DOMAIN I. SCIENTIFIC INQUIRY AND PROCESSES

Competency 001 The teacher understands how to select and manage learning activities to ensure the safety of all students and the correct use and care of organisms, natural resources, materials, equipment, and technologies.

Laboratory safety procedures

All science labs should contain the following **safety equipment**.

-Fire blanket that is visible and accessible.
-Ground Fault Circuit Interrupters (GFCI) within two feet of water supplies
-Signs designating room exits.
-Emergency shower providing a continuous flow of water.
-Emergency eye wash station that can be activated by the foot or forearm.
-Eye protection for every student.
-A means of sanitizing equipment.
-Emergency exhaust fans providing ventilation to the outside of the building.
-Master cut-off switches for gas, electric, and compressed air. Switches must have permanently attached handles. Cut-off switches must be clearly labeled.
-An ABC fire extinguisher.
-Storage cabinets for flammable materials.
-Chemical spill control kit.
-Fume hood with a motor that is spark proof.
-Protective laboratory aprons made of flame retardant material.
-Signs that will alert of potential hazardous conditions.
-Labeled containers for broken glassware, flammables, corrosives, and waste.

Students should wear safety goggles when performing dissections, heating, or while using acids and bases. Hair should always be tied back and objects should never be placed in the mouth. Food should not be consumed while in the laboratory. Hands should always be washed before and after laboratory experiments. In case of an accident, eye washes and showers should be used for eye contamination or a chemical spill that covers the student's body. Small chemical spills should only be contained and cleaned by the teacher.

Kitty litter or a chemical spill kit should be used to clean a spill. For large spills, the school administration and the local fire department should be notified. Biological spills should only be handled by the teacher. Contamination with biological waste can be cleaned by using bleach when appropriate. Accidents and injuries should always be reported to the school administration and local health facilities. The severity of the accident or injury will determine the course of action.

It is the responsibility of the teacher to provide a safe environment for his or her students. Proper supervision greatly reduces the risk of injury and a teacher should never leave a class for any reason without providing alternate supervision. After an accident, two factors are considered, **foreseeability** and **negligence**. Foreseeability is the anticipation that an event may occur under certain circumstances. Negligence is the failure to exercise ordinary or reasonable care. Safety procedures should be a part of the science curriculum and a well managed classroom is important to avoid potential lawsuits.

Storing, identifying, and disposing of chemicals and biological materials

All laboratory solutions should be prepared as directed in the lab manual. Care should be taken to avoid contamination. All glassware should be rinsed thoroughly with distilled water before using and cleaned well after use. All solutions should be made with distilled water as tap water contains dissolved particles that may affect the results of an experiment. Unused solutions should be disposed of according to local disposal procedures.

The "Right to Know Law" covers science teachers who work with potentially hazardous chemicals. Briefly, the law states that employees must be informed of potentially toxic chemicals. An inventory must be made available if requested. The inventory must contain information about the hazards and properties of the chemicals. This inventory is to be checked against the "Substance List". Training must be provided on safe handling and interpretation of the Material Safety Data Sheet.

The following chemicals are potential carcinogens and not allowed in school facilities: Acrylonitriel, Arsenic compounds, Asbestos, Bensidine, Benzene, Cadmium compounds, Chloroform, Chromium compounds, Ethylene oxide, Ortho-toluidine, Nickle powder, and Mercury.

Chemicals should not be stored on bench tops or heat sources. They should be stored in groups based on their reactivity with one another and in protective storage cabinets. All containers within the lab must be labeled. Suspected and known carcinogens must be labeled as such and stored in trays to contain leaks and spills.

Chemical waste should be disposed of in properly labeled containers. Waste should be separated based on its reactivity with other chemicals.

Biological material should never be stored near food or water used for human consumption. All biological material should be appropriately labeled. All blood and body fluids should be put in a well-contained container with a secure lid to prevent leaking. All biological waste should be disposed of in biological hazardous waste bags.

Material safety data sheets (MSDS) are available for every chemical and biological substance. These are available directly from the distribution company and the internet. Before using lab equipment, all lab workers should read and understand the equipment manuals.

Use of live specimens

No dissections may be performed on living mammalian vertebrates or birds. Lower order life and invertebrates may be used. Biological experiments may be done with all animals except mammalian vertebrates or birds. No physiological harm may result to the animal. All animals housed and cared for in the school must be handled in a safe and humane manner. Animals are not to remain on school premises during extended vacations unless adequate care is provided. Any instructor who intentionally refuses to comply with the laws may be suspended or dismissed.

