

COMPETENCY 0001 UNDERSTANDING THE HISTORICAL AND CONTEMPORARY CONTEXTS OF THE STUDY OF BIOLOGY.**Skill 1.1 Historical Perspectives**

The history of biology follows man's understanding of the living world from the earliest recorded history to modern times. Although the concept of biology as a field of science arose only in the 19th century, its origins could be traced back to the ancient Greeks (Galen and Aristotle).

During the Renaissance and the Age of Discovery, a renewed interest in the rapidly increasing number of known organisms generated greater interest in biology.

Andreas Vesalius (1514-1564) was a Belgian anatomist and physician whose dissections of the human body and the descriptions of his findings began to correct the misconceptions of biology. The books Vesalius wrote on anatomy were the most accurate and comprehensive anatomical texts of time.

Anton van Leeuwenhoek is known as the father of microscopy. In the 1650s, van Leeuwenhoek began making tiny lenses which magnified objects up to 300x the original size. He was the first to see and to describe bacteria, yeast plants, and the microscopic life found in water.

Over time, light microscopes 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 greatest disadvantage of the SEM is that the chemical and physical methods used to prepare the sample result in the death of the specimen.

In the late 1800s, Pasteur discovered the role of microorganisms in the cause of disease, leading to the Germ Theory. Pasteur's knowledge led to pasteurization to stop mild from going sour, and he developed the rabies vaccine. Koch took Pasteur's observations one step further by formulating that specific diseases were caused by specific pathogens. **Koch's postulates** are still used as guidelines in the field of microbiology: the same pathogen must be found in every person with a specific disease caused by the pathogen, the pathogen must be isolated and grown in culture, the same disease can be induced in experimental animals from the culture, and the same pathogen must be isolated from the experimental animal.

The discovery of the structure of the DNA molecule was another key event in the history of Biology. In the 1950s, James Watson and Francis Crick discovered the structure of a DNA molecule as that of a double helix structure. The discovery of DNA's structure made it possible to explain DNA's ability to replicate and to control protein synthesis.

The use of animals in biological research has expedited many scientific discoveries. Animal research has allowed scientists to learn more about anatomy and physiology. One significant use of animals is for the testing of drugs, vaccines, and other products (such as perfumes and shampoos) before use or consumption by humans. Along with the pros of animal research, the cons are also very significant. The debate about the ethical treatment of animals has been ongoing since the introduction of animals into research. Many people believe the use of animals in research is cruel and unnecessary. Animal use is federally and locally regulated. The purpose of the Institutional Animal Care and Use Committee (IACUC) is to oversee and to evaluate all aspects of an institution's animal care and use program.

Skill 1.2 Current Issues

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 impacts biological research and funding. Political pressures have led to bans and restrictions on human cloning research in the United States and in many other countries. 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.

Genetically modified crops have steadily increased over the years and has led to nutritional enhancement for some crops. Crops have been genetically modified for many reasons, including increased growth and insect resistance.

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 right or wrong answers to these questions. The U.S. Food and Drug Administration (FDA) regulates the use of humans and animals in clinical research.

Society depends on science, yet it is necessary that the public be scientifically literate and informed in order to prevent potentially unethical procedures to occur. This is especially true in the areas of fertility and genetic research. It is important

for science teachers to stay abreast of current research and to involve students in critical thinking and ethics whenever possible.

COMPETENCY 0002 UNDERSTANDING THE NATURE OF SCIENCE AND SCIENTIFIC INQUIRY.

Science may be defined as a body of knowledge that is systematically derived from study, observation, and experimentation. The goal of the scientific method is to identify and to establish principles and theories that may be applied to solving 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 astrology, the occult, and phrenology.

Skill 2.1 Processes by which science advances (Scientific Inquiry)

Scientific inquiry is an understanding of science through questioning, experimentation and drawing conclusions.

The basic skills involved in scientific inquiry are:

1. Observing
2. Identifying problem
3. Gathering information/research
4. Hypothesizing
5. Experimental design, which includes identifying control, constants, independent and dependent variables
6. Conducting experiment and repeating the experiment for validity
7. Interpreting analyzing and evaluating data
8. Drawing conclusions
9. Communicating conclusions

Uses of scientific inquiry include:

1. Finding solutions for world problems
2. Encouraging problem solving approach to thinking, learning and understanding
3. To apply math and language skills
4. To confirm by experimentation that which is already known to the scientific community
5. Offer explanations, conclusions, and critical evaluations
6. Encourage the use of modern technology for research, experiments, analysis, and to communicate data
7. To be up to date with recent advances in science

The simplest form of science inquiry involves the following steps:

1. Question

2. Hypothesis

(A plausible explanation/an educated guess)

3. Experimental design

(Identifying control, constants, independent and dependent variables)

4. Experimenting and repeating the experiment for reliability

5. Data

(Analysis, evaluation and evaluation)

6. Conclusions

Hypothesis correct/incorrect

7. Communicating the conclusions

(Visual, models, written and oral)

Scientific inquiry is a very powerful and highly interesting tool to teach and learn science.

Skill 2.2 Role of empirical data

Observations, however general they may seem, lead scientists to create a viable question and an educated guess (hypothesis) about what to expect. While some science occurs in laboratories under controlled settings, it is possible for scientists to uncover unexpected results. It is always important to be open-minded and to look at all of the information. An open-minded approach to science provides room for more questioning, and, hence, more learning.

A central concept in science is that all evidence is empirical. This means that all evidence must be observed by the five senses. The studied phenomenon must be both observable and measurable, with reproducible results. The question stage of scientific inquiry involves repetition. By repeating the experiment you can discover whether or not you have reproducibility, thereby verifying your results and validating your hypothesis. When the results are not reproducible, this may lead to more questions.

