Radio Works' documentary, *The Science of Smart* (http://www.americanradioworks.org/documentaries/the-science-of-smart/).

14

This is an opportunity to model notes that you expect your students to take in a science class. For students who are unfamiliar to the subject (or school in general), it is helpful to have models to refer to in subsequent classes when they are asked to take notes and write summaries. The summary model is a way to provide scaffolding for an activity that can be challenging for many students.

What Would Happen If...?

Imagine the following interactions. What happens? Make some notes in the second column. Then ask questions about each interaction, such as "Why does the gasoline catch on fire but the water doesn't? Can we explain the difference?"

INTERACTION	WHAT WOULD HAPPEN?	QUESTIONS
You drop a lit match into a gas tank full of gasoline.		
You drop a lit match into a glass of water.		
You stir one spoonful of sugar into a glass of water.		
You put small pieces of iron into a glass of water and leave them there for one month.		
You leave a bowl of ice cream in the sun.		
You pour oil into water.		
You pour blue ink into water.		

Reading

As you read this article, choose a passage that stands out to you. Underline it. Why does it stand out to you? Write a few notes in the margin about why you choose it.

The Making of a Scientist

by Richard Feynman

We used to go to the Catskill Mountains, a place where people from New York City would go in the summer. The fathers would all return to New York to work during the week and come back only for the weekend. On weekends, my father would take me for walks in the woods and he'd tell me about interesting things that were going on in the woods. When the other mothers saw this, they thought it was wonderful and that the other fathers should take their sons for walks. They tried to work on them but they didn't get anywhere at first. They wanted my father to take all the kids, but he didn't want to because he had a special relationship with me. So it ended up that the other fathers had to take their children for walks the next weekend.

The next Monday, when the fathers were all back at work, we kids were playing in a field. One kid says to me, "See that bird? What kind of bird is that?"

I said, "I haven't the slightest idea what kind of a bird it is."

He says, "It's a brown-throated thrush. Your father doesn't teach you anything!"

But it was the opposite. He had already taught me: "See that bird?" he says. "It's a Spencer's warbler." (I knew he didn't know the real name.) "Well, in Italian, it's a Chutto Lapittida. In Portuguese it's a Bom da Peida. In Chinese, it's a Chung-long-tah, and in Japanese, it's a Katano Tekeda. You can know the name of the bird in all the languages of the world, but when you're finished, you'll know absolutely nothing whatever about the bird. You'll only know about humans in different places, and what they call the bird. So let's look at the bird and see what it's doing—that's what counts." (I learned very early the difference between knowing the name of something and knowing something.)

He said, "For example, look: the bird pecks at its feathers all the time. See it walking around, pecking at its feathers?"

"Yeah."

He says, "Why do you think birds peck at their feathers?"

I said, "Well, maybe they mess up their feathers when they fly, so they're pecking them in order to straighten them out."

"All right," he says. "If that were the case, then they would peck a lot just after they've been flying. Then, after they've been on the ground a while, they wouldn't peck so much anymore—you know what I mean?"

"Yeah."

He says, "Let's look and see if they peck more just after they land."

It wasn't hard to tell: there was not much difference between the birds that had been walking around a bit and those that had just landed. So I said, "I give up. Why does a bird peck at its feathers?"

"Because there are lice bothering it," he says. "The lice eat flakes of protein that come off its feathers."

He continued, "Each louse has some waxy stuff on its legs, and little mites eat that. The mites don't digest it perfectly, so they emit from their rear ends a sugar-like material, in which bacteria grow."

Finally he says, "So you see, everywhere there's a source of food, there's some form of life that finds it."

Now, I knew that it may not have been exactly a louse, that it might not be exactly true that the louse's legs have mites. That story was probably incorrect in detail, but what he was telling me was right in principle.

Not having experience with many fathers, I didn't realize how remarkable he was. How did he learn the deep principles of science and the love of it, what's behind it, and why it's worth doing? I never really asked him, because I just assumed that those were things that fathers knew.

My father taught me to notice things. One day, I was playing with an "express wagon," a little wagon with a railing around it. It had a ball in it, and when I pulled the wagon, I noticed something about the way the ball moved. I went to my father and said, "Say, Pop, I noticed something. When I pull the wagon, the ball rolls to the back of the wagon. And when I'm pulling it along and I suddenly stop, the ball rolls to the front of the wagon. Why is that?"

"That, nobody knows," he said. "The general principle is that things which are moving tend to keep on moving, and things which are standing still tend to stand still, unless you push them hard. This tendency is called 'inertia,' but nobody knows why it's true." Now, that's a deep understanding. He didn't just give me the name.

He went on to say, "If you look from the side, you'll see that it's the back of the wagon that you're pulling against the ball, and the ball stands still. As a matter of fact, from the friction it starts to move forward a little bit in relation to the ground. It doesn't move back."

I ran back to the little wagon and set the ball up again and pulled the wagon. Looking sideways, I saw that indeed he was right. Relative to the sidewalk, it moved forward a little bit.

That's the way I was educated by my father, with those kinds of examples and discussions: no pressure—just lovely, interesting discussions. It has motivated me for the rest of my life, and makes me interested in all the sciences. (It just happens I do physics better.) I've been caught, so to speak—like someone who was given something wonderful when he was a child, and he's always looking for it again. I'm always looking, like a child, for the wonders I know I'm going to find—maybe not every time, but every once in a while.

