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Micro Life in a Macro World: Understanding Life at the Microscopic Scale and the Spread of Disease

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Background

In *Micro Life in a Macro World*, ten to thirteen year old students learn how invisible creatures affect our lives. Students are introduced to the building blocks of matter and the states in which it exists. Atoms and their parts, the elements, and molecules are covered. Units of measure at the microscopic level are explored to help students understand that tiny things vary greatly in size. Abiotic and biotic matter and the Kingdoms of Living Things are studied. Cells, cell types, organelles and their functions, and DNA are analyzed. Students learn about microbes and how they live and proliferate. Bacterial disease is contrasted with non-bacterial disease, such as genetic disorders. Treatment for illness is addressed. Viruses and their traits are investigated. Human behaviors that promote or inhibit the spread of disease are identified. Students conduct and present research on careers in science related to any segment of the unit.

My goal for this unit is to impact the future by giving accurate and clear information to children so that they can comprehend fundamental processes of the natural world. Building upon a solid foundation, they will advance in the sciences and never say that they "aren't the science type." I want children to know that they are all scientists and innumerable well-paying and interesting jobs in scientific fields exist so they can begin considering career choices, which will make all our lives better. Elementary school teachers often underestimate what children can understand when taught appropriately. Accurate information of nature (Greek φύση, phusika, physics 'nature') is the foundation of knowledge.

Pittsburgh Public Schools curriculum introduces fifth grade students to Life Sciences in the first months of the school year. Students learn about cells, but the curriculum is flat with a lots of content information and few applications to make the information meaningful. Intrinsically interesting material is presented in a dull fashion which lacks connections to other science disciplines and applications of science. This unit creates a context for studying cells with a realistic investigation into interrelated aspects life science and physical science by examining the physical structure and different types of microscopic life. Lessons will be tiered to facilitate multiple entry points into the learning and scaffolded to support students who lack background knowledge and those who need multiple iterations to ensure learning, as well as students who enjoy extending their learning beyond the essential concepts. The Disciplinary Core detailed in Next Generation Science Standards is referenced throughout the unit.

These goals are particularly important at my school, Pittsburgh Colfax K-8, because of our unusual demographics. About a third of our students are “identified as gifted,” many of whom have parents working at Carnegie Mellon University, University of Pittsburgh, other colleges, as well as the numerous Pittsburgh hospitals and research facilities. About another third of our students are English Language Learners, often the children of Ph.D. students and visiting professors and doctors. The home languages are diverse, including Chinese, Japanese, Dutch, French, Spanish, and Portuguese. Additionally, more than a quarter of our students are economically disadvantaged and have not had access to the knowledge and resources of the more affluent children. These demographics underscore the importance of making scientific learning accessible so that all students can pursue scientific endeavors in the future.

Matter: What Everything Is Made of

The “stuff” that the physical world is made of is called *matter*. The word matter is used in science to refer to physical substances in general. Matter occupies space (volume) and has mass, especially as distinct from energy. The opposite of matter is space or *void*. Matter is not things like mind, spirit or energy. We use our five senses to understand matter, particularly sight and touch.

When we learn about matter, we must talk about *kinetic energy* and volume. Kinetic energy is manifested in the motion of an object. Changes in energy cause changes in states of matter. Volume, or how much space something takes up, is important because similar “amounts” of matter take up different volumes.

The term *particle* is useful when learning about matter. Particle is used as a generic, non-exact word for any thing. Grains of sand, dust, and salt can all be called particles, as can cookie crumbs or the rainbow jimmies on ice-cream. In science, particles can refer to cells, molecules, atoms (and the parts that they are made of), as well as subatomic particles like neutrinos and quarks. We cannot see with our unaided eyes the extremely tiny bits that everything is made of. They are *microscopic*. Micro- comes from a Greek word mīkrós, which means little, small, short and/or insignificant. The symbol for micro is µ. A scope (-scopic) is a lens that helps our eyes see something better. Microscopes let us see things that are extremely tiny.

Atoms

All matter is composed of extremely tiny particles called *atoms* (Greek: ἄτομο, “unable to cut”). Atoms are the most basic building blocks of all the matter in the universe. Most of an atom is void (empty space) but they are constructed of even smaller particles called protons, neutrons, and electrons. The center of the atom is the densest part, the *nucleus,* where the protons and neutrons are. Protons have a positive charge and neutrons are neutral. These two parts are held together by a force called the nuclear force (aka the strong force). The nuclear force is the strongest of the four fundamental forces (the others are gravity, electromagnetism, and the weak force) but it can only act over very short distances. Nuclear energy gets released when the nucleus is either split apart (fission) or collapsed together (fusion). If a nucleus could be enlarged a billion times, it would be about the size of a grapefruit.

The electrons in atoms are extremely interesting for many reasons. Electrons are much smaller than the particles in the nucleus. They are negatively charged which causes them to be attracted to the protons in the nucleus. They hover around outside of the nucleus and the attraction between their negative charge to the positive change of protons holds the atom together as a distinct particle. If the nucleus was the size of a golf ball, the electrons would be between one-half and six miles away from it.

Atoms can have different numbers of protons, neutrons, and electrons. The atom types based on these numbers are called *elements*. All the elements that we know are itemized on the *Periodic Table* which is organized by how many protons they have in their nucleus from the least, Hydrogen (symbol, H protons: 1) to Oganesson (symbol, Og protons: 118). Scientists are always on the lookout for undiscovered elements and so the Periodic Table can expand as needed.

Atoms can exist in the pure, elemental state or they can combine with each other. When they do this, they form *molecules*. When atoms come together to form molecules, their properties (characteristics) change. For example, when two Hydrogen atoms join an Oxygen, they make water. Before joining each other, Hydrogen and Oxygen are gases, but together they form water, which we know as liquid, solid (ice), and gas (steam). There are innumerable combinations of atoms which form molecules. No matter what their combination, matter exists in four states, solid, liquid, gas, and plasma.

