Science 9–10

Contents

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Aboriginal and Torres Strait Islander content has been excluded as accuracy cannot be guaranteed, and it is better to be respectful than cover the entire curriculum inaccurately.

Significant effort has been made to ensure this content is legal. Please send any areas of concern to admin@vwx.au with appropriate document/legal references so errors can be verified and changes be made.

Contents

This book is the **Science 9–10** student workbook. It is written for the **Levels 9 and 10** band of the Victorian Curriculum F–10 Version 2.0 (VC2), Science. **The band is one scope.** All twenty-nine content descriptions in this book are tagged "Levels 9 and 10" — not one is tagged Level 9 alone or Level 10 alone — so the book does not split them into a Year 9 part and a Year 10 part. Schools choose their own two-year rotation, and the book works with any rotation.

The book is eighteen booklets:

- **Chapter 1 — Nature and development of science** — `Science910_Chapter01` — subtopics 1A, How scientific knowledge is validated and refined, and 1B, Science, technology and engineering advance together *(38 pp)*
- **Chapter 2 — Questioning and predicting** — `Science910_Chapter02` — subtopics 2A, Investigable questions, variables and testable relationships, and 2B, Hypotheses, reasoned predictions and explanatory models *(27 pp)*
- **Chapter 3 — Planning and conducting** — `Science910_Chapter03` — subtopics 3A, Planning valid, reproducible investigations, 3B, Safe and ethical investigation: risk, ethics and protocols on Country and Place, and 3C, Equipment, calibration, sample size and precision, and Topic test 1 — How science works, and planning an investigation, with its answers and fully-worked solutions *(77 pp)*
- **Chapter 4 — Processing, modelling and analysing** — `Science910_Chapter04` — subtopics 4A, Organising and summarising data: tables, graph choice and descriptive statistics, 4B, Models, symbols, formulas and mathematical relationships as representations, and 4C, Patterns, trends, relationships and anomalies — including correlation versus causation *(50 pp)*
- **Chapter 5 — Evaluating** — `Science910_Chapter05` — subtopics 5A, Validity, reproducibility, random and systematic error, and areas of uncertainty, and 5B, Building an evidence-based argument, assessing claims, and the ethics and cultural protocols of using secondary sources *(41 pp)*
- **Chapter 6 — Communicating** — `Science910_Chapter06` — subtopics 6A, The scientific report, and 6B, Communicating and justifying to diverse audiences, and Topic test 2 — Data, evidence and communication, with its answers and fully-worked solutions, and Scientific Investigation Task 1 — Designing and analysing *(64 pp)*
- **Chapter 7 — Biological sciences A: reproduction and heredity** — `Science910_Chapter07` — subtopics 7A, Reproductive cells and organs in plants and animals: structure related to function, 7B, Sexual and asexual reproduction, variation and survival of the species, 7C, DNA, chromosomes, genes and alleles; mitosis and meiosis, and 7D, Mendelian inheritance: monohybrid crosses, ratios and pedigrees *(69 pp)*
- **Chapter 8 — Biological sciences B: coordination, homeostasis and disease** — `Science910_Chapter08` — subtopics 8A, The nervous and endocrine systems, 8B, Homeostasis and negative feedback, 8C, Infectious and non-infectious disease: pathogens, agents and causes, and 8D, Controlling transmission: hygiene, quarantine, medical treatment and public education *(69 pp)*
- **Chapter 9 — Biological sciences C: evolution and biodiversity** — `Science910_Chapter09` — subtopics 9A, Evolution by natural selection, and 9B, The evidence for evolution, and biodiversity and relatedness, and Topic test 3 — Biological sciences, with its answers and fully-worked solutions *(53 pp)*
- **Chapter 10 — Chemical sciences A: atoms, isotopes and the periodic table** — `Science910_Chapter10` — subtopics 10A, How the model of the atom changed, 10B, Isotopes, natural radioactive decay and half-life, and 10C, The periodic table: groups, periods, electron shells and trends *(53 pp)*
- **Chapter 11 — Chemical sciences B: chemical reactions** — `Science910_Chapter11` — subtopics 11A, Conservation of mass and the rearrangement of atoms, 11B, Writing and balancing word and symbol equations, 11C, Reaction types: synthesis, decomposition and displacement, and 11D, Energy changes and reaction rate, and Topic test 4 — Chemical sciences, with its answers and fully-worked solutions, and Scientific Investigation Task 2 — Full investigation report *(99 pp)*
- **Chapter 12 — Earth and space sciences A: Earth's systems, carbon and climate** — `Science910_Chapter12` — subtopics 12A, Earth's four interrelated systems and the carbon cycle, 12B, Fire, weathering, vulcanism and fossil-fuel combustion, 12C, Climate dynamics and how climate is modelled,

and 12D, Mitigation: power generation, deforestation, manufacturing, transport, food production and consumption *(74 pp)*

- **Chapter 13 — Earth and space sciences B: the universe and space exploration** — `Science910_Chapter13` — subtopics 13A, Features of the universe and the scales used to describe them, 13B, The big bang theory and its evidence, and 13C, Space exploration: what it seeks to learn, and Topic test 5 — Earth and space sciences, with its answers and fully-worked solutions *(71 pp)*
- **Chapter 14 — Physical sciences A: energy transfer and waves** — `Science910_Chapter14` — subtopics 14A, Particle and wave models of energy transfer: conduction, convection and radiation, 14B, Waves: mechanical and electromagnetic, and 14C, Conservation of energy in systems: transfers, transformations and efficiency *(52 pp)*
- **Chapter 15 — Physical sciences B: electricity generation, forces and motion** — `Science910_Chapter15` — subtopics 15A, Generating electricity: AC from magnets and turbines, DC from photovoltaic cells and batteries, 15B, Newton's laws and the relationship between force, mass and acceleration, and 15C, Analysing motion quantitatively: graphs, formulas and vehicle-safety applications, and Topic test 6 — Physical sciences, with its answers and fully-worked solutions *(57 pp)*
- **Chapter 16 — Use and influence of science** — `Science910_Chapter16` — subtopics 16A, Socio-scientific issues: projected outcomes, and why people adopt or resist a scientific practice, and 16B, Interpretation, misinformation and the values that set research priorities, and Topic test 7 — Science in society, with its answers and fully-worked solutions *(49 pp)*
- **Chapter 17 — End-of-band review and solutions** — `Science910_Chapter17_Review` — the end-of-band review, one cumulative paper across Chapters 1 to 16, and its fully-worked solutions *(25 pp)*
- **Chapter 0 — Contents** — `Science910_Chapter00_Contents` — this booklet: how to use the book, what it covers, teacher notes, safety notes and the band word list *(0 pp)*

Series total: eighteen booklets ≈ 968 pages. The built booklets — `Science910_Chapter01` to `Science910_Chapter16`, `Science910_Chapter17_Review` and `Science910_Chapter00_Contents` — are in `S:\Files\VC2Science\Textbook9_10\`.

