DP BIOLOGY | SKILLS 1 OF 3

Research methods

How do biologists plan a fair test?
How far can we trust a result?

Use with the Skills page notes and before the internal assessment. All examples use invented data.



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What you will learn


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1 Planning

Write a focused research question, name the variables, and state a hypothesis


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2 Collecting data

Choose sample sizes and repeats, and tell experiments from observations


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3 Judging results

Tell accuracy from precision, and random from systematic error

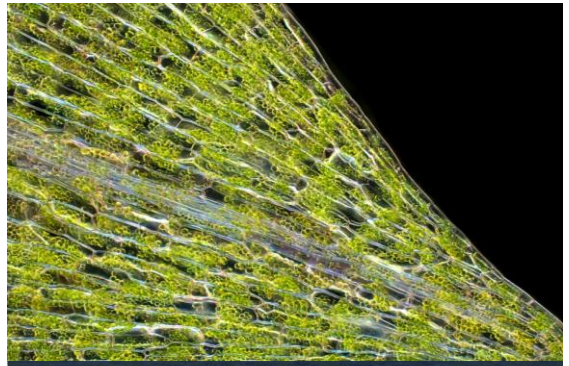

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4 Concluding

Work safely and ethically, then conclude and evaluate

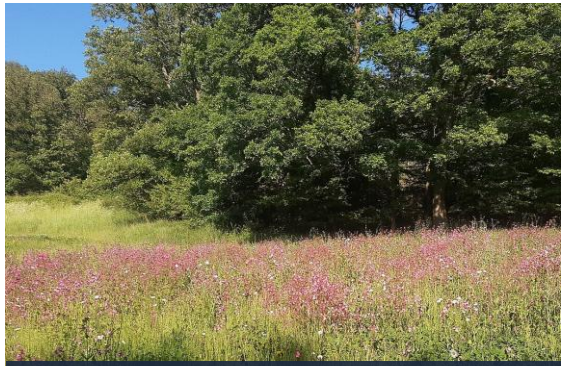
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Research questions