Plasma

Plasma is the most unusual of the four states of matter. *Plasma* is a gas which has so much energy that some of the electrons in its atoms break free from, but travel with, their nucleus. Gases can become plasmas in several ways but all include the gas gaining energy. A spark in a gas can create a plasma. Plasmas are the most abundant state of matter in the universe because some of the most massive objects in the universe, our sun and most other stars, are made of it. While it is interesting, plasma is rare on Earth and is studied very little at the elementary school level.

Solid

The *solid* state of matter makes up the things that we can hold and touch, like bricks, furniture, iPads, and hamburgers. Particles in solids have a low amount of energy, but they are not still. Particles in solids wiggle and vibrate in place but do not easily change their location. Solids have a definite shape and a definite volume. Solids are typically easy to see and feel firm (hard, like a rock or soft, like a cotton ball), although solids can be malleable (squishy).

Liquid

Particles in the *liquid* state take the shape of their container (a solid). For example Sprite fills the bottom of a bottle, latex contains the water in a balloon, veins and arteries contain blood. If a liquids are not in a container, (spilled on the floor, table, etc.) they spread out. Particles in liquids have a much higher level of energy than particles in a solid. They slide around and move past each other. Liquids have a definite volume, i.e., take up a definite amount of space, but not a definite shape of their own like a solid. Liquids are typically easy to see and usually feel wet.

Gas

Gases are usually invisible to the naked eye. They sometimes can be detected through our sense of smell, though not always. The particles of a gas are high in energy which causes a high level of activity. Because of this, gas particles will spread out if not inside a (solid) container. Gases have neither a definite volume nor shape.

Scale: Measuring Microscopic Matter

A *scale* is a tool that humans have made to measure things. There are many different scales but they all measure physical traits, like distance, weight, and size. Scales have names which define the units (standardized smaller parts) used with that scale. Scales are very important for describing things clearly. For example, when a contractor is making a building, accurate measurements are need so the walls and doorways are straight. When baking cupcakes, careful measurements ensure the results are tasty and fluffy every time.

	Metric	Customary
Length	meter	inches feet yards miles
Weight/Mass	gram	ounces pounds tons
Volume	liter	teaspoon tablespoon ounces cups pints quarts gallons
Temperature	Celsius	Fahrenheit
Water Freezes	0°	32°
Water Boils	100°	212°

Table 1: The simplicity and logic of Metric units are contrasted with the subjectivity of the Customary system.

The units within a scale are fixed and discrete (inches, millimeters, miles, gallons). They are specific, measurable and inarguable. What is arguable is the quality of various scales. In the United States, we use "Customary Units" which have a more historical than scientific origin, while 96% of the rest of the world and all of the scientific community use the Metric System of measurement.

Customary Units are based on a very human scale. For example, an inch is based on the width of a man's thumb and the foot was based on the average length of a man's foot. These units of measure were convenient in their historical context but from a scientific perspective they are inefficient because they do not easily convert from one level of degree to another. The *Metric System* is much easier to use because it is based on units of 10 (deci-), 100 (centi-), 1000 (milli-/kilo-), etc. This makes it easy to convert from one level to another.

Table 5. SI prefixes

Factor	Name	Symbol	Factor	Name	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	µ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y

Table 2: Common prefixes, symbols and exponents of the Metric system

Microscopic particles are tiny but they still vary vastly in size. Exponents, also known as powers of ten, are way of writing very large (or tiny) numbers. Essentially, the exponent (little raised up number) tells you how many zeros come after the base number (ex. 10^{9} =10,000,000,000). Common measurement units at the microscopic level include the Angstrom (Å) micrometer, and nanometer. Angstrom equals one hundred-millionth of a centimeter, 10^{-10} meter, or 0.1 nanometer. The angstrom and multiples of it, the micron (104 Å) and the millimicron (10 Å), are also used to describe extremely small particles.

Biotic or Abiotic: What Does It Mean To Be Living?

Everything in our physical world is built out of matter. Some things in our world are living and some things are nonliving but all of them are made from matter, which itself is not living. Two important scientific words that mean living are *biotic* and *organic*. Biotic comes from the Greek biōtikós which means “pertaining to life” or bios, simply meaning life, hence biography is story of someone’s life, biology is the study of life. Organic comes from Latin organicus, "serving as an organ or instrument," and Greek órganon, implement, tool, bodily organ, akin to érgon work.

Non-living things can be called *abiotic* (a- “not” biotic/living) and *inorganic* (in- “not, opposite of” organic). Abiotic matter is abundant in the universe. All of the objects that we know of outside of earth, suns/stars, moons, planets, asteroids, and everything else are abiotic (no living things have yet been identified). This is a massive, incomprehensible amount of matter! The vast majority of matter on earth is abiotic: oceans of water, mountains of rock and dirt, and heaps of man-made goods (cell phones, airplanes, bottles, concrete).

Non-living things should not be confused with dead things. In fact a defining characteristic of a living thing is that it can die, however, even dead, it is still organic. This is because all organic matter contain particular chemical compounds which are carbon-based. Inorganic matter is not carbon-based. So even dead things that were once alive are considered organic. Abiotic things never were and never will be alive.

Living, biotic, things are rare in the universe, but common on Earth. Any living thing can be referred to as an *organism* (Greek ὄργανον "organ" and the –ism "process"', "state"). All organisms are made of atoms in different combinations of molecules. The atoms and molecules from which they are built are not what we consider living. Living things have special properties and characteristics that non-living things lack.

