Science 9–10

Chapter 2 — Questioning and predicting

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Investigable questions: variables, relationships to test, and what makes a question testable

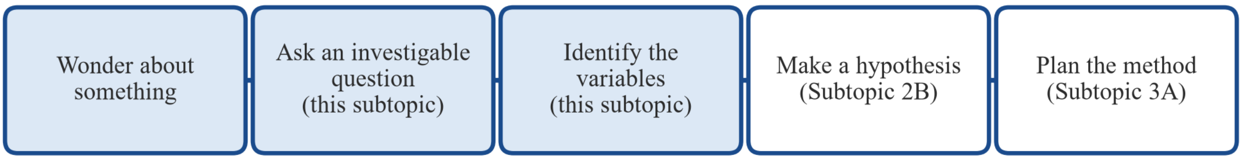
Chapter 2 — Questioning and predicting (Science, Levels 9 and 10)

Subtopic 2A · VC2 Science Inquiry — Questioning and predicting

CD code: `VC2S10I01` (split delivery †; this subtopic is the accountable owner) **Content description (verbatim):** "investigable questions, reasoned predictions and hypotheses can be used in guiding investigations to test and develop explanatory models and relationships" **This subtopic's limb (TOC §4 clause split):** investigable questions and testable relationships. The partner subtopic `2B` delivers the other limb: hypotheses, reasoned predictions, explanatory models. **Elaboration ids drawn on:** `VC2S10I01.E01` · `VC2S10I01.E02` · `VC2S10I01.E03` (id `VC2S10I01.E04` is drawn on by Subtopic 2B) **Achievement standard (verbatim):** "Students formulate and refine questions and hypotheses to make reasoned predictions, test relationships and develop explanatory models when investigating scientific questions, problems and claims." This subtopic serves the *formulate and refine questions* and *test relationships* limbs of that sentence; the hypothesis and explanatory-model limbs are served by Subtopic 2B.

Theory

Every investigation begins with a question. Science does not start with answers; it starts with someone noticing something and asking about it. But not every question can be answered by science, and a question that is asked badly cannot be answered cleanly even when it could be. This subtopic teaches the first two steps of any investigation: asking a question that science *can* answer, and naming the things the question is about clearly enough that a test can be planned. The picture below shows where those steps sit in the investigation sequence this book builds across Chapters 2–6.



Five boxes in a row showing the investigation sequence: wonder about something, ask an investigable question, identify the variables, make a hypothesis, plan the method; the two middle boxes are shaded to mark this subtopic's steps.

This subtopic owns the two shaded steps. The later steps are other subtopics: turning the question into a hypothesis is Subtopic 2B, and planning the method is Subtopic 3A. You cannot do those later steps well until the question and the variables are right, which is why the question comes first.

A word the curriculum uses but does not define. The Victorian Curriculum uses the term *investigable question* but does not define it. This subtopic therefore treats it as working terminology with this meaning: **an investigable question is a question that science can answer by collecting evidence — that is, by measuring or observing something in the world.** A question is investigable when you can say what would be measured or observed to answer it. That single test — *what would need to be measured?* — is the tool this whole subtopic uses.

Three sorts of questions. With that test in hand, questions sort into three piles.

Investigable now	Refine it first	Not answerable by science
How does exercise intensity affect heart rate?	Which paper towel is best?	Is rugby a better game than soccer?
How does water temperature affect the time for sugar to dissolve?	Do plants respond to music?	Are some numbers luckier than others?

Same skill for every card: what would need to be measured to answer it?

Three columns sorting six question cards: investigable now, refine it first, and not answerable by science, with two example cards in each column.

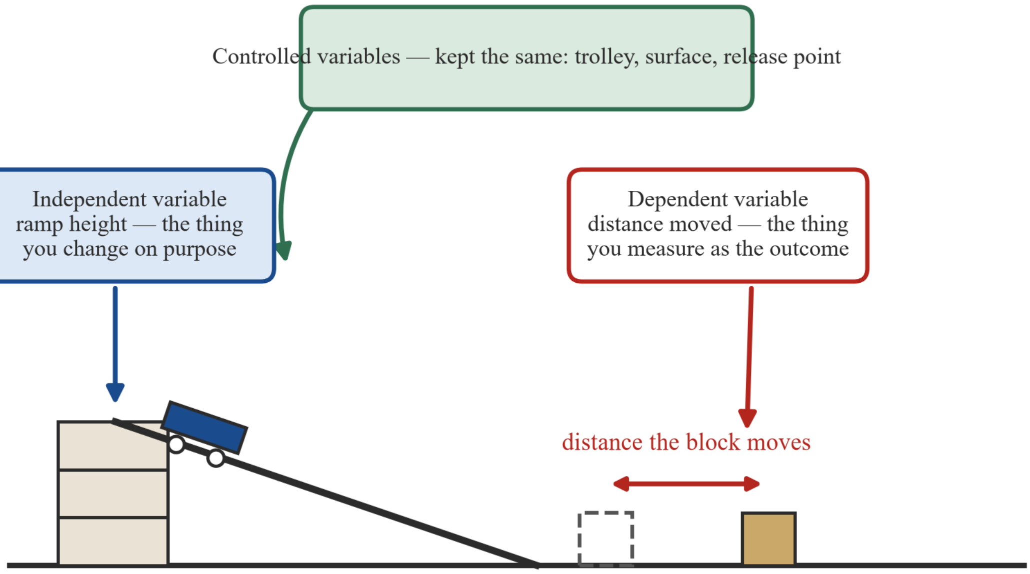
- **Investigable now.** The question already says what would be changed and what would be measured. “How does exercise intensity affect heart rate?” names something you can change (how hard the exercise is) and something you can measure (heart rate, in beats per minute). It is ready to plan.
- **Refine it first.** The question points at something measurable, but as written it is too vague to test. “Which paper towel is best?” never says what *best* means — strongest when wet? most absorbent? cheapest? — so there is no measurement yet. “Do plants respond to music?” never says which plants, what kind of music, for how long, or what would be measured. These questions are not dead ends; they are first drafts. Refining them is a skill, practised below.
- **Not answerable by science.** No measurement can settle these, because they are questions of taste, opinion or value. “Is rugby a better game than soccer?” asks for a judgement, and two people with the same measurements could still disagree. “Are some numbers luckier than others?” appeals to luck, which is not a thing you can measure or observe at all. Science respectfully leaves such questions to you — they are yours to answer, just not with a measuring cylinder.

Sorting a question is always the same move: ask *what would need to be measured to answer it?* If the answer comes easily, the question is investigable. If the answer is “it depends what you mean”, refine it. If there is no answer at all, science is not the tool.

The three kinds of variable. Once a question is investigable, the next step is to name its **variables** — the things in the test that could vary, meaning the things that could differ from one run to the next. Science uses three names, and this subtopic defines them precisely:

- the **independent variable** is the one thing you change *on purpose* to see what it does. It is the “thing changed” in the question;
- the **dependent variable** is the thing you measure or observe as the outcome. It is the “thing measured” in the question;
- the **controlled variables** are all the other things that could matter, which you keep the same on purpose so they cannot interfere.

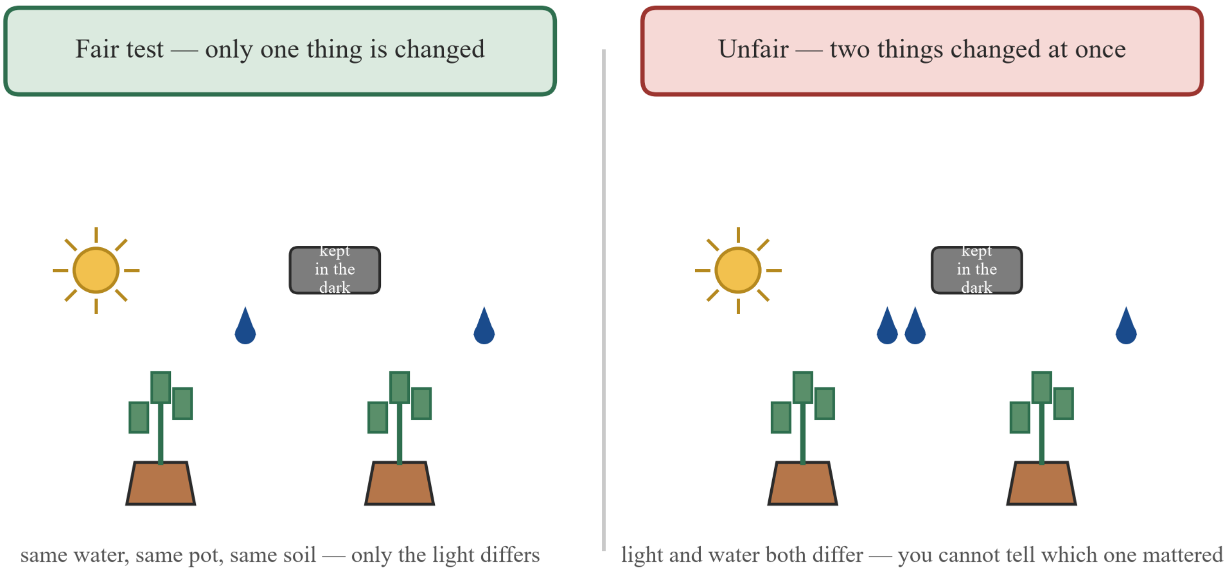
The picture makes the three names concrete.



A trolley on a ramp raised on books, about to roll down and push a block, with labels naming the ramp height as the independent variable, the distance the block moves as the dependent variable, and the trolley, the surface and the release point as controlled variables.

The question here is: *how does the height of the ramp affect the distance the block moves?* The ramp height is changed on purpose (independent), the distance the block moves is measured as the outcome (dependent), and everything else that could matter — the same trolley, the same surface, the same release point — is kept the same (controlled). Notice how the question itself carries the two key variables: "how does *the height of the ramp* affect *the distance the block moves*?" A well-written investigable question names its independent and dependent variables inside the sentence.

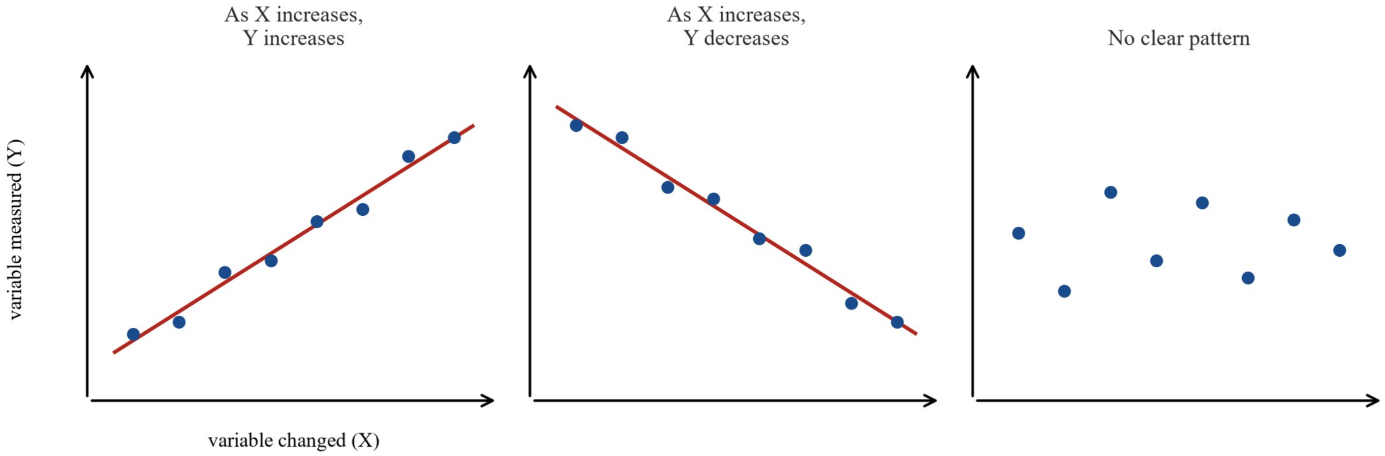
Fair tests change only one thing. The controlled variables are what make a test fair. If two things are changed at once and the outcome differs, you cannot tell which change caused it — the test has two answers tangled together, which is the same as having none.



Two pairs of potted plants side by side: a fair test in which one pot gets light and one stays in the dark with everything else the same, and an unfair test in which light and water both differ at once.

On the left, only the light differs, so any difference in growth can be put down to the light. On the right, the plant in the light also got more water, so if it grows better you cannot say whether the light or the water did it. The unfair version is not a slightly worse test; it is a test that cannot answer its own question. Keeping every variable the same except the independent variable is the single most important habit in all of experimental science, and it is the habit Subtopic 3A builds whole methods around.