How to use this book

The chapters are in a teaching order. Chapter 1 frames the band: what scientific knowledge is, how it is validated, and how science, technology and engineering advance together. Chapters 2 to 6 are the five Science inquiry sub-strands — questioning and predicting, planning and conducting, processing, modelling and analysing, evaluating, and communicating — one chapter each, taught as a front block **and then revisited**: every investigation task in every knowledge chapter cites the numbered Chapter 2–6 subtopic it draws on, because a student cannot plan a valid investigation in Chapter 11 with the variables, controls, precision and error material still ahead. Chapters 7 to 15 carry the four Science understanding sub-strands — biological sciences (Chapters 7–9), chemical sciences (Chapters 10–11), Earth and space sciences (Chapters 12–13) and physical sciences (Chapters 14–15). Chapter 16, use and influence of science, is the capstone: socio-scientific issues ask students to reason *about* science, and that reasoning needs the science first, so the chapter sits after the knowledge chapters, immediately before the end-of-band review. **This is a teaching order, not a mandated sequence.** The curriculum states no order within the band, and a school that runs the chapters in another order is not out of compliance — but keep Chapter 1 first, and Chapter 16 after the knowledge chapters it draws on. The teaching order implies no year-level allocation.

One band, two years. The band is not split by year level: there are no Year 9 chapters and no Year 10 chapters, because the curriculum itself makes no Year 9 / Year 10 split. No chapter, subtopic, test or contents line in this book is tagged with a year level. Whichever way a school rotates the chapters across Year 9 and Year 10, every subtopic in this book is taught as written.

A subtopic is not one lesson. Each of the 46 subtopics is several lessons of work. The band is two school years, and the book is sized for the two-year band as a whole, with room left to go back over things.

Inside each subtopic. Every subtopic opens with a header block that names its content description code, quotes the content description verbatim, gives the achievement-standard extract the subtopic serves, and lists the elaboration ids

it draws on — and, where the mathematics matters, names the enabling VC2 Mathematics code. Then comes the theory — short paragraphs, with every new science word named and explained the first time it is used — and the activities. That is followed by four worked examples — two worked with support and two worked without — then about sixteen questions, six with support and about ten without, spanning the major variations of the subtopic, each with answers and fully-worked solutions. Investigations in the knowledge chapters plan and analyse practical work, and each one says which Chapter 2–6 subtopic it is drawing on.

The assessment travels with the chapters. Each block's topic test is appended to the booklet of the block's last chapter; Scientific Investigation Task 1 sits in the Chapter 6 booklet and Scientific Investigation Task 2 in the Chapter 11 booklet; the end-of-band review and its solutions fill the Chapter 17 booklet. See the teacher notes below.

The numbers stay inside what VC2 Mathematics Levels 9 and 10 delivers. Every quantitative demand in the book cites the enabling Mathematics code at the point of use: scientific notation and very large and small quantities (`VC2M9M02` — half-life in 10B, light-years and astronomical units in 13A); absolute, relative and percentage error (`VC2M9M04` — 3C, 5A); direct proportion, rates, ratio and scale (`VC2M9M05` — 4B, 12D, 14C and beyond); linear graphs and gradient (`VC2M9A03`/`VC2M9A04` — motion graphs in 15C); substituting into and rearranging formulas (`VC2M10A05` — $F = ma$ in 15B); survey reports and sampling method (`VC2M9ST01`/`VC2M9ST02` — 3C, 5A); quartiles and the interquartile range (`VC2M10ST01` — 4A); scatterplots and line of good fit (`VC2M10ST02` — 4C); claims and inferences in statistical reports (`VC2M10ST04` — 5B). Anything beyond these is out of band.

Everything real is really real. Every data set, record and named case in the book is real, Victorian or Australian where the curriculum asks for it, and carries a source line with a retrieval date, so students can see where the numbers come from. Facts are correct for Victoria: the mains supply is 230 V, 50 Hz AC wherever it appears, named generation and facilities are cited to AEMO or DEECA with a retrieval date, seasons are southern-hemisphere, units are SI, and dates are Australian (7 August 2026, not August 7). Where a plausible example cannot be sourced, the book uses a clearly-labelled hypothetical data set — never a fake attribution.

Every science word is gathered once. Every new science word is named and explained the first time it appears, and all the words are gathered again, chapter by chapter, in the band word list at the back of this booklet.

The tests and the review are untimed. There is no time to beat on any instrument in this book, and if a student needs it, the teacher will read any question out. See the teacher notes below.

What this book covers

The table below lists all 29 content descriptions of the Levels 9 and 10 band, in the coverage register the series checks itself against. Every one of the 29 codes appears here exactly once, with exactly one owner subtopic; there are no gaps and no deferrals — no content description is left to another book, and no code from another band appears anywhere in this one. A `Partner` is the second subtopic of a split delivery, marked † in the chapter plan, and is **not** an owner; a coverage audit checks the owner *and* the partner for those codes. The `Not authored (D10)` column lists elaboration ids withheld under the estate's Aboriginal and Torres Strait Islander content decision — a recorded decision, not a gap.

#	CD code	Strand	Owner	Partner (†, not an owner)	Elaboration ids (all)	Not authored (D10)	MCQs
1	VC2S10H01	Nature and development of science	1A	—	.E01–.E07 (7)	—	93
2	VC2S10H02	Nature and development of science	1B	—	.E01–.E06 (6)	—	82
3	VC2S10H03	Use and influence of science	16A	—	.E01–.E06 (6)	.E06 *(b)*	78

#	CD code	Strand	Owner	Partner (†, not an owner)	Elaboration ids (all)	Not authored (D10)	MCQs
4	VC2S10H04	Use and influence of science	16B	—	.E01–.E07 (7)	.E06 *(c)*	74
5	VC2S10U01	Biological sciences	7A	7B	.E01–.E06 (6)	—	91
6	VC2S10U02	Biological sciences	8A	8B	.E01–.E06 (6)	—	94
7	VC2S10U03	Biological sciences	8C	8D	.E01–.E07 (7)	.E06 *(c)*	89
8	VC2S10U04	Biological sciences	7C	7D	.E01–.E05 (5)	—	94
9	VC2S10U05	Biological sciences	9A	9B	.E01–.E07 (7)	.E06 *(b)*	96
10	VC2S10U06	Chemical sciences	10A	10B	.E01–.E06 (6)	.E05 *(b)*	93
11	VC2S10U07	Chemical sciences	10C	—	.E01–.E06 (6)	—	84
12	VC2S10U08	Chemical sciences	11A	11B	.E01–.E06 (6)	—	85
13	VC2S10U09	Chemical sciences	11C	11D	.E01–.E07 (7)	.E06 .E07 *(b)*	88
14	VC2S10U10	Earth and space sciences	12A	12B	.E01–.E07 (7)	.E04 .E05 *(b)*	93
15	VC2S10U11	Earth and space sciences	12C	12D	.E01–.E06 (6)	—	86
16	VC2S10U12	Earth and space sciences	13C	—	.E01–.E06 (6)	—	81
17	VC2S10U13	Earth and space sciences	13A	13B	.E01–.E06 (6)	.E01 *(b)*	78
18	VC2S10U14	Physical sciences	14A	14B	.E01–.E07 (7)	.E07 *(b)*	83
19	VC2S10U15	Physical sciences	14C	—	.E01–.E06 (6)	.E04 *(b)*	96
20	VC2S10U16	Physical sciences	15A	—	.E01–.E05 (5)	—	83
21	VC2S10U17	Physical sciences	15B	15C	.E01–.E06 (6)	.E02 *(b)*	94
22	VC2S10I01	Questioning and predicting	2A	2B	.E01–.E04 (4)	—	87
23	VC2S10I02	Planning and conducting	3A	3B	.E01–.E07 (7)	.E04 *(b)*	93

