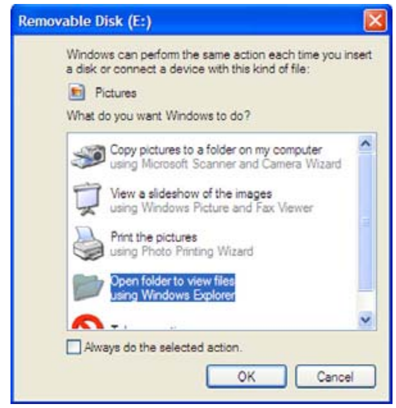
Scientific Methodology

Most people mistakenly believe that the scientific method is only used in the practice of science. This is untrue – people use the scientific method all the time to solve common, everyday problems. Consider the following scenario: A student named Brandon plans to print his lab report in the library from a file on a thumb drive (a SanDisk Ultra). After inserting the thumb drive into the USB port, there is no response from the computer. Brandon begins to worry since the report is due that afternoon. Instinctively he begins to trouble-shoot the problem using the scientific method – by developing **hypotheses** and **experimental tests,** and then **evaluating the results**.



The first thing Brandon considers is that the USB port of the computer doesn't work.

Hypothesis 1: "The problem is in the USB port."

Experimental test	**Predicted outcome if hypothesis is correct**	**Observed outcome**
He borrows someone else's thumb-drive and inserts it into the USB port.	A "Removable Disk (E:)" window <u>will not</u> appear.	A "Removable Disk (E:)" window does appear.

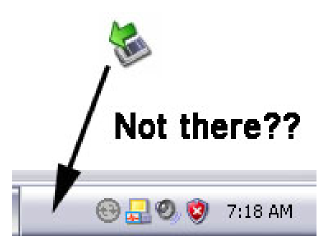
Brandon concludes that his hypothesis is incorrect; the problem is not the USB port. He's now starting to get worried. He next wonders if SanDisk Ultra type thumb-drives do not work on library computers.

Hypothesis 2: "The library computers do not recognize SanDisk Ultra thumb-drives."

Experimental test	**Predicted outcome if hypothesis is correct**	**Observed outcome**
Brandon tries using his thumb-drive in two other computers in the library.	A "Removable Disk (E:)" window <u>will not</u> appear.	The computers do not respond.

Conclusion: The hypothesis is accepted.

During this process Brandon observes that the "Safely Remove Hardware" icon does not appear in the notifications tray in the lower right hand side of the computer screen. He knew that this should be clicked before removing thumb-drives, but Brandon usually just yanked it out without doing so. Now he worries that his thumb-drive no longer works, and he needs some way to test it.



Brandon also wonders why he did not make a backup copy of his lab report file.

Problem-solving is a use of the scientific method.

In his attempts to solve the problem described above, Brandon applied the scientific method - he made observations, developed hypotheses, ran experiments to test the hypotheses, predicted the expected results of the experiments, and drew conclusions based upon the actual experimental results.

Hypothesis-making involves inductive reasoning.

Problem-solving requires making an educated guess to explain an observation; and that educated guess is a hypothesis. Hypothesis-making involves a process called **inductive reasoning,** and you do this when you use existing knowledge to create new ideas. Brandon's existing knowledge came from prior experiences working with computers, and he also made observations as he worked on the problem. **Induction requires creativity** to put ideas together in innovative ways. Good "problem solvers" and good scientists are creative thinkers.

An acceptable hypothesis must be testable.

Proposing just any hypothesis does not satisfy scientific inquiry. A hypothesis testable must be **testable with existing technology,** i.e., it must be possible to design an experiment to test the hypothesis. Brandon might have also considered this hypothesis, but it is untestable:

"Someone took my thumb-drive and broke it."

– whether this is true or not, there is no practical way to test it!

Predictions anticipate the outcome of the experiment.

A prediction is an expectation of the results of the experiment. The experiment is designed to test the hypothesis; thus, you must have some notion of what the result of that experiment will be if the hypothesis is correct. Only if the observed results agree with the predicted results is the hypothesis accepted.

Drawing conclusions involves deductive reasoning.

Deductive reasoning is used whenever you use observations or experimental results to evaluate if a statement is true or false. In evaluating Hypothesis 1, Brandon used the following deductive reasoning when evaluating Hypothesis 1: "The problem is in USB port."

Assumption: Appearance of a "Removable Disk (E:)" window indicates that a USB port functions correctly.