Relationships you can test. An investigable question always asks about a **relationship** — a link between two variables, the one changed and the one measured. Before any data is collected, it is useful to know the three shapes a relationship can take, because the shape is what you will be looking for in the results.

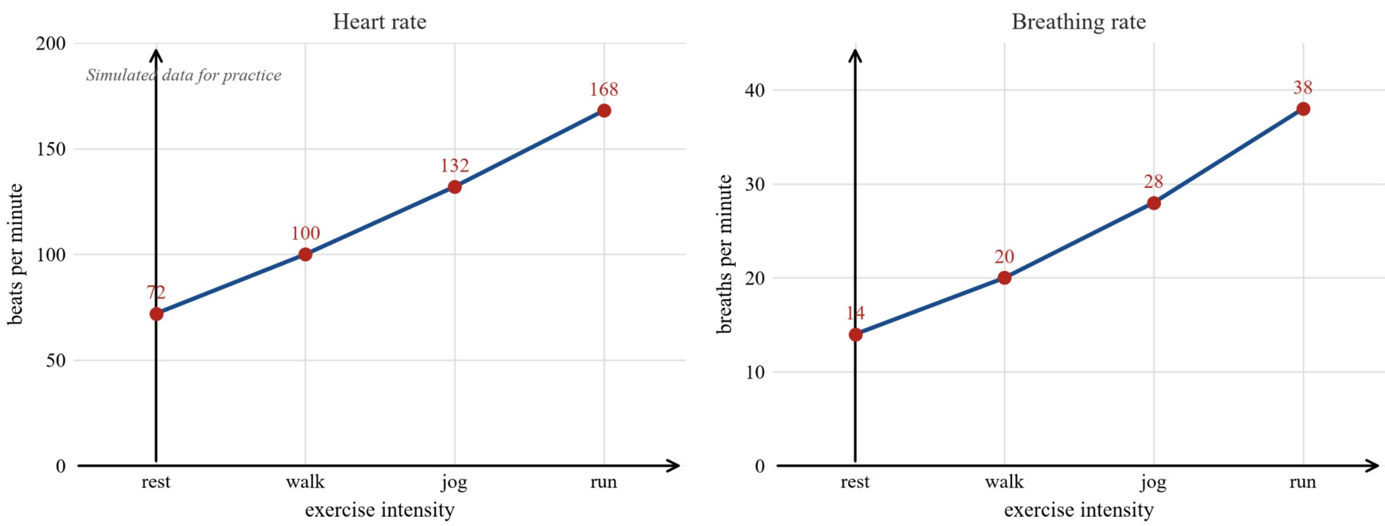


Three scatter graphs side by side showing the three shapes a relationship can take: as X increases Y increases, as X increases Y decreases, and no clear pattern.

- **As the variable changed increases, the variable measured increases** — the points climb together;
- **As the variable changed increases, the variable measured decreases** — the points fall as you move across;
- **No clear pattern** — the points scatter, and the two variables show no relationship worth testing further.

Naming the two variables and the shape you expect to look for is exactly what makes a relationship *testable*: once both variables are named and measurable, any collected data can be checked against the three shapes. (Describing real data patterns in detail — trends, outliers, and whether a link is cause or coincidence — is the work of Subtopic 4C. Here the skill is setting the question up so that work is possible.)

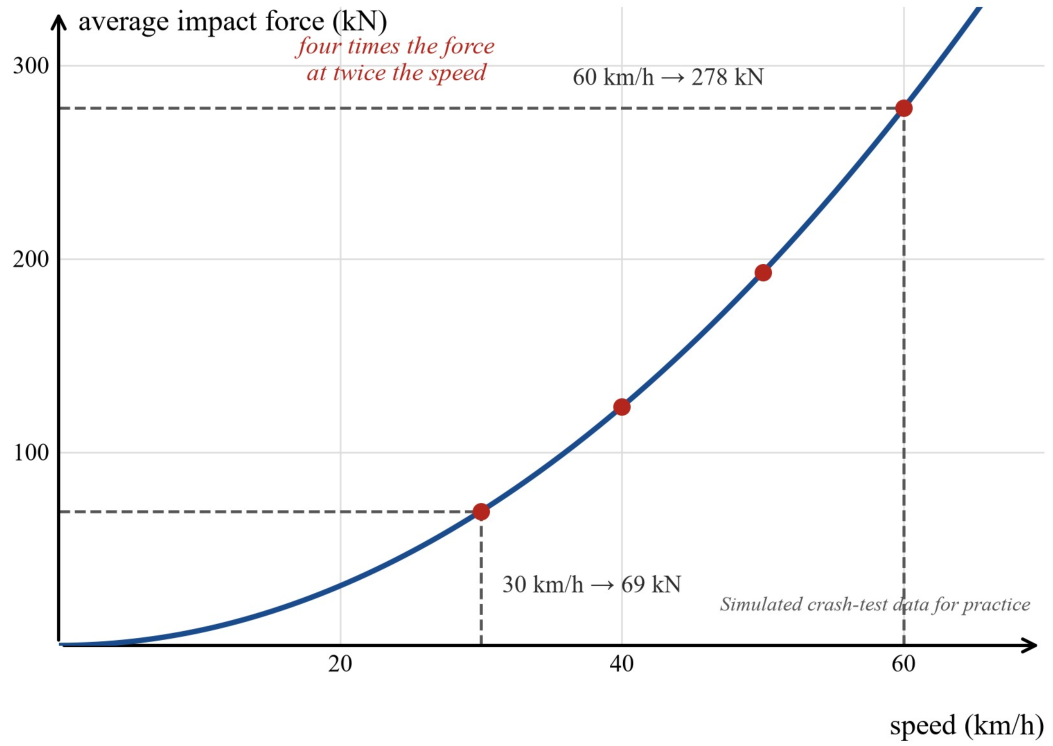
Drawing on elaboration `VC2S10I01.E01` — the body and everyday events. The elaboration's own example is an ideal investigable question: *"How does the intensity of exercise affect heart rate and breathing rate?"* It works because every word earns its place: the intensity of exercise is the independent variable (rest, walk, jog, run), and heart rate and breathing rate are two dependent variables, both measured in counts per minute.



Two bar charts of simulated data showing heart rate in beats per minute and breathing rate in breaths per minute at rest, walk, jog and run; both climb steadily as the exercise gets harder.

Read the simulated data and both relationships are easy to state: as the intensity of exercise increases, heart rate increases (72 beats per minute at rest climbing to 168 at a run), and as the intensity of exercise increases, breathing rate increases too (14 to 38 breaths per minute). Both are the first shape in the three-shapes picture. The question needed no science knowledge beyond knowing that heart rate and breathing rate can be counted — which is the point of this subtopic. You do not need to know the *answer* before asking the question; you need to know what would be *measured*. (Turning the question into a reasoned prediction — "I expect heart rate to rise because…" — is Subtopic 2B's skill.)

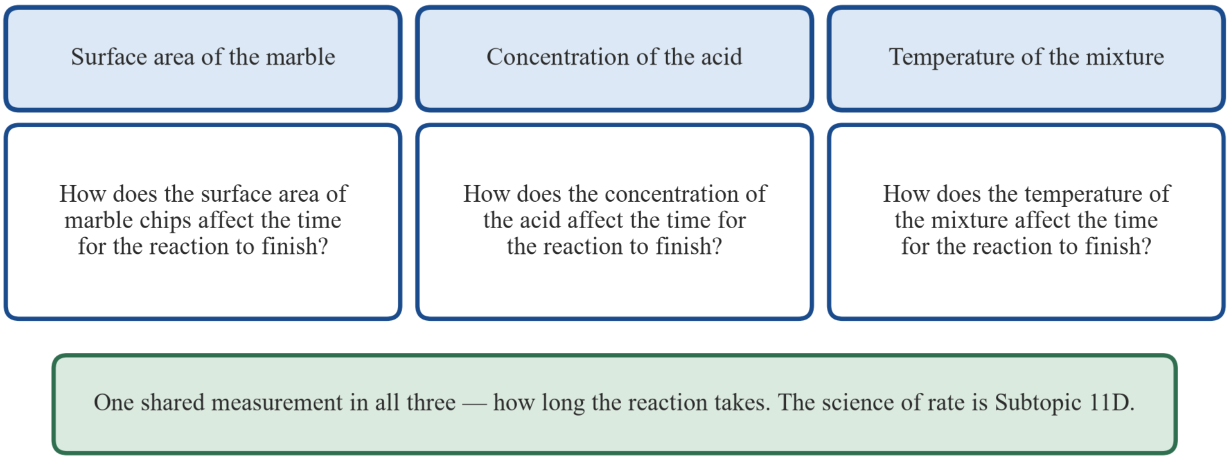
Drawing on elaboration `VC2S10I01.E02` — crash impact force and speed. The elaboration asks about "the relationship between crash impact force and speed", and the investigable question is: *how does the speed of a vehicle affect the force of impact in a crash?* Speed is changed (independent), impact force is measured (dependent), and the same car, the same barrier and the same crash-test set-up are controlled. Force here is measured in **kilonewtons** (kN), a unit of force: roughly, 10 kN is the pull of gravity on a one-tonne car, so the numbers below are large.



A curve of simulated crash-test data showing impact force in kilonewtons climbing ever more steeply as speed rises from 0 to 60 kilometres per hour, with dashed guides marking 30 km/h at 69 kN and 60 km/h at 278 kN.

The simulated crash-test data shows the first shape, but a steep one: as speed increases, impact force increases, and by more each time. Double the speed from 30 km/h to 60 km/h and the force does not double — it goes from 69 kN to 278 kN, about **four times** the force. That single pattern is why speed limits matter more than intuition says, and it is a relationship a student can test at model scale with a trolley, a ramp and a block — the set-up pictured earlier in this subtopic. *Why* force climbs this steeply is physics about energy and motion, developed in Chapters 14–15; this subtopic's job is the question and the relationship, and both are fully in reach.

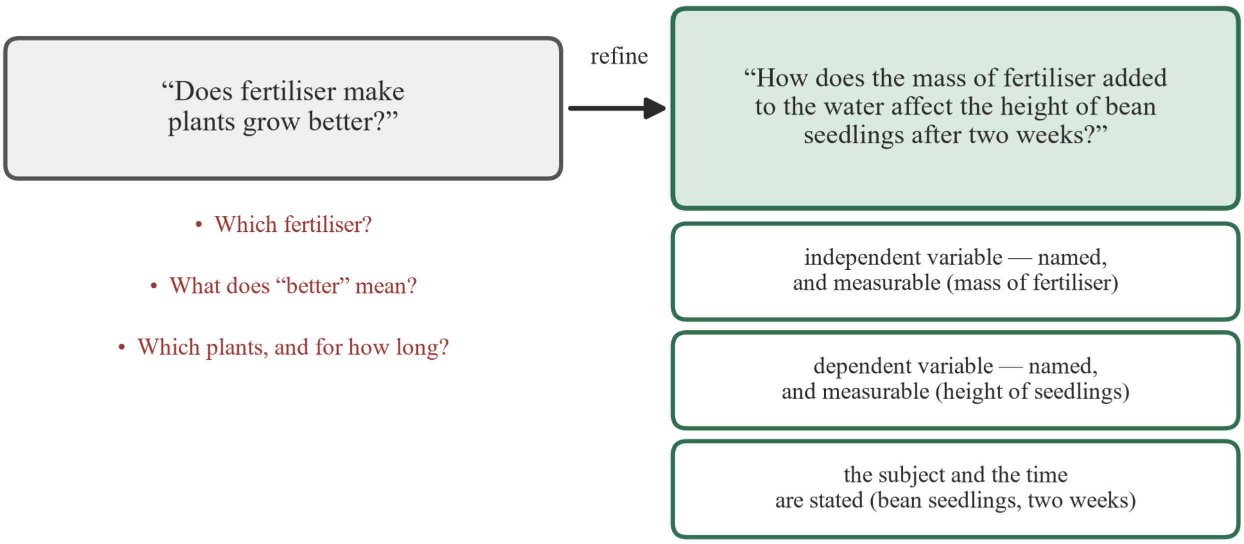
Drawing on elaboration `VC2S10I01.E03` — three questions, one shared measurement. The elaboration's investigation changes surface area, concentration and temperature to see how each affects the rate of a chemical reaction. What matters for this subtopic is that those three factors become three separate investigable questions, and all three are built the same way.



Three cards, each turning one factor — surface area of the marble, concentration of the acid, temperature of the mixture — into a question about the time for the reaction to finish, above a shared strip noting the one measurement common to all three.