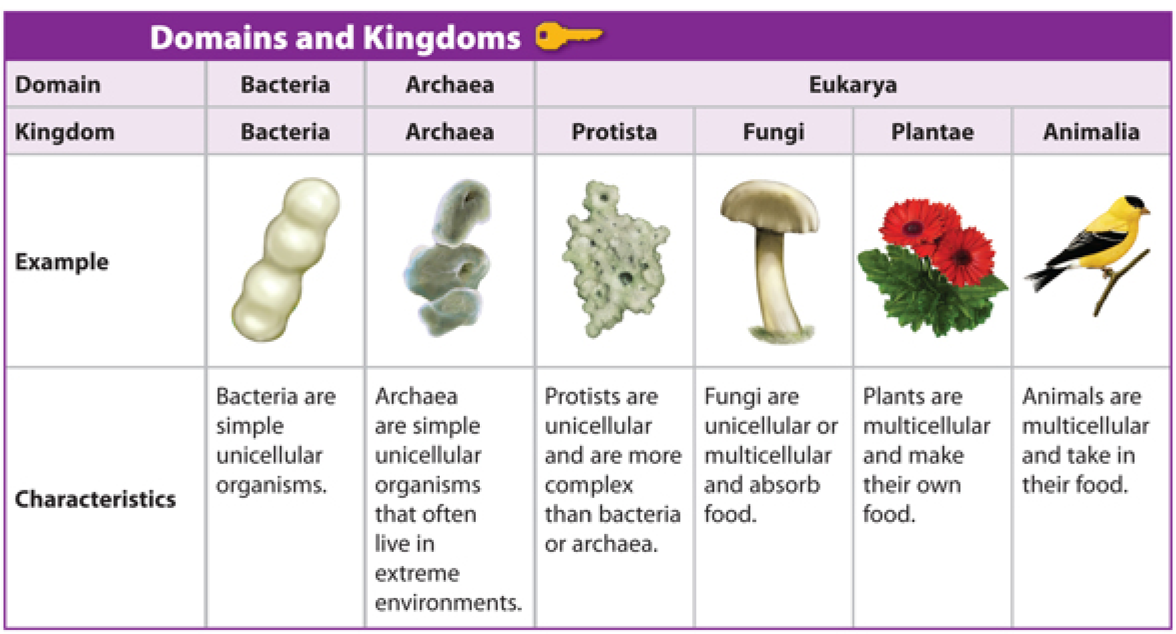
Life

So, what does it mean to be living? Physicist Erwin Schrodinger said, "The arrangement of the atoms in the most vital part of an organism differ in a fundamental way from all those arrangements of atoms which physicists and chemists have hitherto made the object of their experimental and theoretical research. The situation is unprecedented—it is unknown anywhere else except in living matter."[1]

First and most obviously, living things can die. Even creatures like lobsters and the Immortal Jellyfish (Turritopsis doohmii) which live for extremely long times, can be killed or die from disease. Main characteristics of life include the ability to reproduce, movement (which may happen internally or at the cell level), responding to the environment, i.e., avoid harm/death, maintaining homeostasis (keep their internal environment in balance, hydrated, right temperature, etc.) and passing traits on to offspring.

All organisms are built from a basic structural unit called a *cells*. There are single-celled organisms (amoebas, protozoa), simple multi-celled organisms (bacteria, algae), and complex organisms that are built from numerous systems of cell groups working together (trees, humans).

Kingdoms of Life



Domains and Kingdoms

Domain	Bacteria	Archaea	Eukarya			
Kingdom	Bacteria	Archaea	Protista	Fungi	Plantae	Animalia
Example						
Characteristics	Bacteria are simple unicellular organisms.	Archaea are simple unicellular organisms that often live in extreme environments.	Protists are unicellular and are more complex than bacteria or archaea.	Fungi are unicellular or multicellular and absorb food.	Plants are multicellular and make their own food.	Animals are multicellular and take in their food.

Figure 1: The Kingdoms of Living Organisms

Because smaller units and groupings of similar things are easier to study and understand, part of scientists' job is to classify and organize information. All living things have been categorized according to similarities in grouping called a *taxonomy* (from Greek taxis "arrangement" + -nomia "method") Aristotle (300c B.C.) divided the world into two kingdoms, plant and animal. Later, German biologist Earnst Haeckel (1866) added Protists, single celled organisms. In 1969, R. H. Whittaker added Fungi. Carolus Linnaeus is widely recognized for his *Systema Naturae* (1735) which established the animal, vegetable and mineral kingdoms. Scientists currently recognize six kingdoms. Listed from most complex to least complex, these kingdoms are Animals, Plants, Fungi, Protists (mostly single celled organisms), Eubacteria (all are single-celled), and Archaebacteia.

Animals are multicellular organisms that consume organic matter for energy. They can move independently for at least part of their life cycle and have thin cell membranes. The Kingdom Animalia includes mammals, birds, insects, reptiles and arthropods.

Plants have rigid cell walls stiffened by cellulose and do not move independently. Chlorophyll in their cells creates energy from sunlight and carbon dioxide. Plants include trees, bushes, grasses, ferns and green algae.

Fungi, like plants, have stiff cell walls and do not move independently. Like ferns, they reproduce through spores but they differ from plants because, like animals, fungi consume external organic matter for energy, and have no chlorophyll and no cellulose. Mushrooms, yeasts and molds are members of the Kingdom Fungi.

Protists have only one cell or are cell colonies that do not form differentiated tissues. These cells contain a nucleus and organelles. Protozoa, red algae, slime molds and water molds are all Protists.

Eubacteria, also called Bacteria and Monera, are single-celled organisms that lack organized nuclei and rarely have organelles. Bacterial organisms are found everywhere on Earth from deep-sea hot springs to the human gut.

Archaebacteria, or Archaea, are single-celled organisms without a distinct nucleus or organelles. They resemble bacteria but have different genetic structures and metabolic processes. Archaebacteria were once thought to live only in extreme environments like sulfur springs but have been found all over the Earth. They are especially plentiful in plankton.

Microscopic Life

Cells

Just as atoms are the most basic building block of all matter, cells, which are built from molecules of atoms, are the most basic unit of a living thing, and they come in a vast variety. The average human body is made up of trillions upon trillions of over 200 different types of cells. Groups of cells that work together in an organism are called tissues. Groups of tissues make up organs (heart, liver) and the organs make up systems that serve a purpose for the organism (digesting food, circulating oxygen). Only biotic creatures have cells, incredible tiny cretures do so much amazing jobs, like busy little factories cranking out work according to set rules.