Variables and controls


Hypotheses


Sampling and repeats

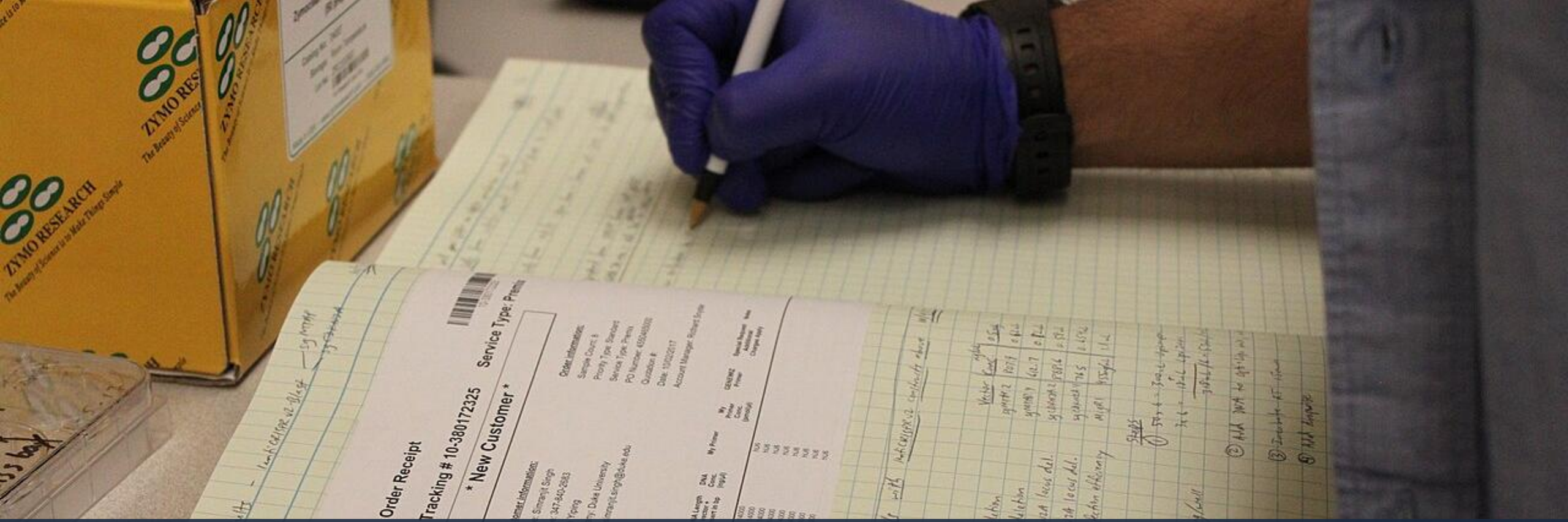


Kinds of investigation


Accuracy and errors


Safety and ethics


Conclusions



01

Planning

A good investigation starts with a question that someone else could repeat.

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A focused research question

Too vague

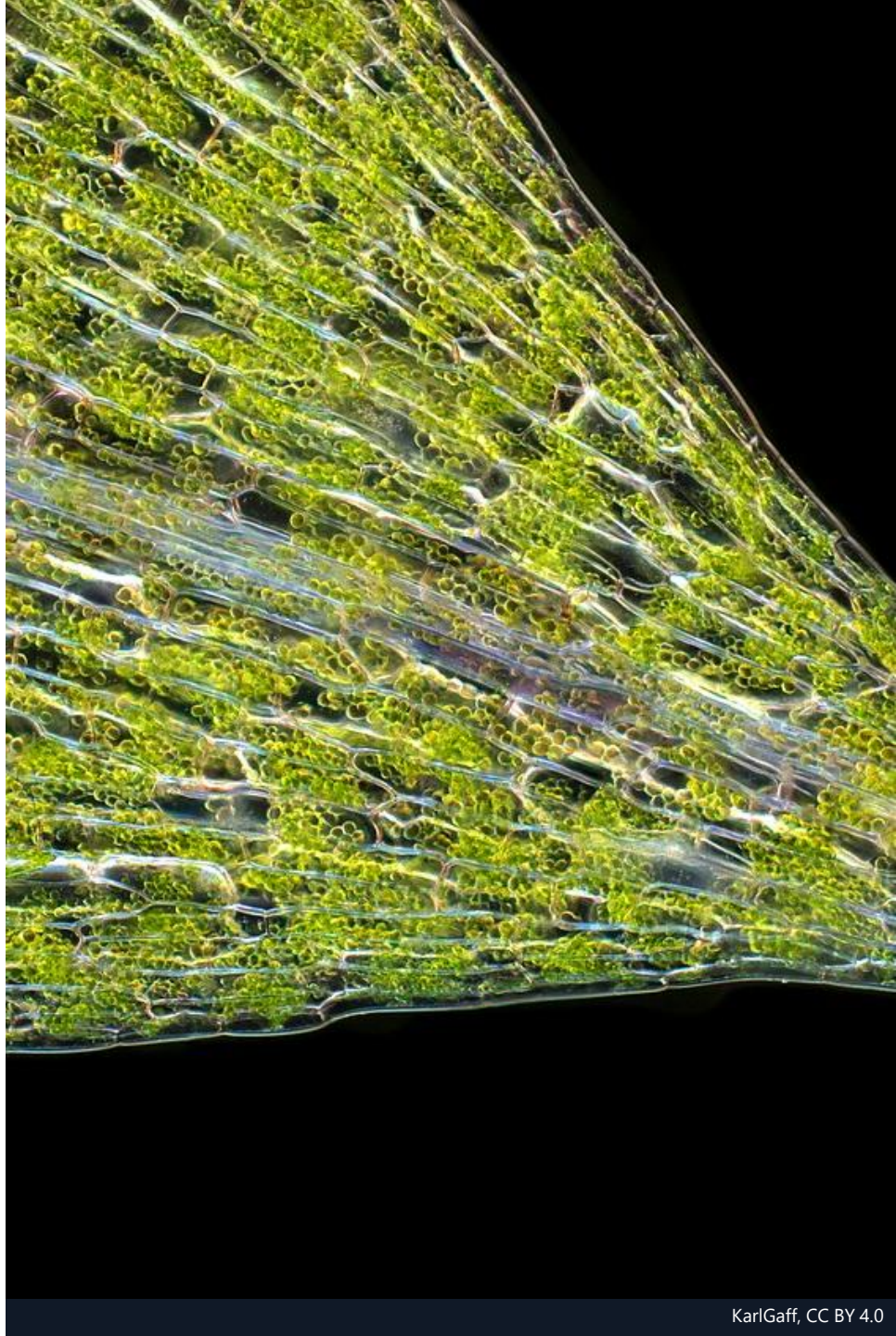
"Does light affect plants?" Which plant? Which light? Measured how?