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Notes on Today's Lesson

- Different branches of science:
  - Biology
  - Chemistry
  - Physics
  - Earth science
  - Astronomy

- We don't have time to learn each field, so we'll focus on ideas that are common to all of them by studying "Matter, energy, and interactions."

- **Interaction** = two or more things come together and have an effect on each other. We used our past experiences to say what the result of certain interactions would be. We also asked questions about these interactions.

- Observations and questions are central to how science is done.

- Read "The Making of a Scientist," which gave an example of people making observations and asking questions.

- Structure of science lessons:
  1. Quiz
  2. New lesson (take notes)

- Summarize

Homework

Dear Students,

Welcome to our science unit! I'm excited to work with you in this section–we are going to work hard to learn a lot, but we also will do a lot of fun activities in class together.

I know that not everyone has had good experiences learning science. It's helpful for me to understand how you feel about learning science as we start this part of the class. To help me, please write me a letter about your past experiences. You can be honest–if your experiences were good, bad, or forgettable, you can tell me.

I'd like you to include a paragraph on each of these topics:

1. **How do you feel about learning science? (Excited, bored, scared, intimidated?) Why?**
2. **Describe one teacher, class, or learning experience you've had related to science. Pick your most memorable memory—good or bad!**
3. **Finally, what are your plans for after you pass the HSE test? Are you interested in attending college, and if so, what would you like to study? What kinds of jobs appeal to you?**

I look forward to reading your letters!

Warmly,

Your Science Teacher

UNIT 2 What Is Matter?

Lesson Plan

NOTE TO THE TEACHER

The first half of this curriculum is devoted to matter. It covers what matter is (and isn't), what some of the properties of matter are, how you can change the phase of matter, and finally ends with atomic theory: that all of matter is made up of atoms. Once they have this, you can discuss how the structure of atoms determines if atoms will participate in chemical reactions and join together to form molecules, which in turn form proteins and other macromolecules, which in turn form plants and animals. Without chemical reactions, our whole world would just be a soup of lonely atoms.

In this lesson, we focus on what matter is. Matter has a formal science definition as anything that has mass and takes up space (or has volume). This lesson covers matter, mass, and volume in some depth. You might also add that all of matter is made up of particles, but we'll also get that in future lessons.

If you have a scale in class, it's worth having students measure the mass of some objects. You can bring objects in or just have them measure things in the classroom: Keys, phones, pens, chalk, books. This lesson does not go into how to measure volume, but it would fit well with this lesson if you are interested in adding it.

When we taught this lesson recently, we used kitchen scales to weigh one-inch density cubes, which have the same volume, but have different mass because they are made of different materials. The scale gave students a tangible way to talk about mass, which is measured in ounces or grams. Pocket kitchen scales are now available for $10-20.

A big challenge of this lesson is that gas is matter, too. Most students don't recognize gas as matter. The final section is devoted to undoing this misconception, but in my experience this is something that needs to be reviewed many times over the course of the semester before students are convinced that gas has mass and volume and, thus, is matter.

OBJECTIVES

- ✔ **Students understand what is and is not matter.**
- ✔ **Students understand mass, volume, and how they are different.**
- ✔ **Students understand that gas is matter too.**

MATERIALS

- **Quiz, copies for all students**
- **Sorting cards, one pack for each pair of students**
- **Handout: Sentence Starters**

We used readings from the McDougal Littell Science textbook, *Matter and Energy* (2005) to review and extend the concepts covered in class. The American Chemical Society also has an extensive free lesson set on matter that includes readings appropriate for pre-HSE and HSE classes (http://www.middleschoolchemistry.com/lessonplans).

- **Handout: Is it Matter?**
- **Reading: *Matter has Mass and Volume***
- **2 balloons of the same size**
- **Tape**
- **Yardstick or ruler**

LESSON STEPS

Give the quiz.

1 Ask students to work on it by themselves, without consulting notes, for a few minutes. Remind them that this is excellent practice, asking their brains to try to remember what you talked about last time. After a few minutes, tell them that they can use their notes or talk with a partner. Review the answers briefly.

2 Review the goals of the quizzes:

a. Every time you try to access a memory, your brain gets the signal that this is an important piece of information and it builds that memory stronger. Quizzing yourself is a great way to reinforce memories, which is why flashcards work.

b. It gives everyone a chance to remember what you did last time and ask questions about it.

c. Because all the science lessons are connected, it sets the stage for the next lesson.

2a

Recent research shows that we learn even, or maybe especially, when we make mistakes. According to Stanford professor, Jo Boaler, making mistakes actually makes neurons develop and grows the brain. This information can be helpful as we teach our students to be persistent in facing challenges in learning. For more on the subject, look for Boaler's articles on YouCubed.org.

Introduce matter.

3 Write **Matter, Energy, and Interactions** on the board. Ask students which word you focused on last time (Interactions). Today, we will focus on MATTER.

4 Introduce two definitions of matter.

a. The first definition is STUFF. Matter is stuff in the world. Include some examples like water, people, clothes, iPhones, grass, food, air.

b. The second definition is the formal science definition. Matter is anything (or stuff) that has mass and takes up space.

