BIOE 183 Fall 2013

Undergraduate Research in Ecology and Evolutionary Biology

Philosophy of Science and The Scientific Method

Class meeting 2: 7 October 2013

Philosophy of science: the scientific method

Philosophy → **How we understand the world**

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Science → **A "method" for achieving this goal**

Develop theory
Formulate hypotheses - predictions
Test predictions

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Expt/Obs Design → **How we test (assess) predictions**

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Statistics → **Tools for quantitatively evaluating data**

Definitions

Theory: Set of ideas formulated to explain observations or phenomenon

Hypotheses:

General: supposition or conjecture stated as a prediction (from theory, observation, belief or problem)
→ WEAK

✓**Specific:** applies to a specific test (observation OR experiment) (from theory, observation, belief or problem)

✓**Null:** expected outcome if supposed mechanism is not observed (i.e. "no effect")

Prediction: expected outcome(s) if *both* assumptions and conjecture are correct

More Definitions

Induction (or inductive reasoning):

→ General laws exist because particular cases seem to be examples of it.

Deduction (or deductive reasoning):

→ something must be true because it is a particular case of a general (universal) law known to be true.

$$\textbf{specific} \;\; \underset{\xleftarrow[\hspace{8em}]{\text{deduction}}}{\xrightarrow[\hspace{8em}]{\text{induction}}} \;\; \textbf{general}$$

5 swans seen that are all white — all swans are white

Induction (or inductive reasoning):

(if) (particular/observation), (then) (universal/ inference)

Obs: All 5 swans that I've seen are white.

Hyp: All swans are white.

Inductive Is Specific to General

Deduction (or deductive reasoning):

(if) (univeral/theory), (then) (particular/observation)

Obs: We know that all swans are white.

Hyp: The next swan I see will be white.

"DIGS": Deductive Is General to Specific

→ We use both…….

BUT: which should we use to test a particular hypothesis?

Inductive Hyp: All swans are white.

Deductive Hyp: The next swan I see will be white?

Comparison:

1. Which is more testable?
   → What if next swan is not white?

2. Which is normally used in everyday experience?

3. Which is more repeatable by different people?

Phases of a Research Program

1. **Conception -** a new idea or insight (inductive)

   -- theory, observation, belief, problem

   -- creative, difficult to teach

2. **Assessment:** should be repeatable (deductive)

Together: hypothetico-deductive reasoning

Hypothetico-deductive reasoning

I. Conception

Largely inductive reasoning

***Note: Hypotheses stated as alternative H_A to null H_O**

Perceived Problem

People/objects don't float

Previous Observations

Belief

INSIGHT

Gravity

Existing Theory

General hypothesis*

Gravity keeps objects on the ground.

II. Assessment

Deductive reasoning

Specific hypotheses*
(and <u>predictions</u>)

If I drop a ball, it will hit the ground.

