Practical skills

Planning investigations, variables, measurement and uncertainty, data handling and graphs, statistics, evaluation, safety and ethics, and an overview of the core practicals.

Planning an investigation

A good plan, in answer to a question or **hypothesis**, states:

- the **independent variable** (what you change) and the range and intervals,
- the **dependent variable** (what you measure), how and when,
- the **control variables** (what you keep constant) and **how** (for example, a water bath for temperature, a buffer for pH),
- the **apparatus** and **volumes or quantities**,
- the **number of repeats**,
- a **control experiment** (a negative control with no treatment, and sometimes a positive control),
- a **risk assessment**, and
- how the data will be **analysed**.

Prediction and explanation: state a **hypothesis** with the **expected result** and a **biological explanation**.

Measurements and uncertainty

- **Resolution** is the smallest division on the scale. The **uncertainty** of a single reading is about ± half the smallest division.
- **Accuracy**: close to the true value. **Precision**: closeness of repeated results.
- **Random errors** make results scatter. **Systematic errors** shift all results in the same direction (a zero error).
- **Percentage uncertainty** $= \dfrac{\text{uncertainty}}{\text{measurement}} \times 100$. To reduce it, use a **larger quantity** or an instrument with finer resolution.
- **Repeat** readings and calculate a **mean**, ignoring **anomalous** results (and say why).

Presenting data

- A **table** with headings that give the quantity and **units**, and the same number of decimal places for readings.
- A **graph**: the independent variable on the **x-axis**, labelled axes with units, a **suitable scale**, plotted points (small crosses) and a **line of best fit** or a point-to-point line, as appropriate. A **bar chart** is for **discontinuous** data (categories), and a **histogram or line graph** for **continuous** data.

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- The **rate of reaction** is found from the **gradient** of a tangent, or as $1/\text{time}$. A **percentage change** is $\frac{\text{change}}{\text{original}} \times 100$.
- Give answers to an **appropriate number of significant figures**.

Statistics

Test	Used for
Mean, median, mode, range	Describing data
Standard deviation	The spread of data around the mean. About 68% of values lie within ±1 SD in a normal distribution
Error bars	Show the variability; **overlapping** error bars suggest the difference may not be significant
Student's t-test	Whether there is a **significant difference between the means** of two sets of data
Chi-squared test	Whether **observed frequencies** differ from **expected** frequencies (e.g. in a genetic cross)
Spearman's rank correlation	Whether there is a **correlation** between two variables

A **null hypothesis** says there is **no** significant difference (or correlation). If the probability, p, is **less than 0.05**, the null hypothesis is **rejected** and the difference is significant (there is less than a 5% chance it arose by chance).

> **A correlation does not show that one factor causes the other. Say that the data are consistent with the hypothesis, and discuss other factors.**

Evaluating

For each investigation, identify **limitations**, say whether the errors are random or systematic, and suggest **improvements** (more repeats, a larger sample, better control of variables, more precise apparatus, a wider range). Judge whether the data are **reliable** (repeatable), **valid** (answers the question) and **accurate**. Draw a **conclusion** that the data support, and comment on how **confident** you can be.

Safety and ethics

- Identify the hazards and the **precautions**: eye protection and gloves for acids, stains and bacteria; aseptic technique; no naked flames near flammable liquids; disposal of cultures by autoclaving.

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- **Ethical use** of living organisms: minimise harm, use as few as possible, keep them in suitable conditions, return wild organisms to the habitat, and use **informed consent** for human subjects.

The core practicals at a glance

No.	Practical	Key idea
1	Benedict's and iodine, colour standards	Semi-quantitative: sugars and starch
2	Vitamin C	DCPIP titration
3	Membrane permeability	Beetroot pigment leakage
4	Enzyme initial rates	Temperature, pH, concentrations
5	Light microscope, graticule	Drawing and measuring cells
6	Root tip squash	Mitotic index
7	Plant sections	Plan diagrams and tissues
8	Tensile strength of fibres	Breaking force
9	Antimicrobial properties of plants	Aseptic technique; zone of inhibition
10	Photosynthesis rate	Pondweed, light, temperature, CO_2
11	Ecology of a habitat	Quadrats, transects, abiotic factors
12	Temperature and development	Seedling growth, brine shrimp
13	Growth of microorganisms	Liquid culture, growth curve
14	Antibiotics	Zones of inhibition
15	Yeast respiration with a redox indicator	Time for colour change
16	Respirometer, RQ	Rate of respiration
17	Exercise and spirometer traces	Tidal volume, minute ventilation
18	Amylase in germinating grain	Gibberellin and starch digestion

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