Review mass.

5 In order to understand this, we need to understand what mass and volume is. Define mass.

a. Mass is a measurement of how much something weighs. We use a scale to measure mass. We can measure mass in pounds or kilograms. (Example: He weighs 160 pounds.) I make a list of words on the board to associate with mass:

- Weight
- Heaviness
- Use a scale to measure it
- Pounds, ounces, grams

b. Ask students to vote on which of the above four words seems like the best, most memorable definition for them. (This is not about getting a consensus but about having students evaluate information and make a decision about what will help them remember the concept the best.)

c. Distribute one pack of sorting cards to each pair of students. Ask them to sort the cards based on how much mass they think each image has. Draw a continuum on the board and label it:

less mass ⟶ **more mass**

Working with a partner, students should place their cards in order from less to more mass. Ask them to record the order on a piece of paper.

d. Review as a class. Ask, *Does anything have the exact same mass?*

5a

We have found the distinction between mass and weight unnecessary for HSE students. The formal definition of weight vs. mass won't come up until Physics 101, but mass OFTEN comes up, so it is important that students can recognize mass as a measurement taken on a scale. In this curriculum, we treat mass and weight interchangeably.

Review volume.

6 Define volume.

a. Volume is a measurement of how much space something takes up. We can't use a scale to measure this. We need to use a tape measure. For example, you might have two different sized plates, one small and one large. These plates have different volumes. They take up different amounts of space. Here are two ways to define volume. Ask students which one they like better:

- Size
- How big or small it is

b. Ask students to make a second continuum, on a second piece of paper. This time, label it like this:

less volume ⟶ **more volume**

Students should use the same sorting cards, but now re-sort them based on volume. This should give a different result. Ask them to record the new order on a piece of paper.

c. Review as a class. A few questions to ask: *What changed position when you organized by volume? Why? Does the empty or full Coke can have more volume?*

7 Ask students, *What is the difference between mass and volume?* Talk about how they will remember the difference. Explain that thinking about HOW to remember something really does help you remember it. For example, say that you think of mass as how HEAVY something is, and you think of volume as how much SPACE it takes up. You might draw a weight on the board, label it "100 pounds" and write *Mass* above it. For volume, you might draw a bus and a small car or bicycle, or a small and large suitcase.

8 Distribute the sentence starters and give students a choice to work on it with a partner or alone.

Is it matter?

9 Let's come back to matter! If you erased the definition of matter, ask students, *What is matter again?* Ask students how they would decide if something is matter or not. (Get to the answer that they would need to test if it had mass and volume. If it has both mass and volume, it is matter.)

10 Distribute Is it Matter? Students should work in groups of 2 or 3. Encourage them to make notes on the final question about how they decided. Review as a class.

10

Students will often say that air, helium and oxygen are not matter. Though it is difficult to put a gas on a scale, there are other ways of demonstrating that gases have mass and volume. Heat, light, sound and electricity are all forms of energy and are not matter. They don't have volume or mass. Energy is a property of matter, or something that matter has. One way to talk through this with students is to go back to the basic definition of matter: Stuff that takes up space and has weight. Does light take up space? Could you put it in a balloon? Fill a bowl with it? Not exactly. Does it have weight? Could you put it on a scale to weigh it?

Gas is matter too.

11 It's worth spending some time talking about gas. Many students don't recognize gas as a form of matter. Discuss how you might test is a gas has mass or volume. If time allows, ask students to brainstorm ways to measure the mass and volume of a gas.

12 One way to test if air has volume is to blow air into a balloon. Does that air take up space inside the balloon? Yes.

13 In order to test if the air has mass, you might compare the weight of the filled balloon with the weight of an empty balloon. If you have a sensitive scale in the classroom, you can weigh the empty balloon and then weigh the full balloon (although it's hard to keep the balloon from rolling off of the scale). You could also bring a basketball and an air pump to class and compare the weight in grams of an empty basketball and a full basketball. An empty basketball may weigh about 576 grams and a full basketball should weigh about 5 more grams. These demonstrations show that air has weight.

If you don't have a scale, you can attach the full balloon to one end of a meter stick and an empty balloon to the other end. Ask students what would happen if you balance the stick on your finger (your finger is in the center of the meter stick) if the balloons weigh the same. Ask them what would happen if you balance it on your finger and they don't weigh the same. Do it to show that the filled balloon weighs more than the empty balloon. You can pass it around the class and have people try to balance it, so that they can see that the side with the full balloon always tips down.

13 The full balloon is heavier because the air we breathe (mostly nitrogen and oxygen) has mass (weight) as well as volume (what makes the balloon expand). A word of warning: Try this on your own before class. Unforeseen variables in how much tape is used or where the balloon is attached to the yardstick can throw this off. You may also want to use larger balloons that can hold more air, in order to have more obvious results.

Summary

14 Do the summary as a group. Write the following on the board and ask the students to tell you what you learned about each concept in today's class.

a. Matter

b. Mass

c. Volume

d. Gas

15 (Make sure you have a coherent definition for matter, mass, and volume. For gas, you should note that not everyone was sure that gas was a form of matter, so you decided to test to see if air met the definition of having both mass and volume. You used a balloon to see that air took up space, and then you compared the weight of a full and empty balloon to see that it has mass, so air has both mass and volume and therefore must be matter.)