Because they are so tiny, there are far more single-celled organisms (bacteria, protists, etc.) than multicellular organisms, like gerbils or banana trees. In fact, microbes are the simplest and most successful organisms on the Earth. For tiny creatures, gravity has little influence, oxygen and nutrients simply pass in and out, and no complicated body systems are needed. Although there are more than 500,000 different kinds of single-celled orgnaisms, because they are so small we usually do not detect them with our unaided senses and are unaware of them.

All cells are either *prokaryotic* or *eukaryotic*. In the Kingdoms of Life, only archaeabacteia and bacteria have prokaryotic cells. This is because many of them are among the most ancient life forms. Prokaryotes (Greek: πρό- , pro- before, καρυό, karuon, nut or kernel) existed before nuclei evolved. Their structure is very simple with fewer and less organized internal structures than eukaryotic cells.

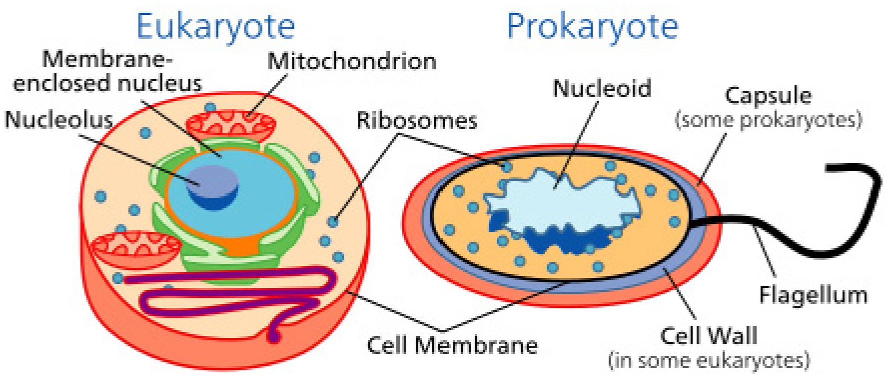


Figure 2: Structure of eukaryotic and prokaryotic. Note that eukaryotic cells often contain many more structures than those shown in this illustration.

Eukaryotic comes from the Greek ευ- "well, good, proper" and καρυό, karuon, (still meaning kernel), meaning that they have a well-formed, good or proper nugget inside them (nucleus). Eukaryotic cells have well defined parts, including *nuclei* (nucleus) and other internal structures called *organelles*.

While cells and atoms both have a nucleus, they are not the same structure! The meaning of nucleus from Latin is *nucula*, "little nut." Many things are referred to as nuclei, including the solid part of the head of a comet. A nucleus is a central, very important part of an object, the basis for it functioning. In atoms, the nucleus is protons and neutrons; in cells, it contains the organism's genetic material which determines the functioning of the cell.

Organelles

Within many cells are organelles (Latin: *organelle* or "little tool") that do many jobs. One can see that organ, organelle, and organism are related words. Plant, animal, fungi and microbes are built from cells which have some organelles in common and some differences.

A cell can be envisioned as a water balloon with filled with fruit cocktail jello instead of water. The balloon parallels the cell membrane, the jello is like the cytoplasm, and the fruit are the different organelles.

The surface of the *cell membrane* gives the cell shape and is covered with pores, channels and molecules which regulate the flow of food molecules into the cell and waste molecules out. *Cytoplasm* is a jelly-like substance which surrounds and protects the organelles. Movement can occur within cytoplasm. Cell membranes and cytoplasm are common to both prokaryotic and eukaryotic cells.

Within all eukaryotic cells there is a *nucleus* which contains the genetic material that directs the functioning of the organism. It contains chromosomes which are made up of the DNA and contains genes which determine the characteristics of an organism. We have around 24,000 genes. *Ribosomes* direct the production of proteins according to the information in the DNA*. Lysomes* make enzymes to dispose of cellular garbage while the *endoplasmic reticulum* moves molecules through the cell, builds proteins and disarms toxins. *Mitocondria* convert energy. Mitochondria within most eukaryotic cells comes from the mother's egg, as sperm contains no cytoplasm, hence no mitochondria. Mitochondrial DNA is being used to map patterns of migration of human ancestors.

Scientists believe that ancient life evolved with organelles initially being independent organisms which over long spans of time developed symbiotic relationships and eventually fused to form mutually beneficial cell systems.

Disease: How Microscopic Life Can Affect Me

Sometimes people talk about the awful times we are living in and "the good old days." A brief investigation into the history of disease reveals a different story. Fretting about politics is a luxury that was not entertained during the innumerable plagues which have beset our planet. Mind-boggling and ruthless maladies have swept through human civilizations for time immemorial. Natural selection caused us to evolve bodies which allow us to survive and thrive because they are adapted to our environment.

Natural selection is completely logical: creatures which do not survive do not reproduce. Dead things do not pass on their genes. And often they are dead for good reasons. For example, if you cannot outrun the saber toothed cat chasing you but your buddy can, it is beneficial to the species for you to get eaten and for your buddy to pass on his speedy genes to later generations so they too can outrun predators. Similarly, if your body is able to fight off diseases, it is beneficial to the species for you to reproduce and pass along your genetic material so that your offspring are more likely to be disease resistant. From the species level it is good for the diseased to die so their genetic weakness dies with them.

Worldwide, far more deaths have always been due to microbes than to any other cause. In the Kingdoms of Life Archebacteria are not known to cause illness in humans, and in fact some scientists think that they could hold a genetic key to curing disease due to their unique make-up. Protists (aka protozoa) cause many illnesses. They usually live in liquid water and are *parasitic* (live off another organism to the organisms detriment). Eubacteria cause a huge number of illnesses. Fungal diseases are fairly common and range from yeast infections to ringworm to some pneumonias. Plants can make you sick but this happens in a different way, usually by getting a harmful substance from it on our skin which causes a reaction, or by making us sick if we ingest it. Animals do not directly make us sick, but they do sometimes kill and eat us.