Focused

How does lamp distance, 10 to 50 cm, affect the rate of oxygen release by Elodea, in bubbles per minute?

1. Name the **independent variable** and its range
2. Name the **dependent variable** and how it is measured
3. Name the organism or system

Test: could another student repeat your work from the question alone?



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TRY IT

Improve a question

A student writes: "Does temperature affect enzymes?" Rewrite it as a focused research question for an investigation with catalase from potato in a school lab.

> Hint: Include the independent variable with a range, the dependent variable with a method, and the source of the enzyme.

The answer is on the next slide.

ZooFari, Public domain

ANSWER

Improve a question

Compare your working with each step.

1. One good version: "How does temperature, from 10 to 60 °C, affect the rate at which potato catalase breaks down hydrogen peroxide, measured as the volume of oxygen collected in 30 s?"
2. Independent variable and range: temperature, 10 to 60 °C
3. Dependent variable and method: volume of oxygen in 30 s
4. Organism or system: catalase from potato

Key point

Other answers are fine if they name both variables, a range and a method of measuring.

Variables and controls



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Independent

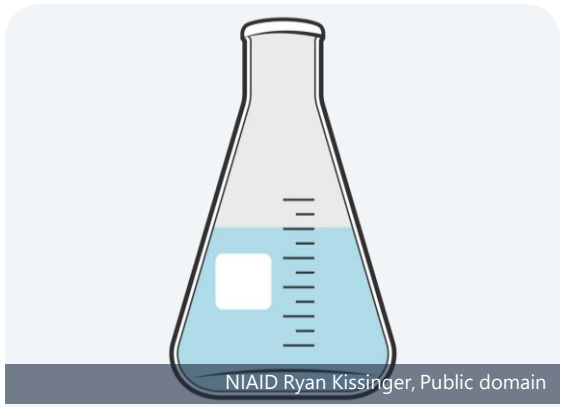
The one you change on purpose. Example: temperature of the water bath.



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Dependent

The one you measure. Example: volume of oxygen in 30 s.



NIAID Ryan Kissinger, Public domain

Controlled

Kept the same, as they could also change the result. Example: pH, volumes, concentrations.



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Control

A separate treatment for comparison. Example: boiled potato, which releases no oxygen.

Common mistake

"Keep everything else the same" earns no credit. Name each controlled variable, say how you keep it constant, and why it matters. A control is not the same as a controlled variable.

TRY IT

Spot the variables

Seeds are germinated at 5, 10, 15, 20 and 25 °C. After 7 days, the percentage that have germinated is recorded. Every dish holds 20 seeds of the same variety on wet filter paper in the dark.

Name the independent variable, the dependent variable, and three controlled variables.

The answer is on the next slide.

