

## **COMPETENCY 1.0**

## **KNOWLEDGE OF THE INVESTIGATIVE PROCESSES OF SCIENCE**

### **SKILL 1.1 Demonstrate knowledge of the proper use and care of the light microscope.**

Light microscopes are commonly used in high school laboratory experiments. Total magnification is determined by multiplying the ocular (usually 10X) and the objective (usually 10X on low, 40X on high) lenses. Several procedures should be followed to properly care for this equipment.

- Clean all lenses with lens paper only.
- Carry microscopes with two hands; one on the arm and one on the base.
- Always begin focusing on low power, then switch to high power.
- Store microscopes with the low power objective down.
- Always use a coverslip when viewing wet mount slides.
- Bring the objective down to its lowest position then focus moving up to avoid breaking the slide or scratching the lens.

### **SKILL 1.2 Recognize and distinguish between the types of microscopy and uses.**

Anton van Leeuwenhoek is known as the father of microscopy. In the 1650s, Leeuwenhoek began making tiny lenses which gave magnifications up to 300x. He was the first to see and describe bacteria, yeast plants, and the microscopic life found in water. Over the years, light microscopes have advanced to produce greater clarity and magnification. The scanning electron microscope (SEM) was developed in the 1950s. Instead of light, a beam of electrons passes through the specimen. Scanning electron microscopes have a resolution about one thousand times greater than light microscopes. The disadvantage of the SEM is that the chemical and physical methods used to prepare the sample result in the death of the specimen.

**SKILL 1.3 Identify common laboratory techniques (e.g., dissection; preserving, staining, and mounting microscope specimens; preparing laboratory solutions).**

Some of the most common laboratory techniques are: dissections, preserving, staining and mounting microscopic specimens, and preparing laboratory solutions.

**Dissections**

Animals that are 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 desirable. If gloves are not available, students with sores or scratches should be excused from the activity. Formaldehyde is a 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.

**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. Many state laws state that any instructor who intentionally refuses to comply with the laws may be suspended or dismissed. 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.

**2. Staining:**

Specimens have to be stained because they are mostly transparent (except plant cells which are green) under the microscope and are difficult to be seen under microscope against a white background. The stains add color to the picture, making the image much easier to see. The stains actually work by fixing themselves to various structures on or in the cell. The exact structure determines the staining process used.

It is amazing to know that the variety of stains available are numerous, and are a vital tool to determine what the cellular components are made of. Starch, protein and even nucleic acids can be brought out using special stains.

Some common stains used in the laboratories are: methylene blue, chlorazol black, lignin pink, gentian violet, etc.

### **3. Mounting of specimens:**

In order to observe microscopic specimens or minute parts, mounting them on a microscope slide is essential. There are two different ways of mounting. One kind of procedure is adapted for keeping mounted slides for a long time to be used again.

The second type of procedure is for temporary slides. We will discuss temporary mounting since 12<sup>th</sup> Grade students are mostly concerned with the temporary mounting. Their work does not require permanent mounting. Water is a very common mounting medium in high school laboratories since it is cheap and best suited for temporary mounting. One problem with water mounting is that water evaporates.

Glycerin is also used for mounting. One advantage with glycerin is that it is non-toxic and is stable for years. It provides good contrast to the specimens under microscopic examination. The only problem with glycerin as a medium is that it supports mold formation.

### **4. Preparation of laboratory solutions:**

This is a critical skill needed for any experimental success. The procedure for making solutions must be followed to get maximum accuracy.

- i) weigh out the required amount of each solute
- ii) dissolve the solute in less than the total desired volume (about 75%)
- iii) add enough solvent to get the desired volume

#### **1. Weight/volume:**

Usually expressed as mg/ml for small amounts of chemicals and other specialized biological solutions. e.g. 100 mg/ml ampicillin = 100 mg. of ampicillin dissolved in 1 ml of water.

#### **2. Molarity:** moles of solute dissolved/ liter of solution

Mole =  $6.02 \times 10^{23}$  atoms = Avogadro's number

Mole = gram formula weight (FW) or gram molecular weight (MW)

\* These values are usually found on the labels or in Periodic Table.

e.g. Na<sub>2</sub>SO<sub>4</sub>

2 sodium atoms - 2 times 22.99g = 45.98 g

1 sulfur atom - 1 times 32.06g = 32.06 g

4 oxygen atoms - 4 times 16.00g = 64.00 g

Total = 142.04g

1M = 1 mole/liter, 1 mM = 1 millimole/liter, 1 uM = 1 umole/liter

\* How much sodium is needed to make 1L of 1M solution?

Formula weight of sodium sulfate = 142.04g

Dissolve 142.04g of sodium sulfate in about 750mL of water, dissolve sodium sulfate thoroughly and make up the volume to 1 liter (L)

**SKILL 1.4 Identify proper field techniques (e.g., site selection, field procedures, sampling, capture/recapture, transects, collecting techniques, environmental quality assessment).**

Some of the field techniques described here are site selection, field procedures, sampling, capture/recapture, transects, collecting techniques, and environmental assessment. We will look at each of these individually.