16 Remind them that they will have a quiz on these topics at the beginning of the next class.

HOMEWORK

Distribute the reading. In our class, we used the reading, MATTER HAS MASS AND VOLUME from *Matter and Energy* from McDougal Littell. An alternative might be an edited version of the first reading from the ACS Middle School Chemistry curriculum: http://www.middleschoolchemistry.com/pdf/chapter1/chapter1_student_reading.pdf.

Ask students to read and summarize the main ideas in one paragraph for homework.

VOCABULARY

Matter • Mass • Volume

Quiz 1: Interactions

1. What's an interaction?

2. Give two examples of interactions.

3. Fill in the blank:

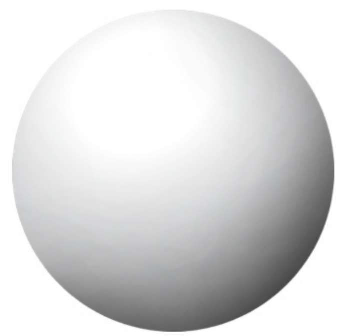
   The theme of our science study is Matter, ________________, & Interactions.

Matter Sorting Cards

styrofoam cooler
24 inches wide
12 inches tall
12 inches deep

plastic cooler
24 inches wide
12 inches tall
12 inches deep

golf ball



ping pong ball

ceramic pan
12 inches long
6 inches wide
3 inches deep

foil pan
12 inches long
6 inches wide
2 inches deep

Matter Sorting Cards

empty Coke can

full Coke can

popped popcorn kernel

unpopped popcorn kernel

1 cup of honey

1 cup of water

Sentence Starters

Complete each sentence, or answer the question.

1. Mass is…

2. Volume is…

3. How are mass and volume different?

4. An example of something that has a lot of mass is…

5. An example of something that has a lot of volume is…

6. An example of something that has a lot of mass but not a lot of volume is…

7. An example of something that has a lot of volume but not a lot of mass is…

Is it Matter?

This list includes things that are matter and things that are not matter. Discuss with a partner which things are matter. Mark each thing that is matter.

rocks	salt	dissolved sugar
baby powder	Mars	electricity
milk	steam	human being
air	rotten apples	light
love	heat	opinions
dust	water	sound
music	bacteria	helium
atoms	oxygen	cells

Explain your thinking. How did you decide if something is matter or not?

Adapted from *Uncovering Student Ideas in Science, Volume 1*, by Page Keeley, Francis Eberle, and Lynn Farrin, NSTA Press.

UNIT 3 Scale and the Atomic Theory

Lesson Plan

NOTE TO THE TEACHER

The last lesson introduced matter, mass, and volume. This lesson picks up on volume and introduces the huge scope of the size of matter. In looking at matter, we could be talking about the size of an atom, a cell, a human, an ocean, the atmosphere, the Earth, or the solar system. I wrote this lesson after noticing that some students didn't distinguish between the size of an atom and a cell. Both are microscopic, so it makes sense to just categorize them together. But the size difference is enormous—in fact, there are about the same number of atoms in one cell as there are cells in the human body!

But the concept of this lesson is more important than just heading off a misunderstanding between atom/cell. The Next Generation Science Standards list "scale, proportion, and quantity" as one of their crosscutting concepts, and I think that's right. Students (and all of us!) have a hard time visualizing and comprehending the very tiny or the very vast—it's just too abstract. I hope that this lesson, while basic, sets up a framework for students that you can refer back to through the rest of the lessons.

In the first part of this lesson, students sort things in order of size. If it's possible, post this on the wall of your classroom after this lesson so that you can refer to it and continue to add to it. If students struggle with sorting the objects on the macro/micro continuum, have them first make a pile of "smallish" things and "big" things. Then they can work with only one of those piles and put things into order as well as they can. They don't have to do this activity perfectly—it's not a test.

In the second part of this lesson, students are again working with scale, but this time within one system. For example, you can start with the ocean, and then look at what makes up the ocean: Fish, water, salt, shells, sand, seaweed. And then you can look at what makes up a fish: head, tail, bones, muscles. And eventually, you get down to atoms. This is the heart of the first part of this curriculum: the atomic theory, which states that "Everything is made up of atoms."

The atomic theory is the foundation for biology, chemistry, physics, earth science, and astronomy. Without a clear understanding of this idea, students can't come to learn photosynthesis, genes and inheritance, climate, or pollution in an in-depth way.

Making mathematical connections to measurement and exponents can be helpful in this lesson. Teaching conversion between measurements of distance (miles to kilometers, for example) would be appropriate. The scale of things from the atom to the solar system also provides an useful justification for teaching scientific notation, because there are so many zeros involved in writing very big and very small numbers.

Scientific notation makes life easier for us because we can just count the zeros and write that number as an exponent. It can be easier than including all the zeros and commas necessary to write a number like 1,000,000,000,000 (which is the approximate number of cells in the human body, by the way).

The final message of this lesson is that the structure and behavior of these atoms (on the micro level) explains a lot of the visible (macro) phenomena in the world. This lesson introduces this idea but doesn't go into it in depth. We will come back to this idea in future lessons.

