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

SCIENTISTS ask QUESTIONs:

I. <u>What</u>? — <u>Informational questions</u>

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

II. <u>How</u>? — <u>Functional questions</u> ("***Mechanistic***")

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

III. <u>Why</u>? — <u>Adaptive questions</u> ("***Teleological***"; ultimate function)

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

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

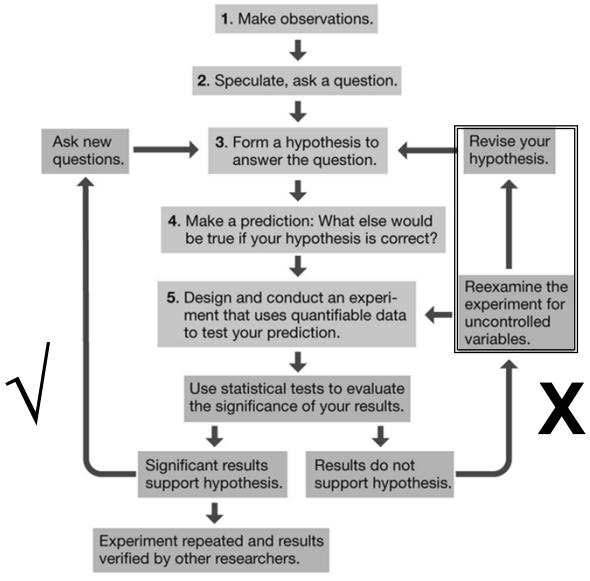
A. Biology is a Science

The SCIENTIFIC METHOD: There are 5-6 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…..
6. **Collect and Analyze data** to form conclusions. (Then, reformulate Hypothesis and retest?)

- *(Observe, Question, Hypothesize, Predict, Test, Analyze….)*

Figure 1.12 The Scientific Method



LIFE 9e, Figure 1.12

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.
- *"Why Are Frogs Croaking?"*

- **Step 1: Making observations:**
  - Abnormal frogs are found in some ponds, but not others.
  - Hayes knew that agricultural chemicals (pesticides and herbicides) are in high concentrations in US rains (1-40ppb) and bodies of water. Atrazine, a common herbicide, is legal at <40 ppb (3 ppb in drinking water).
  - 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).

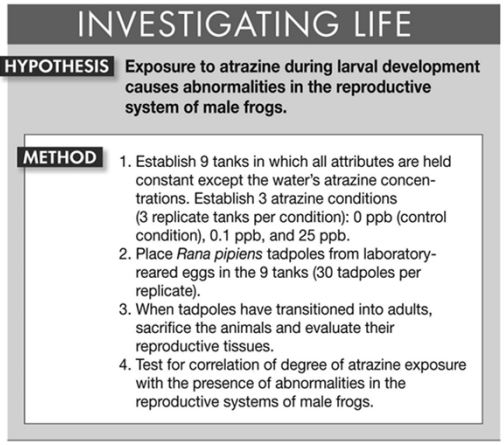
- **Hypothesis #1**: Certain levels of atrazine found in U.S. fresh water areas cause reproductive / developmental abnormalities in frogs.
- **Prediction #1**: Control samples will show normal frog development, while some samples with atrazine will display abnormal frog development.

- ***[Reword into: "If ___, Then ___" format.]…….***

Scientific Method - Example

- **Step 5: Testing hypotheses:**

Figure 1.13 Controlled Experiments Manipulate a Variable (Part 1)

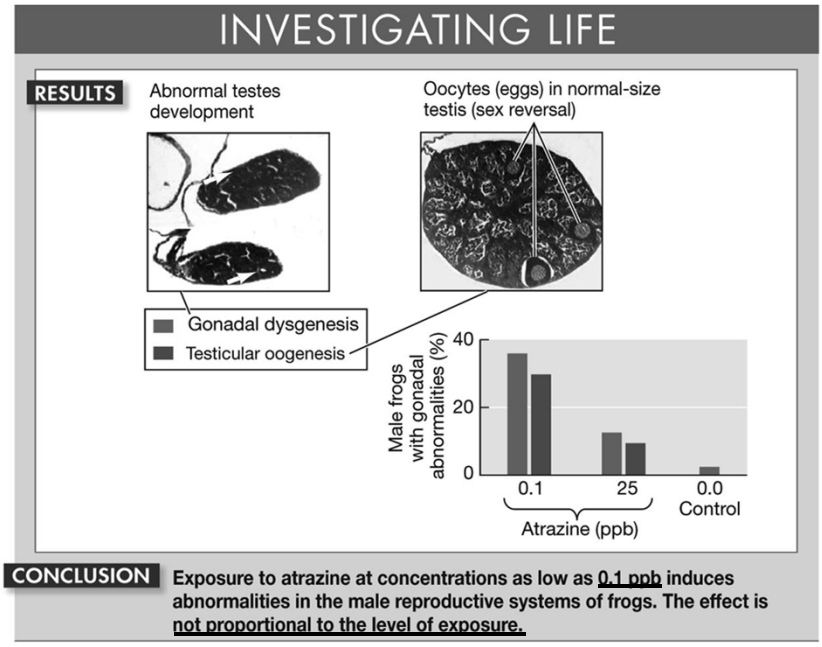


LIFE 9e, Figure 1.13 (Part 1)

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

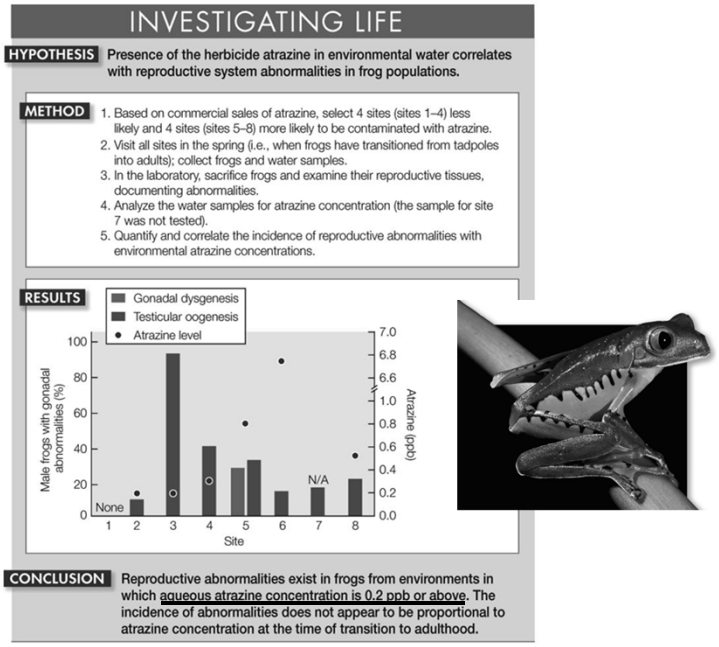
- Must use **Controls**: conditions, same as experimental, except for 1 other variable.
- To confirm no other variables affected your results.

Figure 1.13 CONTROLLED Experiments Manipulate a Variable (Part 2)



LIFE 9e, Figure 1.13 (Part 2)

Figure 1.14 COMPARATIVE Experiments Look for Differences among Groups



***LIFE 9e*, Figure 1.14**

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/manipulated variable.