

What is Science?

By Stephen D. Veirs, Jr.

Sometimes, we think scientists do science and other folks, including resource managers, do not. Most of us do science in informal ways all the time. The gap, if any, between resource managers and researchers shouldn't exist. Some of us have more skills than others. Some of us do more actual research than others. Some of us do research but we call it management study.

What is science? Science is an informal and formal system of discovery based upon communication, logic, rules of experimentation and so on. Scientific discoveries, new theories, and experimental results are meant to be communicated, exposed to the light of critical examination, repeated, refuted, massaged and fed back into the system. By exposing methods and results, the system builds an improved understanding of the natural world. There is no sleight of hand, no magic. There may be competition and other human vices among scientists, but also there is and has to be review and professional criticism, because science requires independent verification, not just authoritative pronouncements. The recent topic of "fusion in a test tube"² is an excellent example of how verification and criticism work in science.

The scientific method is similar to the way most of us, more or less well, comprehend our world. We observe regular events in the world around us. We test them by experience. If they hold up we come to rely upon them as facts of life. Day follows night. Summer follows winter. Water flows downhill, becomes a solid when cooled, and so on.

As we become more sophisticated or curious, we may wonder how these wonderful things happen. What rules guide the events we observe? Can we predict future events based on our knowledge? Here I want to tell you what science is, and is not. I want to give you some examples to show you what bad science or non science might be. I want you to be sure that even though you might not be a research scientist, there are things that you can do and should do in your work to make it better. I also want to tell you what science can't do for you.

First, it is essential that you know clearly what you want to understand about your resources. You must ask very specific questions of your surroundings if you want answers that will permit you to manage them. To predict future events or effects you must have a clear understanding of the relationships of facts and the laws or theories which describe the way the facts of observations are strung together.

Much of the science done in the parks from long ago to the present has been descriptive – gathering facts, making geologic maps, mapping vegetation, taking photographs. Gathering facts, making observations, is the essential first step in understanding our park resources. Assembling the observations in some sort of order is the beginning of understanding their relationships. Based upon our perception of this information we may begin to draw inferences about how the organisms, the physical setting and natural processes work to produce the landscape we see before us. Thus we begin to construct our own theories describing these relationships whether in our work or in formal scientific study.

The observations we make in everyday life as well as the more systematic observations of science reveal certain repetitions or regularities in the world. The laws

of science are nothing more than statements expressing these regularities as precisely as possible. Facts are particular events, and are distinguished from laws, which are universal statements. **Science begins with direct observations of single facts. When many observations are compared with one another, regularities may be discovered.³ These regularities are expressed by statements of theory.** Scientific theories are regularly proposed to explain observed phenomena. Before they can become accepted explanations, part of scientific knowledge, they must prove their worth. Until then they are merely hypotheses and as the history of science shows, even highly plausible hypotheses all too frequently turn out to be false. What is the method by which they are tested and found acceptable or unacceptable?

Scientific theories are tested by deducing from them consequences regarding observable states of affairs and comparing these consequences with the results of observation and experiment. Hypotheses are tested by appropriate tests that have a high probability of a positive outcome if the hypothesis is true and a high probability of a negative outcome if the hypothesis is false. A hypothesis is either accepted because it has passed an appropriate test or rejected because it has not. Statistical methods are widely employed today as a part of the procedures by which we accept or reject hypotheses. The science of statistics has developed over the last hundred years and is increasingly used in formal scientific studies.

Unhappily, it is not possible to arrive at a complete verification or confirmation of a law or theory even after much testing of hypotheses. There is, however, a simple way laws or theories can be falsified or found untrue. We need only to find a counter instance. It is, of course, important that we be sure the counter instance is certain in itself, that we have not made an error. It is easy to refute a law, but it is exceedingly hard to find strong confirmation. The theories of evolution have been tested many times over with confirming results. Is evolution proven? No, but it is the best theory we have explaining observed changes in populations of living organisms. The recent assault by creationists on the teaching of evolution in science classes was facilitated in part by the rules of science. Evolution is an accepted scientific theory, not a provable fact, but well supported by the great preponderance of biological evidence. Other theories of why things are as they are have been set forth, but these are only weakly supported by facts and their contradictions have excluded them from serious scientific consideration. Scientists accept this ambiguity as they look to refine the "theory", but creationists use scientific skepticism as an opportunity to establish their views as a co-equal "scientific theory".