Pathogenic organisms must never be used for experimentation. Students should adhere to the following rules at all times when working with microorganisms to avoid accidental contamination:

1. Treat all microorganisms as if they were pathogenic.
2. Maintain sterile conditions at all times.

Dissection and alternatives to dissection

Animals which were not obtained from recognized sources should not be used. Decaying animals or those of unknown origin may harbor pathogens and/or parasites. Specimens should be rinsed before handling. Latex gloves are recommended. If not available, students with sores or scratches should be excused from the activity. Formaldehyde is likely carcinogenic and should be avoided or disposed of according to district regulations. Students objecting to dissections for moral reasons should be given an alternative assignment. Interactive dissections are available online or from software companies for those students who object to performing dissections. There should be no penalty for those students who refuse to physically perform a dissection.

Knowledge of appropriate use of laboratory materials

Light microscopes are commonly used in high school laboratory experiments. Total magnification is determined by multiplying the magnification of the ocular and the objective lenses. Oculars usually magnify 10X and objective lenses usually magnify 10X on low and 40X on high.

Procedures for the care and use of microscopes include:

- cleaning all lenses with lens paper only,
- carrying microscopes with two hands (one on the arm and one on the base),
- always beginning on low power when focus in before switching to high power,
- storing microscopes with the low power objective down,
- always using a coverslip when viewing wet mount slides, *and*
- bringing the objective down to its lowest position then focusing, moving up to avoid breaking the slide or scratching the lens.

Wet mount slides should be made by placing a drop of water on the specimen and then putting a glass coverslip on top of the drop of water. Dropping the coverslip at a forty-five degree angle will help avoid air bubbles.

Chromatography uses the principles of capillarity to separate substances such as plant pigments. Molecules of a larger size will move slower up the paper, whereas smaller molecules will move more quickly producing lines of pigment.

An **indicator** is any substance used to assist in the classification of another substance. An example of an indicator is litmus paper. Litmus paper is a way to measure whether a substance is acidic or basic. Blue litmus turns pink when an acid is placed on it and pink litmus turns blue when a base is placed on it. pH paper is a more accurate measure of pH, with the paper turning different colors depending on the pH value.

Spectrophotometry measures percent of light at different wavelengths absorbed and transmitted by a pigment solution.

Centrifugation involves spinning substances at a high speed. The more dense part of a solution will settle to the bottom of the test tube, where the lighter material will stay on top. Centrifugation is used to separate blood into blood cells and plasma, with the heavier blood cells settling to the bottom.

Electrophoresis uses electrical charges of molecules to separate them according to their size. The molecules, such as DNA or proteins are pulled through a gel towards either the positive end of the gel box (if the material has a negative charge) or the negative end of the gel box (if the material has a positive charge). DNA is negatively charged and moves towards the positive charge.

One of the most widely used genetic engineering techniques is the **polymerase chain reaction (PCR)**. PCR is a technique in which a piece of DNA can be amplified into billions of copies within a few hours. This process requires a primer to specify the segment to be copied, and an enzyme (usually taq polymerase) to amplify the DNA. PCR has allowed scientists to perform multiple procedures on small amounts of DNA.

The metric system

Science uses the **metric system** (or SI system), as it is accepted worldwide and allows easier comparison among experiments done by scientists around the world.

The meter is the basic metric unit of length. One meter is 1.1 yards. The liter is the basic metric unit of volume. 3.846 liters is 1 gallon. The gram is the basic metric unit of mass. 1000 grams is 2.2 pounds.

The following prefixes define multiples of the basic metric units.

deca- 10X the base unit	deci - 1/10 the base unit
hecto- 100X the base unit	centi - 1/100 the base unit
kilo- 1,000X the base unit	milli - 1/1,000 the base unit
mega- 1,000,000X the base unit	micro- 1/1,000,000 the base unit
giga- 1,000,000,000X the base unit	nano- 1/1,000,000,000 the base unit
tera- 1,000,000,000,000X the base unit	pico- 1/1,000,000,000,000 the base unit

Length is the distance from one point to another. The SI unit of length is the meter (m). 1000 meters make 1 kilometer (km).

Volume is the amount of space a substance occupies. The SI unit of volume is the liter (L). 1000 mL makes 1 liter.

Mass is the amount of matter in an object. The SI unit of mass is kilogram (kg). There are 1000 grams in a kilogram.

Time is the period between two events. In SI, time is measured in seconds.

Temperature is a measure of heat in something. The SI scale for measuring temperature is the Kelvin scale (K).In science, temperature is measured in Celsius because it is easier.

Appropriate measuring devices

The common instrument used for measuring volume is the graduated cylinder. The standard unit of measurement is milliliters (mL). To ensure accurate measurement, it is important to read the liquid in the cylinder at the bottom of the meniscus, the curved surface of the liquid.

The common instrument used in measuring mass is the triple beam balance. The triple beam balance can accurately measure tenths of a gram and can estimate hundredths of a gram.

The ruler and meter stick are the most commonly used instruments for measuring length. As with all scientific measurements, standard units of length are metric.