In every card the dependent variable is the same — how long the reaction takes — while the independent variable swaps between surface area, concentration and temperature. That is the discipline of the skill: one question per independent variable, each with a named measurement, so that each variable gets its own fair test. (The science of *why* these factors change the rate — particles and collisions — belongs to Subtopic 11D; here the questions stand on their own.)

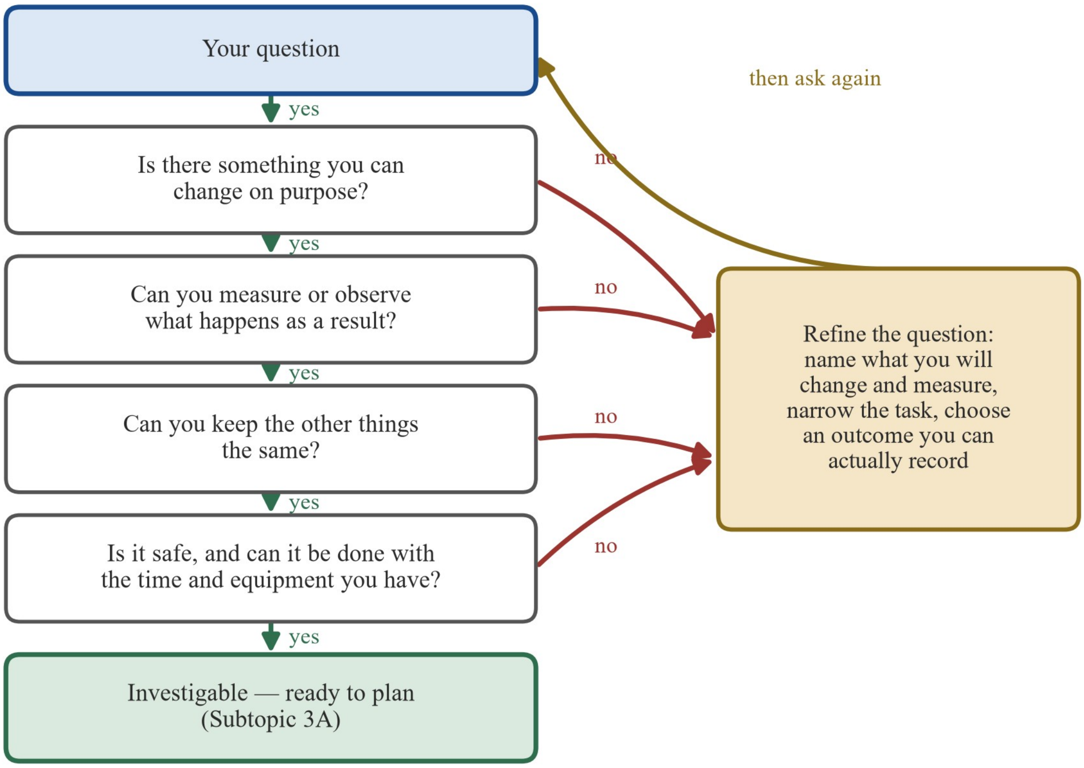
Refining a question. Most real questions arrive as first drafts, and refining them is a routine part of the skill — the achievement standard pairs "formulate" with *refine* for exactly this reason. The picture walks a vague first draft into a testable question.



A vague first-draft question, "Does fertiliser make plants grow better?", with three red objections — which fertiliser, what does better mean, which plants and for how long — refined into a testable question naming the mass of fertiliser added, the height of bean seedlings and a two-week time.

Every objection is the same question in disguise — *what would need to be measured?* — and the refined version answers all three: the independent variable is named and measurable (the mass of fertiliser added), the dependent variable is named and measurable (the height of the seedlings), and the subject and the time are stated (bean seedlings, two weeks). Nothing about the science changed; only the wording became testable. That is what refining is.

The testable checklist. All of the above compresses into four checks. Run any question through them before planning begins.



A flow chart checking a question against four tests — can one thing be changed on purpose, can the outcome be measured or observed, can the other things be kept the same, and is it safe and doable — with a yes-path leading to ready to plan and a no-path looping back to refine the question.

If any check fails, the question is not finished — refine it and ask again. When all four pass, the question is investigable and ready to hand to Subtopic 3A, where the method is planned. The checklist is also a complete summary of this subtopic: a testable question names a change, a measurement, a set of controlled variables, and it is safe and doable.

Activities

Activity 1 — Sort and refine. Sort each question below into one of the three columns of the sorting picture — *investigable now*, *refine it first*, or *not answerable by science* — and give the one-line reason.

1. How does the number of ice cubes in a cup affect the time for the water to cool to 10 °C?
2. Which chocolate bar tastes nicest?
3. Do seedlings grow better in a warm room?
4. How does the height a ball is dropped from affect the height it bounces back to?
5. Is it ever right to keep animals in zoos?
6. What makes a song a good song?

Then take question 3 and refine it into a fully testable question: name the independent variable, the dependent variable with its measurement, the subject, and the time.

Activity 2 — Heart rate and breathing rate (elaboration `VC2S10I01.E01`). In pairs, one student rests quietly for two minutes, then counts their partner's pulse at the wrist for 30 seconds and doubles the count to get beats per minute, and counts breaths per minute by watching the chest. Record both at rest, then repeat after one minute of walking on the spot, one minute of jogging on the spot, and one minute of running on the spot, resting one minute between each. Tabulate the results, identify the independent variable and the two dependent variables, list two things you kept the same, and write one relationship sentence for each dependent variable using the words *as … increases*. Compare your group's pattern with the three shapes in the relationships picture. Safety: do this in an open space, wear suitable shoes, and any student with a heart or breathing condition observes and times instead — the data can also be taken from the simulated chart in this subtopic.

Activity 3 — Trolley, ramp and block. Set a ramp on one book and place a wooden block at the bottom so the trolley strikes it. Release the trolley from the same marked point each run and measure how far the block is pushed. Repeat at ramp heights of one, two and three books, with three runs at each height, recording the middle distance. State the investigable question, identify all three kinds of variable, and say which of the three relationship shapes your results are closest to. Was the test fair? Point to the controlled variables you actually kept the same, and name one thing you did not control that might have added spread to your runs.

Activity 4 — Three rate questions (elaboration `VC2S10I01.E03`). The three cards in the rate-questions picture each change a different independent variable while measuring the same dependent variable. For each of the three questions, write a table row naming the independent variable, the dependent variable, and two controlled variables that must be kept the same for that test to be fair. Then answer in one sentence: why must each factor be tested in its own separate investigation, rather than changing all three at once? Finally, choose one of the three and refine it further by stating exactly how the independent variable will differ between runs (for example, whole marble chips against crushed chips of the same mass).

Worked examples

Example 1 — scaffolded

A student writes the question: *"Does exercise affect the body?"*

(a) Which column of the sorting picture does it belong in, and why?
(b) Refine it into a fully testable question.
(c) Name the independent and dependent variables of your refined question.
(d) State two controlled variables for a fair test of it.

Working	Comment
(a) Refine it first	Something measurable is pointed at, but "exercise" and "the body" are too vague — no measurement is named yet.
(b) *How does the intensity of exercise affect heart rate?*	The change (intensity) and the measurement (heart rate, in beats per minute) are now named.
(c) independent: intensity of exercise; dependent: heart rate	The two key variables sit inside the question sentence itself.
(d) same person; same length of each exercise bout	Any two of: same person, same exercise time, same room temperature, same rest before measuring.

Example 2 — scaffolded

A crash-test laboratory simulates one car hitting a barrier at four speeds. The table is **simulated data for practice**.

Speed (km/h)	30	40	50	60
Impact force (kN)	69	123	193	278

(a) Write the investigable question this data answers.
(b) Identify the independent and dependent variables.

(c) Describe the relationship using the words *as … increases*.
(d) Compare the force at 60 km/h with the force at 30 km/h. What does doubling the speed do to the force?

Working	Comment
(a) *How does the speed of a vehicle affect the force of impact in a crash?*	The question names the change and the measurement.
(b) independent: speed; dependent: impact force	Same car, same barrier held constant.
(c) as speed increases, impact force increases, and by more each step	The first relationship shape, but steepening.
(d) 30 → 60 km/h doubles speed; 69 → 278 kN is about four times the force	4 × 69 = 276, close to 278. Doubling speed roughly quadruples the force.

Example 3 — unscaffolded

A group times how long a level teaspoon of sugar takes to disappear in 100 mL of water, stirred the same way, at five temperatures. The table is **simulated data for practice**.

Water temperature (°C)	10	20	30	40	50
Time for sugar to dissolve (s)	90	55	35	24	17

(a) Write the investigable question.

(b) Identify the independent variable, the dependent variable, and two controlled variables.

(c) Describe the relationship in one sentence.

(d) A classmate claims the time halves every time the temperature rises by 10 °C. Check the claim against the data.

(e) *How does the temperature of the water affect the time for a teaspoon of sugar to dissolve?*

(f) Independent: water temperature. Dependent: time for the sugar to dissolve. Controlled (any two): same volume of water, same amount of sugar, same stirring, same type of sugar.

(g) As the water temperature increases, the time for the sugar to dissolve decreases — the second relationship shape.

(h) The claim fails. From 10 °C to 20 °C the time falls from 90 s to 55 s, but half of 90 s is 45 s, not 55 s. The time does fall at every step (−35 s, −20 s, −11 s, −7 s), yet the steps get smaller — the relationship is a falling one, but not a halving one.

Example 4 — unscaffolded

A group wants to know whether light affects the growth of potted plants. They place one pot on a sunny sill and give it two drops of water a day, and one pot in a dark cupboard with one drop a day. After three weeks the sun plant has grown more.

(a) Explain why the group cannot conclude that the light caused the difference.

(b) Redesign the test so it is fair.

(c) Write the investigable question the fair test answers.

(d) Name the independent and dependent variables in your redesign.

(e) Two things were changed at once — the light *and* the water. The sun plant grew more, but it also got more water, so the result has two possible causes tangled together and the test cannot choose between them.

(f) Keep the water identical — same amount, same times — and same pot, same soil, same species and size of plant, same time; change only the light (sunny sill against dark cupboard).

(g) *How does the amount of light a pot plant receives affect the height it grows in three weeks?*

(h) Independent: the amount of light. Dependent: the height grown, measured in centimetres after three weeks.

Practice questions

Scaffolded questions

Question 1 Words that matter. (a) State the working meaning this subtopic gives to *investigable question*. (b) Define the independent variable, the dependent variable and a controlled variable. (c) Explain in one sentence why a fair test changes only one thing at a time.

Question 2 Sort these. Place each question in a column of the sorting picture and give a one-line reason. (a) How does the length of a pendulum's string affect the time for ten swings? (b) Which soft drink is the nicest? (c) Do seeds grow better somewhere warm?

Question 3 Name the variables. A student investigates the question *How does the temperature of water affect the time for a teaspoon of sugar to dissolve?* Name the independent variable, the dependent variable, and two controlled variables for a fair test.

Question 4 Three shapes. (a) Name the three shapes a relationship can take, as in the relationships picture. (b) Match the heart-rate data of this subtopic to one of the shapes. (c) Match the sugar-dissolving data of Example 3 to one of the shapes.

Question 5 Reading the heart-rate chart (elaboration `VC2S10I01.E01`). (a) State the heart rate at rest and at a run from the chart. (b) By how many breaths per minute did breathing rate rise from rest to a jog? (c) Write the relationship between exercise intensity and heart rate in one sentence.

Question 6 The checklist. (a) List the four checks of the testable checklist. (b) State which subtopic takes over once a question passes all four.

Unscaffolded questions

Question 7 Refine it. *"Which paper towel is best?"* Refine this first draft into a fully testable question, and name the independent and dependent variables of your version.

Question 8 Crash data again (elaboration `VC2S10I01.E02`). A second crash-test run of the same car gives the table below, **simulated data for practice**.

Speed (km/h)	20	30	40	50
Impact force (kN)	31	69	123	193

(a) Write the investigable question.
(b) Identify the independent and dependent variables.
(c) Describe the relationship in one sentence.
(d) Compare the force at 40 km/h with the force at 20 km/h, and state what doubling the speed did to the force in this data.

Question 9 Outside science's reach. Explain why *"Are some numbers luckier than others?"* cannot be answered by science, using the idea of measurement in your answer.

Question 10 The unfair pots, in words. One pot plant stands in sunlight and receives two drops of water a day; a second stands in a dark cupboard and receives one drop a day. The sun plant grows more. State the two things that were changed, explain why the result cannot be read, and describe the fix.

Question 11 Write three questions. Write a fully testable question for each scenario, naming the change and the measurement in the sentence. (a) The width of a paper parachute and the time it takes to fall. (b) The amount of light a pot plant receives and the height it grows. (c) The temperature of water and the time for sugar to dissolve.

Question 12 Parachute variables. For your question 11(a), identify the independent variable, the dependent variable, and two controlled variables.

Question 13 The three rate questions (elaboration `VC2S10I01.E03`). (a) State the independent variable in each of the three rate questions in the cards picture. (b) State the dependent variable shared by all three. (c) Explain why the other two factors must be kept the same in each separate test.

Question 14 Refine again. *"Do plants respond to music?"* Refine this into a fully testable question about bean seedlings, naming the change, the measurement and the time.

Question 15 No pattern. Eight students record their hand span and how many hours they slept last night. The table is **simulated data for practice**.

Hand span (cm)	16	17	18	19	20	21	22	23
Sleep last night (h)	8.0	9.5	7.5	9.0	8.5	7.0	9.5	8.0

(a) Which of the three relationship shapes does this data most resemble?
(b) What should the group conclude about a relationship between hand span and hours of sleep?

Question 16 The full sequence. Take the first-draft question *"Do plants respond to music?"* (a) Which column of the sorting picture does it start in, and why? (b) Refine it into a testable question. (c) Name the independent and dependent variables of your refined question. (d) State two controlled variables, and confirm the investigation would be safe and doable in a classroom.

Answers

Question 1 (a) a question science can answer by collecting evidence — by measuring or observing something; (b) independent — the one thing changed on purpose; dependent — the thing measured as the outcome; controlled — a thing kept the same so it cannot interfere; (c) if two things change at once, a difference in the outcome cannot be put down to either one. **Question 2** (a) investigable now — length changed, time for ten swings measured; (b) not answerable by science — taste is a judgement, no measurement settles it; (c) refine it first — which seeds, what does "better" mean, how warm, how long? **Question 3** independent: water temperature; dependent: time for the sugar to dissolve; controlled (any two): volume of water, amount of sugar, stirring, type of sugar. **Question 4** (a) as X increases Y increases; as X increases Y decreases; no clear pattern; (b) first shape (heart rate climbs with intensity); (c) second shape (time falls as temperature rises). **Question 5** (a) 72 beats per minute at rest, 168 at a run; (b) 14 breaths per minute (14 to 28); (c) as the intensity of exercise increases, heart rate increases. **Question 6** (a) one thing changed on purpose; the outcome measured or observed; the other things kept the same; safe and doable; (b) Subtopic 3A — planning the method. **Question 7** see solution (example refinement given; any testable version with named variables accepted). **Question 8** (a)–(c) see solution; (d) 31 → 123 kN, about four times the force for double the speed. **Question 9** see solution (luck is not measurable or observable; no evidence could settle it). **Question 10** see solution (light and water both changed; make the water identical). **Question 11** see solution (three example questions given). **Question 12** see solution. **Question 13** (a) surface area of the marble; concentration of the acid; temperature of the mixture; (b) the time for the reaction to finish; (c) see solution. **Question 14** see solution (example given). **Question 15** (a) no clear pattern; (b) see solution (no relationship worth testing in this data). **Question 16** (a)–(d) see solution.

Fully-worked solutions

Question 1 (a) An investigable question is a question that science can answer by collecting evidence — by measuring or observing something in the world. The working test is: *what would need to be measured to answer it?* (b) The **independent variable** is the one thing changed on purpose; the **dependent variable** is the thing measured or observed as the outcome; a **controlled variable** is any other thing that could matter, kept the same so it cannot interfere. (c) If two things are changed at once and the outcome differs, the result has two possible causes tangled together, so the test cannot say which one mattered — which is why a fair test changes only the independent variable.

Question 2 (a) **Investigable now.** The string length is changed on purpose and the time for ten swings is measured — both variables are already named. (b) **Not answerable by science.** "Nicest" is a judgement of taste; two people with the same measurements could still disagree, so no evidence can settle it. (c) **Refine it first.** It points at something measurable (growth), but which seeds, what "better" means, how warm, and for how long are all unstated.

Question 3 Independent variable: the temperature of the water. Dependent variable: the time for the teaspoon of sugar to dissolve. Controlled variables (any two): the volume of water, the amount of sugar, the way and amount of stirring, the type of sugar, the same beaker.

Question 4 (a) As the variable changed increases, the variable measured increases; as the variable changed increases, the variable measured decreases; and no clear pattern. (b) The heart-rate data is the first shape: as exercise intensity increases, heart rate increases. (c) The sugar data is the second shape: as water temperature increases, the dissolving time decreases.

Question 5 (a) 72 beats per minute at rest; 168 beats per minute at a run. (b) Breathing rate rose from 14 to 28 breaths per minute — a rise of 14 breaths per minute. (c) As the intensity of exercise increases, heart rate increases.

Question 6 (a) 1 — one thing is changed on purpose; 2 — the outcome is measured or observed; 3 — the other things are kept the same; 4 — the test is safe and doable. (b) Subtopic 3A, where the method for the investigation is planned.

Question 7 Example refinement: *How does the brand of paper towel affect the volume of water a single sheet soaks up?* Independent variable: the brand of paper towel. Dependent variable: the volume of water soaked up, measured in millilitres. (Any refinement that names a measurable change and a measurable outcome — for example tensile strength when wet — is accepted.)

Question 8 (a) *How does the speed of a vehicle affect the force of impact in a crash?* (b) Independent: the speed of the vehicle. Dependent: the force of impact, in kilonewtons. (c) As speed increases, impact force increases, and by more each step. (d) At 20 km/h the force is 31 kN; at 40 km/h it is 123 kN. Doubling the speed gave about four times the force ($4 \times 31 = 124$), matching the pattern in the crash-force picture.

Question 9 For a question to be investigable, something must be measurable or observable that could settle it. “Luck” is not a thing that can be measured or observed — there is no instrument, no count, no observation that would show one number to be luckier than another, and any data collected would not bear on the claim. With no possible evidence, science has nothing to work with, so the question sits outside science’s reach.

Question 10 The two things changed were the light (sunny sill against dark cupboard) and the water (two drops against one drop a day). The result cannot be read because the sun plant’s extra growth might be due to the light, the extra water, or both — the two causes are tangled. The fix is to make the water identical for both pots — same amount, same times — and keep pot, soil and plant the same, so that only the light differs.

Question 11 (a) *How does the width of a paper parachute affect the time it takes to fall two metres?* (b) *How does the amount of light a pot plant receives affect the height it grows in three weeks?* (c) *How does the temperature of the water affect the time for a teaspoon of sugar to dissolve?* Each names the change and the measurement in the one sentence.

Question 12 Independent variable: the width of the parachute. Dependent variable: the time it takes to fall two metres, in seconds. Controlled variables (any two): the same paper, the same length of string, the same mass attached, the same drop height, the same still air (indoors, no fan).

Question 13 (a) Card 1: the surface area of the marble. Card 2: the concentration of the acid. Card 3: the temperature of the mixture. (b) All three measure the same dependent variable: the time for the reaction to finish. (c) Because each of the three factors could change the rate on its own. If, say, the temperature were allowed to differ during the surface-area test, a faster reaction could not be put down to the surface area — the uncontrolled factor would have broken the fair test. Testing one factor at a time, with the others controlled, is what keeps each question answerable.

Question 14 Example refinement: *How does playing music to bean seedlings for one hour a day affect their height after three weeks, compared with seedlings kept in silence?* The change is named (music against silence), the measurement is named (height in centimetres), and the subject and time are stated (bean seedlings, three weeks).

Question 15 (a) No clear pattern — the points would scatter with no climbing or falling line. (b) In this data, hand span and hours of sleep show no relationship: students with bigger hands did not sleep more or less than students with smaller hands. There is no pattern here worth testing further.

Question 16 (a) *Refine it first.* It points at something measurable (plant growth), but which plants, what music, for how long, and what would be measured are all unstated. (It is not “not answerable by science” — plant growth is measurable; the draft is simply not ready.) (b) Example: *How does playing music to bean seedlings for one hour a day affect their height after three weeks?* (c) Independent: whether the seedlings hear music (music against silence). Dependent: the height of the seedlings after three weeks, in centimetres. (d) Any two of: same species and size of seedlings, same pots and soil, same water and light, same room temperature. Safety and doability: growing beans on a sill beside a speaker is safe and plainly doable in a classroom, so all four checklist items pass.

Where this leads: the question-and-variables skills taught here are the entry ticket to the rest of the investigation spine. Subtopic 2B takes a finished question and turns it into a hypothesis and a reasoned prediction — the other limb of `VC2S10I01` — and Subtopic 3A plans the method that the checklist hands over. The relationship shapes named here are analysed properly, with trends, anomalies and the cause-versus-coincidence question, in Subtopic 4C; arguing from the resulting evidence is Subtopic 5B; and the whole sequence is assessed together in SIT-1 after Chapter 6. Beyond school, every VCE science’s practical investigation is graded starting from exactly this point — an investigable question with clearly identified variables — across Biology, Chemistry, Physics, Psychology and Environmental Science (reference-only for this book, TOC §5). This subtopic teaches the question; the rest of the book teaches what to do with a good one.

Hypotheses, reasoned predictions and explanatory models

Chapter 2 — Questioning and predicting (Science, Levels 9 and 10)

> **Subtopic 2B** · VC2 Science Inquiry — Questioning and predicting
>
> **CD code:** `VC2S10I01` (split delivery †; the accountable owner is `2A`; this subtopic is the partner delivering the second limb) **Content description (verbatim):** "investigable questions, reasoned predictions and hypotheses can be used in guiding investigations to test and develop explanatory models and relationships" **This subtopic's limb (TOC §4 clause split):** hypotheses, reasoned predictions, explanatory models. Partner `2A` (not an owner) delivers investigable questions and testable relationships. **Elaboration ids drawn on:** `VC2S10I01.E02` · `VC2S10I01.E03` · `VC2S10I01.E04` **Achievement standard (extract served):** "Students formulate and refine questions and hypotheses to make reasoned predictions, test relationships and develop explanatory models when investigating scientific questions, problems and claims." **Maths interlock (D11):** none drawn on here — the work is relational and verbal, not calculational; graphs appear only as patterns to compare against a prediction.

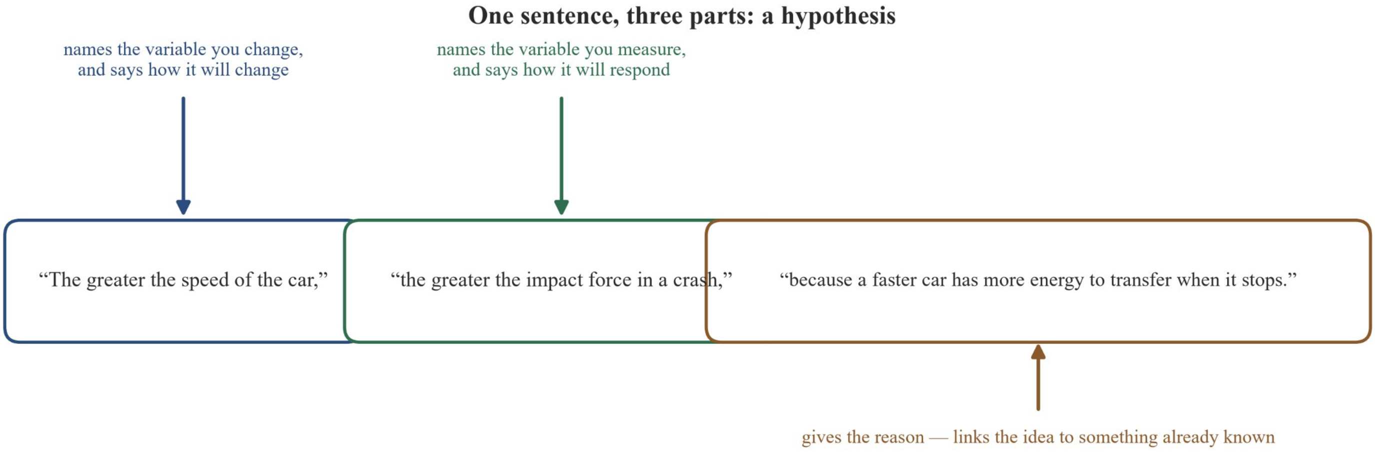
Theory

What a hypothesis is. Subtopic 2A builds investigable questions — questions that name the variables and a relationship that can be tested. A **hypothesis** is the proposed answer to such a question, written before the data are in: a testable statement that names a relationship between two variables **and gives a reason for it**. It is not a guess. A guess ("it will probably bounce higher, I reckon") has no reason behind it and nothing solid to test. A hypothesis says what relationship you expect *and why*, so an investigation can check it.

The crash context from `VC2S10I01.E02` gives a clean example.

> "The greater the speed of the car, the greater the impact force in a crash, because a faster car has more energy to transfer when it stops."

That one sentence has three parts, shown in the figure below: a clause naming the variable you change and how it changes, a clause naming the variable you measure and how it responds, and a clause giving the reason.



A hypothesis states a relationship between variables and gives a reason for it.

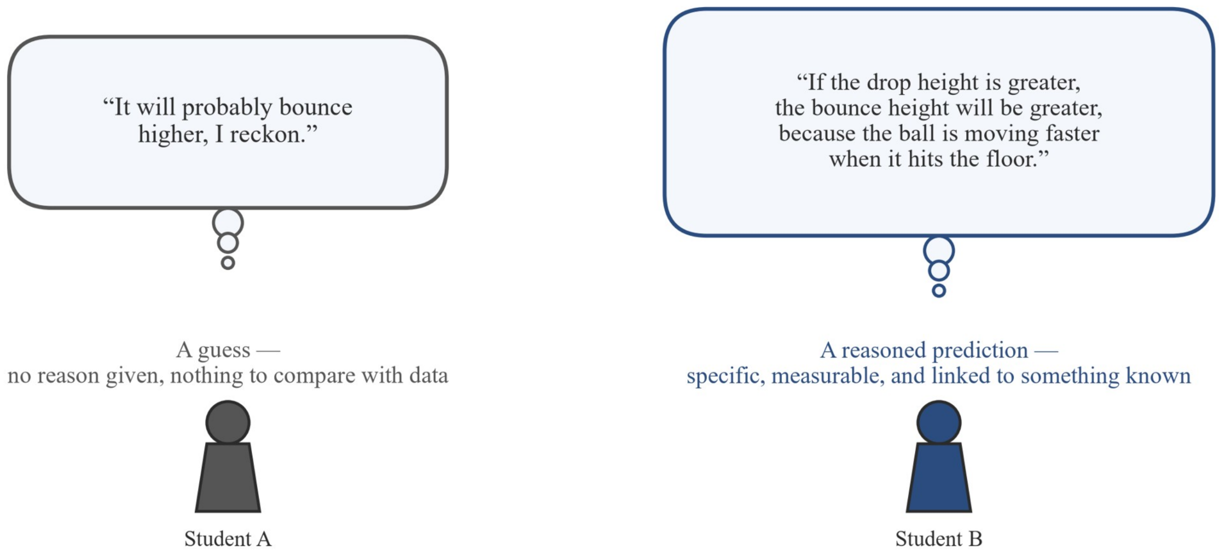
Three colour-coded boxes split one hypothesis sentence into its three clauses: the changed variable ('The greater the speed of the car,'), the measured variable ('the greater the impact force in a crash,') and the reason ('because a faster car has more energy to transfer when it stops.').

Notice what makes the hypothesis testable: both variables can be measured or changed in a real investigation, and the reason links the idea to something already known (here, energy transfer). If a statement names no variables, or names one that cannot be measured, it cannot be a hypothesis for a science investigation — it sits back with the guesses.

Reasoned predictions. A **prediction** is what a hypothesis leads you to expect in one particular investigation — what you think you will observe or measure this time, with this equipment. A prediction is **reasoned** when it follows from the hypothesis or from a model and carries its reason with it. The usual shape is *if … then … because …*:

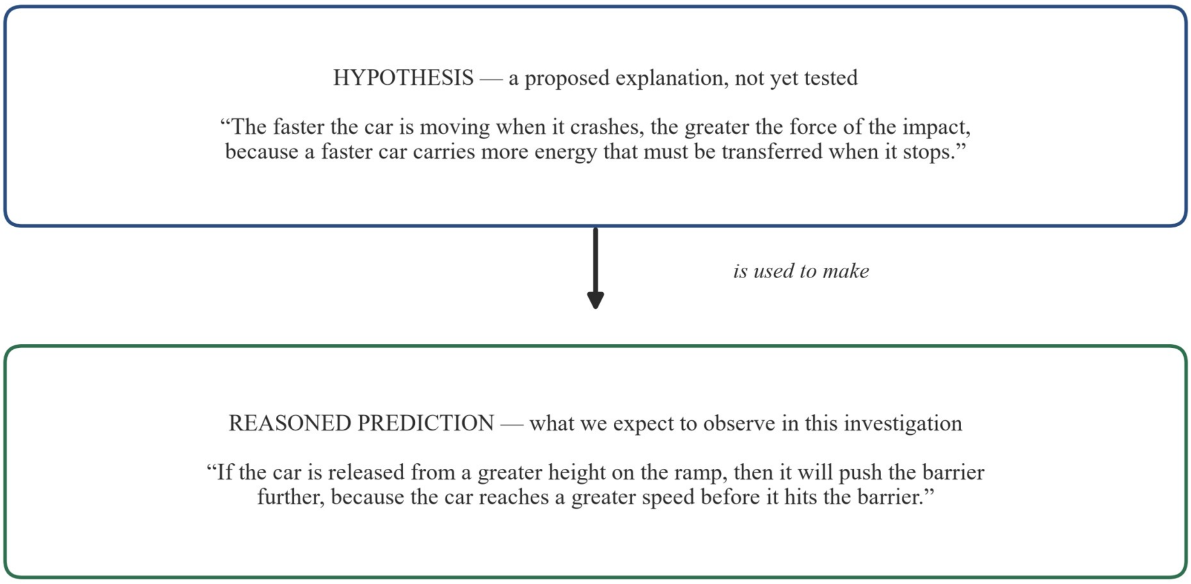
> "If the car is released from a greater height on the ramp, then it will push the barrier further, because the car reaches a greater speed before it hits the barrier."

The figure below contrasts a guess with a reasoned prediction about the same event.



Two thought bubbles above two students: Student A guesses 'It will probably bounce higher, I reckon' with no reason; Student B gives a reasoned prediction, 'If the drop height is greater, the bounce height will be greater, because the ball is moving faster when it hits the floor.'

And the figure below shows the link between the two ideas: the hypothesis is the general idea; the reasoned prediction is the observable, measurable test of that idea in one investigation.



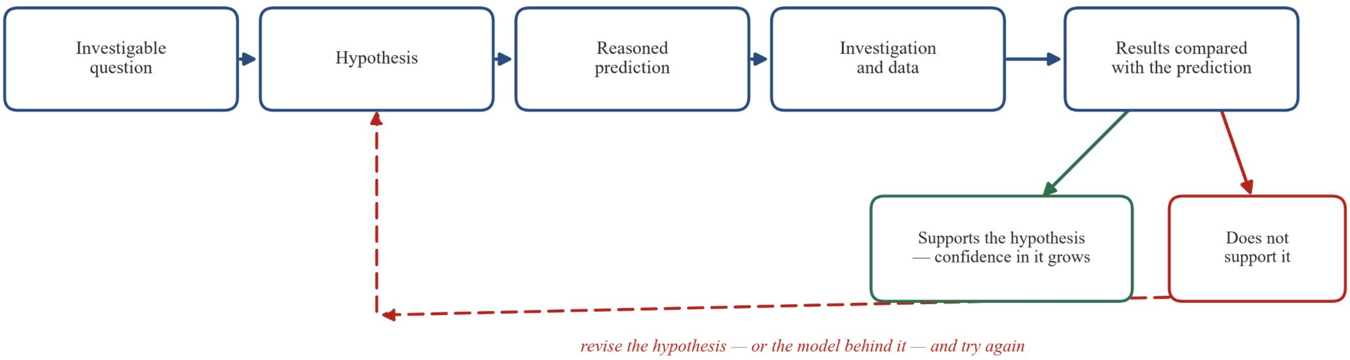
The hypothesis is the idea. The prediction is the observable test of the idea — specific enough to be compared with data.

A HYPOTHESIS box (‘a proposed explanation, not yet tested’, with the crash example) connected by an arrow labelled ‘is used to make’ to a REASONED PREDICTION box (‘what we expect to observe in this investigation’, with the ramp-and-barrier example).

A good reasoned prediction is specific enough that, after the investigation, you can say clearly whether the results match it or not. “The barrier will move more” is testable; “something interesting will happen” is not.

How a hypothesis guides an investigation. The whole chain is shown in the next figure. The investigable question (2A) comes first; the hypothesis proposes a relationship with a reason; the reasoned prediction says what will be observed in this investigation; the investigation collects data; and the results are compared with the prediction.

How a hypothesis guides an investigation

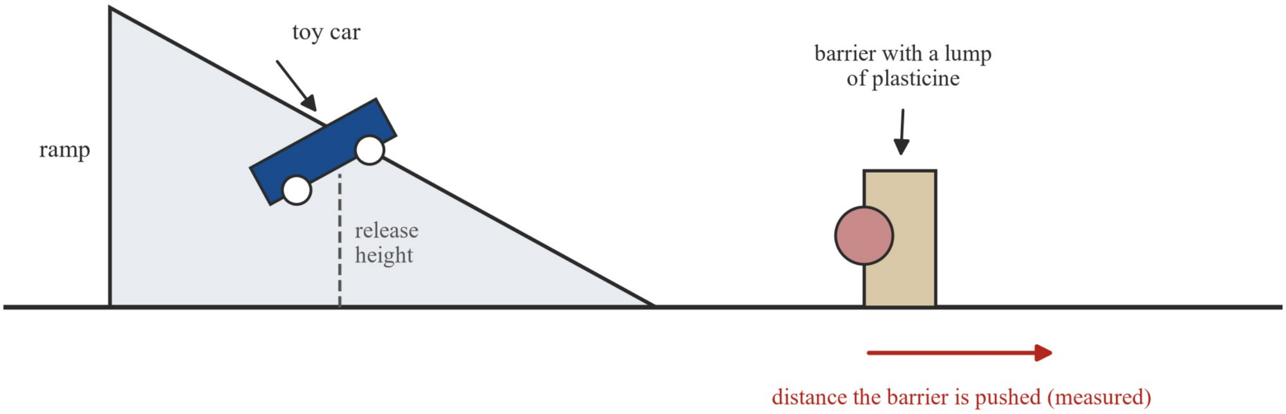


A five-box chain: Investigable question, Hypothesis, Reasoned prediction, Investigation and data, Results compared with the prediction; from the last box, one arrow leads to ‘Supports the hypothesis — confidence in it grows’ and another to ‘Does not support it’, with a dashed return arrow labelled ‘revise the hypothesis — or the model behind it — and try again’.

The prediction does two jobs. It tells you **what data to collect** (the barrier’s movement, at each release height) and **what pattern to look for** (more movement at greater heights). An investigation without a prediction collects data with nothing to compare it against.

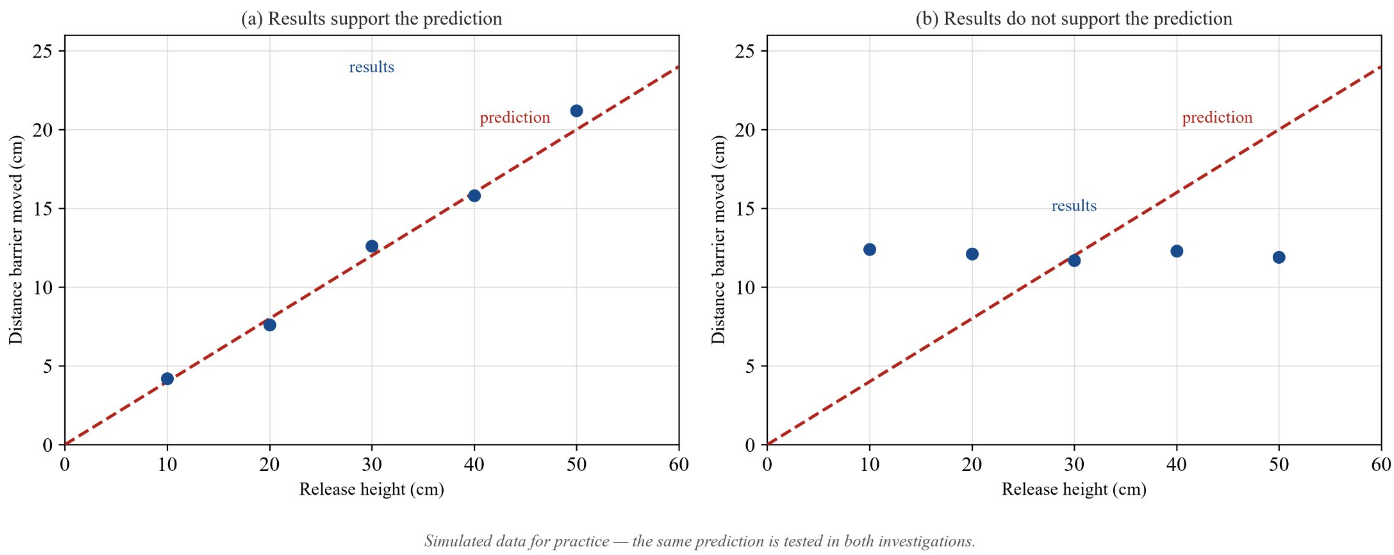
The ramp-and-barrier setup makes the crash hypothesis testable. Releasing the car from different heights on the ramp gives it different speeds at the bottom; the distance the barrier is pushed stands in for the impact force.

Investigating crash force and speed — the ramp gives the car different speeds



Side view of the apparatus: a ramp with a toy car on it at a marked release height, and at the bottom a barrier with a lump of plasticine on its face; a red arrow shows the distance the barrier is pushed, which is what is measured.

After the data are in, there are two honest outcomes, shown in the next figure using simulated data for practice. In panel (a) the points follow the predicted line: the results **support** the hypothesis, and confidence in it grows. In panel (b) the barrier moves about the same distance at every release height while the prediction said it should grow: the results **do not support** the hypothesis.



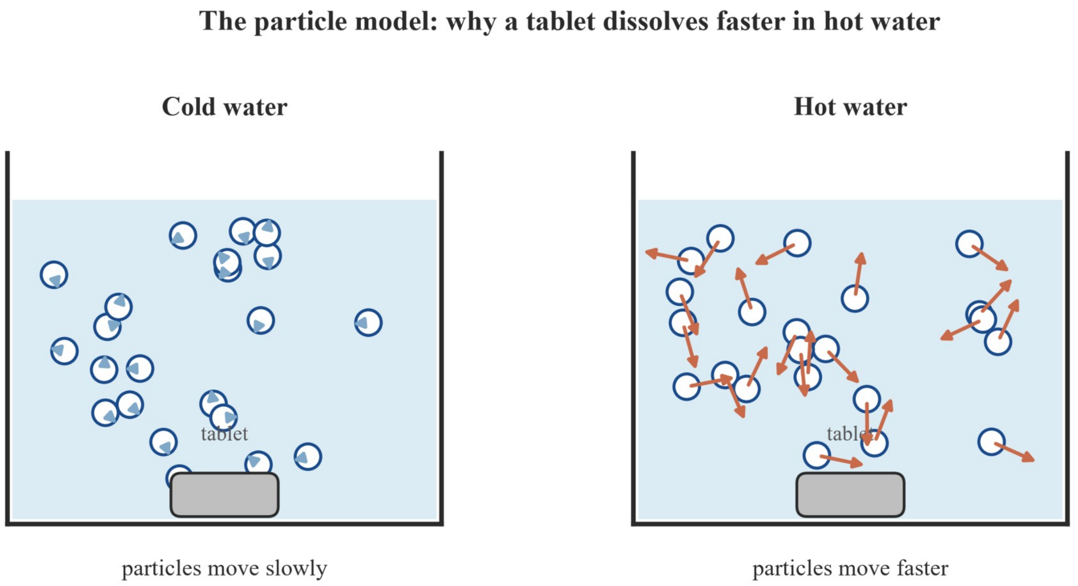
Two panels with the same dashed red prediction line (distance barrier moved growing with release height). Panel (a) 'Results support the prediction': five blue data points lying close to the line. Panel (b) 'Results do not support the prediction': five blue points sitting flat at about 12 cm while the line rises away from them. Labelled 'Simulated data for practice'.

Neither outcome is a failure. A result that does not support the hypothesis still tells you something real, and it points to the next step: check the method (was it a fair test? — that is subtopics 3A and 5A's business), and if the method was sound, revise the hypothesis or the model behind it. One more thing to hold on to: results **support** a hypothesis; they do not **prove** it. Any single investigation is one test, and confidence comes from repeated testing — by you and, in real science, by others (Chapter 1).

Explanatory models. The curriculum expects investigations to test and develop *explanatory models*, but it does not say what one is. This subtopic therefore states its working definition openly.

Explanatory model — working definition. The Victorian Curriculum uses the term *explanatory model* in `VC2S10I01` but does not define it. This subtopic therefore treats it as follows: an explanatory model is a representation — a picture, a particle story, a diagram or an analogy — that explains **why** a relationship holds, not just that it holds. The hypothesis states the relationship; the model behind it explains the relationship; the reasoned prediction tests both.

A familiar model is the **particle model** of matter: everything is made of tiny particles, and the particles move faster when the material is hotter. The model explains an everyday relationship — a tablet dissolves faster in hot water — and from that explanation it generates new hypotheses and predictions.

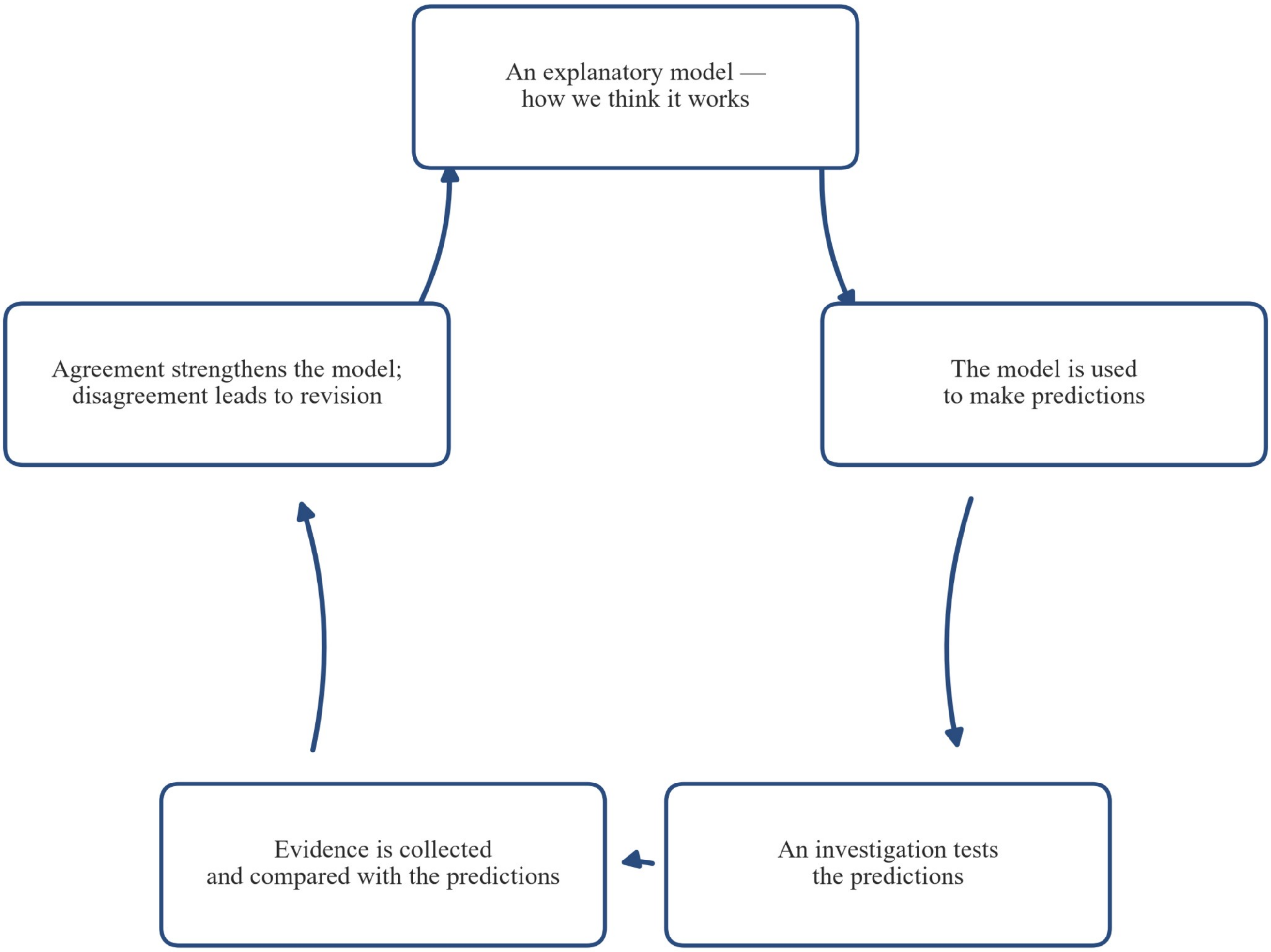


Two beakers side by side, cold water and hot water, each with a tablet at the bottom and water particles drawn as circles with velocity arrows: short arrows in the cold beaker ('particles move slowly'), long arrows in the hot beaker ('particles move faster').

In the particle model, faster-moving water particles strike the tablet more often and harder, so particles are pulled off the tablet more quickly. That is the *why* behind the relationship. The full story of reaction rates — temperature, surface area, concentration — is developed later, in 11D; here the particle model is doing its job as an explanatory model: explaining a relationship and generating testable predictions.

Models are not just checked; they are **developed**. The cycle in the next figure is how science actually runs: a model generates predictions, an investigation tests them, the evidence is compared with the predictions, and the model is either kept with growing confidence or revised. A revised model makes better predictions next time.

Explanatory models are developed, not just checked



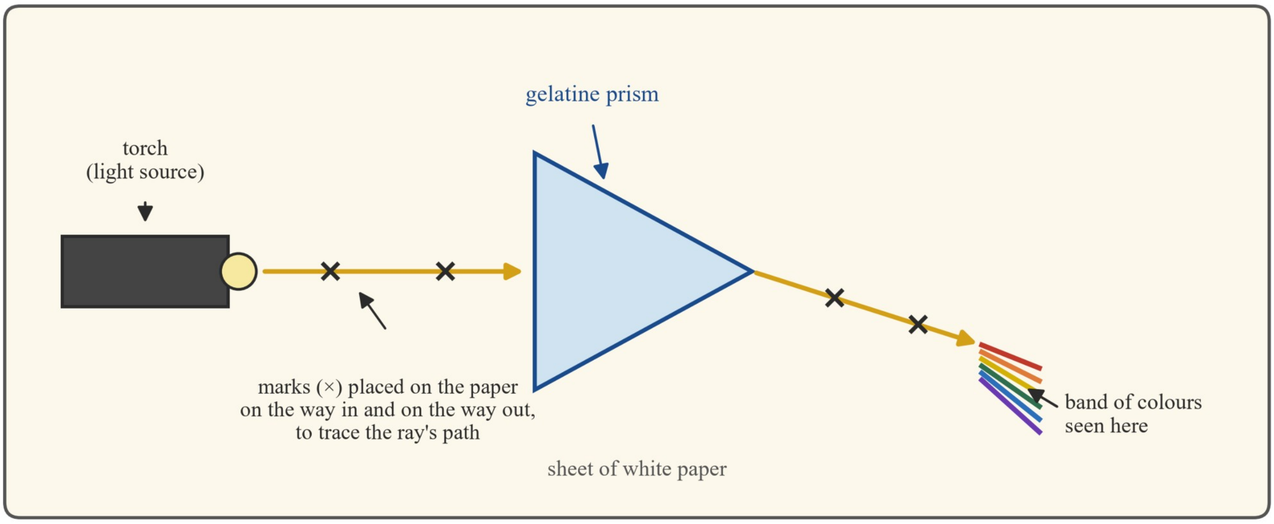
A five-stage cycle in a pentagon: Model, Predictions, Investigation, Evidence, Agreement? confidence grows / disagreement? revise, with the revision arrow returning to Model.

This is why a result that does not support a prediction is valuable: it is the model's only opportunity to improve. A model that has never been tested explains everything and nothing.

Predicting with a model: light through a gelatine prism. `VC2S10I01.E04` suggests making prisms from gelatine and shining a torch through them to predict and investigate how light is bent and dispersed. The explanatory model here is a simple **ray model** of light: light travels in straight-line paths called rays; a prism bends a ray as the light enters and again as it leaves; and different colours are bent by different amounts, so white light **disperses** — spreads out — into a band of colours. You do not need the full wave story of light (that is Chapter 14) to use the model: it is enough that the model lets you make predictions and then check them.

The apparatus, seen from above, is a torch, a sheet of white paper and the gelatine prism. Crosses marked on the paper record the ray's path in and out, so the bent path can be drawn afterwards.

