Science and the Scientific Method

NRC 601
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“Supposing is good, but finding out is better.”

-- Mark Twain

**What is Science?**

- Latin *scientia* or *sciêns* for “to know”

- *Not* an activity, collection of facts, or advanced technology

- *It Is* . . .
  - a process, beyond the “scientific method”
  - a philosophy, for thinking about the world
  - an objective search for “truth”

*(given that “ultimate” truth is an elusive and unreasonable goal)*
What is the Scientific Method?

- the Scientific Method is *not* Science

  *the philosophy, process, & practice of Science* is much more

- it is a *TOOL* for...
  
  forming and framing questions

  collecting information to answer those questions

  revising old and developing new questions

This *Feedback Loop* is a key characteristic

of the Scientific Method
Four basic methods of Knowing

(1) Tenacity - holding tight to traditional beliefs.

(2) Authority - expert opinion.

(3) A Priori Method - consequences based on a set of assumptions.

(4) Science - a circular process of information, based on theory >>> testing >>> feedback

Science is the only method that is self-correcting; there are built in checks along the way.
Early Developments

- One of the early papers on the scientific method - 1890


- Formalized by Popper: hypotheses are tested & rejected


- Further emphasis: testing of multiple, alternate hypotheses

Natural resource conservation and management were built on natural history observations and conclusions from associations.

\[\textit{e.g.,}\]

- Fish stocks decline given certain levels of sustained exploitation.
- Ungulate reproductive rates are affected by severity of winter weather.
- Tree growth is influenced by stand stocking levels.

Thus we have a long tradition of management based on laws of association rather than on experimental tests of specific hypotheses.
Approaches to Research

(1) Descriptive Studies

-- search for a pattern, and then infer a mechanism

-- biggest problem is that a mechanism must be invoked to explain the pattern . . .

however,

-- several different mechanisms may produce the same pattern
(2) **Comparative Studies**

-- follow directly from descriptive studies

-- observational data are used to describe patterns

-- patterns compared in order to infer differences

*however,*

-- have the same problems of more general descriptive studies
(3) **Models**

-- “all models are wrong, but some are useful”

-- can provide insights and help us think about how a system may work

however,

-- modeling exercises alone do not help us to infer the underlying cause or causes
(4) **Experiments**

-- requires the researcher, in advance, to specify:
  a. a question
  b. a means of answering that question

  thus,

-- experiments tend to be better designed

-- the goal is to hold all variables stable while manipulating a variable (or variables) of interest
Two classes of experiments

1. natural experiments
   -- the system provides the manipulation
   -- e.g., fire, windstorm, drought, annual differences

2. manipulative experiments
   -- involve treatments ($t$) and controls ($c$)
   -- can be conducted in the lab or field
   -- e.g., dose-response experiments
   removal or additive experiments
Approaches to Research . . .

Two classic early experiments in ecology:


What is the goal of Science?

To offer explanations about the natural world.

-- the scientific method is the most efficient technique for acquiring *reliable knowledge*.

-- it enables us to determine the underlying mechanisms to observed patterns.

-- we are thus able to go beyond mere description and ask *WHY* these patterns occur.
There is nothing inherently wrong with descriptive, comparative, or modeling studies.

Well planned and executed descriptive studies often form the first step into new areas of inquiry and research.

However, the results from these studies are often equivocal, they do not address cause-and-effect, and they do not answer the question “Why?”
How does the Scientific Method work?

Six steps

(1) Hypothesis development.
(2) Experimental design.
(3) Experimental execution.
(4) Data analysis.
(5) Interpretation of results ... and ...
(6) Feedback to Step 1...