Competency 002 **The teacher understands the nature of science, the process of scientific inquiry, and the unifying concepts that are common to all sciences.**

Similarities among systems in math, science, and technology

Math, science, and technology share many common themes. All three use models, diagrams, and graphs to simplify a concept for analysis and interpretation. Patterns observed in these systems lead to predictions based on these observations. Another common theme among these three systems is equilibrium. **Equilibrium** is a state in which forces are balanced, resulting in stability. Static equilibrium is stability due to a lack of changes, and dynamic equilibrium is stability due to a balance between opposing forces.

Processes by which hypotheses are generated and tested

Science is a body of knowledge systematically derived from study, observations, and experimentation. Its goal is to identify and establish principles and theories that may be applied to solve problems. Pseudoscience, on the other hand, are beliefs that are not supported by hard evidence. In other words, there is no scientific methodology or application. Some classic examples of pseudoscience include witchcraft, alien encounters, or any topic explained by hearsay.

Scientific experimentation must be repeatable. Experimentation results in theories that can be disproved and changed. Science depends on communication, agreement, and disagreement among scientists. It is composed of theories, laws, and hypotheses.

Theory - A statement of principles or relationships relating to a natural event or phenomenon, which have been verified and accepted.

Law - An explanation of events that occur with uniformity under the same conditions (e.g., laws of nature, law of gravitation).

Hypothesis - An unproved theory or educated guess followed by research to best explain a phenomena. A theory is a proven hypothesis.

Science is limited by the available technology. An example of this would be the relationship between the discovery of the cell and the invention of the microscope. As our technology improves, more hypotheses will become theories and possibly laws. Data collection methods also limit scientific inquiry. Data may be interpreted differently on different occasions. Limitations of scientific methodology produce explanations that change as new technologies emerge.

The first step in scientific inquiry is posing a question. Next, a hypothesis is formed to provide a plausible explanation. An experiment is then proposed and performed to test this hypothesis. A comparison between the predicted and observed results is the next step. Conclusions are then formed and it is determined whether the hypothesis is correct or incorrect. If incorrect, the next step is to form a new hypothesis and repeat the process.

Methods or procedures for collecting data

The procedure used to obtain data is important to the outcome. Experiments consist of **controls** and **variables**. A control is the experiment run under normal, unmanipulated conditions.

A variable is a factor or condition the scientist manipulates. In biology, the variable may be light, temperature, pH, time, etc. Scientists can use the differences in tested variables to make predictions or form hypotheses. Only one variable should be tested at a time. In other words, one would not alter both the temperature and pH of the experimental subject.

An **independent variable** is one is the researcher directly changes or manipulates. This could be the amount of light given to a plant or the temperature at which bacteria is grown. The **dependent variable** is the factor that changes due to the influence of the independent variable.

Knowledge of appropriate and effective graphic representation of data

The type of graphic representation used to display observations depends on the type of data collected. **Line graphs** compare different sets of related data and help predict data. For example, a line graph could compare the rate of activity of different enzymes at varying temperatures. A **bar graph** or **histogram** compares different items and helps make comparisons based on the data. For example, a bar graph could compare the ages of children in a classroom. A **pie chart** is useful when organizing data as part of a whole. For example, a pie chart could display the percent of time students spend on various after school activities.

Knowledge of labeling graphs with independent and dependent variables

As previously noted, the researcher controls the independent variable. The independent variable is placed on the x-axis (horizontal axis). The dependent variable is influenced by the independent variable and is placed on the y-axis (vertical axis). It is important to choose the appropriate units for labeling the axes. It is best to divide the largest value to be plotted by the number of blocks on the graph, and round to the nearest whole number.

Competency 003 The teacher understands the history of science, how science impacts the daily lives of students, and how science interacts with and influences personal and societal decisions.

The impact of social factors on biological study

Society as a whole impacts biological research. The pressure from the majority of society has led to bans and restrictions on human cloning research. The United States government and the governments of many other countries have restricted human cloning. The U.S. legislature has banned the use of federal funds for the development of human cloning techniques. Some individual states have banned human cloning regardless of where the funds originate.

The demand for genetically modified crops by society and industry has steadily increased over the years. Genetic engineering in the agricultural field has led to improved crops for human use and consumption. Crops are genetically modified for increased growth and insect resistance because of the demand for larger and greater quantities of produce.

With advances in biotechnology come those in society who oppose it. Ethical questions come into play when discussing animal and human research. Does it need to be done? What are the effects on humans and animals? There are no absolute right or wrong answers to these questions. There are governmental agencies in place to regulate the use of humans and animals for research.