#	CD code	Strand	Owner	Partner (†, not an owner)	Elaboration ids (all)	Not authored (D10)	MCQs
24	VC2S10I03	Planning and conducting	3C	—	.E01–.E05 (5)	—	94
25	VC2S10I04	Processing, modelling and analysing	4A	4B	.E01–.E07 (7)	—	95
26	VC2S10I05	Processing, modelling and analysing	4C	—	.E01–.E06 (6)	—	90
27	VC2S10I06	Evaluating	5A	—	.E01–.E03 (3)	—	93
28	VC2S10I07	Evaluating	5B	—	.E01–.E05 (5)	—	93
29	VC2S10I08	Communicating	6A	6B	.E01–.E07 (7)	.E07 *(b)*	88
	Total	**11 strands**	**29 owners**	**17 partners**	**175**	**15**	**2,568**

Notes on this table:

- Elaboration ids are shown short inside a row whose CD code is already given — row 5's `.E03` is `VC2S10U01.E03`. The elaborations are VCAA's illustrations of what a content description might look like: they are contexts and examples, **not the requirement**. The content description is the expectation; a subtopic that teaches its content description properly from three of seven elaborations is complete, not deficient, and coverage is measured against the 29 content descriptions, never against the 175 elaboration ids. The id lists are provenance, not a running order — a subtopic structured as a march through its elaboration list in VCAA's order would have taught VCAA's examples instead of VCAA's curriculum. The ids are recorded here because they are what joins each subtopic to the banked question set.
- The `MCQs` column is the count of questions already keyed to that code in the question bank, read from the curriculum authority file on 7 August 2026. It is the **CD-level** figure: for a split (†) code it is not pre-divided between owner and partner — a job selecting items for one half filters the code's items by clause. It is not a target, and it is not a claim about how many the book will print.
- **The `Not authored` ids are a recorded decision, not a gap.** Fifteen elaboration ids across fourteen content descriptions mention Aboriginal and/or Torres Strait Islander Peoples, and this book withholds them in two groups, marked *(b)* and *(c)* in the column. *(b)* — thirteen ids that ask for Aboriginal and Torres Strait Islander knowledges, techniques or community practice to be taught as science content — are not authored, following the estate's position that it is better to be respectful than to cover the curriculum inaccurately; each affected content description retains five or six other elaborations. *(c)* — two ids (`VC2S10U03.E06`, `VC2S10H04.E06`) that ask students to examine documented Australian history and the misuse of science — are not authored by default either, pending review. **The mandated protocol limb is taught either way.** `VC2S10I02`'s own content description requires following protocols when accessing cultural sites and artefacts on Country and Place, and `VC2S10I07` requires consideration of ethical issues and cultural protocols when accessing, using or citing secondary data. That is content description text, not an elaboration, and it is not optional: 3B and 5B teach it as method and obligation — risk assessment and permissions before fieldwork, the Victorian cultural-heritage framework, Indigenous Cultural and Intellectual Property, and attribution and citation ethics — from published statutory and institutional instruments named only, never with invented section numbers or provisions: the *Aboriginal Heritage Act 2006* (Vic), the *Aboriginal Heritage Regulations 2018* (Vic), Registered Aboriginal Parties and Cultural Heritage Management Plans, and the

AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research. Accordingly this book does not deliver the Aboriginal and Torres Strait Islander Histories and Cultures cross-curriculum priority, and does not claim or imply that it does; a school wanting that priority covered must source it directly with the relevant Traditional Owner community under the appropriate protocols. The notice on the first page of every booklet states the estate's position.

- **The counts close.** 29 codes · 29 owners · 17 partners · 12 whole-CD subtopics → 17 × 2 + 12 = **46 subtopics**. Elaborations: 160 drawn on in the chapter plan + 15 not authored = **175**, reconciled per code. Banked multiple-choice questions: **2,568**, summed from the authority file. One shared-standard note for auditors: `VC2S10U15` and `VC2S10U16` share a single achievement standard in the export, so 14C and 15A quote the same sentence, each against its own code — that is in the export, not a duplication error.

Clause split for the seventeen † codes — which limb each half delivers; this is what a coverage audit checks. Neither limb alone is the whole content description:

CD code	Owner limb	Partner limb
VC2S10U01	7A: reproductive cells and organs, structure → function	7B: sexual and asexual reproduction → survival of the species
VC2S10U02	8A: nervous and endocrine systems coordinating response to stimuli	8B: homeostasis and negative feedback
VC2S10U03	8C: infectious vs non-infectious disease and their causes	8D: transmission-control measures
VC2S10U04	7C: DNA, chromosomes, genes, alleles, mitosis and meiosis	7D: Mendelian monohybrid prediction of genotype and phenotype ratios
VC2S10U05	9A: variation, isolation, adaptation, selection	9B: fossil record, biogeography, comparative embryology; biodiversity and relatedness
VC2S10U06	10A: changing atomic model, subatomic particles	10B: isotopes, natural radioactive decay, half-life
VC2S10U08	11A: Law of Conservation of Mass, rearrangement of atoms, representations	11B: word and balanced symbol equations
VC2S10U09	11C: synthesis, decomposition, displacement	11D: exothermic/endothermic classification and rate factors
VC2S10U10	12A: Earth's 4 systems, carbon cycle, photosynthesis and respiration	12B: fire, weathering, vulcanism, combustion; change to system composition over time
VC2S10U11	12C: climate dynamics, greenhouse gases, energy exchange, modelling	12D: mitigating activities by sector
VC2S10U13	13A: galaxies, stars, solar systems, black holes	13B: big bang theory and supporting evidence
VC2S10U14	14A: wave/particle models of energy transfer — conduction, convection, radiation	14B: wave properties, features and applications
VC2S10U17	15B: Newton's laws, force–mass–acceleration	15C: quantitative motion analysis and applications
VC2S10I01	2A: investigable questions and testable relationships	2B: hypotheses, reasoned predictions, explanatory models
VC2S10I02	3A: valid, reproducible design; error and bias in sampling/observation	3B: safety, ethics, risk assessment, protocols on Country and Place
VC2S10I04	4A: tables, graphs, descriptive	4B: models, symbols, formulas,

CD code	Owner limb	Partner limb
	statistics	mathematical relationships
VC2S10I08	6A: report structure, conventions, vocabulary, referencing	6B: format and representation choice for diverse audiences

What this book does not cover. This book covers Levels 9 and 10 only. The other Science bands — Foundation to Level 2, Levels 3 and 4, Levels 5 and 6, and Levels 7 and 8 — live in their own books. The years before Foundation (Birth–Foundation) are not covered by this series at all, and nothing in this book implies that they are. Towards Foundation Levels A–D are a separate product for students with disability, and are not in this book. VCE content, vocabulary and unit references do not appear on any student-facing page of this book.