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ANSWER

Spot the variables

1. Independent variable: temperature
2. Dependent variable: percentage of seeds germinated after 7 days
3. Controlled: number of seeds (20), variety, water (wet filter paper), light (dark), time (7 days)

Compare your working with each step.

Key point

Give a reason for each controlled variable. For example, water is needed for germination, so it must not vary between dishes.

Hypotheses and predictions

Hypothesis

A testable explanation, with a biological reason: warmer water speeds up photosynthesis, because enzymes collide with substrates more often.

Prediction

What you expect to measure if it is correct: more bubbles per minute at 25 °C than at 15 °C.

Null hypothesis

For a statistical test: temperature has no effect on the rate.

Data can support a hypothesis, or fail to. They never prove it.



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02

Collecting data

How many measurements do we need, and where should we take them?

Gerda Arendt, CC0

Sampling and repeats

- **Random sampling**: every individual or place has an equal chance of being chosen, so there is no bias
- **Bigger samples**: the mean gets closer to the true mean
- **Repeats**: show how much results vary, and make anomalies easier to spot

5 × 3

At least five values of the independent variable, each repeated at least three times.

Discuss

A student measures 5 leaves from one side of a hedge. Give two reasons the mean may be misleading, and improve the method.



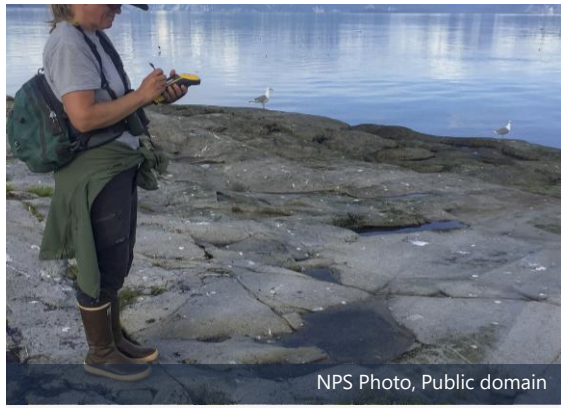
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Kinds of investigation


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Experiment

Change one variable and control the rest, so a cause can be shown.


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Field observation

Record what happens naturally. Shows a correlation.


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Database

Use data others collected, such as gene sequences.


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Model

Test ideas too slow, large or unethical to test directly.

Which one?

An IA usually uses an experiment. A field study is often the only way to study whole ecosystems, but other factors are not controlled.

Correlation is not causation

Ice cream and sunburn

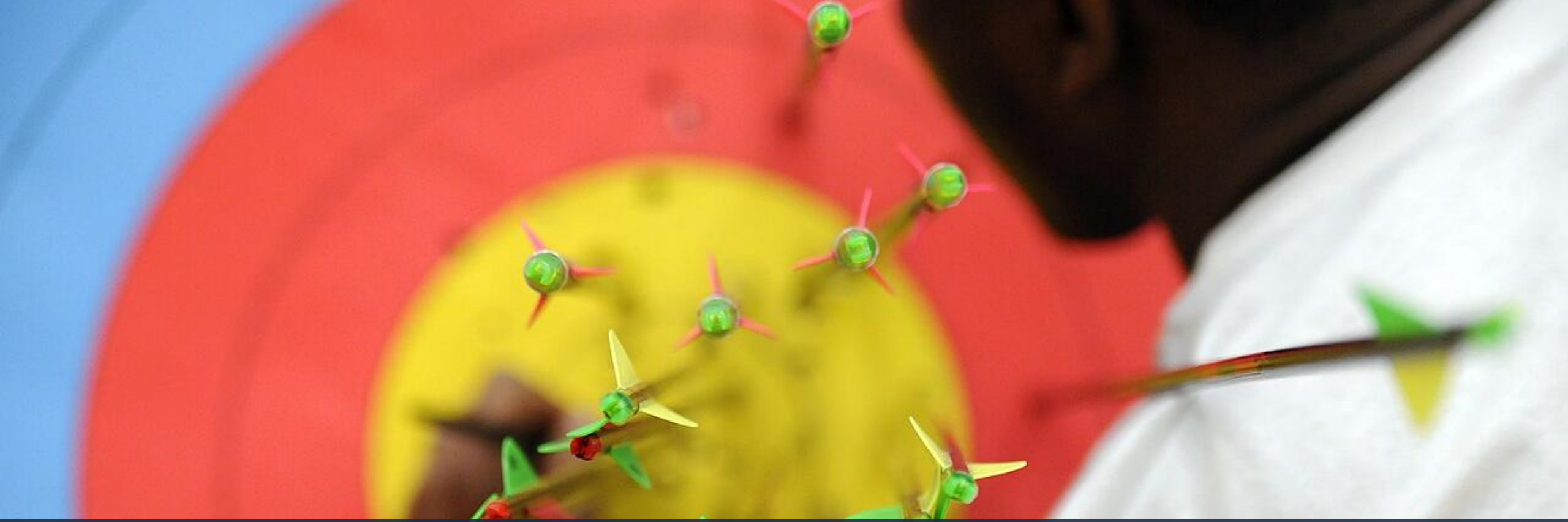
On days when more ice cream is sold, more people get sunburnt. Does ice cream cause sunburn?