Comparison with
new observations
or experimental results

Hypothetico-deductive reasoning

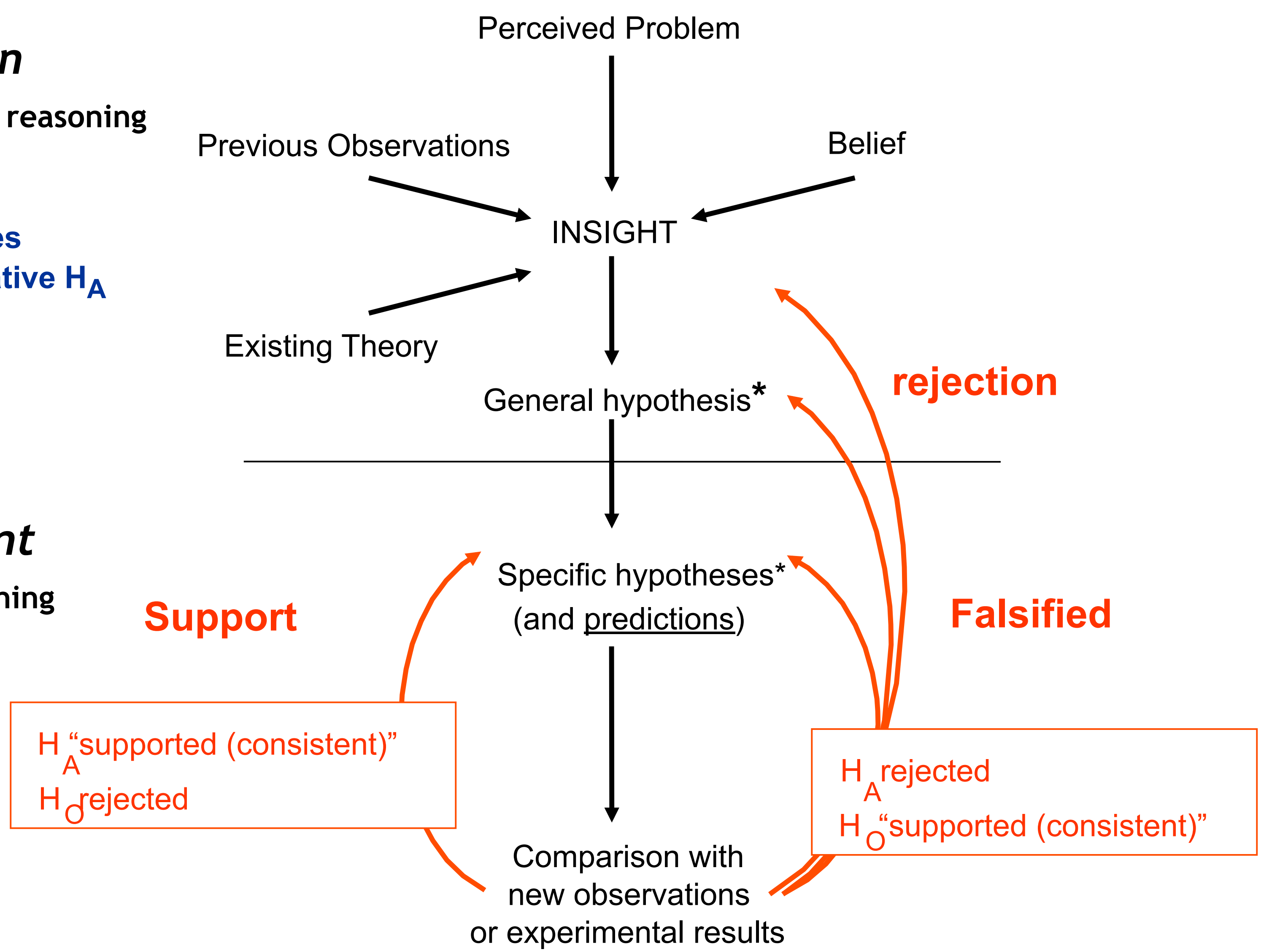
I. Conception

Largely inductive reasoning

***Note: Hypotheses stated as alternative H_A to null H_O**

II. Assessment

Deductive reasoning



Stating Specific (or working) Hypotheses and/or Questions

Should indicate

→**direction**

→**what** you will **measure or estimate.**

	Wrong	Right
Hyp:	The size of X is affected by Y.	The size of X is reduced by Y.
Q:	Does Y affect the size of X?	Does Y reduce size of X?

NOTE: we don't "prove" an hypothesis

Why not??