This book also does not pre-teach VCE. It teaches each content description, names the destination in the chapter's forward note, and stops there. Explicitly, then, there is no mole or stoichiometric calculation and no concentration; no dihybrid crosses or linkage, and no pedigrees beyond simple dominant/recessive and sex-linked patterns; no immunological mechanism — no antibodies, lymphocytes or immune response; no vectors, no projectile motion in two dimensions, no momentum and no calculus-based kinematics; no collision theory expressed as activation-energy diagrams and no equilibrium; and no nuclear equations or binding energy. Each of those belongs to a VCE study, and the VCE study designs are reference-only for this book.

Teacher notes

VCAA prescribes no assessment for F–10 Science: there is **no external examination, no study score and no mark VCAA receives** at Levels 9 and 10. Victorian schools report achievement against the Victorian Curriculum F–10 achievement standard on teacher judgement. Every instrument below is a **school instrument**, and the mark totals are a school convenience for consistency across classes. Every test carries this standing notice:

> This is a school-designed paper. It is not a VCAA instrument. Achievement at Levels 9 and 10 is reported against the Victorian Curriculum achievement standard on teacher judgement; the marks here are one source of evidence towards that judgement.

The instruments. Seven topic tests — one per block — are folded into the booklet of the block's last chapter at build time, each with its answers and fully-worked solutions. Scientific Investigation Task 1 travels with the Chapter 6 booklet, Scientific Investigation Task 2 with the Chapter 11 booklet, and the end-of-band review and its worked solutions fill the Chapter 17 booklet.

Instrument	Covers	Structure	Marks	Planned for	Inquiry marks (min)	Host
Topic test 1 — How science works, and planning an investigation	Chapters 1–3 (H01, H02, I01, I02, I03)	A: 10 MC · B: 30 marks short/structured	40	about 50 minutes	6	Chapter 3 booklet
Topic test 2 — Data, evidence and communication	Chapters 4–6 (I04, I05, I06, I07, I08)	A: 10 MC · B: 30 marks incl. one data-set analysis	40	about 50 minutes	6	Chapter 6 booklet
Topic test 3 — Biological sciences	Chapters 7–9 (U01–U05)	A: 10 MC · B: 30 marks incl. one Punnett/pedigree item	40	about 50 minutes	6	Chapter 9 booklet
Topic test 4	Chapters 10–	A: 10 MC ·	40	about 50	6	Chapter 11

Instrument	Covers	Structure	Marks	Planned for	Inquiry marks (min)	Host
— Chemical sciences	11 (U06–U09)	B: 30 marks incl. equation balancing and a half-life calculation		minutes		booklet
Topic test 5 — Earth and space sciences	Chapters 12–13 (U10–U13)	A: 10 MC · B: 30 marks incl. one sourced climate data interpretation	40	about 50 minutes	6	Chapter 13 booklet
Topic test 6 — Physical sciences	Chapters 14–15 (U14–U17)	A: 10 MC · B: 30 marks incl. $F = ma$, efficiency and motion-graph items	40	about 50 minutes	6	Chapter 15 booklet
Topic test 7 — Science in society	Chapter 16 (H03, H04)	A: 5 MC · B: 25 marks incl. one 8-mark issue analysis	30	about 40 minutes	6	Chapter 16 booklet
SIT-1 — Designing and analysing	the inquiry strands (I01, I02, I04, I05, I06, I07)	a supplied method and data set	30	untimed	whole task	Chapter 6 booklet
SIT-2 — Full investigation report	the inquiry strands (I02, I03, I04, I05, I06, I07, I08)	a student-planned, student-conducted investigation	40	untimed	whole task	Chapter 11 booklet
End-of-band review	the whole book, Ch1–16	A: 30 MC · B: 50 marks · C: 2 × 10-mark extended response	100	about 120 minutes	25	Chapter 17 booklet
Total			**440**			

Each topic test has a multiple-choice section A drawn from the banked items keyed to its codes, and a short and structured-response section B: T2 carries one supplied data set to analyse, T3 one Punnett-square or pedigree item, T4 one equation-balancing item and one half-life calculation, T5 one sourced climate data interpretation, T6 $F = ma$, efficiency and motion-graph items, and T7 one 8-mark issue analysis.

Administration — untimed, with reading support. These rules apply to every instrument in the book, and each instrument states them on its first page:

- Completion is **untimed**. The times in the table above are planning guidance for a Years 9–10 timetable and attention span; there is no time to beat, and a student may take as long as they need.
- **Reading support** is permitted. The teacher may read any question aloud to a student who needs it. Reading is not what is being looked at, and the teacher does not help with the answer.

- A **scientific calculator** is permitted for T4, T5 and T6 and for the end-of-band review, and is not required for T1, T2, T3 or T7.
- Item types: 1-mark multiple choice (four options, A–D), short response and structured response, with at least one extended item per paper built on a supplied stimulus — a data table, a graph, a labelled diagram or a short scenario.
- **Science inquiry is examinable in its own right, so it is examined in every paper.** At least 6 marks of every topic test are inquiry-strand marks — in T3 to T6 those marks attach to that chapter block's own practical work — both SITs are inquiry tasks through their whole length, and 25 of the review's 100 marks are inquiry. A student cannot pass this book on recall.
- **Marking guides ship with every instrument.** Each guide gives the acceptable responses and the mark allocation per response; the SITs carry a point-based marking guide plus a full model response — no holistic-only rubrics anywhere in the book.
- **A mark is a record that evidence was seen.** The records are for reporting against the Levels 9 and 10 achievement standard. They are not used to rank students.

The Scientific Investigation Tasks. SIT-1 sits after Chapter 6, when the inquiry spine is complete: on a supplied method and data set, students identify the variables and the flaws (I01, I02), process and represent the data (I04), analyse trends and anomalies (I05), evaluate validity and error (I06), and justify a conclusion from the evidence (I07). SIT-2 sits after Chapter 11: a student-planned, student-conducted investigation from one of three approved contexts drawn from Chapters 7 to 11, with a written risk assessment and ethics statement (I02, I03), a logbook, processed data, an evaluation, and a written report to a stated audience (I04–I08). The approved contexts are specified in the task, so a school does not have to invent one, and each is achievable with standard Victorian secondary laboratory equipment. SIT-2's risk assessment and ethics statement is where `VC2S10I02`'s protocols limb is assessed: a student planning fieldwork must show the cultural-heritage and permissions check, because the achievement standard asks for exactly that.

The end-of-band review. Run once, after Chapter 16: one cumulative paper across the whole book. Section A is 30 one-mark multiple-choice questions spread across all 11 strands; section B is 50 marks of short and structured response; section C is two 10-mark extended-response questions — one socio-scientific (H03/H04) and one investigation-design (inquiry strand). The strand weighting — Science as a human endeavour 10, Science inquiry 25, Biological 17, Chemical 16, Earth and space 16, Physical 16 — is printed in the paper's front matter, so a teacher can see the balance without counting. The inquiry weighting is deliberately the largest single block, one quarter of the paper. The review is a teaching instrument for reporting against the Levels 9–10 achievement standard, **not a mock examination**, and it must not be retitled or reformatted as one.