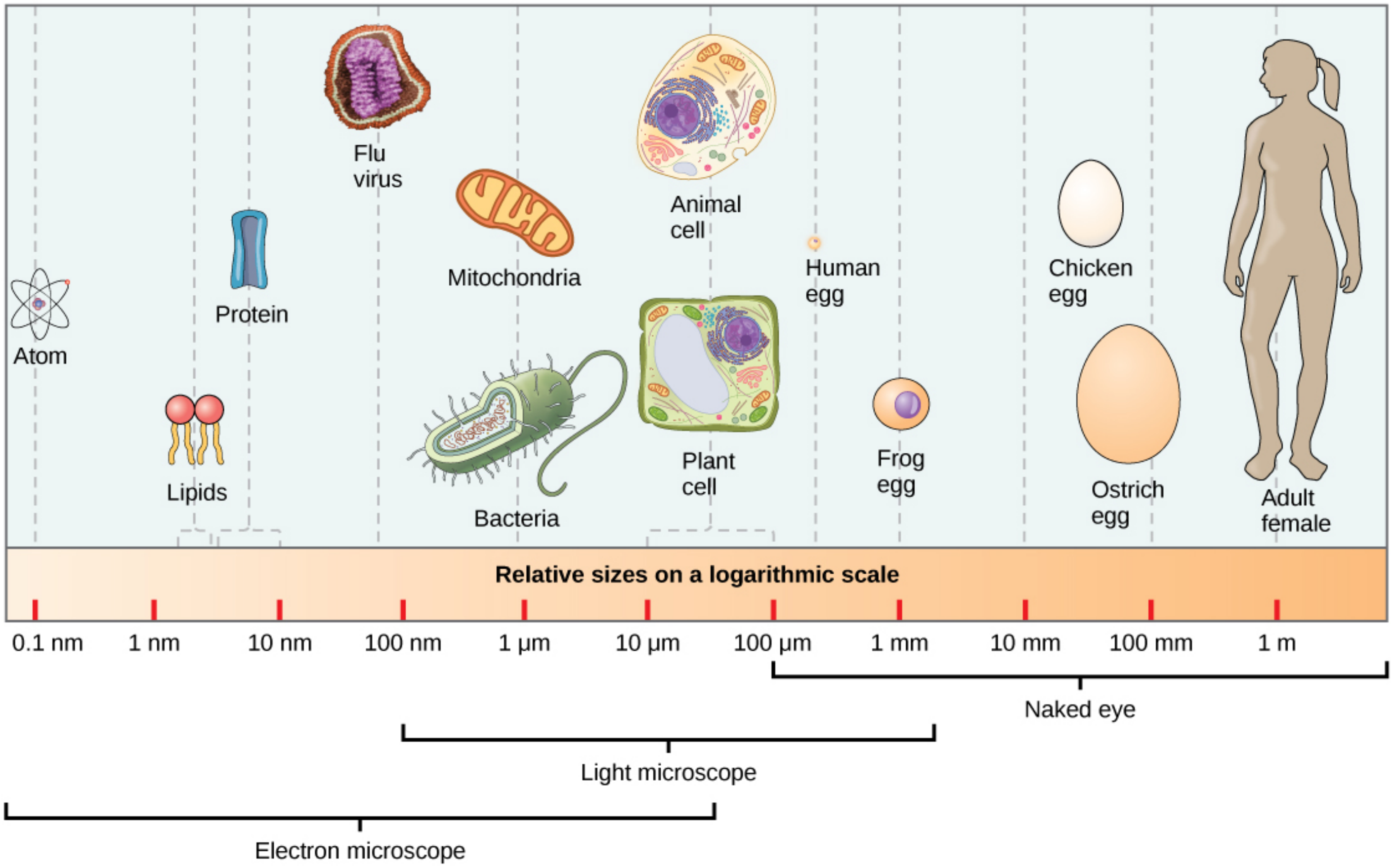


Figure 3: Sizes from atoms to humans are shown with their sizes listed below, along with technology needed to see them. Note that the items on the chart are not to scale, relative to each other.

Many microbes are harmless or even beneficial. There are trillions of microorganisms living inside of you right now which help you survive. In fact, you have about one kilo of them in your gut alone, in addition to the trillions covering the surface of your body.

Infection

Illness caused by microorganisms are called *infections* (from Latin inficere 'dip in, taint'). Infections are transmitted in different ways. The microorganism itself is often referred to as a *pathogen* (from Greek pathos "disease") or *germ*. The four major ways that germs are spread are via air, water, direct contact, or by a *vector* (organisms that do not cause the illness, but spread the germ from one host to another). Airborne illnesses cause one-half of all diseases when microscopic droplets are breathed, coughed, or sneezed into the air.

Some infections, called *zoonosis* (from zoo- "animal" and nosos "disease"), begin in animals then spread to humans. For example, colds originated in horses and measles came from dogs. Zymotics (arom Ancient Greek ζυμωτικός, zumōtikós, "causing fermentation") are diseases that are successful in crowds (herds). These diseases can sweep through a community and cause population crashes, as happens with plagues and epidemics. Estimates say that Bubonic Plague, which is 95% fatal, killed half of Europe which opened the way for invasion and conquest by Islam. In warm places parasites tend to proliferate, like protozoans and helminths (worms). Bacteria and viruses tend to thrive in cool places.

Parasites

Parasites are obviously unpleasant and can directly cause illnesses but often they are vectors which transfer the pathogen to an organism. This is how ticks cause Lyme disease, fleas from rats caused the Bubonic Plague, and mosquitos cause malaria. In West Africa, some individuals had the genes that caused sickle shaped red blood cells which effectively starved a specific form of malaria. While this adaptation allowed individuals to survive that specific disease, those genes also cause weakness, debility and early death, so while life-ending malaria is averted, life-shortening anemia remains in the form of Sickle Cell Anemia.