→Can only say…

…the data are 'consistent' with or support $H_{A;}$ or we 'accept' H_A

This is why science has 'theories' – and why the public sometimes assumes that means a theory is only tentative (e.g., the evolution controversy)

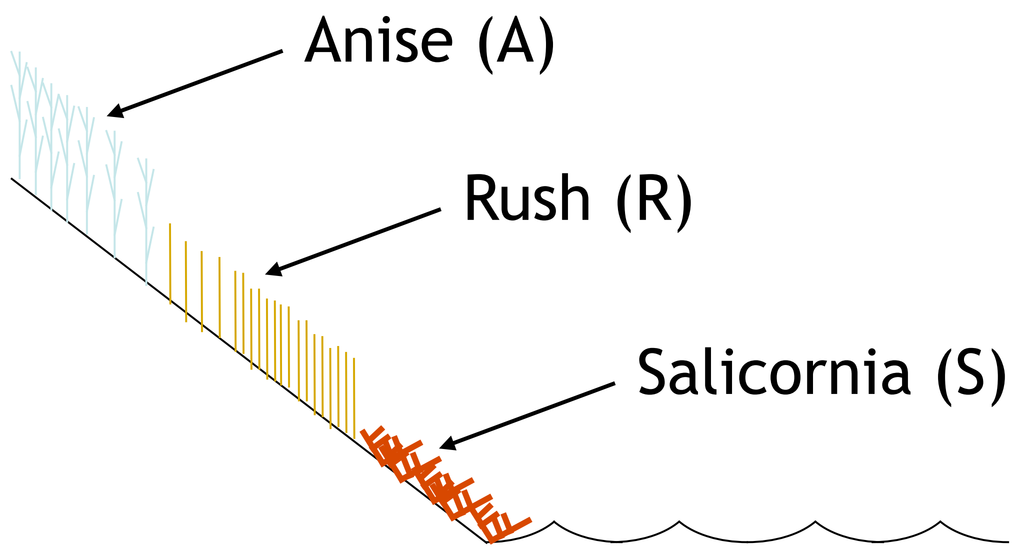
Scientific Process

1) Propositions that are not subject to rejection (not falsifiable) are not "scientific".

2) Progress made by repeated testing (rejection or confirmation) of alternative hypotheses until all reasonable ones have been tested ("last man standing").

Example - Platt's (1964) "Strong Inference"

1) **Observation:** discrete distributions of vegetation along elevation gradient (zonation) adjacent to Younger Lagoon



Example - Platt's (1964) "Strong Inference"

1) **Observation: zoned distribution of species**

Is there any existing theory to explain this pattern?

Limits of species distributions often set by their relative tolerance to physical factors:

-- water immersion
-- salinity
-- desiccation
-- soil characteristics

Insight: distribution limits set by tolerance to water immersion

→Restate as a general hypothesis:

Example - Platt's (1964) "Strong Inference"

2) General hypothesis (H_A): lower limit of rush zone is set by tolerance to immersion

General N**ull hypothesis** (Ho): no effect of immersion on lower limit of rush distribution

How would you test H_A?

Is it clear from H_A what you need to measure?
→ NO

→**The general hyp needs to be made more concrete (operational):**

→What does **"is set by"** really mean?

Example - Platt's (1964) "Strong Inference"

3) Specific hypotheses:

Observational –

H_A: average water level coincides with lower limit of rush;

H_o: no relationship between water level and lower limit.

Experimental –

H_A: rush plants transplanted to clearing below lower limit will die.

H_o: no difference in survival between transplants and controls

Example - Platt's (1964) "Strong Inference"

4a) Test of prediction by OBSERVATION: repeatedly observe

→ lower limit of rush **DOES** coincide with mean water level

(→ support hypothesis that lower limit set by immersion).

Consider other tests (e.g., other species; other variables possibly correlated with water level; mechanisms/reasons why H_A is supported) of general hypothesis

4b) Test of prediction: repeatedly observe

→ lower limit of rush does **NOT** coincide with mean water level

(→ reject hypothesis that lower limit set by immersion).

Consider other alternative hypotheses until you can't reject one.

AND/OR

5a,b) Test of prediction by EXPERIMENT:

Parallel process with experimental tests of predictions

“Strong Inference” : Summary

1) **Observation** (or theory)

2) **General hypothesis**

3) **Specific hypothesis** (that state testable predictions that are directly related to the general hypothesis)

4) **and/or 5) Test(s) of prediction(s)**

support hypothesis → consider other tests of general hypothesis to possibly reject or further substantiate.

reject hypothesis → consider other alternative hypotheses until you can’t reject one.