OBJECTIVES

- ✔ **Students consider how huge the difference in size of matter is, and that there is a huge range of sizes even within matter that is considered microscopic.**
- ✔ **Students think about breaking matter down into its "ingredients."**
- ✔ **Students learn that everything in the world is ultimately made up of tiny particles called atoms.**

MATERIALS

- Quiz
- Sorting card sets (one set for every two students) (Print and cut these up ahead of time and mix them up so that they are out of order.)
- Handout: Scale
- Handout: What's it made up of?
- Handout: Paraphrasing the Atomic Theory
- Handout: Summary
- Reading: *Matter is made of atoms*
- Optional: Internet access & screen to show a YouTube movie

LESSON STEPS

Give the quiz.

1. This quiz is meant to ask students to recall information from the previous lesson on matter, mass, and volume. Ask students to work on it for a few minutes alone, without consulting their notes. Walk around the classroom to get a sense of who understands and remembers.

2. After most of them have written down what they can, have them discuss it with a partner and consult notes.

3 Review the quiz as a class. Pay special attention to the differentiation between mass and volume. Ask them what helps them understand each concept the most.

Introduce the idea of scale of matter.

4 Draw the macro/micro continuum on the board as it is in the handout. Define macro and micro. Say, *Today we'll talk more about matter—the huge range of size of matter, from a planet to a virus.*

5 Distribute packs of sorting cards, one pack per pair of students. Ask them to sort them according to SIZE on the continuum. (Reminder: Does size refer to mass or to volume?) Make sure that this is a partner activity and not done alone—the point is the conversation between students. If they aren't sure what an object is, they can leave it out. Remind them that it's okay to be wrong.

6 Once half of the groups have finished, have two groups compare their answers. Did they come up with the same order?

7 Take notes on the micro/macro continuum as students dictate an order for the items to you. Ask them to take notes on the handout.

8 If time and technology allow, show the 9-minute film on scale called "Powers of Ten," free on YouTube: https://www.youtube.com/watch?v=0fKBhvDjuy0. After watching, ask students what things we might add into our continuum (cell, DNA, atom, possibly). Add only those things students suggest.

Look at the scale within one "system." (If a cookie is your system, you could break it down into smaller and smaller parts)

cookie → butter → fats → atoms

9 Say you just ate the most glorious, delicious cookie you've ever had. You want to know why it was so delicious. What would you find out about? Elicit questions from the students. A few examples:

a. What ingredients?

b. How it was made—temperature, mixing technique, equipment, etc.?

How the cookies were made is important, but right now we're especially interested in the ingredients. Knowing what ingredients are in something can tell you a lot about it. The ingredients can tell you how healthy or unhealthy it is, how sweet or bitter or salty it might taste, what color it might be, etc. This is the same in science. Knowing what substance/matter/objects are made up of will tell us a lot about the properties of that substance.

8

This classic short film by the designers Charles and Ray Eames is a great way for students to get a sense of the scale of the universe, while being introduced to powers of 10 (10^1, 10^2, 10^3, etc.) in meters. After watching the film, you might start by exploring the powers of ten with positive exponents while thinking about the scale of things in the universe. This is also an opportunity to look at the metric system as compared to the U.S. customary measurement system. (For more information about the film along with educational materials, visit: http://www.eamesoffice.com/education/powers-of-ten-2/)

10 Distribute the handout What's It Made Up Of? Students should work with a partner to make a list of "ingredients" of each of these things from the sorting activity.

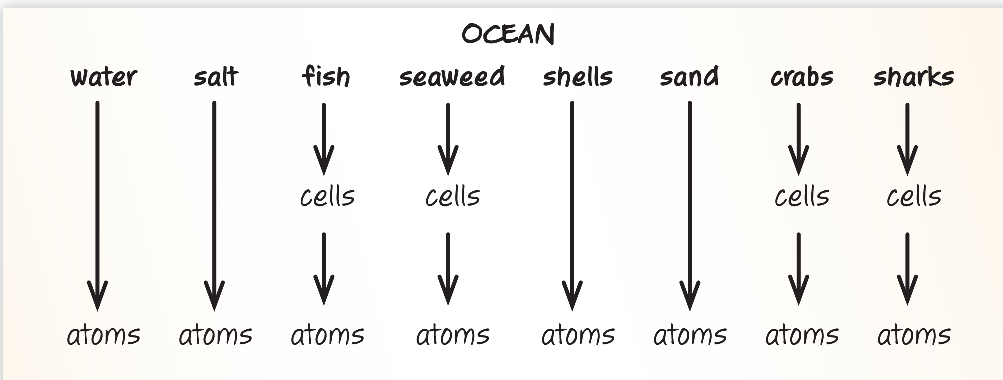
a. Ocean

b. New York City

c. Human

11 What if you continued to break the ingredients down into smaller and smaller pieces? What would you end up with? The ultimate ingredient is the atom. **Atoms make up all of matter. This is a core idea for all sciences.** It's okay if students don't know what an atom is. We will learn all about atoms in the next few lessons.

12 Elicit from the students the "ingredients" of one of the things listed on the handout. Ask which things are alive. Circle the things that are alive. Ask if anyone know what living things are made up of. (Cells.) Show this in your board illustration, and then point out that all things, cells included, are made up of atoms.



