Workshop 1: Experimental Design

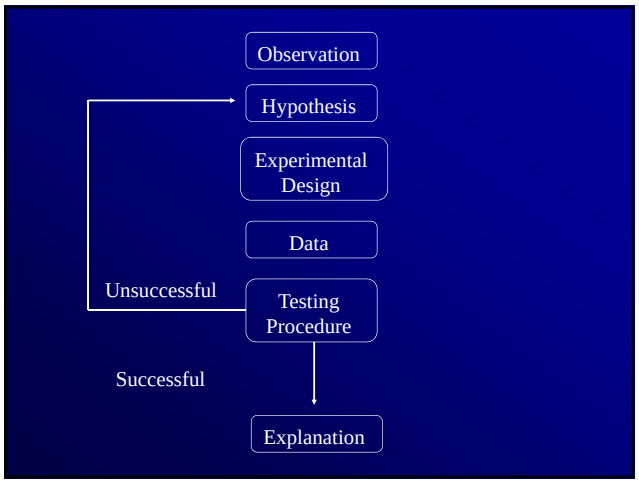
I. Acquiring Knowledge
   A. Kerlinger
   B. Scientific Method
II. Approaches to Science
   A. Observational studies
   B. Experimental studies
III. Replication, Sample Size and Randomization

I. Methods of Gaining Knowledge

A. Kerlinger (1973) 4 basic methods of knowing

1. **Method of tenacity – utilize traditional beliefs even when there is no scientific basis.**
2. **Method of authority – practiced in practical way when we contact an expert in a subject area for advice.**
3. ***a priori* method – used in development of theories; series of assumptions are made and simulations used to determine consequences of assumptions.**
4. **Method of science – circular process in which previous information is synthesized into a hypothesis, predictions are deduced, and tested through experimentation or observation. Hypothesis is modified or expanded based on results.**

Process is self-correcting, checks built into the system.



B. Method of science

1. **Begins with problem or question**
2. **Suggest a possible answer – hypothesis**

Simple declarative statement proposing a cause of a phenomenon.

Arise from

-previous research

-intuition

-inspiration

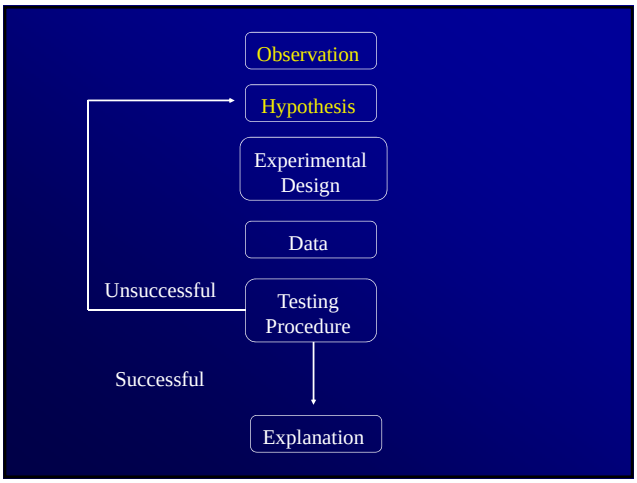
The constructed hypothesis must make predictions.

In order to test the hypothesis observations are made to check the predictions.

Why do Brown Thrashers have speckled eggs?

Hypothesis - Brown Thrasher eggs are speckled in order to camouflage them from visually-searching nest predators.

Prediction – If the eggs are not camouflaged then nest predation would be higher.