Result: A "Removable Disk (E:)" window did appear when another thumb-drive was inserted.

Conclusion: The USB port functions correctly.

Results will not "prove" that a hypothesis is correct.

The results of an experiment will either **support or contradict** the hypothesis, but will not prove a hypothesis. Results can support a hypothesis, but if the results are evaluated using false assumptions, then the conclusions will still be wrong. This is evident when Brandon evaluates Hypothesis 2: "The library computers do not recognize SanDisk Ultra thumb-drives":

Assumption: Failure of a "Removable Disk (E:)" window to appear means that a computer can not recognize a particular type of thumb-drive.

Result: A "Removable Disk (E:)" window did not appear when the thumb-drive was inserted into two other computers.

Conclusion: library computers cannot recognize SanDisk Ultra thumb-drives.

The results supported the hypothesis, but the conclusion is still wrong. This is because the hypothesis was based upon an incorrect assumption; i.e., there are other reasons why a computer may not show the “Removable Disk (E:)” window, for example the thumb-drive itself may not be working. This is an example of an **alternative explanation** of the results. There are always alternative explanations for results, although not all explanations are reasonable (“The Sandisk Ultra only works on library computers after 11:00AM). Scientists run **controls** to test other reasonable alternative explanations.

“Controls” test alternative explanations of results.

Controls are other experiments performed to test alternative explanations. For example, Brandon would have more accurately interpreted results for Hypothesis 2 if he ran a control.

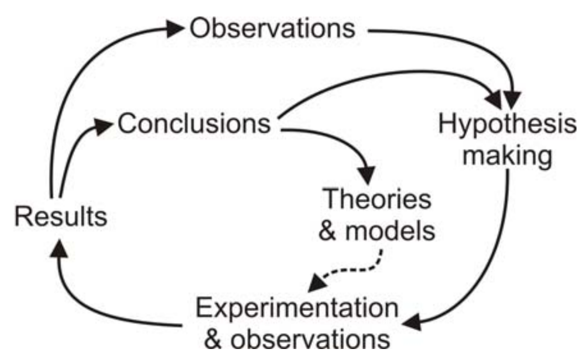
Alternative explanation: Brandon’s thumb-drive does not work.

Control: Test different SanDisk Ultra thumb-drive on several library computers.

Together, the results of the experimental test and control might have shown that the problem was in Brandon’s thumb-drive, not in the ability of the computers to recognize SanDisk Ultra thumb-drives.

Scientific methodology is a cyclic process.

Like trouble-shooting, the scientific method is a cyclic process. The results of experiments provide new observations, and the conclusions inspire new hypotheses in creative minds. While certain conclusions become widely accepted and established as theories and models, no scientific principle is above further validation. Thus, well established biological principles such as the mechanisms of evolution and heredity, the structure and dynamics of ecosystems, basic cell structure, and the structure of genes are all actively researched by biologists.



Scientific knowledge yields "models" of nature.

Scientists prefer to assemble scientific knowledge into intellectual **models** of nature. Scientific models can be considered simplified versions of reality, good enough to make certain predictions about the ‘real thing’ but not a complete explanation. As long as the model conforms to observations of nature, it’s a good model. But when observations begin to disagree with the predictions of the model, a new or revised model is required. By viewing scientific knowledge as models, we avoid its misrepresentation as absolute “facts” that do not change.

Scientific Methodology Questions Name: ___________________________

1. A _______________________ is an "educated guess" that attempts to explain observations.

2. A prior notion of the outcome of an experiment is called a _________________________.

3. We are employing ____________________ reasoning when we draw upon existing knowledge to develop a creative new hypothesis, and ___________________ reasoning when we evaluate a hypothesis.

4. Even if during a lab exercise your results and predictions agree, you should not write in a lab report that the results "prove" your hypothesis: why?

5. Why is "model" better than "fact" as a description of scientific knowledge?

6. Suppose after a living a month in your dorm room, you begin to develop a rash on your arms. It does not seem serious, but it is somewhat itchy.

A. Propose a hypothesis to explain the appearance of the rash.

B. What prior knowledge did you draw upon to develop that hypothesis?

C. Propose an experiment to test that hypothesis:

D. Give a prediction of the outcome of the experiment if the hypothesis is correct:

E. Give an alternative explanation of the expected results:

F. Describe a control to test for that alternative explanation:

G. Suppose your roommate said that the rash is “due to something in the air”. Explain why you would reject this hypothesis: