

General Science: Living Systems, Materials, Waves and Evidence

GAC023 outcome practice; check the current centre brief.

What can a pond observation actually establish?

What is observed

A plant occurs beside a pond.

A treatment record shows a lower dissolved concentration.

What still needs evidence

Plant presence cannot establish drinking-water safety.

A lower concentration cannot establish that the substance was destroyed. Track where material went.

The module includes science and how the team works

- Connect biology, ecosystems, resources, chemistry and waves.
- Keep supplied practice data distinct from observations.
- Follow the current centre brief for practical and report tasks.

Living systems have structures, functions and change

Prokaryotic cells

DNA is not enclosed in a membrane-bound nucleus.

Describe structures supported by the available observations.

Eukaryotic cells

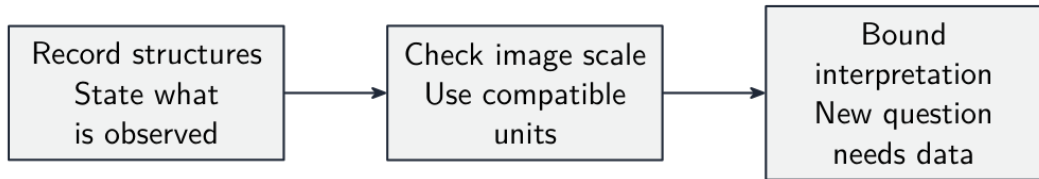
Typically contain a nucleus and other membrane-bound structures, with specialised exceptions.

A poor image failing to show a structure does not establish that it is absent.

A historical observation and a modern interpretation differ

Claim	Evidence and reach
Historical development	Hooke's Micrographia used "cell" for cork spaces in 1665; this is one selected development.
Homeostasis	Regulation within suitable limits as conditions vary; internal values need not stay exactly constant.
Growth over time	A single image supplies no time-series measurement. A growth study needs a defined measure and period.

Record the structures, then check the scale



- State the structures actually visible.
- Use compatible units in the magnification ratio.
- A new question needs appropriate additional evidence.

Your turn: magnification and units

Your turn

A printed cell is 30.0 mm long; its stated actual length is 0.0500 mm. Calculate magnification and explain its unit. Can the image establish growth rate?

Attempt the complete task before advancing. Show the method and interpret the result.

Magnification is a ratio without a length unit

- 1 **Known** Image length 30.0 mm; stated actual length 0.0500 mm.
- 2 **Choose the relation** Magnification compares image length with actual length in the same units: $M = L_{\text{image}}/L_{\text{actual}}$.
- 3 **Substitute** $M = \frac{30.0 \text{ mm}}{0.0500 \text{ mm}} = 600$
- 4 **Interpret** Magnification is $\times 600$, a ratio without a length unit. This calculation cannot establish growth rate.

Classification uses relationships as well as visible features

Traditional hierarchy: kingdom, phylum, class, order, family, genus, species.



Groups can contain several groups at the next level; inherited traits and molecular information inform relationships.



An identification key can separate needle-like and broad leaves, then smooth and toothed margins.



The key identifies prepared cards from features; branch order is not evidence of evolutionary chronology.

One family can contain different genera and species



- Lion and tiger: *Panthera leo* and *Panthera tigris*.
- Domestic cat: *Felis catus*, within Felidae.
- The two-word species name needs its genus and epithet.

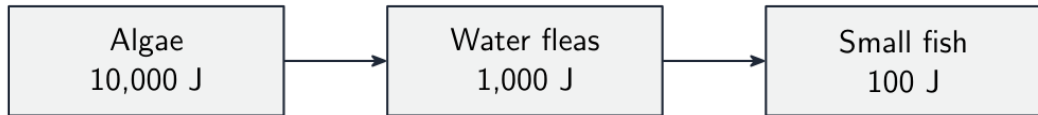
An ecosystem includes organisms and nonliving conditions

Ecosystem role	Material and energy relationship
Producer	Makes organic material using an energy source.
Consumer	Obtains organic material from other organisms.
Decomposer	Breaks down dead material and waste, returning nutrients to available forms.

Use the evidence

Food-chain arrows point from food to consumer. Include nonliving conditions when describing the ecosystem.

Energy transfers while matter can cycle



- The illustrated algae chain has supplied energy values.
- Energy dissipates through respiration and other pathways.
- Matter can cycle and can cross the system boundary.