#### **Site selection:**

Site selection in any field experiment is a critical factor. It depends on a number of issues including the type of research that will be conducted in that site, the duration of the investigation, and the accessibility of the site to city/town and transportation to that site. The selection of a site is determined by a group of researchers from the team who study all of the site aspects, make their recommendations, and then site selection may be approved by the research team. If the first choice is found to be unsuitable a second site, more suitable, will be selected. The most important thing is that all the researchers must be reasonably comfortable with the site.

#### **Field procedures:**

Field procedures are procedures that are done for a successful sample collection.

These are:

1. Preparing for field study: identifying learning objectives, the purpose of field study
2. Site selection: finding out a suitable site for the type of investigation
3. Sample collection: collecting samples
4. Preserving collected specimens

**Sampling:**

Sampling is collecting pieces/specimens or making instrument data points/observations at determined intervals or areas for the purpose of research/investigation. Sampling includes animal tracking, capturing, plant and animal tagging, plot sampling, specimen collecting, transect sampling, water sampling, etc. The results obtained are used as representative of the whole research area or population.

**Capture/recapture:**

Capture /recapture are methods very commonly used in ecological studies. This method is also known as mark/capture, capture-mark-recapture, sight-resight and band recovery.

A researcher visits the study area (see site selection) and uses traps to capture organisms alive. Each of these is marked with a unique identifier- a numbered tag/band- and then is released unharmed back into the environment. Next, the researcher returns and captures another sample of organisms. Some of the organisms in the second sample will have been marked during the first visit and are known as recaptures. The unmarked organisms are tagged just like the previous ones.

Population size can be estimated from as few as two visits to the study area, but usually more than two visits are made.

**Transect:**

A transect is a path along which one records and/or counts occurrences of the phenomenon of study (e.g. animals, for instance by noting each individual animal's distance from the path, species of plants, in the process of estimating population densities in a study area). This action requires an observer to move along a fixed path and to count occurrences along the path and, at the same time, obtain the distance of the object from the path. This results in an estimate of the area covered, an estimate of the way in which detectability drops off from probability 1 to 0 as one moves away from the path. Using these two figures one can arrive at an estimate of the actual density of objects.

## **Collecting techniques:**

The objective of capturing an animal is to identify it. It is much easier this way since the animal is in our possession. There are 6 steps involved in this seemingly simple procedure:

1. Catching – it is very difficult to catch insects like butterflies and dragon flies since they are very quick and the person trying to catch them must be quicker. The easy way is to use a net. This is safe and quick and eliminates running around with the insects.
2. Enveloping – Place the dragon/butter fly wings folded in a glassine (stamp/coin collection bag), label it, and number it. This way, when this bag is opened at a later date, the information needed is on the envelope.
3. Acetoning – After leaving the specimens for awhile (in the mean time, they will empty their intestines), one sacrifices the specimen by immersing it in acetone briefly. Straighten the insect and then return it to acetone and leave it there for 16-24 hours. Acetone extracts water and fat from the specimens and they dry much better, though some specimens may become discolored.
4. Removing – Remove from acetone and allow the specimens to dry in a spot away from people, since acetone fumes are not good for our health.
5. Labeling – All the pertinent information must be attached to the specimens so that information is much clearer at a later date when someone else is studying them.
6. Storing – The preserved specimens must be stored in a box protected from humidity and pests.

## **Environmental quality assesment:**

Environmental assessment is to study, collect information, and analyze it using scientific principles and evaluate the quality and conditions of the type of environment under study – e.g., marine, coastal, lake, etc. This is absolutely essential to determine the hazards that are causing pollution and their effect on human and other life forms. The environmental quality assessment is done in a site or multi site, for a short period of time or lasting for a number of years. Whatever may be the size of the test site or the duration of the investigation, the basic aim is to determine the quality of that particular environment. Some environmental projects study water quality, air quality, sediment and soil assessment, ground water assessment, oil spills and their effect on marine life, etc.

### **SKILL 1.5 Identify the uses of PCR, chromatography, spectrophotometry, centrifugation, and electrophoresis.**

**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 in avoiding 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 the 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 toward 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 **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 primer to specify the segment to be copied, and an enzyme (usually taq polymerase) to amplify the DNA. PCR has allowed scientists to perform several procedures on the smallest amount of DNA.

**SKILL 1.6 Identify terms in a formula (e.g., chemical, ecological, physical) and assess the relationships among the terms.**

A formula is a shorthand way of showing what is in a compound by using symbols and subscripts. The letter symbols let us know the elements that are involved and the number subscripts tell us how many atoms of each element are involved. No subscript is used if there is only one atom involved. For example – CH<sub>4</sub> – This compound is methane gas and it has one carbon atom and 4 hydrogen atoms.

