Misinterpretations of the Scientific Process

These explanations are adapted from the "Misconceptions about Science" section of the Understanding Science Website:
http://undsci.berkeley.edu/teaching/misconceptions.php

Science is a collection of facts. Facts are only part of the picture. Science *is* a body of knowledge that one can learn about in textbooks, but it is also a process. Science is a process for discovering how the world works and building that knowledge into powerful and coherent frameworks.

Science is complete. Science is an ongoing process, and there is much more yet to learn about the world. In fact, in science, making a key discovery often leads to many new questions ripe for investigation. Furthermore, scientists are constantly elaborating, refining, and revising established scientific ideas based on new evidence and perspectives.

There is a single Scientific Method that all scientists follow. “The Scientific Method” is often taught in science courses as a simple way to understand the basics of scientific testing. In fact, the Scientific Method represents how scientists usually write up the results of their studies (and how a few investigations are actually done), but it is a grossly oversimplified representation of how scientists generally build knowledge. The process of science is exciting, complex, and unpredictable. It involves many different people, engaged in many different activities, in many different orders.

The process of science is purely analytic and does not involve creativity. Perhaps because the Scientific Method presents a linear and rigid representation of the process of science, many people think that doing science involves closely following a series of steps, with no room for creativity and inspiration. In fact, many scientists recognize that creative thinking is one of the most important skills they have — whether that creativity is used to come up with an alternative hypothesis, to devise a new way of testing an idea, or to look at old data in a new light. Creativity is critical to science!

Experiments are a necessary part of the scientific process. Without an experiment, a study is not rigorous or scientific. Perhaps because the Scientific Method and popular portrayals of science emphasize experiments, many people think that science can't be done *without* an experiment. In fact, there are *many* ways to test almost any scientific idea; experimentation is only one approach. Some ideas are best tested by setting up a controlled experiment in a lab, some by making detailed observations of the natural world, and some with a combination of strategies.

“Hard” sciences (e.g. chemistry and physics) are more rigorous and scientific than “soft” sciences (psychology and sociology). Some scientists and philosophers have tried to draw a line between “hard” sciences (e.g., chemistry and physics) and “soft” ones (e.g., psychology and sociology). The thinking was that hard science used more rigorous, quantitative methods than soft science did and so were more trustworthy. In fact, the rigor of a scientific study has much more to do with the investigator's approach than with the discipline. Many psychology studies, for example, are carefully controlled, rely on large sample sizes, and are highly quantitative.

Scientific ideas are absolute and unchanging. It's true that some scientific ideas are so well established and supported by so many lines of evidence, they are unlikely to be completely overturned. However, even these established ideas are subject to modification based on new evidence and perspectives. Furthermore, at the cutting edge of scientific research, scientific ideas may change rapidly as scientists test out many different possible explanations trying to figure out which are the most accurate.

Because scientific ideas are tentative and subject to change, they can't be trusted. Especially when it comes to scientific findings about health and medicine, it can sometimes seem as though scientists are always changing their minds. There are several reasons for such apparent reversals. First, press coverage tends to draw particular attention to disagreements or ideas that conflict with past views. Second, ideas at the cutting edge of research (e.g., regarding new medical studies) may change rapidly as scientists test out many different possible explanations trying to figure out which are the most accurate. This is a normal part of the process of science.

If evidence supports a hypothesis, it is upgraded to a theory. If the theory then garners even more support, it may be upgraded to a law. This misconception may be reinforced by introductory science courses that treat hypotheses as "things we're not sure about yet" and that only explore established and accepted theories. In fact, hypotheses, theories, and laws are rather like apples, oranges, and kumquats: one cannot grow into another, no matter how much fertilizer and water are offered. Hypotheses, theories, and laws are all scientific explanations that differ in breadth — not in level of support. Hypotheses are explanations that are limited in scope, applying to fairly narrow range of phenomena. The term *law* is sometimes used to refer to an idea about how observable phenomena are related — but the term is also used in other ways within science. Theories are deep explanations that apply to a broad range of phenomena and that may integrate many hypotheses and laws.

Scientific ideas are judged democratically. When newspapers make statements like, "most scientists agree that human activity is the culprit behind global warming," it's easy to imagine that scientists hold an annual caucus and vote for their favorite hypotheses. But of course, that's not quite how it works. Scientific ideas are judged not by their popularity, but on the basis of the evidence supporting or contradicting them.

The job of a scientist is to find support for his or her hypotheses. Science gains as much from figuring out which hypotheses are likely to be wrong as it does from figuring out which are supported by the evidence. Scientists may have personal favorite hypotheses, but they strive to consider multiple hypotheses and be unbiased when evaluating them against the evidence. A scientist who finds evidence contradicting a favorite hypothesis may be surprised and probably disappointed, but can rest easy knowing that he or she has made a valuable contribution to science.

Investigations that don't reach a firm conclusion are useless and unpublishable. Perhaps because the last step of the Scientific Method is usually "draw a conclusion," it's easy to imagine that studies that don't reach a clear conclusion must not be scientific or important. In fact, *most* scientific studies don't reach "firm" conclusions. Scientific articles usually end with a discussion of the limitations of the tests performed and the alternative hypotheses that might account for the phenomenon. That's the nature of scientific knowledge — it's inherently tentative and could be overturned if new evidence, interpretations, or a better explanation come along. In science, studies that carefully analyze the strengths and weaknesses of the test performed and of different alternative explanations are particularly valuable since they encourage others to more thoroughly scrutinize the evidence and to develop new ways to test the ideas.

Scientists are completely objective in their evaluation of scientific ideas and evidence. Scientists do strive to be unbiased as they consider different scientific ideas, but scientists are people too. They have different personal beliefs and goals — and may favor different hypotheses for different reasons. Individual scientists may not be completely objective, but science can overcome this hurdle through the action of the scientific community, which scrutinizes scientific work and helps balance biases.

Scientists work without considering the applications of their ideas. It's true that some scientific research is performed without any attention to its applications, but this is certainly not true of all science. Many scientists choose specific areas of research (e.g., malaria genetics) because of the practical ramifications new knowledge in these areas might have. And often, basic research that is performed without any aim toward potential applications later winds up being extremely useful.

In science, a prediction usually refers to something that we expect to happen in the future. In everyday language, *prediction* generally refers to something that a fortune teller makes about the future. In science, the term *prediction* generally means "what we would expect to happen or what we would expect to observe if this idea were accurate." Sometimes, these scientific predictions have nothing at all to do with the future. Ironically, scientific predictions often have to do with past events.

Science is a solitary pursuit. When scientists are portrayed in movies and television shows, they are often ensconced in silent laboratories, alone with their bubbling test tubes. This can make science seem isolating. In fact, many scientists work in busy labs or field stations, surrounded by other scientists and students. Scientists often collaborate on studies with one another, mentor less experienced scientists, and just chat about their work over coffee. Even the rare scientist who works entirely alone depends on interactions with the rest of the scientific community to scrutinize his or her work and get ideas for new studies. Science is a social endeavor.