Your turn: two energy transfers

Your turn

Grass has 5000 J, grasshoppers receive 600 J and frogs receive 60 J. Calculate each transfer efficiency. Explain whether these numbers establish a universal ten-percent rule.

Attempt the complete task before advancing. Show the method and interpret the result.

The meadow record gives two different efficiencies

- 1 **Known** Meadow record: grass 5000 J, grasshoppers 600 J, frogs 60 J.
- 2 **Relation** Transfer efficiency: $\eta = E_{\text{next}}/E_{\text{previous}} \times 100\%$.
- 3 **First transfer** $\eta_1 = \frac{600}{5000} \times 100\% = 12\%$
- 4 **Second transfer** $\eta_2 = \frac{60}{600} \times 100\% = 10\%$

Decision

These are case-specific transfers, not a universal ten-percent law. This budget supplies no population trend.

Biodiversity needs a measure suited to the question

Species richness

Counts how many species are represented under the chosen sampling method.

A count of one species cannot describe all variety.

Abundance distribution

Describes how records are distributed among species.

Select the measure for the question; diversity does not guarantee resistance to every disturbance.

Rock changes have several possible routes

Process	Rock change
Cooling / solidification	Forms igneous rock.
Deposition, compaction, cementation	Can form sedimentary rock.
Heat and pressure without melting	Can form metamorphic rock.
Weathering / erosion / melting	Provide other routes to sediment or molten material.

Use the evidence

A rock need not follow one compulsory circular sequence. A photograph alone does not establish exact age.

Renewable does not mean unlimited

Renewal and timescale

A renewable resource replenishes on a relevant timescale.

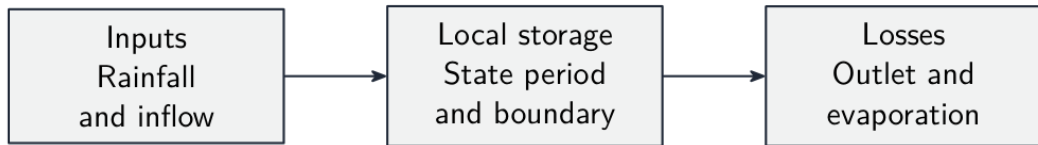
Demand can exceed replacement; ecosystem needs also matter.

Water movement and storage

Evaporation, condensation, precipitation, runoff, infiltration and groundwater connect stores.

A local pond receives inputs and loses water across its boundary.

A water budget needs a boundary and a period



- Inputs and losses change local storage.
- The supplied budget excludes other changes by assumption.
- An extra extraction can reverse the sign of storage change.

Your turn: storage with extraction

Your turn

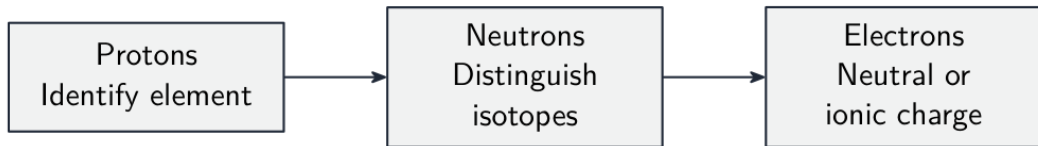
Inputs are 30 m^3 , outlet loss 18 m^3 and evaporation 7 m^3 . Other changes are excluded. Find storage change with and without a proposed extra extraction of 12 m^3 . State a limit of the model.

Attempt the complete task before advancing. Show the method and interpret the result.

Check both budgets before evaluating the proposal

- 1 Known and model** Inputs 30 m^3 ; outlet loss 18 m^3 ; evaporation 7 m^3 . Other changes are excluded by assumption.
- 2 Without extraction** $\Delta S = I - O - E = 30 - 18 - 7 = +5 \text{ m}^3$
- 3 With proposed extraction** $\Delta S = I - O - E - X = 30 - 18 - 7 - 12 = -7 \text{ m}^3$
- 4 Interpret** The proposal reverses this period's storage change. Initial storage, long-term sustainability and permission to extract remain unknown.

Protons identify elements; neutrons distinguish isotopes



- Atomic number is the number of protons.
- Mass number counts protons and neutrons.
- Isotopes share proton number but differ in neutron number.

Sodium-23 keeps eleven protons when it becomes an ion

Particle count	Sodium-23	Na ⁺ from sodium-23
Protons	11	11: element identity unchanged
Neutrons	$23 - 11 = 12$	12
Electrons	11	10: one electron lost

Use the evidence

Neutron count $N = A - Z$. Sodium-24 has $24 - 11 = 13$ neutrons and remains sodium: an isotope change differs from an electron change.