The question bank. The bank holds 2,568 multiple-choice items keyed to the 29 codes in the table above — ample for all seven tests plus the review with no reuse. They are a practice and diagnostic resource for the subtopics that own and partner each code — **they are not the assessment instrument, and there are no multiple-choice-only papers in this book.** The band's achievement standard is written in verbs — plan, conduct, analyse, evaluate, justify, communicate — that a pick-one item cannot evidence. Where a split (†) code supplies items to a test, selection filters the code's items by clause; the bank's CD-level count is never divided between owner and partner and recorded as fact.

Safety notes

Safety in this book is stated **at the point of use**: every practical activity carries a risk assessment on the same page as the activity, written to **Science ASSIST (ASTA)** guidance, cited with a retrieval date, and naming the personal protective equipment required. This is not a formality — it is also how 3B is modelled for the student, and 3B teaches the pattern: name the hazard, name the risk, name the control, and agree it all before the work starts. Standing rules, in every part of the book:

1. **The subtopics that carry real hazards say so.** 10C (reactions of the alkali metals — teacher-only, in tiny pieces, with eye protection, and metals with dilute acid; nothing is tasted), 11A (reactions that produce a gas, in closed and open systems), 11B (heating, and the limewater test for carbon dioxide), 11C (displacement reactions; copper sulfate is an irritant; nitrile gloves), 11D (dilute acids and alkalis are irritants; hydrogen

peroxide and the manganese(IV) oxide catalyst; the flour-dust explosion hazard; students with asthma check with the teacher before combustion work) and 14A (convection over a flame — tie back long hair, wear eye protection) each carry their risk assessment at the point of use, and the teacher's risk sign-off precedes the work.

2. **Radioactivity is modelled, never handled.** 10B teaches decay and half-life with coin and dice simulations and digital simulations; no radioactive source is used in student work. Ionising radiation — its penetration, its hazards and its uses — is taught as content, never as an activity.
3. **Electricity stays low-voltage.** The generator activities of 15A use hand-wound coils, magnets, small motors and cells; no student circuit touches the mains. Mains electricity — supplied at 230 V, 50 Hz AC in Victoria — is taught as content, cited correctly, and never as an activity.
4. **The risk assessment names the personal protective equipment** — eye protection wherever there is heating, splashing or a projectile — and teacher supervision is stated where required.
5. **The investigation pages plan and analyse practical work — they do not replace it.** No page implies that a written exercise satisfies a practical requirement. The activity, the site, the equipment, the supervision, the teacher's risk sign-off and the school's fieldwork permission process are all beyond what a printed page can supply.
6. **Fieldwork gets its permissions before it starts.** Subtopic 3B teaches it and SIT-2 assesses it: where an investigation leaves the classroom, permission is obtained before work starts. For cultural sites and artefacts on Country and Place that means the instruments 3B names — the *Aboriginal Heritage Act 2006* (Vic), the *Aboriginal Heritage Regulations 2018* (Vic), Registered Aboriginal Parties and Cultural Heritage Management Plans — and for secondary data it means the attribution and cultural-protocols obligations 5B teaches. Visiting a cultural site is a matter of permission and respect; access may be restricted or refused.
7. **No photographs of identifiable children appear in this book, and no claims are made about living private individuals.**

Word list

Every science word in this book is named and explained the first time it appears. This list gathers those words, chapter by chapter, as the book teaches them. A word that the book teaches again in a later subtopic is listed again where the book teaches it again.

Chapter 1 words

1A — How scientific knowledge is validated and refined

- **contestable** — in science, no claim is true just because someone says so; every claim is open to being questioned, tested and shown wrong. That is a strength, not a weakness — the claims that survive checking are the ones worth trusting.
- **validation** — showing that a claim stands up by running the checks — publication, peer review and replication — never just announcing it. Validation is a process, not a date; it waits for the checks to catch up.
- **scientific methods** — the ways science gathers and checks evidence. They keep expanding: each new instrument or technique adds a kind of evidence nobody had before.
- **statistics** — once results are numbers, a mathematical test that asks whether a pattern could have arisen by luck alone.
- **publication** — writing a result up in a scientific journal so that anyone, anywhere, can read exactly what was done and what was found.
- **Method** — the section of a published paper that says exactly what was done, so the work can be repeated. The hinge of the whole system, because it is what makes replication possible.
- **peer review** — the check before publication: a journal editor sends a paper to two or three experts in the field who were not part of the work, without their names being revealed. It is a check, not the final word — replication is the harder test that comes after.
- **replication** — another group, in another lab, doing the same work with its own equipment and getting the same answer.

- **consensus** — the state reached when the independent checks have all been run and agree — not a vote, not an opinion. Consensus is what textbooks are allowed to report, and it is always open to new evidence.
- **pseudoscience** — not bad science, or science done badly; it is what claims to be science while refusing the checks — claims that cannot really be tested, failures explained away after the event, results that do not repeat.
- **double-blind test** — a test in which neither the people being tested nor the judges scoring the results know which item belongs where, so no hints or expectations can nudge the score.

1B — Science, technology and engineering advance together

- **science** (from 1A) — tested knowledge about the natural world — knowledge checked by replication, publication, peer review and consensus. It feeds technology and engineering, and they feed it back, in a loop that runs both ways.
- **technology** — the tools and devices that scientific knowledge makes possible; new technology lets science see further and measure better.
- **engineering** — the work of designing and building those tools and devices so they are safe, reliable and useful.
- **cochlea** — the spiral-shaped part of the inner ear that normally changes sound vibrations into nerve signals.
- **auditory nerve** — the hearing nerve; carries nerve signals from the cochlea to the brain.
- **electrode** — a small electrical contact; in a cochlear implant, a wire thread of electrodes sits inside the cochlea and gives the auditory nerve the pulses it would normally get from the ear.
- **cochlear implant** — a device that does the cochlea's job when it is damaged: a microphone and small computer turn sound into signals, and the electrodes stimulate the auditory nerve so the person hears.
- **visual cortex** — the part of the brain at the back of the head that interprets sight.
- **spray-on skin** — skin grown in the laboratory from a sample of the patient's own cells, then sprayed over a burn as a fine suspension; the cells attach and grow into new skin, and the body does not reject them because they are its own.
- **fast Fourier transform** — a mathematical method that breaks a messy signal into its clean parts; developed by CSIRO radio-astronomers, and now a building block of wi-fi.
- **atomic clock** — the most exact clocks there are; used to time linked radio dishes so they act as one huge telescope.
- **gravitational wave** — a ripple in space itself, sent out when huge objects such as black holes collide far away; a passing wave stretches space one way and squeezes it the other.
- **Higgs boson** — the particle found at the Large Hadron Collider in 2012 that explains why other particles have mass at all.
- **alloy** — a metal with atoms of other elements mixed in; the foreign atoms disrupt the regular rows of the pure metal so the layers cannot slide freely, making the alloy stronger, and it can be lighter too.