In the physical sciences, the greater ease of experimental testing tends to make confirmation of theories easier, yielding "laws" as we come to know them in the classroom – the gas laws, the law of gravitational attraction, and the periodic table are examples. Those of you dealing with biological systems must realize by now that it's much harder to come by a good biological law. The term "theory" will more often be used to describe regularities of nature as pertains to living organisms and ecosystems. By now you know that a research scientist can prove a theory wrong, but can never prove it right. As a manager you should be careful about asking them to do the impossible.

Teleology is any explanation of a phenomenon that attributes purpose to a biological behavior or function

and refers to motive rather than cause. If it is said that a butterfly mimics a more aggressive organism for the purpose of protecting itself from predators, we must clarify the issue. If it is said that this mimicry is for some purpose inherent in the design of the universe, then clearly we are unable to test the explanation empirically. If we can translate the idea into a non-teleological or non-purposeful statement that deals with the evolution of a trait in relation to differential survival of the individual butterfly and the perpetuation of the species, then we may be able to sort out some tests of the explanation. Green plants will grow toward a strong source of light. Not because they "need" the light (they do) but because of biological mechanisms that we have come to understand from experiment. Cell elongation depends on chemicals produced in the stem tip. Light degrades those chemicals. The side of the stem exposed to strong light grows more slowly than the shaded side and soon the plant is growing toward the light source as all sides of the stem are evenly illuminated. You should avoid seeking "purpose" as an explanation of a natural process.

I can tell the Superintendent at Redwood something about the frequency and effects of fires in his forests. I can tell him "why" in the sense of how and when fires are ignited and spread, but not "why," in some cosmic sense, that the fires occur. Natural fires do not have a purpose. They are neither good nor bad. Their effects are just the "natural" consequences of the fire, the weather, the biological setting and so forth. Any individual may assign a value judgment to the results of a fire, depending upon his frame of reference. A forester seeking to maximize yield of sawtimber views a fire as bad. In the strict sense of managing the natural resources of a park, a naturally ignited fire in a natural ecosystem is neither good nor bad. It is just a part of the natural system.

Many of you have done or will do research, or management studies. If you do a study upon which you base some management action and it is a badly designed study, you may find your management decision reversed in court or in the courtroom of public opinion because of faulty methods, faulty interpretation of the results, poor logic, etc. You may be embarrassed. You may have wasted money. We all need to be sure what question we are asking. If we begin making predictions based on formal or informal hypotheses or theories, we may wish to test our theory by some form of test or experiment. Here are some steps to follow:

1. Carefully define the question;
2. Review what is known about the matter;
3. Consider how you will perform your experiment;
4. Write up the experimental procedure;
5. Have it reviewed by a reliable critic;
6. Revise as appropriate, and determine that you are still asking the right question;
7. Perform the experiment, accept or reject your hypothesis;
8. Assess the implications of the result for your management.

Remember that even if your hypothesis is accepted this time, it does not prove that the hypothesis is true. Your theory may fail in its next test. Or your interpretation of the results may be inappropriate. Just because there is good correlation between some observations does not mean that there is a causal relationship. Fish are always found in water. Just because we find a body of water doesn't mean we will find fish.

Is science real? Scientific realism is the position that scientific theory construction aims to give us a literally

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true story of what the world is like. The acceptance of a theory involves the belief that it is true, even though scientific progress is attained by proving theories false and then moving on to construct another. Bas van Fraassen⁴ makes the point that science is a biological phenomenon, an activity by one kind of organism (we humans) which facilitates its interaction with the environment. He continues, "The Darwinist says: do not ask why the mouse runs from its enemy. Species which do not cope with their natural enemies no longer exist. That is why there are only ones who do." van Fraassen⁵ claims that "the success of current scientific theories is no miracle. For any scientific theory is born into a life of fierce competition, a jungle red in tooth and claw. Only the successful theories survive – the ones which have *in fact* latched onto actual regularities in nature.

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¹ Throughout this presentation I have liberally used ideas and words from a collection of papers on the Philosophy of Science, in the book *Scientific Knowledge – Basic Issues in the Philosophy of Science* by Janet A. Kourany, Wadsworth Publishing Company, Belmont, CA 1987.

² Pool, Robert, 1989. *Research News*, Science 243:1661-1662.

³ Carnap, R. 1987. *The confirmation of laws and theories*, pp. 122-138. In Kourany, J. (see 1.).

⁴ *Ibid* p. 343.

⁵ *Ibid* p. 358.