1. Two variables rise together
2. A third factor, sunny weather, causes both
3. Only an experiment can test cause

Look for a mechanism, and for factors that were not controlled.



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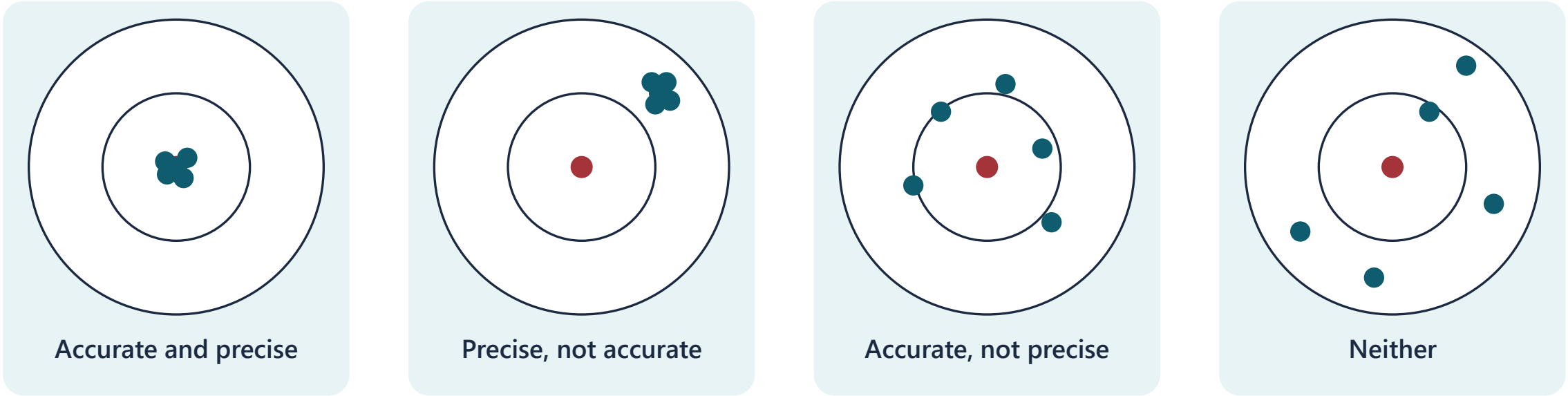
03

Judging results

Close to the true value, close to each other, or both?

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Accuracy and precision



Red dot: the true value. Teal dots: repeated measurements.