Our bodies have natural barriers to *pathogens.* This makes sense, since organisms which did not have protection from pathogens died before they could reproduce and pass on their DNA. That is the essence of Natural Selection. Creatures who are adapted to their environment live long enough to reproduce. Those which are poorly adapted to the environment get eaten by saber-tooth cats or succumb to diarrhea or something else.

Immune Systems

Lucky for us, in one wonderful adaptation, our bodies have evolved epithelial coverings which protect us from external pathogens in the environment. Our skin covers us on the outside and moist epithelia covers the internal tubes that make up our entire digestive tract and lungs. All body openings have specially adapted goo which catches microbes that could otherwise get inside of us and cause harm. Saliva in our mouths contain aggressive. Our eyes are coated with a wet surface and flaps of skin which are fringed and open and close, keeping debris out. Our noses are lined with hairs and slimy mucous which captures both physical particles and microbes. Our ear wax serves the same purpose. Sound comes into our ear canals and vibrates the ear drum which acts as a barrier between the outside world and the inside of our heads. Our skin provides a wonderful physical barrier holding some things in (like water) and keeps other things out (like bacteria). Our internal organ systems (digestive, respiratory, urinary, reproductive) have mucus coated surfaces to trap pathogens, as well as antimicrobial peptides and enzymes providing chemical defense against invaders. Matter which enters the body either gets distributed through various tubes, vessels and organs or passes out of the body (breath, sweat, urine, feces).

Additionally, natural selection has caused our bodies to evolve a dual immune system which monitors what goes on in the body and takes action when problems arise. The *innate system* is active in animals, plants and many classes of microorganisms. It consists of cells, called *macrophages*, and proteins that are always present and ready to fight infection. Macrophages are large cells that travel through body eating up invaders (which can be called *antigens*). When an antigen is detected, the macrophages send off chemical messages signaling that additional defenses are needed. This in turn activates the *adaptive immune system*, which “adapt” to the pathogen and create targeted antibodies to neutralize or eliminate the microbes by binding to antigens. Once these specialized antibodies have been produced, they stay in the body so that if the same pathogen is encountered, they destroy it before the person is made sick. The adaptive immune system is not present in plants or microbes, but only in vertebrates.

Viruses

This brings us to the fascinating little menace, the virus. Viruses are not alive, but in some ways, they seem like they are. They cannot be classified as living because they only reproduce within another cell and cannot metabolize on their own. They are generally much smaller than bacteria. When a virus succeeds, it penetrates into a cell, its protein shell dissolves, and it releases its own genetic material. This genetic material hijacks the cell’s synthetic machinery and forces the cell to produce viral proteins which will eventually infect other cells. Because viruses themselves are not alive and penetrate into the body’s natural cells, they can resist many artificial antibiotics (anti- “against”, biotic “life”),

Genetic Illness

In general, genetic illnesses cannot be prevented. Individuals may inherit certain genes which cause them to be more likely to have or develop particular diseases (for example, Huntington's disease, sickle cell disease, cystic fibrosis). Biomedical engineers and medical professionals are working hard to find treatments to help make the lives of individuals with genetic disorders more comfortable and seeking treatments and cures. Often, even if you do have the genes for a disease, it will not necessarily develop in you. There are many mysterious aspects of disease that are being studied and examined to try to understand why some people manifest genetic traits and others do not.

One treatment that is being developed is gene therapy which is hoped to cure or improve treatment of genetic disorders by replacing the mutated or malfunctioned gene, manipulating or turning off the gene causing the disease or stimulate other bodily functions to fight the disease. The most common method is replacement of a malfunctioning or missing gene with a healthy one.

Hygiene and Sanitation: How Humans Can Help Limit the Spread of Disease

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Living organisms have been in existence for an incredibly long time. Basic to understanding survival is realizing only organisms which live long enough to reproduce (aka, have babies, pass on their DNA) perpetuate subsequent generations that are like the parents. This is a very simple idea but a crucial one. It is the core of Natural Selection, also known as Survival of the Fittest. If a living thing dies or gets killed before it is of age to reproduce, it will not pass on its DNA. Its genotype dies with it, which is probably a good thing because it wasn’t doing very well in that environment anyway and its offspring would likely fare just as poorly.

Vaccinations

Fortunately for us, technological advances have vastly increased our length and quality of life. Vaccines that allow us to avoid deadly and debilitating illnesses like small pox, polio, and even the flu. Antibiotics hasten the end of infections and improvements in hygiene and waste treatment have minimized the proliferation of pathogens.

In 1796 the first vaccine was developed. A physician and scientist named Edward Jenner observed that milkmaids who had cowpox did not develop small pox. He experimented and found that when people were exposed to cowpox, which causes a much less severe disease in humans, they did not develop small pox. When you get a vaccination, a tiny bit of a neutralized pathogen enters the body and, even though it has been rendered harmless, your body still recognizes it as an invader that should not be there (antigen). The body’s natural immunes system is activated and antibodies are produced to attack the antigen. Once they achieve victory, these little soldiers continue to patrol the body so that they can react quickly if the enemy ever tries to invade again, which is why once vaccinated, the real antigen usually cannot harm you.

Jonas Salk developed a very important vaccination against a terrible disease called polio, which caused muscle weakness and could lead to paralysis here in Pittsburgh. In fact the first trials were held in room 102 here at Colfax School. Thanks to the Salk vaccine, polio, which used to be common, has been eradicated from much of the world.

Antibiotics

Penicillin was the first widely used antibiotic. Prior to its introduction, there were no effective treatments for infections. Discovered in 1928 by Alexander Fleming, Professor of Bacteriology in England, and originally called "mold juice", Fleming noticed that it was able to kill a wide range of harmful bacteria.[2] The use of antibiotics increased average life expectancy by eight years between 1945 and 1972.[3] Antibiotics are laboratory created medicines that aid in recovering from infections not due to genetics or viruses. Some of them are based on compounds found in nature and others are manmade. Antibiotics fight infections by interfering with the reproduction of harmful microbes or outright killing them by disrupting basic cellular processes like building of cell walls.