Chapter 2 words

2A — Investigable questions: variables and testable relationships

- **investigable question** — a question 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? Questions of taste, opinion or value cannot be answered by science.
- **variable** — a thing in a test that could vary, meaning it could differ from one run to the next.
- **independent variable** — the one thing you change on purpose to see what it does; the "thing changed" in the question.
- **dependent variable** — the thing you measure or observe as the outcome; the "thing measured" in the question.
- **controlled variable** — any other thing that could matter, kept the same on purpose so it cannot interfere with the test.

- **fair test** — a test that changes only the independent variable and keeps everything else the same. If two things are changed at once, the outcome has two causes tangled together — which is the same as having none — and the test cannot answer its own question.
- **relationship** — a link between two variables, the one changed and the one measured. The three shapes to look for: as one increases the other increases; as one increases the other decreases; or no clear pattern.
- **refining** — turning a vague first-draft question into a testable one by naming the change, the measurement and the details. Nothing about the science changes; only the wording becomes testable.
- **kilonewton** — kN, a unit of force; 10 kN is roughly the pull of gravity on a one-tonne car.

2B — Hypotheses, reasoned predictions and explanatory models

- **investigable question** (from 2A) — a question science can answer by measuring or observing something; a hypothesis is the proposed answer to such a question.
- **variable** (from 2A) — a thing in a test that could vary; a hypothesis names two of them — the one changed and the one measured.
- **hypothesis** — the proposed answer to an investigable question, written before the data are in: a testable statement that names a relationship between two variables and gives a reason for it. Not a guess — a guess has no reason behind it and nothing solid to test.
- **prediction** — what a hypothesis leads you to expect in one particular investigation — what you expect to observe or measure this time, with this equipment.
- **reasoned prediction** — a prediction that follows from a hypothesis or a model and carries its reason with it, usually shaped as "if … then … because …". It must be specific enough that you can say clearly afterwards whether the results match it.
- **support** — results that match a prediction support the hypothesis; they do not prove it. Any single investigation is one test, and confidence comes from repeated testing. A result that does not support a hypothesis is not a failure — it points to checking the method, then revising the hypothesis or the model.
- **fair test** (from 2A) — a test that changes only one variable and keeps everything else the same, so any difference in the results can be put down to the variable changed.
- **explanatory model** — 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 it. Models are developed: tested, then kept with growing confidence or revised.
- **particle model** — an explanatory model of matter: everything is made of tiny particles, and the particles move faster when the material is hotter.
- **ray model** — an explanatory model of light: light travels in straight-line paths called rays, and a prism bends a ray as the light enters and again as it leaves.
- **dispersion** — white light spreading out into a band of colours because different colours are bent by different amounts — red is bent least, violet bent most.

Chapter 3 words

3A — Planning valid, reproducible investigations

- **valid** — an investigation is valid when it actually tests what it set out to test: the comparison is fair (only the factor being tested differs) and the sampling and observations genuinely answer the question asked.
- **reproducible** — an investigation is reproducible when someone else follows your written method and gets results that agree with yours. Repeating the same measurement several times (repeat trials) catches one-off mistakes, but not bias.
- **bias** — a push built into the method that shifts results one way. Not a one-off mistake: a mistake can push either way, but bias pushes the same way every time, so repeating a biased method does not fix it.
- **methodology** — how the question will be answered: fieldwork, surveys, secondary data, modelling and simulations, case studies, participant observation and interviews — chosen by what the question needs, not what sounds impressive.
- **independent variable** (from 2A) — the factor you change on purpose in an experiment.
- **dependent variable** (from 2A) — the thing you measure in response.

- **controlled variable** (from 2A) — every factor kept the same, so only the tested factor differs and the comparison is fair.
- **control group** — a group treated the same way in every respect except the factor being tested; it shows what would have happened anyway, so only the extra change can be credited to the treatment.
- **placebo** — a look-alike treatment with no active ingredient, given to the control group so expectations are the same in both groups.
- **blind test** — a test in which samples carry only codes and the person recording results does not know which is which, so expectations cannot tilt the measuring.
- **sample** — a part chosen to stand for the population, the whole group the question is about. It does its job only if it is representative — resembling the population, not some special corner of it. A bigger sample settles a fair method but never fixes a biased one.
- **quadrat** — a square frame of known size placed on the ground, inside which everything of interest is counted, used to sample plants or slow-moving animals.
- **convenience sample** — a sample chosen for ease rather than by random choice; it is biased, and taking more of the same does not fix it.
- **operational definition** — a definition of a behaviour or measurement written as a rule any observer can follow, so two observers record the same thing the same way.

3B — Safe and ethical investigation: risk, ethics and protocols on Country and Place

- **hazard** — anything that can cause harm: a chemical, a flame, a slippery floor, a steep bank, a living thing.
- **risk** — the chance that a hazard actually causes harm, together with how bad that harm would be. Not the same word as hazard: a large hazard can be a small risk once controls are in place.
- **risk assessment** — the written process of finding the hazards, rating each risk as likelihood × consequence, and deciding the controls — done before the work starts and repeated whenever anything changes. Controls must move the rating down and left on the risk grid: less likely, and less bad if it happens.
- **hierarchy of controls** — the order of controls from most to least effective: remove or swap the hazard, keep it away from people, then written rules, with personal protective equipment (PPE) last, not first — fix the hazard before you wrap the person.
- **safety data sheet (SDS)** — the sheet that comes with a chemical, listing its hazards and how to handle, store and clean it up safely. Hazard symbols on the label say what to look for; the SDS says what the controls should be.
- **ethical consideration** — a question about what is right and fair in the treatment of the people and animals an investigation involves or affects.
- **three Rs** — Replace, Reduce, Refine: first ask if the question can be answered without animals, then use the fewest that can still give an answer, then make the animals' experience better and shorter — applied in that order, with proper approval, before any animal is used.
- **informed consent** — participants are told in plain language what will happen before they agree to take part, not after.
- **voluntary participation** — nobody is pressed into taking part, and anyone can stop at any time without giving a reason.
- **privacy** — no names or details that could identify a person are collected, so results cannot be traced back to anyone.
- **protocol** — an agreed rule for how to act in a situation; on Country and Place, protocols are the correct ways to behave there.
- **Country and Place** — the curriculum's term for the lands, waters and places that Aboriginal and Torres Strait Islander Peoples belong to and carry responsibilities for, including cultural sites and artefacts.
- **Indigenous Cultural and Intellectual Property (ICIP)** — the rights of Aboriginal and Torres Strait Islander Peoples to their knowledge and cultural expressions, which others need permission to use — with free, informed consent, agreed terms, benefit-sharing and credit.

