• Nature of Science
• Asking Testable Questions
• Formulating Scientific Hypotheses
• Experimental Design
• Measurement in Biology
• Analyzing data
Nature of Science

- Focuses on the natural world
- Aims to explain the natural world
- Uses testable ideas

Non-testable ideas:
An explanation is compatible with all possible outcomes

**Question:** Is a sparrow's song genetically-encoded or learned?

**Test:** See what happens when a sparrow is raised in the nest of another species.

- If the song is genetically-encoded...
  - "caw"
  - "caw"
  - ...the sparrow will grow up to sing the usual sparrow song.

- If the song is learned...
  - "caw"
  - "caw"
  - "caw"
  - ...the sparrow will grow up to sing a non-sparrow song.
Nature of Science

• Focuses on the natural world
• Aims to explain the natural world
• Uses testable ideas
• Relies on evidence
• Involves the scientific community
• Leads to ongoing research
Scientific Method

- Make insightful observations
- Pose and clarify testable questions
- Formulate hypotheses
- Do experiments to gather data
- Quantify the data
- Test the hypotheses
- Refine hypotheses and re-test
- Answer questions and make conclusions
Making Observations

Two types of observations:

- Qualitative = “quality” (descriptive)
- Quantitative = “quantity” (numerical)
Observations:
• Dark clouds.
• Air is cool and humid
• Puddles on ground
Inferences

Observations:
- Dark clouds.
- Air is cool and humid
- Puddles on ground

**Inference**: it has recently rained.

You did not SEE rain; you decided that it rained based on your **observations**

Inference = A statement based on your interpretation of observations; cannot be directly observed.
Observations ➔ Testable Questions

• Observation 1: There are fewer elk in Yellowstone National Park than there used to be.

• Observation 2: The density of elk in Yellowstone National Park has declined during the consecutive dry years since the reintroduction of the native wolf population.
Observations ➔ Testable Questions

• Observation 1: Fungi often grow on leftover food.
• Observation 2: Fungi such as mold and yeast grow more on leftover bread than on leftover meat.
Testable Questions ➔ Hypotheses

• Question 1: Do songbird populations respond to the weather?
• Question 2: Do songbirds sing more often in warm weather?

Which question will help us state a testable relationship between weather and birds?

• 1) Songbirds sing more often when the weather is warm.
• 2) The number of bird songs heard per hour during daylight temperatures above 36 C is not significantly different from the number heard per hour at temperatures below 36 C
Hypotheses

• 1) Songbirds sing more often when the weather is warm.
• 2) The number of bird songs heard per hour during daylight temperatures above 36 C is not significantly different from the number heard per hour at temperatures below 36 C

This is a null hypothesis

• Hypothesis: statement that clearly states the relationship between biological variables.
  • Temperature: independent variable (manipulated variable)
  • Number of bird songs heard per hour (dependent/response variable)
Hypotheses

• The number of bird songs heard per hour during daylight temperatures above 36 °C is not significantly different from the number heard per hour at temperatures below 36 °C. This is a null hypothesis; states no difference.

• Hypotheses are statements

• Analysis of data determines whether hypothesis is accepted or rejected.

• A hypothesis can be falsified, but not proven true.
Predictions, Hypotheses, and Theories

• Prediction: What you think will happen

• Scientific/Research Hypothesis: Proposed explanation of something that can be tested.
  • “If... then”

• Scientific Theory: Explanation of some aspect of the natural world that has been substantiated through repeated experiments or testing.
Yeast Experiment

- Observations: Fungi such as mold and yeast grow more on leftover bread than on leftover meat.
- Testable Questions:
Yeast Experiment

• Observations: Fungi such as mold and yeast grow more on leftover bread than on leftover meat.

• Testable Questions:
  • Which nutrients can yeast most readily metabolize?
  • What classes of biological molecules are most readily absorbed and metabolized by yeast?
  • Does yeast absorb and metabolize carbohydrates better than it absorbs and metabolizes proteins?
Yeast Experiment

• Observations: Fungi such as mold and yeast grow more on leftover bread than on leftover meat.

• Testable Questions:
  • Does yeast absorb and metabolize carbohydrates better than it absorbs and metabolizes proteins?

• Null Hypothesis ($H_0$): CO$_2$ production by yeast fed sugar is not significantly different from the CO$_2$ production by yeast fed protein.

• Alternative Hypothesis ($H_a$): Yeast produces more CO$_2$ when fed sugar than when fed protein.
Experimental Design

• CO₂ production by yeast fed sugar is not significantly different from the CO₂ production by yeast fed protein.

• What are the treatments?

• What is the independent variable?

• What is the dependent/response variable?
Experimental Design

- An experiment that accounts for natural variation should:
  - Include replications
  - Test only one treatment variable
  - Include controls

Test Tube 1: Glucose (carbohydrate) + Yeast
Test Tube 2: Protein + Yeast
Test Tube 3: Water + Yeast
Why is the metric system used in science?
<table>
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<tr>
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<th>Prefix meaning</th>
<th>Number of Meters</th>
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<td>Milli</td>
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Activity

620 meters = 0.0620 km = 620,000 millimeters = 62,000 centimeters.
### Example Conversion

<table>
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153 cm = _______ km
Example Conversion

Because the metric system is base ten, all we need to do is move the decimal place once for each step!

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15.3 dm
Example Conversion

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$153 \text{ cm} = \underline{\hspace{2cm}} \text{ km}$

1.53 m
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$153 \text{ cm} = \underline{\hspace{2cm}} \text{ km}$

$0.153 \text{ dam}$
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$$153\text{ cm} = \underline{\text{______}}\text{ km}$$

$$0.0153\text{ hm}$$
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153 cm = _______ km

0.00153 km
Understanding Numerical Data

- What is the mass of a typical apple in an apple orchard?
  - How many apples to measure?

- Mean ~ average of a group of measurements
- Median ~ middle value of a group of measurements
Understanding Numerical Data

Sample 1: 25, 35, 32, 28

Sample 2: 15, 75, 10, 20
Variability

Range
• Difference between extreme measurements, provides a sense of variation of a sample.

Standard Deviation
• How measurements vary about the mean.
• Subtract the mean from the sample value, then square. Add these numbers.