Science and technology are often referred to as a "double-edged sword". Although advances in medicine have greatly improved the quality and length of life, certain moral and ethical controversies have arisen. Unforeseen environmental problems may result from technological advances. Advances in science have led to an improved economy through biotechnology as applied to agriculture, yet it has put our health care system at risk and has caused the cost of medical care to skyrocket. Society depends on science, yet is necessary that the public be scientifically literate and informed in order to allow potentially unethical procedures to occur. Especially vulnerable are the areas of genetic research and fertility. It is important for science teachers to stay abreast of current research and to involve students in critical thinking and ethics whenever possible.

Competency 004 The teacher understands the structure and function of biomolecules.

Compare and contrast hydrogen, ionic, and covalent bonds

Chemical bonds form when atoms with incomplete valence shells share or completely transfer their valence electrons. There are three types of chemical bonds, covalent bonds, ionic bonds, and hydrogen bonds.

Covalent bonding is the sharing of a pair of valence electrons by two atoms. A simple example of this is two hydrogen atoms. Each hydrogen atom has one valence electron in its outer shell, therefore the two hydrogen atoms come together to share their electrons. Some atoms share two pairs of valence electrons, like two oxygen atoms. This is called a double covalent bond.

The attraction for the electrons of a covalent bond is called electronegativity. The greater the electronegativity of an atom, the more it pulls the shared electrons towards itself. Electronegativity of the atoms determines whether the bond is polar or nonpolar. In **nonpolar covalent bonds**, the electrons are shared equally, thus the electronegativity of the two atoms is the same. This type of bonding usually occurs between two of the same atoms. A **polar covalent bond** forms when different atoms join, as in hydrogen and oxygen to create water. In this case, oxygen is more electronegative than hydrogen so the oxygen pulls the hydrogen electrons toward itself.

Ionic bonds form when one electron is stripped away from its atom to join another atom. An example of this is sodium chloride ($NaCl$). A single electron on the outer shell of sodium joins the chloride atom with seven electrons in its outer shell. The sodium now has a +1 charge and the chloride now has a -1 charge. The charges attract each other to form an ionic bond. Ionic compounds are called salts. In a dry salt crystal, the bond is so strong it requires a great deal of strength to break it apart. But, place the salt crystal in water, and the bond dissolves easily as the attraction between the two atoms decreases.

The weakest of the three bonds is the **hydrogen bond**. A hydrogen bond forms when one electronegative atom shares a hydrogen atom with another electronegative atom. An example of a hydrogen bond is a water molecule (H_2O) bonding with an ammonia molecule (NH_3). The H^+ atom of the water molecule attracts the negatively charged nitrogen in a weak bond. Weak hydrogen bonds are beneficial because they can briefly form, the atoms can respond to one another, and then break apart allowing formation of new bonds. Hydrogen bonding plays a very important role in the chemistry of life.

Analyze the structure and function of carbohydrates, lipids, proteins, and nucleic acids

A compound consists of two or more elements. There are four major chemical compounds found in the cells and bodies of living things. These are carbohydrates, lipids, proteins, and nucleic acids.

Monomers are the simplest unit of structure. **Monomers** combine to form **polymers**, or long chains, making a large variety of molecules. Monomers combine through the process of condensation reactions (also called dehydration synthesis). In this process, one molecule of water is removed between each of the adjoining molecules. In order to break the molecules apart in a polymer, water molecules are added between monomers, thus breaking the bonds between them. This process is called hydrolysis.

Carbohydrates contain a ratio of two hydrogen atoms for each carbon and oxygen $(CH_2O)_n$. Carbohydrates include sugars and starches. They function in the release of energy. **Monosaccharides** are the simplest sugars and include glucose, fructose, and galactose. They are major nutrients for cells. In cellular respiration, the cells extract the energy from glucose molecules. **Disaccharides** are made by joining two monosaccharides by condensation to form a glycosidic linkage (covalent bond between two monosaccharides). Maltose is the combination of two glucose molecules, lactose is the combination of glucose and galactose, and sucrose is the combination of glucose and fructose.

Polysaccharides consist of many monomers joined together. They are storage material hydrolyzed as needed to provide sugar for cells or building material for structures protecting the cell. Examples of polysaccharides include starch, glycogen, cellulose, and chitin.

Starch - major energy storage molecule in plants. It is a polymer consisting of glucose monomers.

Glycogen - major energy storage molecule in animals. It is made up of many glucose molecules.

Cellulose - found in plant cell walls, its function is structural. Many animals lack the enzymes necessary to hydrolyze cellulose, so it simply adds bulk (fiber) to the diet.

Chitin - found in the exoskeleton of arthropods and fungi. Chitin contains an amino sugar (glycoprotein).

Lipids are composed of glycerol (an alcohol) and three fatty acids. Lipids are **hydrophobic** (water fearing) and will not mix with water. There are three important families of lipids, fats, phospholipids, and steroids.