13 Here's another visualization: The size of an atom compared with an apple is the same ratio as an apple compared to the size of the earth. It really hard to imagine the size of things at the atomic scale. This TED talk by Jonathan Bergmann provides an animated version: https://www.youtube.com/watch?v=yQP4UJhNn0I

13 Ask the group how many cells they think are in the human body. Write down their guesses. (A human has 37 trillion cells = 37,000,000,000,000 cells.) Talk about how it's really hard to think about that number—it's just so large. Return to the concept that one cell is made up of atoms. Ask students how many atoms they think make up a cell—just a guess. (The answer is almost the same as the number of cells in a person. One cell = 100 trillion atoms = 100,000,000,000,000 atoms.) In this unit on Matter, we'll be talking a lot about atoms.

14 Add CELL and ATOM to the sorted objects that you worked with in the first activity.

15 Distribute the handout PARAPHRASE THE ATOMIC THEORY. Students can work with a partner or alone.

The structure and behavior of atoms explain why many things happen around us.

16 Connect to Unit 1: Lesson on interactions.

a. You stir one spoonful of sugar into a glass of water. (Here, the sugar dissolves into the water. This is an example of a mixture. We'd be able to separate these two by boiling the water out.)

b. You put a piece of iron into a glass of water and leave it there for one month. (Here, the iron reacts chemically with the water molecules to for a new substance: rust.)

Summarize

17 Give students the SUMMARY handout and have them select the best summary. Ask them to make a few notes about what's wrong with the other summaries. After a few minutes, they should discuss their decision with a partner.

HOMEWORK

Distribute a reading about matter. In our class, we used the reading, MATTER IS MADE OF ATOMS from *Matter and Energy* from McDougal Littell. An alternative might be an edited version of the first reading from the ACS Middle School Chemistry curriculum: http://www.middleschoolchemistry.com/pdf/chapter1/chapter1_student_reading.pdf.

Ask students to read it and summarize the main ideas.

VOCABULARY

Macro • Micro • Atom • Atomic theory • Particle

16

In our first lesson, we asked why these two situations lead to such radically different outcomes. We can find the answer in the difference in atoms in iron and sugar. Iron is made up on only one type of large atom. Sugar is made up of three different smaller atoms. At this point, it is enough for students to understand that the very different results of mixing these substances with water can be explained by the kinds of atoms in the substance. One of Feynman's main ideas is that phenomena in the world around us can be explained by basic interactions at the atomic level. Later lessons might explore the structure of the atom, electric charge, chemical bonding, and chemical reactions, in order to deepen students' understandings of these interactions.

Quiz 2: What is Matter?

1 **What is the scientific definition of matter?**

2 **True or false? Air is not matter. Explain why it's true or false.**

3 **Does it go better with mass or with volume? Check one.**

	MASS	VOLUME
A. How much space something takes up		
B. Kilograms or pounds		
C. Heaviness		
D. Size		
E. Weigh it on a scale		

Scale

Macro

Micro

Sorting Cards

Solar system	Human
Sun	Lung
Planet Earth	iPhone
Ocean	Cookie
City	Mosquito
Whale	Bacteria

What's It Made Up Of?

What are they made up of? Make a list. Follow the example.

	WHAT'S IT MADE UP OF?
Cookie	Sugar, butter, flour, eggs, chocolate, Salt, baking soda, vanilla
Ocean	
New York City	
Human	

Paraphrasing the Atomic Theory

Imagine that you are sitting in a lecture in college, and the professor says the following quote. Your friend turns to you and says, "I didn't understand that. What's he mean?" What's this quote saying? Help your friend out by trying to explain what this means.

> If, in some catastrophe, all of scientific knowledge was destroyed, and only one sentence was saved, what statement would contain the most information in the fewest words? I believe it is the atomic theory that *all things are made of atoms—little particles that move around in perpetual motion*. In that one sentence, there is an enormous amount of information about the world.
>
> Adapted from Richard Feynman, *Six Easy Pieces*, page 4.

Feynman is saying that…

Summary

Pick the best summary of today's class. Why is it the best? What's wrong with the other two? How can you improve the best one?

1. Today in class we arranged some things according to size. The solar system was the biggest and the smallest was an atom. Atoms and cells are about the same size: very small. Richard Feynman was a scientist who thinks that the atomic theory is the most important piece of knowledge to pass down to the next generation.

2. Today we talked about big matter and small matter. We arranged things on a scale from micro (small) to macro (big). (We weren't talking about mass or heaviness—we were talking about volume or size.) We learned that all of matter is made up of atoms. Atoms are tiny particles. Apparently knowing about these atoms will explain why things happen in the world.

3. Atoms are like ingredients for everything in the world. Anything that is matter is made up of cells, which are made up of atoms. This is called the atomic theory. First, we demonstrated this by organizing some objects from small to big. Next we talked about the different ingredients in a cookie and how they are made up of atoms. Finally we paraphrased a quote by a scientist, which was about atoms as particles.

Activities from class on Electric Charge.

Science/Math Connections

Making connections between science and math can help students see how math is applied in the world. It also helps deepen students' scientific understanding. Without an understanding of the powers of ten, many students think about atoms and cells being about the same size. They're both really small, right? In fact, there are about the same number of atoms in a human cell as there are cells in the human body.