3C — Equipment, calibration, sample size and precision

- **uncertainty** — the range the true value probably lies in, written with the ± symbol: 3.46 ± 0.05 cm means the true length is probably between 3.41 and 3.51 cm.
- **smallest division** — the gap between two neighbouring marks on a scale. On analogue equipment the uncertainty of a single reading is half the smallest division, estimating one digit beyond the marks; on digital instruments it is ± the smallest displayed digit.
- **parallax** — the apparent shift of a pointer against a scale when your eye is not level with the pointer. The fix is to bring your eye level with the pointer or scale before reading.
- **meniscus** — the curve of a liquid surface in glass; read a measuring cylinder at eye level, at the bottom of the meniscus.
- **calibration** — a check of an instrument against known values before you trust it: a thermometer at the fixed points (melting ice 0 °C, boiling water 100 °C), a balance against a standard mass. If it does not read the known value you know its offset and can correct readings — and a sensible method plans recalibration between uses.
- **data logger and probe** — a probe (sensor) connected to a data logger measures and stores readings at a set rate without a person watching the scale — no parallax, no missed values, and larger sample sizes become practical.
- **precision** — how close repeat readings are to each other: a precise set is tightly clustered, an imprecise set is spread out. Not the same as accuracy (how close readings are to the true value), which is a separate question.
- **range** — the largest value minus the smallest; it puts a number on the spread of repeat readings.
- **mean ± half-range** — with repeat readings, the best single value is the mean and the spread gives the uncertainty: report the result as the mean ± half the range, with the uncertainty to one significant figure (for example 24.2 ± 0.5 °C).
- **sample** (from 3A) — the part of a whole area or population actually measured, used to estimate the whole; useful only if it is large enough and placed fairly, such as at random grid coordinates rather than where it is easy.
- **sample size** (from 3A) — the number of readings or sample plots in a data set; large enough when the running mean has settled and taking more would change it very little. Two points can never show a relationship, and three trials per condition is a workable minimum.
- **percentage uncertainty** — the relative uncertainty (absolute uncertainty ÷ the measurement) × 100. Comparing percentage uncertainties is how you decide whether equipment is fit for the job: the same absolute uncertainty is a larger percentage of a smaller measurement.

Chapter 4 words

4A — Organising and summarising data: tables, graph choice and descriptive statistics

- **categorical data** — data that are labels or words, not numbers, such as flower colour or soil type.
- **numerical data** — data that are numbers you count or measure: discrete (whole-number counts) or continuous (measured values that can sit anywhere on a scale, such as time and temperature).
- **bar graph, line graph and pie chart** — a bar graph compares categories; a line graph shows how the dependent variable changes as a continuous variable, usually time, changes; a pie chart shows how one whole splits into parts.
- **histogram** — looks like a bar graph but is a different tool: continuous data grouped into equal-width bins, so the bars touch because the bins are neighbouring slices of one scale; a bar graph compares separate categories and keeps a gap between bars.
- **independent and dependent variable** (from 2A) — in a table, the independent variable goes in the first column and the dependent variable in the columns that follow; on a graph, independent on the horizontal axis and dependent on the vertical, with each axis labelled with quantity and unit and an even scale filling most of the grid.
- **descriptive statistics** — summary numbers in two families: measures of centre (mean, median, mode) describe a typical value; measures of spread (range, interquartile range) describe how much the values disagree with each other.

- **mean** — the sum of the values divided by how many there are. In this book, average means the mean; the median and mode are always named on their own.
- **median** — the middle value once the data is ordered.
- **mode** — the value that appears most often.
- **range** — the largest value minus the smallest value.
- **outlier** — a value that sits far away from the rest of the data; it pulls the mean far more than the median. It may be a mistake or a genuine but unusual result, so check the raw record before deciding — simply deleting an awkward value is never acceptable.
- **quartile** — the lower quartile (Q1) is the median of the lower half of ordered data and the upper quartile (Q3) the median of the upper half; with an odd number of values the median itself is left out of both halves.
- **interquartile range (IQR)** — Q3 − Q1: the width of the middle 50% of the data. Unlike the range, it is not distorted by one wild value, and a value is flagged as an outlier if it lies more than 1.5 × IQR below Q1 or above Q3.
- **box plot** — a picture of the five-number summary (minimum, Q1, median, Q3, maximum): the box holds the middle 50%, the line inside is the median, and the whiskers reach to the minimum and maximum. Box plots shine when comparing groups side by side.

4B — Models, symbols, formulas and mathematical relationships as representations

- **representation** — a way of standing in for a real situation so you can think about it, share it or calculate with it: a table, graph, formula, sentence, model or symbols. None is "better" — the skill is choosing the tool that fits the job.
- **model** — a simplified stand-in for something real, built to describe, explain or predict it, used when the real thing is too big, small, fast, slow, far away or dangerous. Kinds include physical, conceptual (such as the particle model of matter), mathematical and simulations — and every model leaves something out, so you should always be able to say what.
- **simulation** — a model, usually a computer program, that steps a situation forward in time by applying the same rule again and again; it follows the rules it was given and no others, so its limits are part of the lesson.
- **scale model** — a model that shrinks or enlarges every length of the real object by the same factor; the scale is a ratio of model size : real size, so at 1 : 25 every length on the model is one twenty-fifth of the real one.
- **symbol** — a mark with an exact, agreed meaning that stands for something else: chemical formulas name substances, unit symbols (m, kg, s, °C, N, m/s, J) are shared, and quantity letters (d, t, v, m) stand for measurable amounts. In a chemical formula the small lowered number, the subscript, counts the atoms of the element just before it; no subscript means one atom.
- **reactants and products** — in a chemical equation the arrow → means "react to form": the substances on the left are the reactants and the substances on the right are the products.
- **formula** — a compact mathematical relationship between quantities, such as v = d ÷ t. To substitute means to replace each letter with its number and unit, then calculate: write the formula, substitute, then calculate and keep the unit.
- **energy-flow diagram** — a diagram (also called a Sankey diagram) of how transferred energy splits, with branch widths exactly proportional to the amounts of energy: the useful and wasted branches always add back up to the input, so ratios can be read straight off the picture.
- **direct proportion** — two quantities are in direct proportion when one is always the same multiple of the other — their ratio never changes. Two tests: the ratio is constant, and the graph is a straight line through the origin; doubling one quantity doubles the other.
- **rate** — how quickly one quantity changes: change ÷ time. The average rate over any stretch is the slope of the straight line joining its two ends on the graph, and the unit is always one unit divided by the other (mL/s, m/s, g/min).
- **law of conservation of mass** — in a chemical reaction, matter is neither created nor destroyed, only rearranged: the atom tally is the same on both sides, which is what "balanced" means.
- **algorithm** — a step-by-step set of rules for finishing a task: data in, rules applied, result out — the way simulations and calculations are actually carried out.

- **magnification** — how many times bigger an image is than the object: magnification = image size ÷ actual size. It is a pure ratio with no unit, and it works backward: image size ÷ magnification gives the actual size.

