

Scientific Method

OBJECTIVES: Students should be able to.....

1. Outline the **scientific method**, defining each step, and explain the importance of control experiments and controlling variables.
2. Describe types of **questions that scientists ask**. What types of answers do they expect?
3. *Construct a hypothesis and brainstorm an experiment to test a biological phenomenon that you find interesting!!!!*

1.3 How Do Biologists Investigate Life?

Biologists use many methods to expand our understanding of life.

- ***Observation: improved by new technologies***
 - *Eg: fish tracking – location (GPS), salinity, temp., pH.....*
- Experimentation

Figure 1.11 Tuna Tracking



LIFE 9e, Figure 1.11

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SCIENTISTS ask QUESTIONS:

I. What? — Informational questions

- **Eg:** What is a common behavior of the dolphin?
(dolphins jump out of the water!)

II. How? — Functional questions (“*Mechanistic*”)

- eg: **How** do dolphins jump out of the water?
(molecular/ physiological mechanism).

III. Why? — Adaptive questions (“*Teleological*”; ultimate function)

- eg: **Why** do dolphins jump out of the water? (what is the survival advantage conferred by this activity/ process/ molecular structure??)

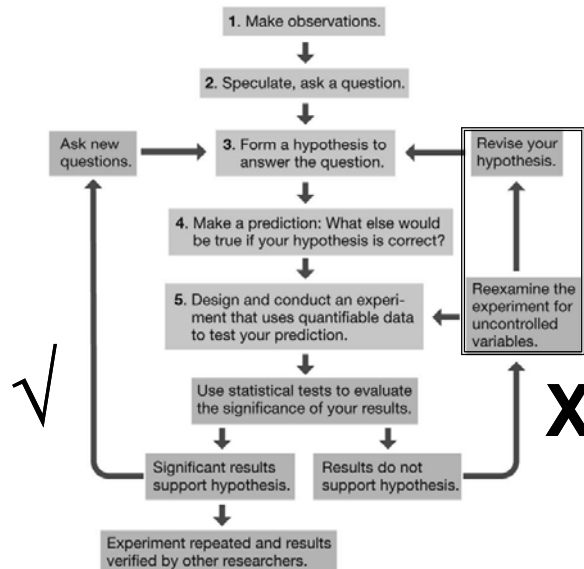
- 1) In order to answer these questions, we make an educated guess (hypothesis) which may answer the question,
- 2) predict possible outcomes if our hypothesis is true,
- 3) then perform tests/experiments & make observations to determine if our hypothesis is true.
- 4) Analyze results, make conclusions, and reformulate hypotheses if necessary.

A. Biology is a Science

The SCIENTIFIC METHOD: There are FIVE parts to the **Hypothesis-Prediction (H-P) system:**

1. Making **observations**
 2. Asking **questions**
 3. Forming **Hypotheses**, tentative answers to the questions (using inductive logic)
 4. Making **predictions** based on these hypotheses (using deductive logic)
 5. **Testing the predictions** by making additional observations or conducting experiments.....
- (*Observe, Question, Hypothesize, Predict, Test....*)

Figure 1.12 The Scientific Method



LIFE 9e, Figure 1.12

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Scientific Method

- 1) **Inductive logic** leads to tentative answers or explanations called **hypotheses**.
 - *Specific observations* → formulate *GENERAL* explanation.
 - 2) **Deductive logic** is used to make predictions and test them!!
 - *General explanation (if true)* → predict *SPECIFIC* result(s). **TEST!!.....**
 - 3) → **Experiments** are designed to test the predictions.
 - 4) If the results of continued testing support the hypothesis, it may come to be considered a **Theory**.
 - If the results do not support the hypothesis, it may be modified or abandoned.
- Most tests of hypotheses are of two types:
 - a) **Comparative experiments** - look for differences between samples or groups. Many variables cannot be controlled. Less invasive (more "natural").
 - b) **Controlled experiments** - manipulate the **variable** that is predicted to cause differences between groups.
 - 2 groups: Control (unmanipulated) & Experimental (manipulated factor).

B. Scientific Method - Example

- The H-P method was used by Tyrone Hayes, a UC Berkeley researcher, to investigate some reasons why the world's frog populations are in severe decline.



- **Step 1: Making observations:**
 - Abnormal frogs are found in some ponds,
 - Hayes knew that agricultural chemicals (pesticides and herbicides) are in high concentrations in US rains and bodies of water. Atrazine, a common herbicide, is legal at <40 ppb.
 - So, pesticides/herbicides such as atrazine could be causes of declining frog populations.

Scientific Method - Example

- **Step 2: Asking questions:**

- Can commonly occurring concentrations of Atrazine cause abnormalities in frog development and/or reproduction?
- If so, what concentrations cause the most damage to frog populations?



Scientific Method - Example

- **Steps 3 & 4: Formulating hypotheses and making predictions:**

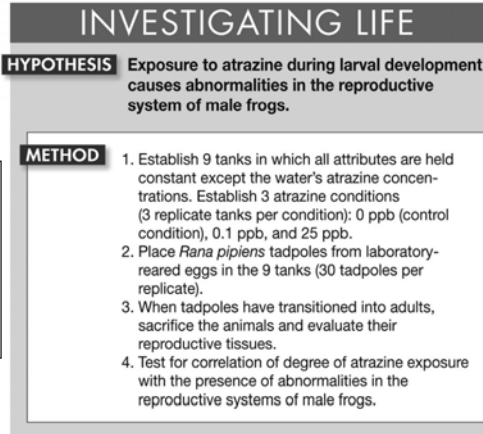
- To develop hypotheses, Tyrone set up both CONTROLLED (0, 0.1 to 25 ppb atrazine) and OBSERVATIONAL experiments (collect frogs and water from locations in Utah to Iowa).
- **Hypothesis #1:** Certain levels of atrazine found in U.S. fresh water areas cause reproductive / developmental abnormalities in frogs.
- **Prediction #1:** Control samples will show normal frog development, while some samples with atrazine will display abnormal frog development.
- ***[Reword into: “If ____, Then ____” format.].....***

Scientific Method - Example

• Step 5: Testing hypotheses:

Figure 1.13 Controlled Experiments Manipulate a Variable (Part 1)

- ❖ **Independent variable:** the variable being manipulated
 - The set condition.
- ❖ **Dependent variable:** the response that is measured.
 - What changes in response to the set conditions.

