Part I: What is Science?

Because this material is covering an area of modern science it is important to understand what modern science is. What do you think of when you hear the word science? Do you think of a person wearing goggles and a lab coat while mixing chemicals; or maybe a person hiding in the woods in order to observe the behavior of wild turkeys; or perhaps even a person in shorts, a T-shirt, and a wide brimmed hat digging into the side of a desert canyon looking for fossils?   All of these things could be considered part of doing modern science.

Simply put, science is an objective pursuit for truth based on the observable world. It is the dynamic human activity of trying to understand how the world works, based on consistently repeatable observation, prediction, and/or experimentation. This requires that the scientist be able to observe (either directly as with the naked eye or indirectly as with a microscope or a telescope) the part of the natural world that they are studying. If they are experimenting they must also be able to affect that part of the natural world. The scientific way of gaining knowledge of our world is different from other ways of understanding the world in that it is falsifiable and dependent entirely on evidence that is acquired through the five senses. This basically means that scientists do not rely on pre-conception or belief in unknown forces in order to understand how the natural world works, and that we have to describe what specific evidence would show that an idea is not correct (there is no such thing as absolute certainty in science). Science deals in levels of probability and accuracy, not in absolute certainty (because what we know can change with new information).

Science is also a process by which we gain knowledge, commonly known as “the scientific method.” The classical scientific method that is discussed in most textbooks refers to areas of science easily controlled, so that we can do well controlled experiments. The steps to this method include:

1. **Define the question**: What exactly is our research interested in knowing? This question must be an answerable question, something that the right observations and/or experimentation can actually address.
2. **Gather information and resources (observe)**: This includes reading the published research of other scientists regarding the topic of our interest.
3. **Form a hypothesis**: Propose an educated guess as a tentative answer to the question. This is where falsifiability comes in. A scientific hypothesis has to be an idea that can be either supported with evidence, or shown to be wrong with evidence.

4. **Perform experiment and collect data**: These experiments should be set up to see if the hypothesis is wrong (part of the way we make sure we are objective is to try to prove our own ideas false). A good scientist is glad to have their hypothesis proven wrong because it brings us one step closer to understanding how something really works. Collecting data as accurately as possible is also essential to good science; making conclusions based on poor data collection is part of what we call pseudoscience.
5. **Analyze data**: This part of the method often involves statistical analysis to see if the results could be due to chance alone.
6. **Interpret data and draw conclusions that serve as a starting point for new hypothesis**: Science never stops. The results of one study often lead us to new questions that beg further research.
7. **Publish results and peer review**: The publishing of results usually involves peer review. Other scientists within the same research area review the work to check for possible errors and/or dishonesty. Work that is shoddy or inaccurate rarely gets published.
8. **Retest**: One experiment does not a theory make. The longer a hypothesis withstands the scrutiny of further experimentation, the more solid it becomes as an answer to the question. This further experimentation is usually done by other scientist (further insuring objectivity).

It is important to understand that the above list of steps is a highly generalized and is really only useful for experimental research. There are many areas of science where controlled experimentation is impractical or impossible. These areas may require observation/prediction rather than observation/experimentation.

It is also important to note that the way science is actually carried out often does not follow the exact step by step process listed above. For example, a planned series of experiments might be altered if initial data points the researcher in a different direction. This would stop the research and cause a redesign of the experiments to address new questions. This might also cause the formation of a new hypothesis. Scientists are not tied to the step by step method listed above.

Terms to understand (at least in the Biological Sciences):

Theory: This is the highest level of intellectual knowledge in science. It is a unifying principle that explains a large body of facts, laws, and tested hypotheses. Science is interested in understanding how the natural world works, and our theories explain our understanding of given areas of our natural world up to the present time.

> Examples include: Evolutionary theory, cell theory, microbial theory of disease, theory of relativity, etc.

Hypothesis: This is an educated guess as to how some part of the natural world works. Hypotheses are usually based on initial observations and previous research. It is important that a hypothesis is a testable statement.

> Example: "Persons that drink green tea regularly are less likely to be diagnosed with skin cancer." Green tea has been shown to decrease the risk of colorectal cancers, so perhaps it decreases skin cancers as well. Can you think of an observation/experiment to test this hypothesis???

Natural Law: a concise verbal or mathematical statement of relation that is always the same under identical conditions. Laws can be referred to as a description of "what happens."

> Examples: Law of gravity $F = G\frac{m_1 m_2}{r^2}$, Boyle's gas law $p_1 V_1 = p_2 V_2.$.

Fact: A piece of information that describes some kind of event. They are as reliable as the senses used to observe the event. It is also important to understand that facts do not explain events, they simply describe them.

> Examples: The pencil fell from the table. The patient has a fever of 101.6 °F. My WBC count increased the last time I got a cold.