Problems

1) This process leads to "**paradigms**", a way of thinking that has many followers, with great inertia. Contrary evidence may be considered an <u>exception</u> rather than evidence for falsification.

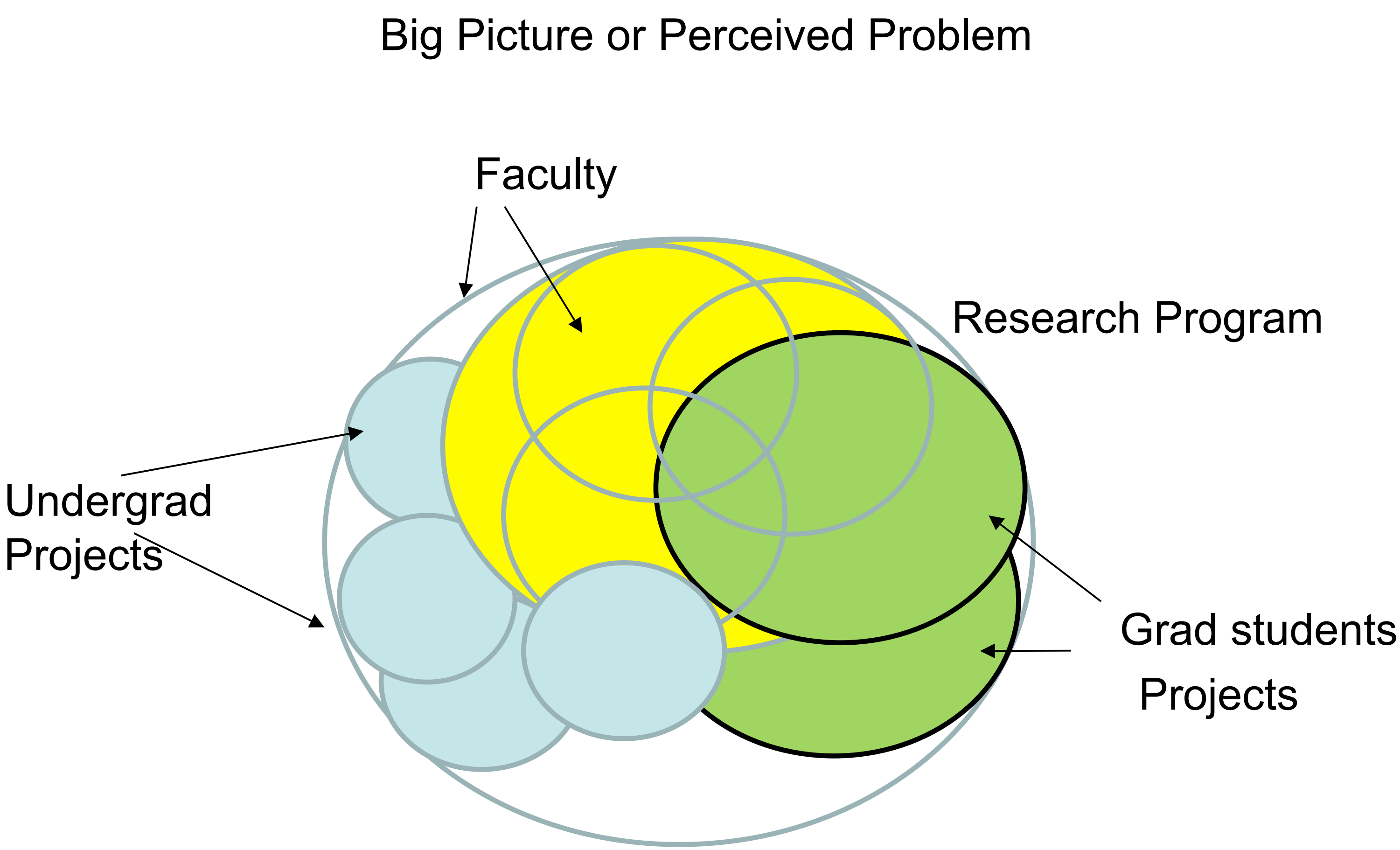
2) Some scientists argue that this (Hyp-deduction) is **not how we do science**, but rather we build a convincing case of many different lines of evidence.