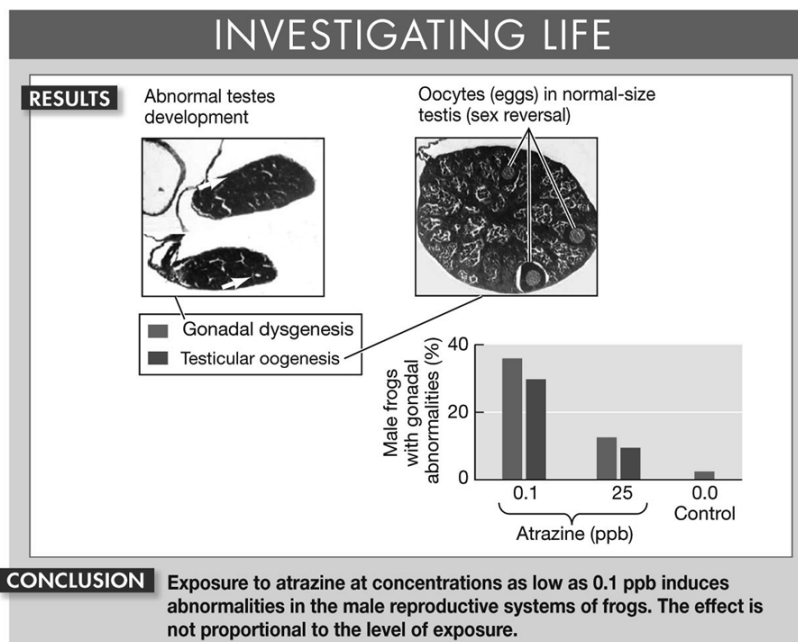


LIFE 9e, Figure 1.13 (Part 1)

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- Must use **Controls**: conditions, same as experimental, except for 1 other variable.
- To confirm no other variables affected your results.

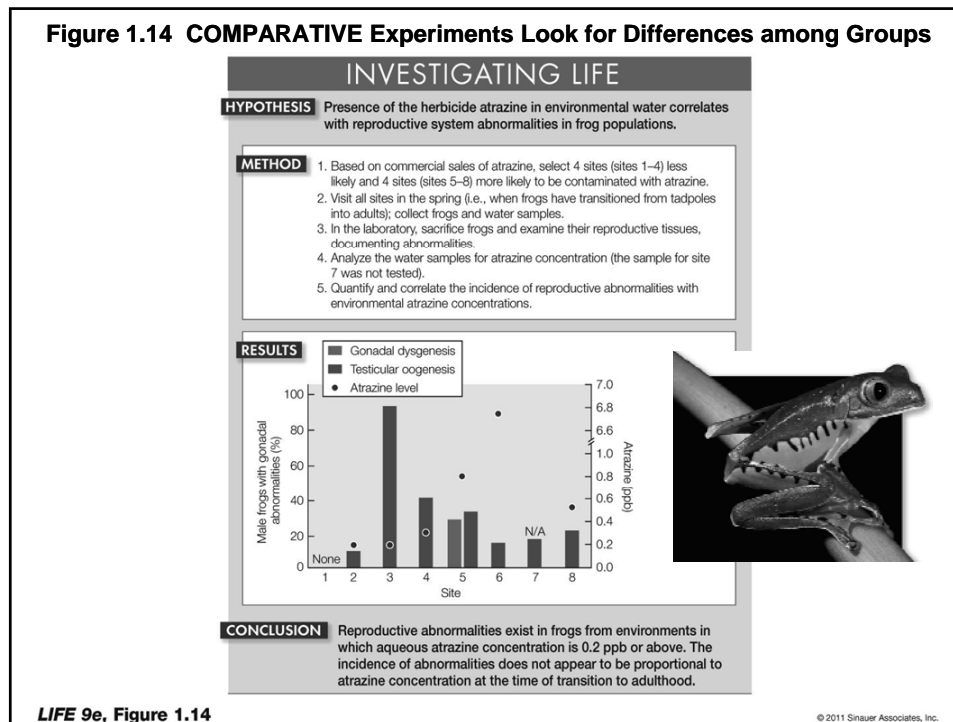
Figure 1.13 CONTROLLED Experiments Manipulate a Variable (Part 2)



LIFE 9e, Figure 1.13 (Part 2)

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Figure 1.14 COMPARATIVE Experiments Look for Differences among Groups



C. Biology is a Science

- It is important to distinguish *science* from *nonscience*.
- Science begins with **observations** and the formulation of **hypotheses that can be tested** and that will be rejected if significant contrary evidence is found.
 - Hypotheses must be **TESTABLE** and have the possibility of being **REJECTED**.
 - Apply **OBJECTIVE DATA** → even if **Null Hypothesis** is proven! (null = no differences exist between samples.)
 - **Statistical methods** analyze the data to eliminate possibility that results are due only to random variation, and not due to the observed/manipulate variable.