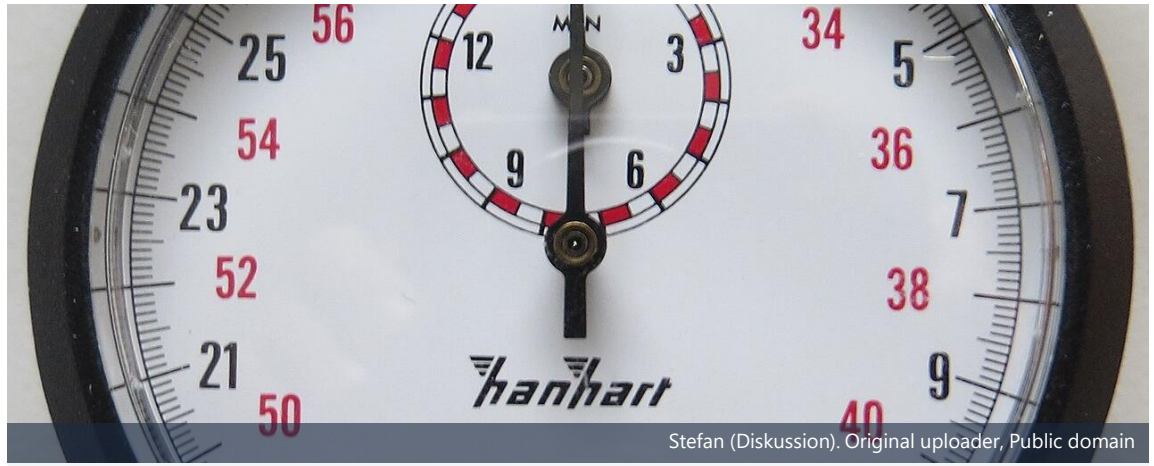


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In words

Accurate: close to the true value. **Precise**: repeated values close to each other. A balance that always reads 0.2 g too high can be very precise but never accurate.

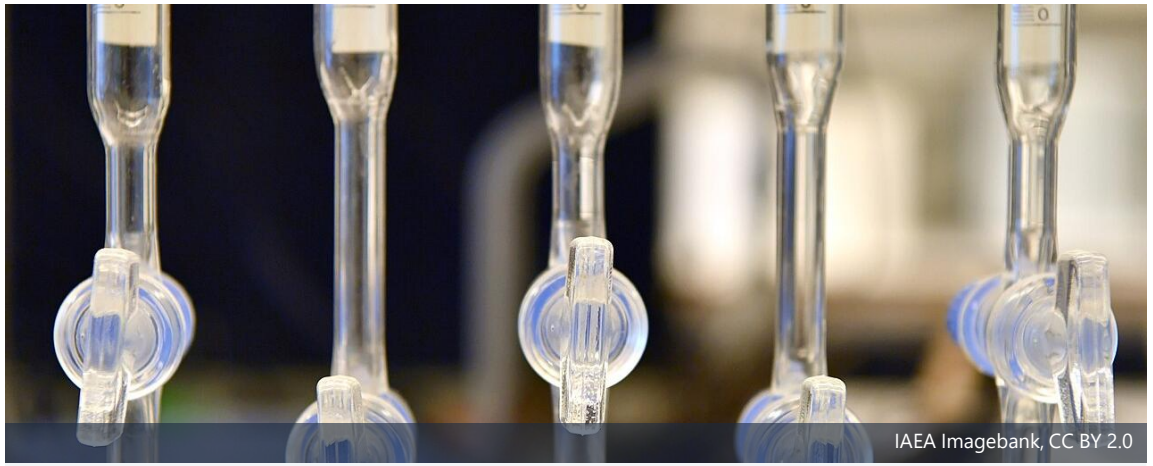
Random and systematic errors



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Random error

Values scatter either side of the true value, such as reaction time when starting a stopwatch. Repeat, and take a mean.



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Systematic error

Every value shifts the same way, such as reading a burette from above the line every time. Repeats do not help: fix the method or instrument.

