BIOLOGY

Science for Life

The Scientific Method

- What is Science?
- The Scientific Method
- Controlled Experiments
- Statistical Analysis
- Theory versus fact
- Scientific Literature
- What is biology?

What is Science?

- Science is not a giant collection of facts to be memorized.
- Science is an organized way (process) of using evidence to learn about the natural world in order to:
  - investigate and understand the natural world
  - explain events in the natural world
  - use those explanations to make useful predictions
- We call the process of science the **scientific method**
  - Observing & Questioning
  - Proposing ideas (hypotheses)
  - Testing
  - Discarding those ideas that fail
- The word science also refers to the body of knowledge that scientists have built up after years of using this process.

The Scientific Method

1. Ask **Question**
2. Make **Hypothesis**
3. **Test** Hypothesis
4. **Analyze** Results
5. Make **Conclusion**

What is it you're trying to figure out?

May lead to multiple hypotheses and thus multiple experiments

Example 1:
Does washing your hands with anti-bacterial soap kill most of the germs?

Example 2:
Does consuming vitamin C protect you from getting sick?

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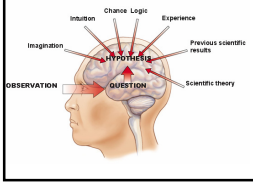
A proposed explanation for the question *based on what is already known (observed)*

Must be:
- Specific (not vague)
- Testable (not supernatural)
- Potentially falsifiable (measurable)



Example 1: Washing your hands with anti-bacterial soap for 30 seconds significantly reduces the bacterial content on them.

Example 2: Consuming the recommended daily allowance (RDA) of vitamin C significantly reduces the number of colds people experience.

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Design a controlled experiment (if…then… statement)

To test:
if vitamin C decreases the risk of catching a cold, then people who take vitamin C supplements will experience significantly fewer colds than people who do not

You might:
*Give one group of test subjects vitamin C supplements and another group **placebos** and see which group catches more colds*

Placebos are fake imitations of the experimental treatment

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Controlled experiments have:

- **Controls** – what would "normally" be expected without the experimental treatment (set of conditions that are kept the same to create a basis for comparison)

Should have only one, but nearly impossible to do this in reality ⇨

- **Independent variables** - conditions controlled by the researcher that create a difference between the control and the test subject (what the researcher is testing)

Results in Data ⇨

- **Dependent variables** – change in response to the independent variables (what the researcher is measuring)

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Also known as
- *Manipulated Variable*
- *Experimental Variable*
- *Test Variable*

- **Dependent variables** – change in response to the independent variables (what the researcher is measuring)

Also known as
- *Responding Variable*

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Make **observations** and record data when you conduct the experiment (**Observation** is the process of gathering information about events or processes in a careful, orderly way)

- **Quantitative** observations/data = measurements
- **Qualitative** observations/data = opinion about a quality

Examples:
1. *Color of the product of a chemical reaction*
2. *Amount of gas produced from a chemical reaction*
3. *Number of bacterial colonies on a culture plate*

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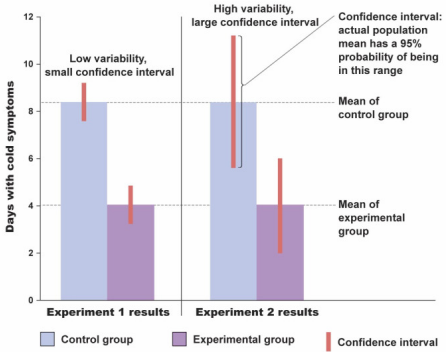
Organize the data using tables and graphs, and compare the data based on statistical analysis

Differences between control and test subject may be due to chance (*sampling error*)

Example: How do you know the differences are not due to age? Genetic variation?

- The more variation there is within the independent variables, the more likely variation in dependent variables will be due to chance
- Statistical analysis determines how likely it is that your results are *not* due to chance by calculating a range in which there is 95% confidence that your results are due to the experimental treatment and not chance

The Scientific Method



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We can extend the results from small samples to an entire population

Less sampling error when:

- Test populations are large (more likely to detect uncontrolled independent variables)

Statistical analysis detects **sampling error**, *not* **observer error**

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Does the data support or disprove the hypothesis?

- A hypothesis that fails the test is rejected and considered *disproven*
- A hypothesis that passes is *supported*, but not proven (because an alternative hypothesis might be the real explanation)

Maybe the people who took vitamin C supplements had fewer colds by chance, or because there was an unrecognized independent variable that was not controlled

NOTE: You cannot prove a hypothesis; you can only disprove a hypothesis (Thus your conclusion will either be that your results support your hypothesis or your results do not support your hypothesis)

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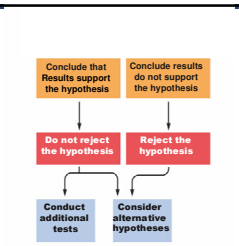


Repeat the Experiment

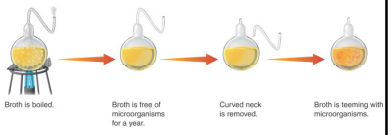
- Why? → to verify the results

Note: *It is critical for scientists to take detailed notes on how they conduct an experiment so that it is absolutely reproducible*

The Impact of Louis Pasteur

- Louis Pasteur's Test of Spontaneous Generation conclusively disproved the hypothesis of spontaneous generation.
- Pasteur showed that all living things come from other living things.
- Pasteur saved the French wine industry, which was troubled by unexplained souring of wine.
- He saved the silk industry, which was endangered by a silkworm disease.
- He began to uncover the nature of infectious diseases, showing that they were the result of microorganisms.

Be able to identify these for Pasteur's experiment



1. **<u>Question</u>:**
2. **<u>Hypothesis</u>:**
3. **<u>Experiment</u>:**

   Controls –

   Independent variables –

   Dependent variables –
4. **<u>Results</u>:**

   Qualitative –

   Quantitative –
5. **<u>Conclusion</u>:**

The Scientific Method

Minimizing Bias in Experimental Design

- If human subjects know whether they have received the real treatment or a placebo, they may be biased
- **Blind experiment:** subjects don't know what kind of treatment they have received
- **Double blind experiment:** the person administering the treatments also doesn't know until after the experiment is over

Theory versus Fact

Scientific Theory

- Powerful, broad explanation of a large set of observations
- Rests on many hypotheses that have been tested
- Generates additional hypotheses
- Theories are considered factual (proven beyond a reasonable doubt) until new evidence disproves them
- Scientific understanding is always changing. Good scientists are skeptics who question both existing ideas (theories) and new hypotheses.

Scientific Literature

Primary Sources

- Researchers can submit a paper about their results to a professional journal (**primary source**)
- **Peer review:** evaluation of submitted papers by other experts (evaluates experimental design, statistical analysis and conclusions, and potential bias)

Secondary sources:

- Review articles, books, news reports, the internet, advertisements
- May be missing critical information or report the information incorrectly
- Beware of *bias*