It is also important for students to understand that their success on the HSE test, and in college, will depend on their ability to apply their skills in different contents. Science offers a rich way to explore math skills such as conversion, understanding of functions, use of formulas, and proportional reasoning. This is a list of some possible mathematical connections to the Science curriculum map.

UNIT CONVERSION

Help students develop an intuitive sense of different measurements. Use meter sticks, measuring tape and rulers. Connect measurements to things your students know. The edge of a dime measures about 1 mm. Your pinkie is about 1 cm wide. A 5 year old might be about 1 meter tall.

- **Unit conversion between cm, mm, m**
- **Take some measurements in cm and convert them to mm and m. Set up equations. (Review prefixes centi-, milli-)**
- **Compare meter system (base ten) and United States customary measurements (Imperial system) inch/ounce/pint (different bases).**
- **What the rest of the world uses and why we ended up with the British system.**
- **Kilograms and pounds**
- **Centimeters and inches**
- **SI* units: meter, second, and kilogram** (*Système Internationale d'Unités—modern version of the metric system)
- **Ounces, cups, pints, quarts, liters. Cooking conversions.**
- **Convert a day into seconds, how many breaths you take a minute, day, year, other interesting things.**
- **Converting Fahrenheit into Celsius and vice-versa**

OTHER CONNECTIONS

- **Electric charge and addition/subtraction of signed numbers.** Protons are positive and electrons are negative. One proton and one electron balance their charges so that the particle is now neutral. What happens when there are two protons? How many electrons would you need to balance the charge? What if there were three electrons and two protons? What would be the total charge of the particle?
- **Lightning, thunder and the speed of sound.** We count seconds between the lightning flash and the thunder, then divide by 5 to get the distance in miles. Why?
- **Measures of central tendency** (mean, median, mode) and range.
- **More on base ten and exponents:** The Powers of Ten and the scale of the universe. Scientific notation. It's inconvenient to write out all those zeros. We need a shorthand way to do it. Tie this to something concrete like the distance to the moon, size of the earth, the size of an atom.
- **Rates and ratios**. Miles per hour, dollars you earn per hour = pay rate. How fast are you accumulating something?
- **What is a formula?** People have figured out how to measure certain things like volume, area, velocity, etc. A formula tells you how to calculate the amounts. Tie to concrete things like how much carpet/linoleum to buy for your floor, how much wallpaper for a room. Give students practice using formulas after they have used other strategies for problem-solving. Formula practice could also include:
    - **velocity = distance / time**
    - **force = mass x acceleration**
- **Balancing chemical equations**—how can you get the same amount on each side?
- **How many calories do we consume in a day?** How many grams of fat? Milligrams of sodium and cholesterol? What percent of our daily recommended values are we getting?
- **Population density.** The population and land area of New York State vs. Wyoming, for example.

Resources for Teaching Science

Online Resources

The following materials have been helpful to us as we plan science curriculum for our classrooms. We live in a wonderful era where there is a wealth of information available with a few keystrokes, but it is often hard to know where to start. CollectEdNY.org responds to this problem by curating and reviewing free educational materials appropriate for adult students. Visit the site to receive email updates.

CollectEdNY: http://www.collectedny.org/techscience/
A collection of web links, including videos and supplementary information, related to the CUNY HSE Science Curriculum Framework.

ACS Matter Lesson Set: http://www.middleschoolchemistry.com/lessonplans
The American Chemical Society has an extensive lesson set on matter, including readings that would be appropriate for pre-HSE and HSE classes.

Reactions in Chemistry: http://nsdl.oercommons.org/courses/reactions-in-chemistry
An eight-part workshop for the professional development of high school chemistry and physical science teachers. The workshop blends chemistry content, history, and technological applications with a range of classroom lessons to provide teachers with updated knowledge and new approa ches to pedagogy.

Crash Course Videos: https://www.youtube.com/user/crashcourse
Crash Course provides fun, quirky videos on chemistry, history, psychology, etc. The videos are an entertaining introduction into a full college semester on different topics. The series on chemistry, biology, and psychology, for example, each have 40 or more videos. They are professionally produced and move quickly through topics in a dynamic way. The videos include a combination of the history of science (Einstein proved that atoms exist by modeling the mathematics that explained Brownian motion, for example) and explanations of the basic science (atoms are defined by the number of protons), illustrated through goofy animations.

Veritasium: https://www.youtube.com/1veritasium
Veritasium is a YouTube channel of science videos, focused mainly on physics, created by the charismatic Dr. Derek Muller. There are more than 200 engaging and visual videos, with more being added all the time. One of the things I really like about the Veritasium videos is the way they focus on drawing out and breaking down common misconceptions about science and how the physical world works.

SciShow: https://www.youtube.com/scishow
Scishow is a series of videos that covers a range of science topics in an interesting way. Titles include "When You Burn Fat, Where Does it Go?" "Why Sex?" etc. The science covered is in depth. When viewers watch "Why We Love Sugar," for instance, they will be exposed to an explanation of photosynthesis and the different sorts of sugar molecules that figure so prominently in life on earth—fructose, sucrose, glucose, and more.

Statistics for Action: http://sfa.terc.edu/
Statistics for Action aims to help adults understand how to read and interpret data, and shares resources with which to do that in a classroom or community setting. The site is focused primarily on data about environmental issues, air pollution, toxins in our drinking water or soil, chemicals in our food.