Sanitation

Louis Pasteur's work led to the end of the idea that life could spontaneously develop from abiotic matter. This led to the practice of pasteurization which kills harmful microbes that humans formerly ingested. As knowledge of microscopic life developed, so did the ability of humans to manipulate our environment in ways that limited the spread of pathogens. Pest controls are ready for hire. Improvements to sanitation has a leading role in the expanding life expectancies. Sewage with its innumerable contaminates, no longer commonly runs in the streets. Water is chlorinated. Pure food practices, pasteurization, and refrigeration have dramatically reduced food-borne illnesses.

Treatment of Simple Illness

Despite all of our magnificent adaptations and advances in sanitation, people get sick. Some sicknesses are caused from pathogens in the outside world and accidents, some illnesses are genetic, and some illnesses are a combination of genes and environment. There are things that can be done to ameliorate the consequences of sickness. The most common ways to treat minor illnesses is through cleanliness, staying home, keeping hydrated, and resting. Frequent hand washing and covering coughs and sneezes with the inner elbow helps minimize the spread of many illnesses. Hot showers and gargling with salt water help make the nose and throat feel better. If antibiotics are prescribed, it is vital that the entire course of medicine be taken to ensure that any infection is entirely killed off. If they are not entirely killed off, you have just trained the remaining survivors to be stronger. By artificial selection, through the antibiotics, you have just killed off the weaker members of the infection and left the strong survivors to reproduce and pass along their hardy genes to subsequent generations. This is how antibiotic resistance is created.

So next time your hear someone fretting about politics, terrorism, and the deterioration of mankind, remember, if you're old enough to be worried, you're not dead and you very well may have the opportunity to pass along your wonderful genes.

Teaching Strategies

Opportunities for students to use the Next Generation Science Standards (NGSS) Eight Practices of Science and Engineering are intrinsic to teaching the unit, especially asking and defining problems, developing and using models, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations, engaging in argument from evidence, and obtaining, evaluating, and communicating information. We will also focus on several of the NGSS Crosscutting Concepts, patterns, cause and effect, scale, proportion, and quantity, systems and system models, structure and function and stability and change of systems. Implementation of the Principles of Learning are foundational to pedagogical practices. These include organizing for effort, clear expectations, fair and credible evaluations, recognition of accomplishment, academic rigor in a thinking curriculum, Accountable Talk® practices, socializing intelligence, self-management of learning, and learning as apprenticeship.

Lessons are designed in the Workshop Model with an Opening, Work-Time and Closing. Students enact classroom responsibility through defined class jobs (Lead Scientist, Chief Investigator, Recorder/Statistician, Project Manager) and maintenance of student notebooks. allow for ongoing formative assessment. Teacher-created rubrics for assignments keep expectations and criteria clear.

Classroom Activities

Sample Lesson 1

Learning Objectives: identify and describe four types of matter and their properties

Opening: QuickWrite in Science Notebook

What is everything made of?

- Write
- Table groups share responses
- Share out
- Chart answers

Work Time: Exploration of the 3 states of water: liquid, solid and vapor.

- Fill sets of 3 balloons to the same size (one set per table group), one with water and frozen, one with liquid water, one with breath.
- Use a mirror to demonstrate that our breath contains water vapor; the steam seen when breathing outside in cold weather or on the bathroom mirror shows the water vapor in one's breath.
- Have table groups carefully handle and explore the 3 balloons.

Closing: Exit Ticket in Science Notebook

Students make the chart below in science notebooks. Record observations.

Solid Liquid Gas

Observations:
What do you see, hear, and feel?

- Class discussion
- Chart insightful responses

Sample Lesson 2

Learning Objectives: identify and explain the properties of abiotic and biotic matter

Opening: QuickWrite in Science Notebook

What does it mean to be living?

- Write
- Table groups share responses
- Share out
- Chart answers

Work Time: Introduce terms abiotic and biotic

- Give each table group an assortment of small items (sticks, leaves, paperclips, pebbles, legos, mushrooms, fruit, pictures of animals, etc.).
- Students sort the items into an Abiotic Group and a Biotic Group.

Closing: In Science Notebooks students answer the question, How can you tell the difference between living and nonliving things?

- Class discussion
- Chart insightful responses

Sample Lesson 3

Learning objective: demonstrate how human behavior influences the spread of bacteria

Opening: QuickWrite in Science Notebook

How can humans help limit the spread of illness?

- Write
- Table groups share responses
- Share out
- Chart answers

Work Time: Use Glo Germ Gel© and a blacklight (available on Amazon) to demonstrate the effort needed to eliminate bacteria when washing food.

- Show how bacteria spreads by cross-contamination by using an unwashed head of lettuce and Glo Germ™ powder to thoroughly coat the lettuce in 'germs,'' between the leaves and on the outside.

Spread the powder around and show students the lettuce and your hands with a blacklight.

- Tear the lettuce apart then rinse the pieces as you would when making a salad. Towel dry the lettuce and put in a bowl.

Use the blacklight to explore the salad and the area where you made it. Little spots of glowing germs will be all over the objects you used to make the salad. Not only is it important to wash your hands, it is important to wash fruits and vegetables carefully. Throw away the lettuce after the demonstration and clean the entire area thoroughly with soap and warm water.

Closing: Exit Ticket in Science Notebook

What have you learned about getting things clean?

- Class discussion
- Chart insightful responses

Sample Lesson 4

Culminating Research Assignment: Conduct research on careers related to any of the areas of science addressed throughout the lessons and develop a way to present career options to the class

Teacher-created Rubric and timeline for research will be provided.