The periodic table and bond models answer different questions

Periodic-table model

Elements are ordered by atomic number.

Outer electron arrangements help explain introductory main-group similarities; do not extend the simple rule indiscriminately.

Bond models

Ionic bonding is attraction between opposite charges; electron transfer explains ion formation.

Covalent bonding involves shared electron pairs. These models are not handling instructions.

Greenhouse effects and acid rain use different mechanisms

Greenhouse effect

Carbon-containing fuel combustion can release carbon dioxide.

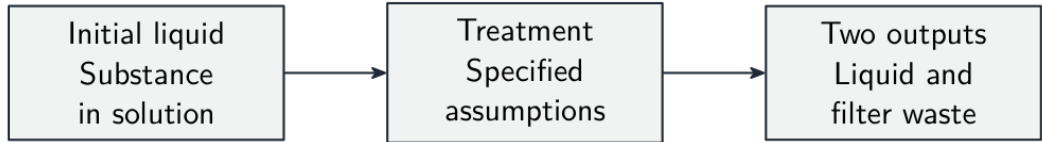
Greenhouse gases absorb and emit thermal infrared.

Acid rain

Sulfur dioxide and nitrogen oxides undergo atmospheric reactions forming acidic compounds.

Different mechanisms require appropriate evidence and responses.

Treatment has both a liquid output and a waste output



- A lower dissolved concentration is one result.
- Retained material can remain in filter waste.
- Benefits, energy use and waste handling need evaluation.

Your turn: treatment mass balance

Your turn

At unchanged volume 10.0 L, an invented treatment changes concentration from 12.0 to 3.0 mg/L. Calculate dissolved mass before and after, and retained filter mass under the case assumptions. Compare the final value with the fictional 2.0 mg/L target.

Attempt the complete task before advancing. Show the method and interpret the result.

Calculate the remaining mass and check the target separately

- 1 **Known** Invented treatment: 10.0 L stays constant; concentration falls from 12.0 to 3.0 mg/L.
- 2 **Initial mass** $m_i = C_i V = 12.0 \text{ mg/L} \times 10.0 \text{ L} = 120 \text{ mg}$
- 3 **Remaining mass** $m_f = C_f V = 3.0 \text{ mg/L} \times 10.0 \text{ L} = 30 \text{ mg}$
- 4 **Retained material** $m_{\text{filter}} = m_i - m_f = 120 - 30 = 90 \text{ mg}$

Decision

The final 3.0 mg/L exceeds the fictional 2.0 mg/L task target. This target is not a real safety standard; students do not discharge chemicals.

Wave propagation differs from particle motion

Transverse disturbance

Oscillation is perpendicular to propagation.

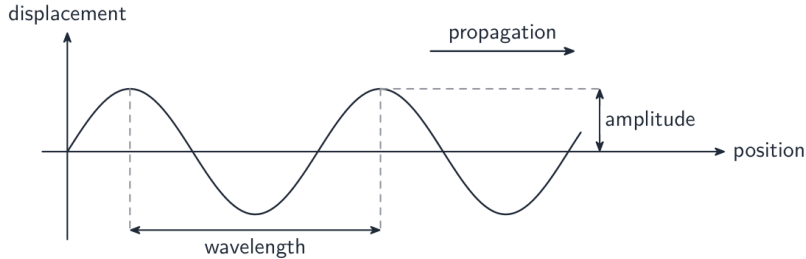
A string point may move vertically while the disturbance travels horizontally.

Longitudinal disturbance

Oscillation is parallel to propagation.

Directions on the page alone cannot decide the type; compare the two physical directions.

A snapshot separates wavelength from amplitude



schematic snapshot; not a time graph

- Wavelength joins successive points in the same phase.
- Amplitude is maximum displacement from equilibrium.
- Crest-to-trough height is twice the amplitude.

Use speed equals frequency times wavelength

- 1 **Known** Frequency 5.0 Hz; wavelength 0.40 m. Choose the wave relation for propagation speed.
- 2 **Wave speed** $v = f\lambda = 5.0 \text{ Hz} \times 0.40 \text{ m} = 2.0 \text{ m/s}$
- 3 **Oscillation period** $T = \frac{1}{f} = \frac{1}{5.0 \text{ Hz}} = 0.20 \text{ s}$
- 4 **Amplitude check** Amplitude 0.030 m gives crest-to-trough height 0.060 m. Neither is the 0.40 m wavelength.