Skill 2.3 Ethical issues related to scientific processes

A common ethical code could be applied to many areas, including science. When the general code is applied to a particular area of human life, it then becomes an institutional code. Hence, scientific ethics is an institutional code of conduct that reflects the chief concerns and goals of science.

Conduct here refers to all aspects of scientific activity including experimentation, testing, education, data evaluation, data analysis, data storing, peer review, government funding, the staff, etc.

The following are some of the guiding principles of scientific ethics:

1. Scientific Honesty: not to fraud, fabricate or misinterpret data for personal gain
2. Caution: to avoid errors and sloppiness in all scientific experimentation
3. Credit: give credit where credit is due and not to copy
4. Responsibility: only to report reliable information to public and not to mislead in the name of science
5. Freedom: freedom to criticize old ideas, question new research, and freedom to research

As science advances, we are seeing a collision of viewpoints. Medicine is entering areas where people are questioning ethics. Physicians and teams are aware of the ethical treatment of patients (informed consent, pursuing only what is in the patient's best interests, etc.). Most recently, the general public is concerned with techniques such as medical engineering and cloning, or stem cell research. These areas are relatively new to the research agenda, and the public, scientists, and government officials are working together to find solutions suitable to the majority.

Skill 2.4 The role of communication among scientists, and between scientists and the public in promoting scientific progress

Clear communication is required in the scientific field. Scientists are ethically bound to peers to be upfront and true in their reports. Often multiple scientists will be working on the same material, and there is always a push to be published first. This is understandable in a competitive field, provided that the science does not suffer. Future scientists will come to regard today's work as a reference point for new projects, and in this way, research is ever evolving. There are also times when we benefit from a less competitive and more collaborative approach. Let's look at the human genome project. The goal of the human genome project is to map and sequence the three billion nucleotides in the human genome, and to identify all of the genes on it. The project was launched in 1986 and an outline of the genome was finished in 2000 through international collaboration. In May 2006, the sequence of the last chromosome was published. While the map and sequencing are complete, scientists all over the world are still studying the functions of all the genes and their regulation. With such an ambitious project, we can each make discoveries sooner if we share information, which may in turn help us to better understand other phenomena.

COMPETENCY 0003 UNDERSTANDING THE PRINCIPLES AND PROCEDURES OF SCIENTIFIC INVESTIGATIONS

Skill 3.1 Measurement

The **metric system** is the accepted measurement scale for scientists worldwide.

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

Skill 3.2 Sampling techniques

In cases where the number of events or individuals is too large to collect data on each one, scientists collect information from only a small percentage. This is known as sampling. If sampling is done correctly, it should give the investigator nearly the same information that he or she would have obtained by testing the entire population. There are a variety of sampling techniques; random, systematic, stratified, cluster, and quota are just a few. While random sampling is typically the “gold standard” sometimes compromises must be made to save time, money, or effort.

Sample size is an important consideration in sampling. Again, a large sample will yield the most accurate information, but other factors often limit sample size. Statistical methods are used to help determine how large a sample is necessary to give an investigator a specified level of certainty (95% is a typical confidence interval). Conversely, if a scientist has a sample of certain size, those same statistical methods can be used to determine how confident the scientist can be that the sample accurately reflects the whole population.

Skill 3.3 Safety

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 the safe handling of and on the interpretation of the Material Safety Data Sheet.

Chemicals should not be stored on bench tops or on 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. Suspect and known carcinogens must be labeled as such and segregated within trays to contain leaks and spills. Chemical waste should be disposed of in properly labeled containers. Waste should be separated and disposed of based on their potential 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 are available for every chemical and biological substance. These sheets are available directly from the company of acquisition and sometimes material safety data is available on the internet. The manuals for equipment used in the lab should be read and understood before the equipment is used.

All science labs should contain the following items of **safety equipment** at minimum. Those marked with an asterisk are requirements by state laws.

- * fire blanket which 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 which can be activated by the foot or forearm
- *eye protection for every student and 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 and 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 which is spark proof
- protective laboratory aprons made of flame retardant material
- signs which will alert potential hazardous conditions
- containers for broken glassware, flammables, corrosives, and waste, all of which are labeled.

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 spill. For large spills, the school administration and the local fire department should be notified. Biological spills should also be handled only 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 to pursue.

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 laboratory is important to avoid potential lawsuits.

It is the responsibility of the teacher to provide a safe environment for their students. Proper supervision greatly reduces the risk of injury and a teacher should never leave a class for any reason without providing alternate supervision.

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

Skill 3.4 Use of Animals

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.

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

Specimens should be rinsed before handling. Have latex and non-latex rubber gloves available for use. According to the International Agency for Research on Cancer, formaldehyde is classified as a known human carcinogen 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. 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. Pathogenic organisms must never be used for experimentation. Animals which are not obtained from recognized sources should not be used. Decaying animals or those of unknown origin may harbor pathogens and/or parasites.

Skill 3.5 The identification of questions that can be answered using methods of scientific inquiry

The scientific method hinges on beginning with a testable hypothesis. It is always necessary to verify hypotheses by following the scientific method. Further, data from repeated experiments must agree to validate the hypothesis. Theories that cannot be tested, for instance, because they do not have observable consequences cannot be studied scientifically. Thus, such theories cannot be proved correct or incorrect by scientific inquiry.

The scientific method works best in situations when we can isolate a phenomenon by eliminating extraneous factors and carefully controlling the experimental conditions. There are some areas, such as human behavior or child development, in which fully controlling variables is impossible or unethical. In these "grey areas" we must be extremely careful in selecting those questions that are within the scope of scientific investigation.