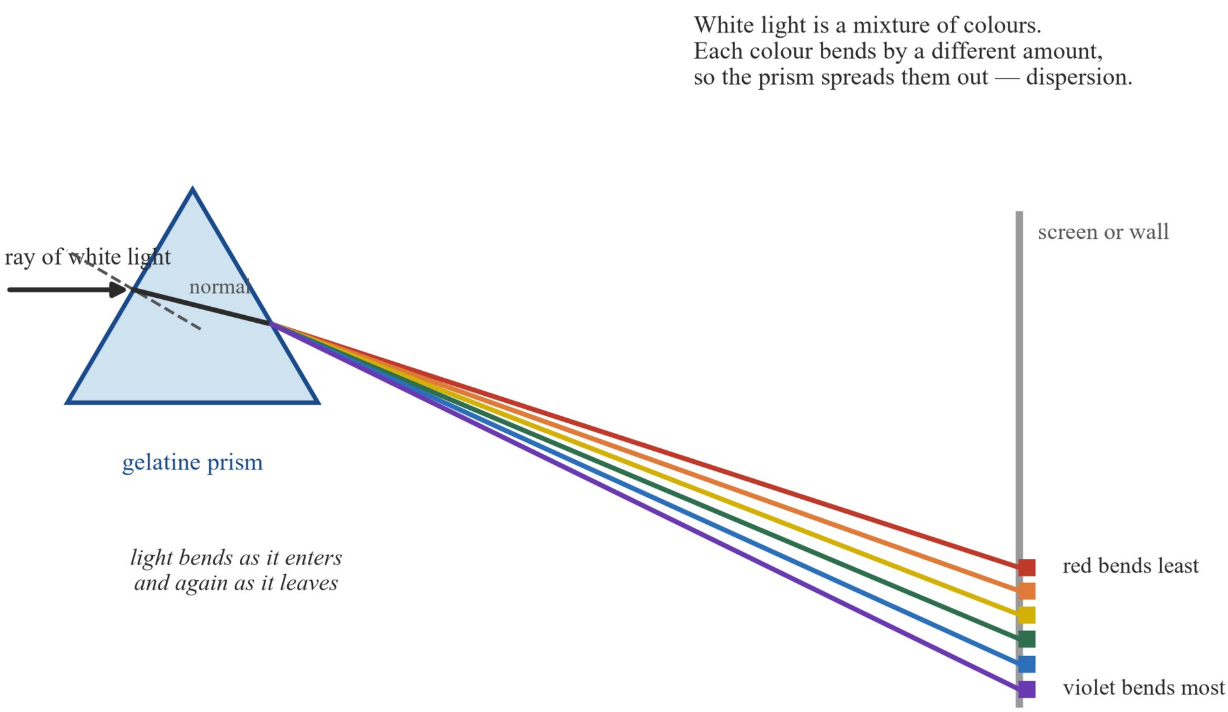
Predicting and testing with a gelatine prism — top view



Top view of the apparatus: a torch on a sheet of white paper shines a ray towards a triangular gelatine prism; crosses mark the ray's path on the way in and on the way out, and beyond the prism a band of colours is seen.

The ray model predicts what you should see: the ray leaves the prism bent from its original direction, and the white ray opens out into a band of colours, with **red bent least** and **violet bent most**.

How a prism bends and spreads white light

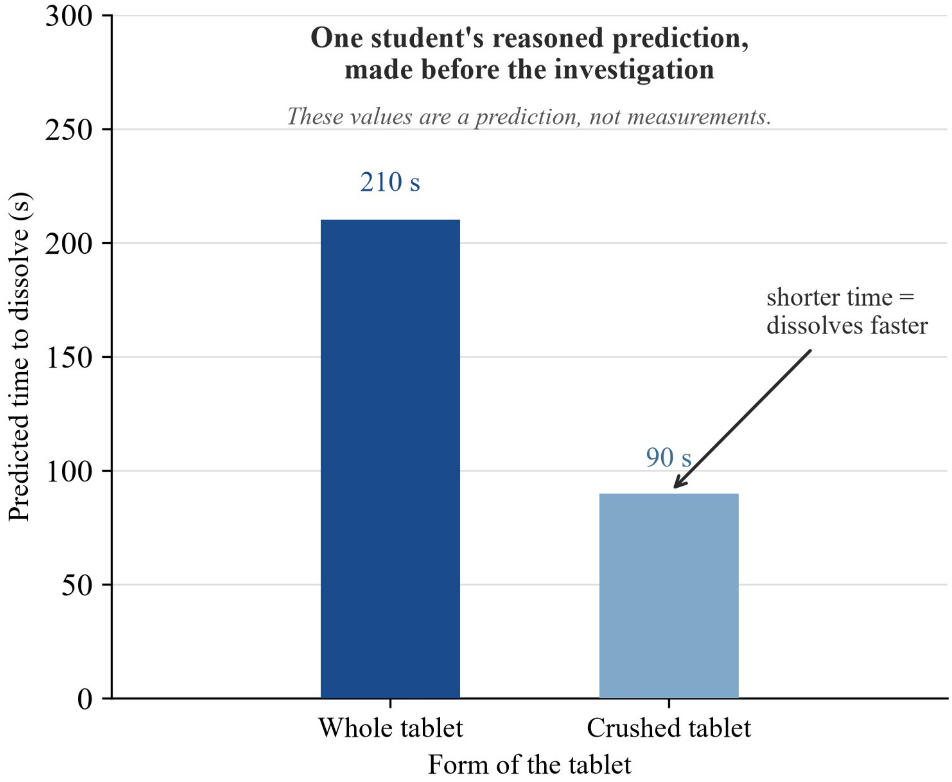


Ray diagram: a white-light ray strikes a gelatine prism, bends as it enters and again as it leaves, and disperses into a fan of colours at a screen; the red ray is bent least and the violet ray bent most.

Shine the torch, mark the path, and compare what happens with what the model predicted. If the ray had gone straight through unbent, or the colours had come out in a different order, the model would need revision. That comparison — prediction against evidence — is the whole game of this subtopic.

Extending an investigation: a reasoned prediction beyond the first results. `VC2S10I01.E03` investigates how changing surface area, concentration and temperature affect the rate of a chemical reaction, and then develops a reasoned prediction about a further investigation as an extension. Suppose a first investigation measured how long a whole effervescent tablet takes to dissolve in water at 20 °C, with three repeats: 205 s, 215 s and 210 s — a mean of 210 s. The particle model says faster particles dissolve the tablet more quickly, so warmer water should give a shorter time.

The *extension* asks for a reasoned prediction about something not yet tested: a crushed tablet instead of a whole one. In the particle model, crushing exposes more of the tablet's surface to the water particles, so more particles can be pulled off at once. A student's reasoned prediction is shown below — made **before** the extension is run, and stated as a prediction, not a measurement.



Bar chart titled 'One student's reasoned prediction, made before the investigation': predicted time to dissolve, whole tablet 210 s, crushed tablet 90 s, with the note 'These values are a prediction, not measurements' and 'shorter time = dissolves faster'.

Two habits make an extension prediction proper science. First, the reason comes from a model, not from mood. Second, the extension changes **one** variable (the form of the tablet) and keeps everything else the same — same volume of water, same temperature, same tablet mass — so any difference in the results can be put down to the variable changed. Planning fair tests like that is 3A's work; here the point is that the hypothesis and the model behind it point to the next worthwhile investigation.

Activities

Activity 1 — Crash force and speed: hypothesis to prediction. Set up the ramp and barrier as in the ramp figure above, with the lump of plasticine on the barrier's face. (Keep feet clear of the car's path.) Before running anything: (a) the investigable question is "How does the speed of the car at impact affect the force of the crash?" Write a hypothesis for it in the three-part form of the anatomy figure. (b) Write a reasoned prediction for *this* apparatus, in *if ... then ... because ...* form, naming the variable you will change (release height, to change the impact speed) and the variable you will measure (distance the barrier is pushed). (c) List two things you would keep the same in every trial, and say why changing them too would make the test unfair. Do not run the investigation until your prediction is written down — the prediction must come before the data.

Activity 2 — Gelatine prism: predict, then test. Set up the torch, white paper and gelatine prism as in the apparatus figure. Before switching the torch on, write in your book: (a) a reasoned prediction of the ray's path after the prism (straight on, or bent? which way?), with your reason from the ray model; (b) a reasoned prediction of what the paper will show beyond the prism (one white ray, or a band of colours? if colours, which colour do you expect to be bent most?). Then shine the torch, mark the ray's path with crosses, draw it, and compare each prediction with what actually happened. State, for each, whether the result supported the prediction.

Activity 3 — Tablet extension: predict before you test. A first investigation found that a whole tablet takes a mean of 210 s to dissolve in water at 20 °C (simulated data for practice). Using the particle model, write a reasoned prediction for the extension — a crushed tablet, same water, same temperature — including a predicted time and a reason. Only then run the extension (or compare with your teacher's supplied result). State whether the result supports your prediction, and name the one variable that was changed between the first investigation and the extension.

Worked examples

Example 1 — scaffolded

The investigable question is: "How does the drop height of a tennis ball affect the height of its first bounce?" Write a hypothesis and a reasoned prediction for it.

Working	Comment
Changed variable: drop height. Measured variable: height of the first bounce.	An investigable question names both variables (2A). The hypothesis must name them too.
Relationship: the greater the drop height, the greater the first bounce height.	This clause states the relationship between the two variables.
Reason: because a ball dropped from greater height is moving faster when it hits the floor, so it squashes more and springs back harder.	The reason links the relationship to something already known. Without it, the statement is a guess.
Prediction: if the ball is dropped from 50 cm and from 150 cm onto the same floor, then the first bounce from 150 cm will be higher, because the ball meets the floor moving faster.	The prediction is about *this* investigation: specific, measurable, and carrying its reason.

The hypothesis is the general claim ("the greater … the greater …, because …"); the prediction is what one investigation should show if the hypothesis is right.

Example 2 — scaffolded

The hypothesis is the crash one from the theory: "The greater the speed of the car, the greater the impact force in a crash, because a faster car has more energy to transfer when it stops." The reasoned prediction for the ramp apparatus is: "The higher the release point on the ramp, the further the barrier will be pushed." Two sets of simulated results for practice are shown in the two-panel prediction figure. Judge each set against the prediction.

Working	Comment
Set (a): release height 10, 20, 30, 40, 50 cm; barrier moved 4.2, 7.6, 12.6, 15.8, 21.2 cm.	List the data. The measured variable should be compared with the prediction, not with a feeling.
Pattern in (a): the distance pushed grows as the release height grows, close to the predicted line.	Look for the pattern the prediction said would be there.
Judgement (a): the results support the prediction, and therefore support the hypothesis.	"Support" is the correct word — one investigation is one test, not proof.
Set (b): same heights; barrier moved 12.4, 12.1, 11.7, 12.3, 11.9 cm.	The distance is much the same at every height.
Judgement (b): the flat pattern does not match the predicted rise, so the results do not support the hypothesis.	A non-supporting result is still a real result. Next steps: check the method for a fair test (3A, 5A), and if the method is sound, revise the hypothesis or the model

Example 3 — unscaffolded

Use the particle model to make a reasoned prediction: a whole tablet is placed in each of two beakers of the same volume of water, one at 20 °C and one at 60 °C. Predict what will be observed, with a reason.

The particle model says the water particles move faster at 60 °C than at 20 °C. Faster particles strike the tablet more often and harder, pulling particles off it more quickly. The reasoned prediction is: *if the same whole tablet is placed in water at 60 °C instead of 20 °C, then it will take less time to dissolve, because the faster-moving water particles strike the tablet more often and harder.* The prediction names what will be observed (the time to dissolve) and how it will differ, and the reason comes from the model — which is what makes it reasoned.

Example 4 — unscaffolded

A torch, a sheet of white paper and a gelatine prism are set up as in the apparatus figure. Before the torch is switched on, use the ray model to make two reasoned predictions: the path of the ray after the prism, and what will be seen on the paper beyond it.

The ray model says light travels in straight lines, that a prism bends a ray as the light enters and again as it leaves, and that different colours are bent by different amounts. Two reasoned predictions follow. First: *if the ray strikes the prism, then it will leave the prism bent from its original direction, because the prism bends light at each face.* Second: *if the white ray leaves the prism, then the paper beyond it will show a band of colours rather than a single white ray, because the different colours in the white light are bent by different amounts — red least, violet most — so they spread out.* Both predictions are specific enough to check with crosses on the paper, which is exactly what makes them scientific predictions.