Science Net Links: http://www.sciencenetlinks.com/
This comprehensive site for teachers is set up for K-12 teaching but includes many resources that are appropriate for the adult classroom. The site is divided into the following sections: lesson plans, tools, afterschool, videos, and career development.

College Transition Webinar: Focus on Science: http://www.collegetransition.org/resources.webinars.scienceseries.html
This recorded webinar features adult educators talking about their experience teaching science and working with adult educators. The webinar provides a tour of free, high quality science teaching and learning resources available on the Internet.

LINCS Science Listserv: https://community.lincs.ed.gov/group/science
This online group explores teaching of science in adult literacy, sharing information, research, and resources. Participants also explore adult education's role in STEM career pathways. Sign up to receive email updates and participate in discussion about teaching science.

Science Texts

We should also remember that there are still many reasons why we should turn to textbooks and introductory readers before looking searching the Internet for content. Much of the readings on science topics available on the Internet are too advanced for our students. We have found that introductory science texts written for elementary and middle school classrooms can be helpful as a way for us as teachers to gain content knowledge. The texts themselves can be useful as an introduction to new material for our students as well.

TEXTS FOR THE CLASSROOM

***Science Concepts* (series), by Alvin Silverstein, Virginia Silverstein, and Laura Silverstein Nunn (Lerner Books)–**Matter, Cells, Food Chains, Forces, and Motion, for example.

***Prentice Hall Science Explorer* (Pearson)**

***Life Science & Physical Science* books (McDougal Littell)**

BOOKS FOR CLASS OR INDEPENDENT STUDENT READING

***Weather and Climate* by Alvin Silverstein, Virginia Silverstein, and Laura Silverstein Nunn**
Every day, billions of people all over the world make plans according to the weather–what to wear, when to hold outdoor activities, whether to prepare for dangerous storms. You'll learn much about our planet and its weather by reading this book. Did you know that the wind makes the weather? Do you know what the jet stream is, and how it was discovered? What is air pressure? Why do your ears pop when you ascend and descend in an airplane. When it is more likely to rain or snow, when clouds are low in the sky or high? You'll never take the weather for granted again after reading this book!

***Climate Change* by Barnaby Newbolt**
Climate change is an issue that affects all of us. This book will help you understand this very important issue. Clear explanations, illustrations, and photographs will help you understand how earth's climate system works, what causes climate change, and what the effects will be. A helpful glossary at the back will help you with words that you don't know.

***What's Science All About?* by Alex Frith, Hazel Maskell, Dr. Lisa Jane Gillespie and Kate Davies**
Have you ever wondered what fire is? Or why things fall to the ground? Or what's alive and what's not? Scientists have asked all these questions and many, many others too. They've found the answers using science–way of learning about world by watching, coming up with ideas and testing them. And there's still lots left to learn.

***What's Physics All About?* by Kate Davies**
If you ever thought the idea of YOU learning PHYSICS was crazy, then this is the book for you. With clear explanations and helpful illustrations, this book will help you understand a wide range of physics topics. You'll learn about speed, motion, and mass; about forces like gravity and pressure–electricity, heat, light, and sound–it's all here! While you read, you will learn the answers to questions that may have occurred to you from time to time. For instance, why is it harder to stop something heavier that is moving fast than something lighter?

***What's Chemistry All About?* By Alex Frith and Dr. Lisa Jane Gillespie**
After you read this book, you will know a lot about chemistry and the way the universe is put together. And you probably will have enjoyed yourself too. Why? This book is not like any other science textbook you may have read. There are subtitles and colorful drawings to illustrate the concepts. More important, the concepts are explained in a clear, easy-to-understand way. Read on and learn what atoms are and how they are structured, how elements make up everything that exists, how chemical reactions take place, and much much more.

***Nitrogen* by John Farndon, from the Elements**
Everything in the universe is made of elements. This series looks at the most important chemical elements and explains where they can be found, how they were discovered, their special characteristics and reactions, and their importance in the body and everyday life. Understanding how the elements behave is the key to understanding chemistry. The Elements provides a fascinating and fact-filled introduction to this important subject.

***Genetics: From DNA to Designer Dog*s by Kathleen Simpson**
The secrets of life are unraveling at a feverish pace in laboratories and research sites the world over. Geneticists are using DNA to solve ancient mysteries, fight pollution, solve crime, save endangered species, feed the world's hungry, cure disease, and learn how aging works. Author Kathleen Simpson introduces us to the men and women whose imaginations and expertise are making history as they reach out to meet the demands of the future. Their work affects all of us on a daily basis, from new "designer" dogs to the food we purchase at the supermarket.

CONTENT KNOWLEDGE FOR TEACHERS

***Six Easy Pieces: Essentials of Physics Explained by Its Most Brilliant Teacher,* by Richard P. Feynman**

***Chemistry for Everyone*, by Suzanne Lahl (Tuxedo Publishing)**

***General Chemistry 1 As a Second Language,* by David M. Klein**

***Chemistry, A Self-Teaching Guide* (Wiley)**

PEDAGOGY

***The Having of Wonderful Ideas and Other Essays on Teaching and Learning,* Eleanor Duckworth (Teachers College Press)**