**1. Chemical formulas:**

Aerobic respiration: Let us look at this example. Our tissues need energy for growth, repair, movement, excretion, and so on. This energy is obtained from glucose supplied to the tissues by our blood. In aerobic respiration, glucose is broken down in the presence of oxygen into carbon dioxide, and water and energy is released, which is used for our metabolic processes.

The above reaction can be written in the form of a word reaction:

Glucose + Oxygen = Carbon Dioxide + Water + Energy

By using chemical symbols and subscripts we can rewrite the above word equation into a proper chemical equation:



The compounds on the left side of the equation are called reactants and the compounds on the right side of the reaction are called products. The reactants in the above equation have to combine in a fixed proportion for a chemical reaction to take place.

**2. Ecological formulas:**

A number of formulas are used in ecological research. We will use one of the most widely used formulas in ecological investigations for an example. It is called the Lincoln- Petersen method of analysis, and is used in population estimations.

$$N = (n_1 n_2) / m$$

Where

N = Estimate of total population size

n<sub>1</sub> = Total number of animals captured in the first visit

n<sub>2</sub> = Total number of animals captured on the second visit

m = Number of animals captured on the first visit that were then recaptured on the second visit

### 3. Physical formulas:

There are a number of formulas that are used in Physical Science and Physics.

Let us look at a very simple one –

$$D = m/v$$

Where

D = density g/cm

m = mass in grams

v = volume in cm

The above formula is used for calculating the density of an object.

It is absolutely important to write the appropriate units e.g., g (gram), cm (centimeter) etc.

The second example is the formula for calculating the momentum of an object.

M = mass (kg) times velocity ( meters/second)

$$M = mv$$

The units of momentum are kg (m/s)

The above are only two of the many formulas that are used in a Physical science classroom.

### **SKILL 1.7 Identify the units in the metric system and convert between dimensional units for one-, two-, and three-dimensional objects.**

Science uses the **metric 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. 1 gallon is 3.846 liters. The gram is the basic metric unit of mass. 1000 grams is 2.2 pounds.

The following prefixes are used to describe the 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
unit	

**SKILL 1.8 Identify assumptions, observations, hypotheses, conclusions, and theories and differentiate between them.**

Science may be defined as a body of knowledge that is 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, is a belief that is not warranted. There is no scientific methodology or application. Some of the more classic examples of pseudoscience include witchcraft, alien encounters or any topic that is explained by hearsay.

Scientific theory and experimentation must be repeatable. It is also possible to be disproved and is capable of change. Science depends on communication, agreement, and disagreement among scientists. It is composed of theories, laws, and hypotheses.

**theory** - the formation of principles or relationships which have been verified and accepted.

**law** - an explanation of events that occur with uniformity under the same conditions (laws of nature, law of gravitation).

**hypothesis** - an unproved theory or educated guess followed by research to best explain a phenomenon. A theory is a proven hypothesis.

**SKILL 1.9 Evaluate, interpret, and predict from data sets, including graphical data.**

**Graphing** is an important skill to visually display collected data for analysis. The two types of graphs most commonly used are the **line graph** and the **bar graph** (histogram). Line graphs are set up to show two variables represented by one point on the graph. The X-axis is the horizontal axis and represents the dependent variable. Dependent variables are those that would be present independently of the experiment. A common example of a dependent variable is time. Time proceeds regardless of anything else going on. The Y-axis is the

vertical axis and represents the independent variable. Independent variables are manipulated by the experiment, such as the amount of light, or the height of a plant. Graphs should be calibrated at equal intervals.

If one space represents one day, the next space may not represent ten days. A "best fit" line is drawn to join the points and may not include all the points in the data. Axes must always be labeled. A good title will describe both the dependent and the independent variable. Bar graphs are set up similarly in regards to axes, but points are not plotted. Instead, the dependent variable is set up as a bar where the X-axis intersects with the Y-axis. Each bar is a separate item of data and is not joined by a continuous line.

The type of graphic representation used to display observations depends on the data that is collected. **Line graphs** are used to compare different sets of related data or to predict data that has yet been measured. An example of a line graph would be comparing the rate of activity of different enzymes at varying temperatures. A **bar graph** or **histogram** is used to compare different items and make comparisons based on this data. An example of a bar graph would be comparing the ages of children in a classroom. A **pie chart** is useful when organizing data as part of a whole. A good use for a pie chart would be displaying the percent of time students spend on various after school activities.

Analyzing graphs is a useful method for determining the mathematical relationship between the dependent and independent variables of an experiment. The usefulness of the method lies in the fact that the variables represent on the axes of a straight-line graph are represented by the expression,  $y = m \cdot x + b$ , where  $m$  = the slope of the line,  $b$  = the y intercept of the line. This equation works only if the data fit a straight-line graph. Thus, once the data set has been collected, and modified, and plotted to achieve a straight-line graph, the mathematical equation can be derived.