Practice questions

Scaffolded questions

Question 1 Here is a hypothesis: “The greater the mass of the toy car, the shorter the distance it rolls after leaving the ramp, because a heavier car presses harder on its wheels and friction is greater.” (a) Which clause names the variable that is changed, and how it changes? (b) Which clause names the variable that is measured, and how it responds? (c) Which clause gives the reason, and what known idea does it link to?

Question 2 Classify each statement as a **guess**, a **hypothesis** or a **reasoned prediction**. (a) “More sugar will dissolve in hot water than in cold water, because the faster-moving particles can pull more sugar particles away.” (b) “If we add sugar to the hot beaker and the cold beaker in this test, the hot one will take more sugar before no more dissolves.” (c) “It will probably just dissolve more. I reckon.”

Question 3 The investigable question is: “How does the amount of fertiliser added affect the height of tomato seedlings after four weeks?” Complete the scaffold to build a hypothesis: “The ___ (greater/smaller) the amount of fertiliser added, the ___ the seedlings will grow, because fertiliser supplies ___ the plant needs to grow.” Then write, in *if … then … because …* form, a reasoned prediction for seedlings given 0 g, 5 g and 10 g of fertiliser.

Question 4 A hypothesis: “The longer a tray of water sits in sunlight, the warmer the water gets, because the water absorbs energy from the sunlight.” Which of the following is a reasoned prediction that follows from it? A. The tray will get warm if left in the sunlight. B. If the water’s temperature is measured every 10 minutes for an hour of sunlight, then the temperature will be higher at each later measurement, because the water keeps absorbing energy from the sunlight. C. If the tray is left out overnight, then the water will get colder, because there is no sunlight. D. Sunlight is warm, so water in sunlight is warm.

Question 5 A student’s reasoned prediction is: “The higher the drop height, the higher the first bounce.” Simulated results for practice: drop height 50 cm, 100 cm, 150 cm; first bounce 28 cm, 55 cm, 80 cm. (a) Describe the pattern in the results. (b) Do the results support the prediction? Explain. (c) Do the results *prove* the hypothesis behind the prediction? Explain.

Question 6 The five steps below are out of order. Put them in the order shown by the inquiry-flow figure, and state which step the reason for a hypothesis belongs to. (a) Results are compared with the prediction. (b) A reasoned prediction is made. (c) An investigable question is asked. (d) An investigation is run and data are collected. (e) A hypothesis is proposed.

Unscaffolded questions

Question 7 Write a hypothesis, in the three-part form, for the question: “How does the size of a parachute’s canopy (the cloth part) affect the time it takes to fall 2 m?” Give a reason you can defend.

Question 8 For your hypothesis in Question 7, write a reasoned prediction for an investigation using canopies of 30 cm, 50 cm and 70 cm across. Name the variable changed, the variable measured, and carry the reason through.

Question 9 Explain the difference between a hypothesis and a reasoned prediction.

Question 10 Explain why “the results support the hypothesis” is not the same as “the results prove the hypothesis”.

Question 11 A hypothesis: “The larger the parachute canopy, the longer the fall time, because a bigger canopy catches more air.” The reasoned prediction was that fall time over 2 m would grow as the canopy grew. Simulated results for practice: canopy 20, 30, 40, 50 cm; fall time 3.1, 3.0, 3.2, 3.1 s. (a) Do the results support the prediction? Explain. (b) The student says the investigation was a waste of time because the prediction was not supported. Give two reasons why that is wrong.

Question 12 Two beakers hold the same volume of water, one at 10 °C and one at 40 °C. A whole tablet of the same mass goes into each. Use the particle model to make a reasoned prediction, with a reason.

Question 13 The torch–gelatine-prism apparatus is set up on white paper. (a) Predict, with a reason from the ray model, what the paper will show beyond the prism. (b) State which colour of light is bent least and which is bent most. (c) What would you observe that would tell you the ray model’s claim about bending was wrong?

Question 14 Tomas explains a bouncing ball like this: “When the ball hits the floor it squashes, stores energy like a spring, and springs back — that is the bounce.” (a) Name the explanatory model Tomas is using. (b) Use Tomas’s model to make a reasoned prediction: a basketball and an inflated balloon are dropped from the same height onto the same floor. Which bounces higher, and why does the model say so?

Question 15 A class investigated how water temperature affects the time for a whole chalk lump to stop fizzing in vinegar: 20 °C → 95 s; 40 °C → 60 s; 60 °C → 35 s (simulated data for practice). As an experiment extension, make a reasoned prediction comparing a crushed chalk lump with a whole one at 40 °C, with a reason from the particle model. State one thing that must be kept the same.

Question 16 A student’s results do not match the prediction made from a model. Give two responses that are good science, and one response that is not.

Answers

Question 1 (a) “The greater the mass of the toy car” — the changed variable, increasing; (b) “the shorter the distance it rolls after leaving the ramp” — the measured variable, decreasing; (c) “because a heavier car presses harder on its wheels and friction is greater” — links to the known idea that greater pressing between surfaces means greater friction. **Question 2** (a) hypothesis; (b) reasoned prediction; (c) guess. **Question 3** greater … taller … nutrients; prediction example: if seedlings are given 0 g, 5 g and 10 g of fertiliser, then the 10 g seedlings will be tallest after four weeks, because fertiliser supplies the nutrients the plant needs to grow. **Question 4** B. **Question 5** (a) bounce height grows as drop height grows; (b) yes — the pattern matches the prediction; (c) no — one investigation is one test; support is not proof. **Question 6** Order: c, e, b, d, a. The reason belongs to the hypothesis step (e). **Question 7** see solution. **Question 8** see solution. **Question 9** see solution. **Question 10** see solution. **Question 11** (a) no — fall time stays about 3.1 s at every canopy size while the prediction said it would grow; (b) see solution. **Question 12** see solution. **Question 13** (a) see solution; (b) red least, violet most; (c) see solution. **Question 14** (a) a spring (squash-and-spring-back) model of the bounce; (b) see solution. **Question 15** see solution. **Question 16** see solution.

Fully-worked solutions

Question 1 (a) The first clause, “The greater the mass of the toy car”, names the variable that is changed (the car’s mass) and says how it changes (greater). (b) The second clause, “the shorter the distance it rolls after leaving the ramp”, names the variable that is measured (roll distance) and how it responds (shorter). (c) The third clause, “because a heavier car presses harder on its wheels and friction is greater”, gives the reason. It links the relationship to the known idea that friction between two surfaces is greater when the surfaces are pressed together harder.

Question 2 (a) A **hypothesis**: it states a relationship between two variables (water temperature and how much sugar dissolves) and gives a reason. (b) A **reasoned prediction**: it says what will be observed in one particular test (the hot beaker takes more sugar), and it follows from the hypothesis with its reason. (c) A **guess**: no relationship named, no reason, nothing specific to compare with data.

Question 3 Completed hypothesis: “The **greater** the amount of fertiliser added, the **taller** the seedlings will grow, because fertiliser supplies **nutrients** the plant needs to grow.” A reasoned prediction: *if seedlings are given 0 g, 5 g and 10 g of fertiliser and grown for four weeks, then the 10 g seedlings will be the tallest, because fertiliser supplies the nutrients the plant needs to grow.* The prediction names the measurements (heights after four weeks, at each fertiliser amount) and carries the reason.

Question 4 B. It is specific (temperature measured every 10 minutes), it states the expected pattern (higher at each later measurement), and it carries the reason from the hypothesis (the water keeps absorbing energy). A is a guess with nothing measurable; C predicts an outcome the investigation described would not test (overnight cooling); D gives a reason but no testable pattern in one investigation.

Question 5 (a) As the drop height grows (50 → 100 → 150 cm), the first bounce height grows (28 → 55 → 80 cm). (b) Yes. The prediction said bounce height would grow with drop height, and that is exactly the pattern in the results, so the results support the prediction. (c) No. The results are one investigation’s worth of support. Proof would mean no further test could ever disagree; repeated testing — different balls, different floors, other investigators — is what builds confidence (Chapter 1). Support, never proof, is the honest claim.

Question 6 Correct order: (c) investigable question → (e) hypothesis → (b) reasoned prediction → (d) investigation and data → (a) results compared with the prediction. The reason for a hypothesis belongs to step (e): a hypothesis is a relationship *with a reason*, and the prediction inherits that reason.

Question 7 Example: “The greater the size of the parachute canopy, the longer the time it takes to fall 2 m, because a bigger canopy catches more air and the air pushes up on the parachute more.” The first clause names the changed variable (canopy size), the second names the measured variable (fall time over 2 m), and the third gives a reason from the known idea that air pushes back on things that push it aside.

Question 8 Example: “If canopies of 30 cm, 50 cm and 70 cm across are dropped from the same height, then the 70 cm canopy will take the longest time to fall the 2 m, because a bigger canopy catches more air and the air pushes up on it more.” The changed variable is canopy size, the measured variable is the fall time over 2 m, and the reason is carried through from the hypothesis.

Question 9 A **hypothesis** is a general proposed explanation: a testable statement of a relationship between variables, with a reason. A **reasoned prediction** is what that hypothesis leads you to expect in one particular investigation — what will be observed or measured this time — specific enough to compare with data, and carrying its reason. The hypothesis is the idea; the prediction is the observable test of the idea.

Question 10 Any single investigation is one test of a hypothesis, run with one method and one set of equipment. Its results can agree with the prediction — support — but a later investigation, a different method or another investigator’s test could disagree. “Proof” would mean no possible test could ever disagree, and science does not deal in that. Confidence in a hypothesis grows as supporting tests accumulate (Chapter 1); it is never finished.

Question 11 (a) No. The prediction said fall time would grow as the canopy grew; the results stay at about 3.1 s for every canopy size (3.1, 3.0, 3.2, 3.1 s — the same within the scatter). The flat pattern does not match the predicted rise, so the results do not support the prediction. (b) First, a non-supporting result is still a finding: the student now knows that, over this range of sizes, canopy size makes no measurable difference to fall time — that is knowledge the prediction did not provide. Second, it points to the next step: check the method (was 2 m too short a fall? were the canopies really different?) and, if the method is sound, revise the hypothesis or the model — perhaps the air push only matters for bigger canopies or longer falls. An investigation that teaches you your idea was wrong is doing its job.

Question 12 In the particle model, water particles move faster at 40 °C than at 10 °C, so they strike the tablet more often and harder and pull its particles away more quickly. Reasoned prediction: *if the same whole tablet is placed in water at 40 °C instead of 10 °C, then it will take less time to dissolve, because the faster-moving particles strike the tablet more often and harder.*

Question 13 (a) The paper beyond the prism will show a band of colours, not a single white ray, because the prism bends the light as it enters and again as it leaves, and the different colours in the white light are bent by different amounts, so they spread out. (b) Red is bent least; violet is bent most. (c) If the marked path showed the ray going straight through the prism unbent, or a single white ray with no band of colours, the ray model’s claims about bending and dispersing would not be supported and the model would need revision.

Question 14 (a) A spring model of the bounce — the ball squashes, stores energy like a spring, and springs back. (b) Reasoned prediction: *if the basketball and the balloon are dropped from the same height, then the basketball will bounce higher, because the basketball squashes and springs back like a stiff spring, returning most of the energy, while the balloon’s skin does not spring back well and the energy of the squash is mostly lost in moving the air inside it.* The model supplies the reason, and the prediction is testable in one drop.

Question 15 Example: “If a crushed chalk lump replaces the whole one at 40 °C, then it will stop fizzing in less than 60 s, because crushing exposes more of the chalk’s surface, so more vinegar particles can strike it at once.” One thing kept the same: the temperature of the vinegar (40 °C) — or equally, the same volume of vinegar and the same mass of chalk. Changing only the form of the chalk keeps the test fair.

Question 16 Good science: (1) check the method — was it a fair test, were there repeats? — and if a flaw is found, fix it and re-run (3A, 5A); (2) if the method is sound, revise the hypothesis or the model and make a new prediction to test. Not good science: discarding or adjusting the recorded results so they match the prediction. The evidence is what it is; the model is the part that gets revised.

Where this leads: the investigations these hypotheses need — fair tests, controls, repeats, careful measurement — are planned in 3A and 3C; reading patterns, trends and results that do not fit belongs to 4C; judging whether a method was sound when results do not support a prediction is 5A, and building an evidence-based conclusion from the comparison is 5B. The *why* behind the rate relationships used here (temperature, surface area, concentration) is developed fully in 11D, and the wave story of light, including why a prism disperses white light, in 14B. In VCE, the key science skills of all five sciences assume exactly this cycle of hypothesis, prediction, test and model revision — reference-only for this book (TOC §5).