Electromagnetic waves need no material medium

Spectrum sequence	Shared property / distinction
Radio, microwaves, infrared	Electromagnetic regions with different frequencies and wavelengths.
Visible, ultraviolet, X-rays, gamma rays	Continue the sequence towards higher frequency and shorter wavelength.
Propagation	No material medium required; electromagnetic waves share the same vacuum speed.

Use the evidence

Mechanical waves do not all share the electromagnetic vacuum speed.

Two reports can describe a pond with very different evidence

Traceable pond report

Record where and when observations were made, their method and the observer.

Readers can check the conclusion against the actual record.

Limited background evidence

Undated photographs and general website statements have narrower uses.

Distinguish your observations from borrowed background and identify missing evidence.

Choose a question that permitted observations can address

A question permitted observations can answer

“How does the proportion of ground covered by the selected plant differ between two accessible, teacher-approved areas?”

Define the two areas, period, frame size and coverage rule before recording.

This compares coverage; it does not automatically establish growth rate or the cause of a difference. Use approved non-destructive observations.

Sampling must not select only attractive examples

Broader sampling

Use the same frame size and counting rule at selected positions.

Agree a selection method instead of choosing attractive examples; accessible-area sampling cannot represent excluded areas.

Repeated view of one patch

Ten photographs of the same patch are not ten independent patches.

The location has not changed, so extra images do not broaden the sampled area.

Assign roles and retain a shared record

Team task	Record or check
Location and time	Identify each selected position, date/time and observer.
Coverage estimate	Apply the shared frame and counting rule consistently.
Entry check	Keep units, deviations, original entries and the correction trail.

Use the evidence

Resolve disagreement using the rule and evidence. Replacing an inconvenient record with the average hides the problem.

The supplied coverage case compares different positions

Position	Area A / %	Area B / %
1	20	40
2	30	50
3	40	60
Mean	30	50

Use the evidence

Fictional supplied data. Each row represents a different selected position using the same frame size and coverage rule.

Your turn: compare coverage

Your turn

Area A records 20%, 30%, 40%; Area B records 40%, 50%, 60%. Calculate each mean and the mean difference in percentage points. Explain why this does not demonstrate pollution as a cause.

Attempt the complete task before advancing. Show the method and interpret the result.

Percentage points are different from relative percent change

- 1 **Mean A** $\bar{x}_A = \frac{20+30+40}{3} = 30\%$
- 2 **Mean B** $\bar{x}_B = \frac{40+50+60}{3} = 50\%$
- 3 **Absolute difference** $\Delta\bar{x} = 50\% - 30\% = 20$ percentage points
- 4 **Relative to A** $r = \frac{50-30}{30} \times 100\% \approx 66.7\%$
- 5 **Ranges** A: $40 - 20 = 20$ percentage points; B: $60 - 40 = 20$ percentage points.

Coverage data cannot invent a pollution explanation

Supported conclusion

In the supplied samples, B has greater mean coverage; both areas show variation.

Three positions do not establish all seasons or every part of the pond.

Untested explanations

No pollution, light, soil or time-series measurements are given.

The table cannot establish pollution as the cause or faster growth. Coverage also does not measure species richness.

Describe physical, chemical and biological features separately

Evidence category	Example and documentation
Physical	Layout, slope, shade or water movement; use a labelled location description.
Chemical	Substance and quantity with source, date, units and measurement method.
Biological	Organisms, distribution and relationships; recognise identification limits.

Use the evidence

An organism photograph cannot establish drinking-water safety. State when information comes from a secondary source.

An online claim needs its source and limits

Online-source check	What to retain
Producer / date / purpose	Relevant expertise, timing and the purpose of the source.
Method / relevance	Read the actual report; a search preview cannot replace it.
Independence	Two sites repeating the same report supply one underlying report, not two independent observations.

The report should let a reader trace claims to evidence

Report part	Traceable content
Question / background	Bounded question; cite borrowed claims and images appropriately.
Method / responsibilities	Selection, common rule, roles and deviations.
Results / discussion	Checked calculations and units; separate observation from explanation.
Conclusion / references	Bounded answer, specific limit and matching improvement; locate every source.

Use the evidence

Reflection should identify actual contributions and a concrete coordination issue. Equal-length paragraphs cannot demonstrate equal participation.

Check yourself

- Why do extra pictures of one patch not broaden sampling?
- What is the correct unit for the mean coverage difference?
- Which missing measurements prevent a pollution claim?
- How should the team resolve a disputed entry?