Presentation Options:

- Poster
- Info graphic
- Detailed tattoo design
- Comic Strip: A day in the life of a…
- PowerPoint
- Written essay
- Speech

Activity: Students present their research to the class. While they are presenting, classmates record the name of the career and take notes.

Closing: Class discussion of the careers they learned about, which careers sound most interesting to them, and why.

Resources

The Scale of the Universe 2. Accessed August 04, 2017. http://www.htwins.net/scale2/.

A beautifully animated website, powers of ten are visually demonstrated through zooming in and out, from string level to the universe.

"Academic Standards for Science and Technology and ..." Accessed August 4, 2017. http://www.bing.com/cr?IG=B3293D947B8C47B8BFD578FB8B7FBE0D&CID=292F473301006EDF3B424DE700066F5A&rd=1&h=qgU55I4mFVVWkIkwvnPG4UGTU6AEto7iCkb5siGOuD0&v=1&r=http%3a%2f%2fstatic.pdesas.org%2fcontent%2fdocuments%2fAcademic_Standards_for_Science_and_Technology_and_Engineering_Education_(Secondary).pdf&p=DevEx,5062.1.

Allen, Terence, and Graham Cowling. *The Cell: a Very Short Introduction*. Oxford: OUP Oxford, 2011.

This slim volume thoroughly details all aspects of cells, their component parts, and mechanisms.

"American Chemical Society." American Chemical Society. Accessed August 04, 2017. https://www.acs.org/.

Crick, Francis. *Of molecules and men*. Amherst, NY: Prometheus Books, 2004.

This investigation into the ordered complexity of living thing observes that, "not all highly ordered, complex objects are biological, but those that aren't are man-made." Minimum requirements for and historical origins of life are explored. Biotonic phenomena are outlined. The development of cells, their components, and processes are described.

Framework for K-12 Science Education. Natl Academy Pr, 2011.

The new "bible" for science educators, this text outlines detailed information of what scientific ideas children should learn at each grade level.

Karlen, Arno. *Man and microbes: disease and plagues in history and modern times*. New York ...: Simon & Schuster, 1996.

A fascinating read, "This book is about new plagues, survival, and the dance of adaptation we carry on with our microbial fellow travelers." The history and variety of microbial diseases are thoroughly and clearly analyzed.

"Kingdom Classification of Living Organism." Biology Discussion. August 27, 2015. Accessed August 04, 2017. http://www.biologydiscussion.com/biology/kingdom-classification-of-living-organism/.

"Online Etymology Dictionary." Online Etymology Dictionary. Accessed August 04, 2017. http://www.etymonline.com/.

"PA.Gov." State Board of Education. Accessed August 04, 2017. http://www.stateboard.education.pa.gov/.

Phelan, Jay. *What is life? a guide to biology*. New York, NY: W H Freeman, 2015.

This beautifully illustrated biology textbook provides detailed, accessible and extensive information on the basic aspects of biological sciences.

Regis, Edward. *What is life? investigating the nature of life in the age of synthetic biology*. Oxford: Oxford Univ. Pr., 2009.

This reader-friendly texts reflects back on Schrödinger's 1944 book of the same title. Regis comments on Schrödinger's observations then extends and expands upon his work, adding scientific developments subsequent to that work.

Saltzman, W. Mark. *Biomedical engineering: bridging medicine and technology*. Cambridge: Cambridge University Press, 2016.

This thorough and complex text provides detailed information on all aspects of biomedical engineering and its impact on human health

Schrödinger, Erwin. *What is life?* Cambridge U.P.: n.p., 1992. Print.

A seminal book based on a series of lectures first delivered in Ireland in 1943, the author endeavored to explain life purely in terms of physics and chemistry, investigating the quantum –mechanical explanations for life and the second law of thermodynamics. The text provide foundational evidence that was profound at the time of publication, however Schrödinger's scientific credibility deteriorated with the 50th anniversary prologue in which he stated, "The only possible inference from these two facts is...that I—in the widest meaning of the word…--am the person who, if any, controls the 'motion of the atoms.'…Hence I am God Almighty…"

Society, Microbiology. "Homepage." Homepage | Microbiology Society. Accessed August 04, 2017. https://www.microbiologysociety.org/.

Appendix

Disciplinary Core Ideas in the Next Generation Science Standards (NGSS)

LS: Life Science

LS1: From Molecules to Organisms: Structures and Processes

LS1.A: Structure and Function

LS1.B: Growth and Development of Organisms

LS3: Heredity: Inheritance and Variation of Traits

LS3A Inheritance of Traits

LS.B: Variation of Traits

LS4: Biological Evolution: Unity and Diversity

LS4.A: Evidence of Common Ancestry & Diversity

LS4.B Natural Selection

LS4.C Adaptation

LS4.D: Biodiversity & Humans

PS: Physical Science

PS1: Matter and Its Interactions

PS1.A: Structure and Properties of Matter

PS1.B Chemical Reactions

ESS: Earth & Space Science

ESS1.C: The History of Planet Earth

PA Academic Standards for Science and Technology

3.3 Biological Sciences

3.3.A Living Forms

3.3.4.A Know the similarities and differences of living things.

3.3.7.A. Describe the similarities and differences that characterize diverse living things.

3.3.10.A. Explain the structural and functional similarities and differences found among living things.

3.3.B Structure and Function

3.3.4.B. Know that living things are made up of parts that have specific functions.

3.3.7.B. Describe the cell as the basic structural and functional unit of living things.

3.3.10.B. Describe and explain the chemical and structural basis of living organisms.

3.3.C Inheritance

3.3.4.C. Know that characteristics are inherited and, thus, offspring closely resemble their parents.

3.3.7.C. Know that every organism has a set of genetic instructions that determines its inherited traits.

3.3.10.C. Describe how genetic information is inherited and expressed.

Endnotes

1. Schrödinger, Erwin. *What is life?* Cambridge U.P.: n.p., 1992. Print.
2. https://www.acs.org
3. https://www.microbiologysociety.org