Random errors limit precision. Systematic errors limit accuracy.

TRY IT

Random or systematic?

Classify each error.

1. A stopwatch is started at slightly different moments each time.
2. A thermometer always reads 2 °C too high.
3. Leaves picked for a test vary in age.
4. A pipette is read from above the line every time.

> Hint: Does the error push every result the same way, or does it vary in direction?

The answer is on the next slide.

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ANSWER

Random or systematic?

1. Random: reaction time varies, so times scatter both ways
2. Systematic: every reading is too high by the same amount
3. Random: leaf age varies unpredictably between samples
4. Systematic: parallax makes every volume wrong in the same direction

Compare your working with each step.

Key point

Repeats reduce the effect of random errors. Systematic errors stay, however many repeats you do.



04

Safety, ethics and conclusions

Work safely, treat living things with care, and say what the data really show.

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Safety, ethics and the environment



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Safety

Risk assessment: hazard, risk, and how you reduce it. Eye protection with hydrogen peroxide.



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Animals

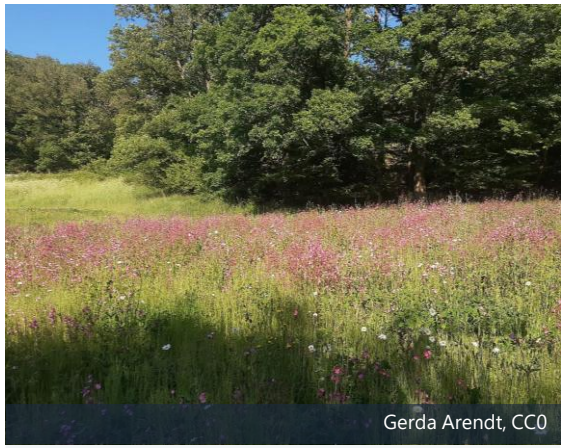
Avoid harm and stress. Return invertebrates. Use plants or microbes where possible.



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People

Get consent, keep data anonymous, and never push anyone beyond safe effort.



