Notes on the Modern Scientific Method

Fathers of the modern Scientific Method:
English philosopher **Francis Bacon** (1561–1626) and Italian scientist **Galileo Galilei** (1564–1642)

Terminology of the Scientific Method:
Observation – the actual data–gathering process employed during an experiment. It is the beginning of the scientific process.

Fact – a close agreement by competent observers of a series of observations of the same phenomenon.

Measurement – a quantitative observation.

Experiment – an observation that is designed and controlled by humans, perhaps in a laboratory.

Scientific Theory – (from the Greek word meaning *to see*) –   coherent mental framework of ideas that explains or unifies a group of observations. It is a way of understanding or a way of seeing the observations. It can be changed or modified over time upon the discovery and confirmation of new and different observations.

Model – a simple structural similarity (mathematical, physical, linguistic) to the phenomenon being studied.

Law – concise general statements about how nature behaves. Often this takes the form of equations.

Hypothesis – a plausible suggestion or educated guess to a problem that is not yet well confirmed. A scientific hypothesis must possess testability. It is more important that there be a means of proving the hypothesis *wrong* than there be a means of proving it correct.

The Scientific Method – the dynamic interplay between **experience** (in the form of experiments and observations) and **thought** (in the form of creatively constructed theories and hypotheses that correlate experiences).

- A **problem** exits for which an explanation is needed.

- A **hypothesis** is formed as to the nature of the problem.

- Make **predictions** about the consequences of your hypothesis.

- **Experiments** are designed to test (either verify or refute) the hypothesis.

- **Data** are gathered in the form of **observations** and **measurements**.

- The data are analyzed in an effort to construct an operating **model**.

- From this model, a **theory** is constructed and more data are gathered to reinforce the theory.

- The theory is modified and detailed to explain new, recurrent **observations**.

- From the theory, formulate the **simplest, most general rule** that organizes the three main ingredients: hypothesis, prediction, and experimental outcome.

Analysis Questions: Write your answers to these questions in the spaces below.

1. Which of these are a scientific hypothesis? After you choose an answer, explain and be able to defend your answer.

    a)   Our universe is surrounded by a second universe, the existence of which cannot be detected.

    b) The amount hard drive space available on the school network will double over the next 3 years.

    c) Albert Einstein is the greatest physicist of the 20th century.

    d) 60% of the students in this class will get a grade above an 80% as their final grade.

2. Theories in science often undergo change. Is this a strength or weakness of science? Explain briefly and defend your answer.

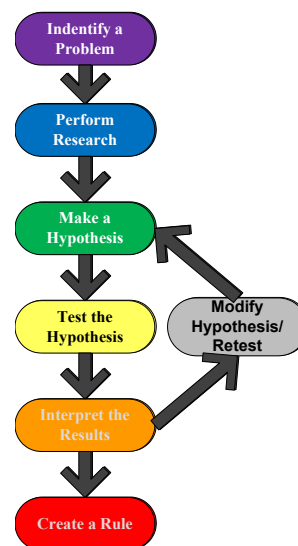**3.** Is a scientific fact something that is *absolute and unchanging*? Explain.

Fill in the blank

    1. A _____ exists for which an explanation is needed.

    2. A _____ is formed as to the nature of the problem.

    3. Make _____ about the consequences of your hypothesis.

    4. _____ are designed to test (either verify or refute) the hypothesis.

    5. _____ are gathered in the form of _____- and _____.

    6. The data are analyzed in an effort to construct an operating _____.

    7. From this model, a _____ is constructed and more data are gathered to reinforce the theory.

    8. The theory is modified and detailed to explain new, recurrent _____.

    9. From the theory, formulate the _____ that organizes the three main ingredients: hypothesis, prediction, and experimental outcome.

Word Bank: theory   data   observations   problem   predictions   model   measurements
                        experiments   hypothesis   simplest, most general rule   observations

We will simplify the scientific method down into 6 steps.

Using the scientific method to create a rule for the following problems.

1. You have quiz tomorrow.

2. You keep missing the bus in the morning.

3. You haven't decided what you plan on doing after you graduate.

Indentify a Problem

Perform Research

Make a Hypothesis

Test the Hypothesis

Modify Hypothesis/ Retest

Interpret the Results

Create a Rule

How Penicillin Was Discovered

In 1928, Sir Alexander Fleming was studying Staphylococcus bacteria growing in culture dishes. He noticed that a mold called Penicillium was also growing in some of the dishes. A clear area existed around the mold because all the bacteria that had grown in this area had died. In the culture dishes without the mold, no clear areas were present.

Fleming hypothesized that the mold must be producing a chemical that killed the bacteria. He decided to isolate this substance and test it to see if it would kill bacteria. Fleming transferred the mold to a nutrient broth solution. This solution contained all the materials the mold needed to grow. After the mold grew, he removed it from the nutruient broth. Fleming then added the nutrient broth in which the mold had grown to a culture of bacteria. He observed that the bacteria died.

1. Identify the problem.

2. What was Fleming's hypothesis?

3. How was the hypothesis tested?

4. Should the hypothesis be supported or rejected based on the experiment?

5. This experiment lead to the development of what major medical advancement?