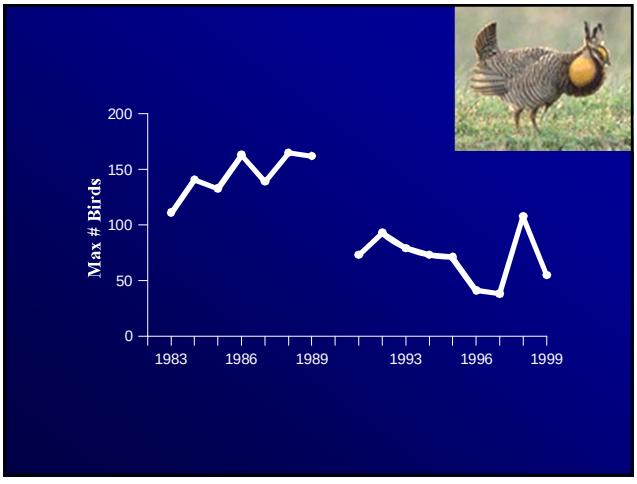


II. Approaches to science

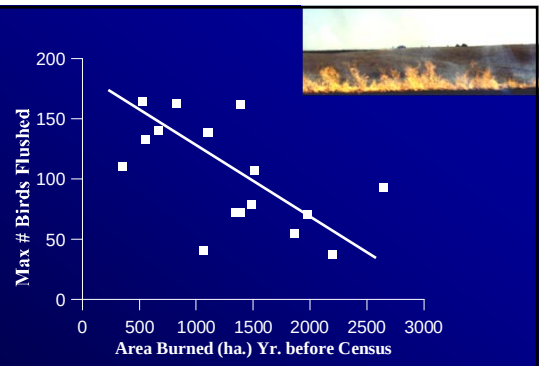
A. Observational or descriptive studies – observing natural variation in order to discover patterns.

Usually an initial and essential phase of science.

Often involves broad objectives rather than tests of specific hypotheses.



Hypothesis – Frequent burning of grasslands negatively affects Greater Prairie-chicken populations.



y = 153 - 0.039x
F = 7.16, P = 0.018

What can we conclude from this study?

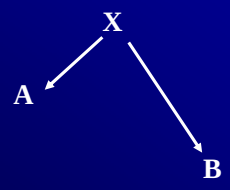
Fires are the cause of GPC decline **NO!**

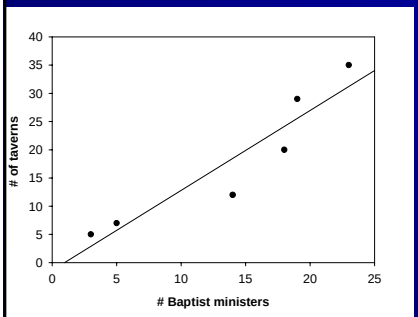
Major goal of biology is to understand causality.

Observation -

A → **B**

But…





Relationship between # Baptist ministers and # of taverns in Wisconsin Counties

So, how do we infer causality?

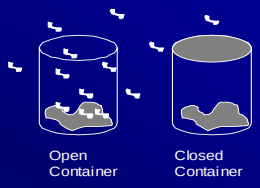
B. Experimentation – procedure designed to collect observations according to a prearranged plan, under defined conditions, under control of investigator.

Correlation does not prove causation. Only experimental manipulation can get at causation.

1. Classic Experiment

It is a common experience to discover a family of young mice in a pile of old rags or maggots infesting rotting meat. Indeed people in the Middle Ages believed that these environmental conditions provided the opportunity for life to arise spontaneously. Old rags and cheese produced mice; rotting meat produced flies.

Francesco Redi (1621-1697), an Italian poet, physician and naturalist, disagreed. He thought that flies could only arise from flies, that adult flies had to lay their eggs on the rotting meat in order for maggots to appear. In 1668 he demonstrated the validity of this hypothesis.

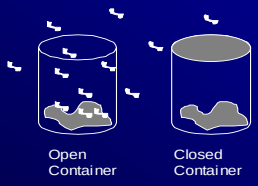


Control and Experimental Groups

Which is the control?

Which is the experimental or treated?

Why is a control necessary?



1. Essentials of an experiment

- Control group – parallel observations used to verify effects of experimental treatments. Controls are the same as experimental group in every way except for the one factor being manipulated.
- Treated group – group to which a manipulation or treatment is applied.

- Experimental unit – the smallest unit that is independent of other units and to which we can randomly assign a treatment.

Hypothesis – Ectoparasites reduce the reproductive success of European Starlings.

Treated Group – fumigate nests with Malathion

Conrol Group – unmanipulated nests.

Prediction – Fumigated nests should produce nestlings in better condition.

What is the experimental unit in this example?

The entire brood of nestlings in each nest. Not individual nestlings!

Nestlings within a nest (brood) are not independent of one another!

Experimental Unit – the smallest unit that is independent of other units and to which we can randomly assign a treatment.

Mean Brood Mass

Fumigated	Control
67.6	59.3
71.2	70.7
57.5	72.5
65.7	55.4
70.7	66.7
73.6	67.5
76.5	63.6
64.6	65.2
67.3	64.5
68.6	48.1

III. Replication, Sample Size and Randomization

A. Replication

Experimental error – random variation among experimental units treated alike.