3) Others (e.g., Quinn & Dunham) argue that ecology, in particular, is **too complex** (many variables that interact with one another) to devise unequivocal tests.

Examples: - multiple mechanisms of succession
- changing interactions depending on species density

4) In EEB-type sciences, we're often interested in **relative effects and strengths of effects** (i.e. direction and magnitude) (rather than presence – absence of effects).

Thinking about your project



Thinking/writing about your project

Writing → develop summary

MOST of you: test a hypothesis

The BIG picture → Perceived Problem

First sentence

↓

INSIGHT

Link between big picture and your project

↓

General hypothesis*

↓

Your project → Specific hypotheses* (and <u>predictions</u>)

Your Hyp (or Q)

General methods (lab/field; expt/obs/model)

How does this help the big picture?

↓

Report/proposal/thesis

Thinking/writing about your project

Writing → develop summary

SOME: do Inductive portion only.

The BIG picture → Perceived Problem

First sentence

↓

INSIGHT

Link between big picture and your project.

Project goals

↓

General hypothesis*

General methods (lab/field; expt/obs/model)

How does this help the big picture?

↓

Your project → Specific hypotheses* (and predictions)

↓

Report/proposal/thesis

SUMMARY/ABSTRACT

(due next Sunday 13 October 2013))

EEB Writing Guidelines (see class website)
www.eeb.ucsc.edu/academics/eeb-writing-guidelines.pdf

Concentrate on pages 1-3 and example in Box 1 on p. 15

Format: Write <u>one paragraph (200 words or less)</u>: 6-8 sentences with these mini-sections
(note this summarizes the Introduction, Methods, Results and Conclusions of a proposal or report):

1. General problem or question; this is critical → gives the ***context*** and purpose
2. What is your organism/research system and why/how does it address #1?
3. Hypothesis or question (or goal) → be specific
4. Method(s) : be very general (experimental, observational, modeling, …)
5. Summarize the key results of the study (not in proposal)
6. General summary statement → how your results might address #1

For ANY writing:

1. **Plan ahead**

- **Don't just write: start with an outline or list** that includes only essentials such as key words or bullet points. Make sure you cover all the points in the guidelines for your assignment.
- **Outline:** edit for structure and content (and much more efficient than doing these after you start to write)
- Leave enough time to edit several drafts of your paper

2. **Write:**

- Write a first draft by amplifying your outline
- Follow the writing guidelines below
- Proofread all of your writing carefully
- Edit your draft several times, checking for grammar, voice, conciseness and flow

3. **Edit: be completely ruthless.**

- Editing means thoughtfully consider each sentence, paragraph and flow of the entire report/paper. You should plan to spend more time on editing than on actually writing your first draft (even of your outline).

Summary/Abstract (for proposals or reports):
•Usually the last section to write. (not for this class!!)
•Importance: it is the first (only?) portion of a paper that readers look at and will greatly influence whether they continue to read the rest of the paper.

Format: Write one paragraph: 6-8 sentences with the following flow (5 mini-sections) that essentially summarizes the Introduction, Methods, Results and Conclusions of your study.

1. Start with the general problem/question → gives ***context*** and purpose.
2. State what you are testing: your hypothesis (or your question/goal).
3. Your organism(s) or research system: why/how does it address #1?
4. What general method(s) will you use (experimental, observational, math)?
5. Summarize the key results of the study [not in a proposal]
6. Provide a general summary statement, including your conclusions (how the details of your project address the general problem you gave in the first sentence).

Note:

No references
No details

For edits: always print double-space (at least)