Gerda Arendt, CC0

Environment

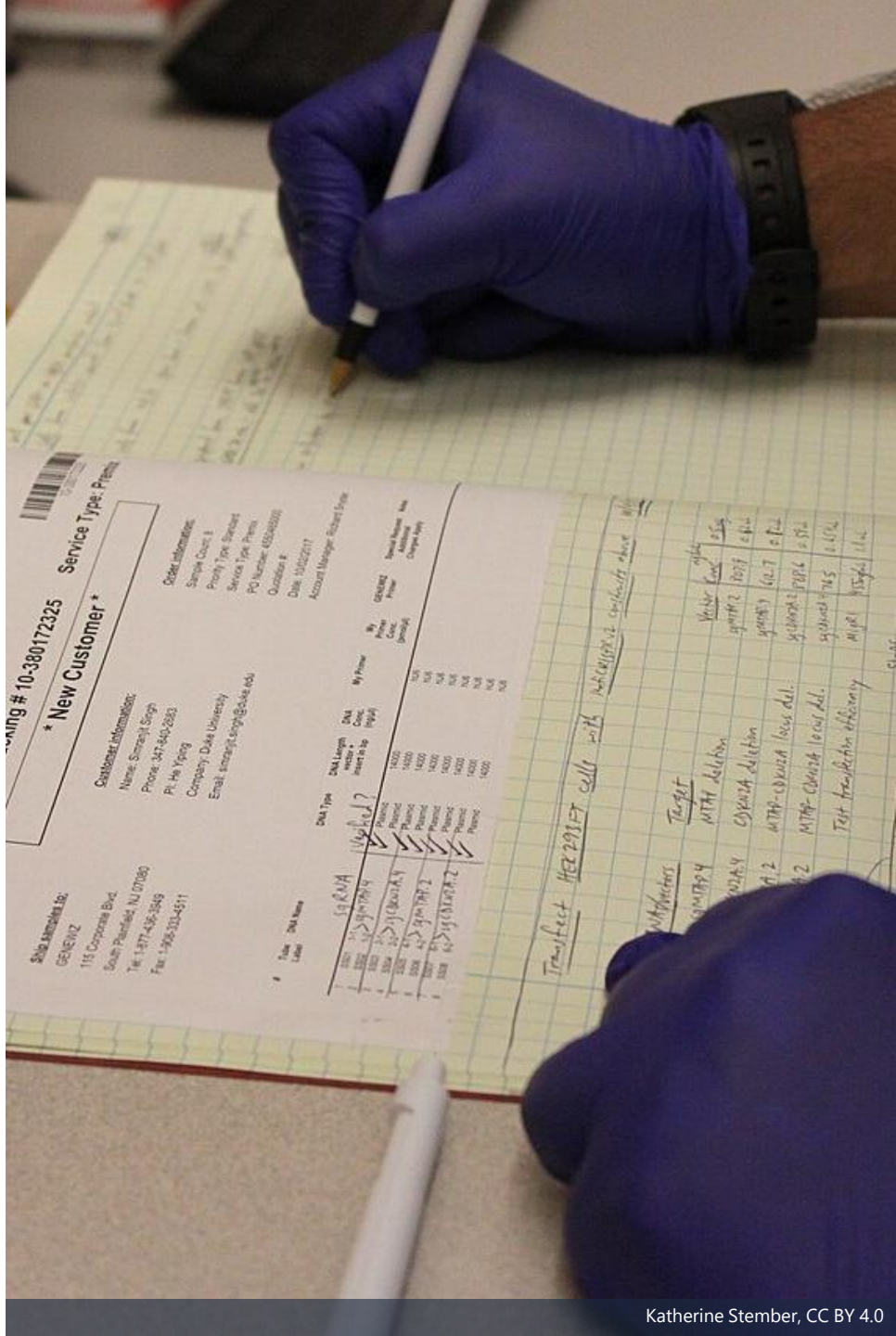
Take only what you need, and leave habitats as you found them.

An ethical plan is part of a good method, not an extra.

Conclusions and evaluation

1. **Conclude**: describe the trend, quote numbers, explain with biology
2. **Evaluate**: weakness, its effect on the data, an improvement
3. **Extend**: ask a new, related question

Weakness	Effect	Improvement
Water bath drifted by 3 °C	Rates vary more, means less reliable	Thermostatic water bath
Only three repeats	Anomalies hard to spot	At least five repeats



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TRY IT

Evaluate a method

In a pondweed experiment, a student counts bubbles for 1 minute at each lamp distance. The bubbles are of different sizes, and the lamp also warms the water. Give two weaknesses, the effect of each, and an improvement for each.

> Hint: Use the pattern: weakness, effect on results, improvement.

The answer is on the next slide.

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ANSWER

Evaluate a method

1. Bubble size varies, so counts do not measure oxygen volume accurately. Collect the gas in a syringe or capillary tube and measure its volume
2. The lamp heats the water, so temperature changes as well as light. Use a heat shield, such as a beaker of water, and monitor temperature

Compare your working with each step.

Key point

Most credit goes to weaknesses that are linked to their effect on the data, not just listed.

Check that you can

1. Write a focused research question
2. Name independent, dependent and controlled variables, and a control
3. State a hypothesis with a reason, and a null hypothesis
4. Explain why sampling is random and repeated
5. Say what an experiment shows that an observation cannot
6. Tell accuracy from precision, and random from systematic error
7. Plan safely and ethically
8. Write a conclusion and a linked evaluation



Esculab, CC0

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. A student tests the effect of pH on amylase. Name the independent variable, the dependent variable, and two controlled variables.

2. Explain the difference between accuracy and precision.

3. State why repeating readings does not remove a systematic error.

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