Mean Brood Mass

Fumigated	Control
67.6	59.3
71.2	70.7
57.5	72.5
65.7	55.4
70.7	66.7
73.6	67.5
76.5	63.6
64.6	65.2
67.3	64.5
68.6	48.1

Replication – number of random, independent experimental units drawn from the research population.

1. Provides estimate of experimental error (provides several observations on experimental units receiving the same treatment)

2. Increases precision of experiment by reducing standard errors.

Standard error of mean, $se = \sqrt{s^2/r}$

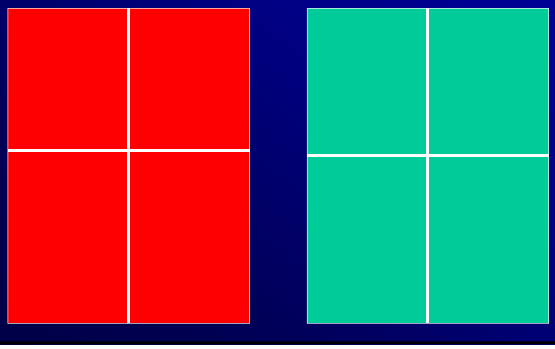
s^2 = sample variance

r = number of observations.

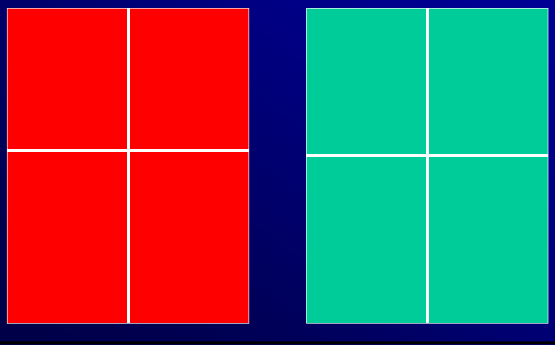
Caveat – only increases if they are true replicates (independent random samples).

Estimate effect of fire on GPC habitat.

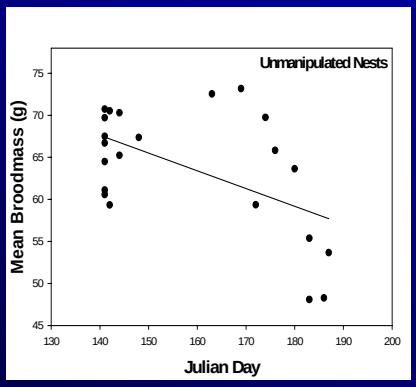
Burned Unburned



Pseudoreplication



B. Randomization – treatments are assigned to experimental units in such a way that any unit is equally likely to receive any treatment.



C	C	C	EF	EF	EF
C	C	C	EF	EF	EF

C = Control

EF = Experimental Feed

1. Eliminate bias – ensures that no treatment is favored or discriminated by systematic assignment to units in a design.
2. Ensures independence – necessary for valid significance tests.

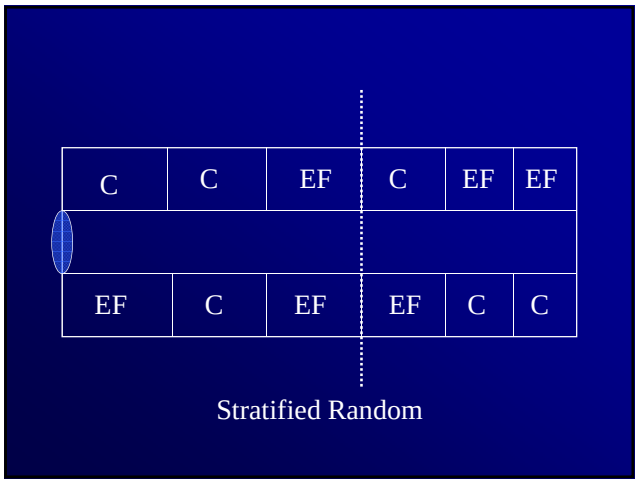
Most efficient means is by using a random number table.

C	EF	EF	C	C	C
EF	EF	C	C	EF	C

Simple Random Design

C	EF	C	EF	C	EF
C	EF	C	EF	C	EF

Systematic Sampling


C
C
EF
C
EF
EF
EF
C
EF
EF
C
C
Stratified Random