4C — Patterns, trends, relationships and anomalies — correlation versus causation

- **analysis** — looking at the data and asking what it is telling you: finding patterns, trends, relationships and anomalies, then stating a conclusion justified by the data.
- **pattern** — repeated or regular behaviour in the data.
- **trend** — the overall direction the data moves in.
- **relationship** — how one variable changes when another changes.
- **quantitative** — numerical data — masses, times, temperatures, counts — so a quantitative pattern is one you can state with numbers.
- **qualitative** — descriptive data — colours, textures, what you saw, heard or smelled — so a qualitative pattern is one you state in words; a pattern does not need numbers to be real.
- **scatterplot** — the graph of paired measurements of two numerical variables, with one point for each pair of values.
- **direction, shape and strength** — the three things to state when describing a scatterplot pattern: direction — rising or falling; shape — linear (points close to a straight line) or non-linear (a curve); strength — points tight along the line or curve (strong) or widely scattered (weak). “There is no relationship” is a perfectly good conclusion.
- **line of good fit** — a straight line drawn through the points of a roughly linear scatterplot so that it balances them, with about as many points above the line as below; not drawn when there is no pattern.
- **half-life** — the time taken for the mass of a radioactive sample to halve; the same fraction is lost each half-life, not the same amount, so the decay is a falling curve that flattens out, and an established pattern can be extended to predict values, stating the assumption.
- **anomaly** — a result that does not fit the pattern shown by the other data. The method is check, repeat, then decide: an anomaly is never just deleted in silence, and if a repeat confirms the odd value it may be a discovery, not an error.
- **correlation** — two variables move together: when one changes, the other tends to change in a predictable way.
- **causation** — one variable actually produces the change in the other. Every causal relationship shows correlation, but a correlation on its own does not prove causation — confusing the two is the most common error in data analysis.
- **third factor** — something that causes both of two correlated variables, producing a correlation that is not causal between them — for example, hot weather drives both ice-cream sales and drownings. Always ask: is it causal, the other way around, or is a third factor driving both?

Chapter 5 words

5A — Validity, reproducibility, error and uncertainty

- **evaluation** — the step that looks back over the whole investigation and judges how much trust the evidence deserves: was the method valid, could others reproduce it, how strong is the conclusion? Not a summary of results — its findings feed back to fix the plan.
- **valid** (from 3A) — an investigation is valid when it actually tests what it set out to test: only the tested factor differs, the comparison is fair, and the sampling and observations genuinely answer the question.
- **reproducible** (from 3A) — an investigation is reproducible when someone else follows your written method and gets results that agree with yours.
- **bias** (from 3A) — a push built into the method that shifts results the same way every time, so repeating does not fix it. Bias can also sit in the choosing of what evidence gets shown.
- **accurate** — a measurement, or the mean of repeats, is accurate when it is close to the true value. Accuracy (where readings sit) is not the same thing as precision (how much they spread).
- **true value** — the value a perfect measurement would give.

- **precision** (from 3C) — how closely repeat readings agree with each other — the spread of the readings, not how close they sit to the true value.
- **random error** — unpredictable, ever-present variations that push readings both ways around the true value. Shows up as spread, so it limits precision; repeating and averaging reduces it.
- **systematic error** — a fault in the instrument or method (e.g. a balance not zeroed) that pushes every reading the same way. Limits accuracy; repeating does not reduce it — it is fixed only by fixing the fault, e.g. by calibrating.
- **calibrate** — check an instrument against a known value (e.g. a thermometer in melting ice) so a systematic error can be found and fixed.
- **assumption** — a fact or premise accepted as true without being checked in this investigation. Every method has them; evaluation demands they are named, and the ones carrying the most weight are tested.
- **conflicting evidence** — when same-style investigations openly disagree. Ordinary in science: respond by comparing methods, checking instruments and calibration, gathering more evidence, and holding the conclusion until the conflict is explained.
- **uncertainty** (from 3C) — the ± spread of repeat readings. A claim can stand only if the difference it rests on is bigger than the uncertainty; if the uncertainty swallows the difference, the claim is weak.
- **area of uncertainty** — a range the data does not cover, where any claim rests on assuming the pattern continues. Where the data stops, the certainty stops.

5B — Building an evidence-based argument, assessing claims, and the ethics and cultural protocols of using secondary sources

- **evidence-based argument** — an argument where a claim is held up by evidence and reasoning.
- **claim** — what you argue; the statement you want your reader to accept.
- **evidence** — what was observed or measured; the data, quoted with its numbers and units.
- **reasoning** — the part that says why that evidence supports that claim, so the reader can follow the thinking rather than take your word for it.
- **limits** — state what the evidence cannot show — the conditions, substances or ranges the argument does not reach. Stating limits makes an argument trustworthy, not weak.
- **primary data** — data collected by the person (or group) who is using it.
- **secondary data** — data collected by someone else that you access for your own work (published results, databases, journal or news articles). Not second-rate — but you inherit two questions: can I trust this source, and am I allowed to use it this way?
- **association** (from 4C) — two things varying together. A survey can show an association but never a cause.
- **cause** — one thing making another happen; shown only by a fair test where only the tested factor differs — not by a survey.
- **citation** — a line that tells the reader exactly what you used and where it came from; every borrow must carry one.
- **plagiarism** — using someone else's work as if it were your own; the one writing failure that cannot be argued away.
- **cultural protocols** — ethical principles that guide behaviour when interacting with Aboriginal and Torres Strait Islander Peoples, protecting their cultural and intellectual property rights. Whether knowledge may be shared, and with whom, is decided by its owners.

Chapter 6 words

6A — The scientific report: structure, conventions, scientific vocabulary and referencing

- **report** — a written account of an investigation that any reader can follow, check, repeat and build on; the step where the work becomes public.
- **aim** — the question the investigation answers; stated as a question, and answered by the conclusion.
- **hypothesis** (from 2B) — the reasoned prediction being tested.

- **results** — the section that reports only the relevant data and observations; it never argues, explains or gives an opinion.
- **discussion** — the section that argues from the results: says what the data show, compares with the hypothesis and accepted values, explains outliers, names errors and their effect, and states the limits.
- **conclusion** (from 5B) — the answer to the aim, no stronger than the evidence allows.
- **outlier** — a reading that sits far outside the pattern of the repeats. It is explained in the discussion, not quietly deleted; a reading is discarded only with a stated reason.
- **absolute error** — |measured − accepted|; the size of the gap between a measured value and the accepted value.
- **percentage error** — the absolute error divided by the accepted value, × 100; the gap as a percentage of the accepted value.
- **register** — the fixed, formal style of scientific writing: say how much and how long, numbers instead of slang, findings with units, the writer kept out of the sentence, past tense for what was done and found, present tense for accepted knowledge.
- **theory** (from 1A) — in science, a well-tested explanation that ties many findings together — not a guess, as in everyday use.
- **significant** (from 5A) — in science, larger than the uncertainty can explain — not just "big" or "important".
- **in-text citation** (from 5B) — (name, year) right beside the borrow; must match the name and year of the full entry in the reference list, or the reader cannot check you.
- **paraphrase** — take the idea and put it in your own words — still needing a citation, because the idea is borrowed even when the words are yours. Quoting (exact words in quotation marks) is kept rare.

6B — Communicating and justifying to diverse audiences — format choice, representations and digital tools

- **communicating** — putting a finding in front of an audience. The finding does not change; what changes with the audience is the format, the detail kept, and the words used.
- **justifying** — showing an audience why a finding deserves to be believed — answering "why should I believe this?" with the claim, the evidence and the reasoning all linked.
- **audience** — the group of people a communication is for; matching the communication to them is the whole skill of this subtopic.
- **format** — the kind of communication it is (report, poster, infographic, video…). Chosen by purpose first, audience second; no format is best in itself — each is best for something.
- **representation** — any way of showing data or an idea — a table, a graph, a diagram, a model. Detail may be dropped for an audience, but never the units or honest scales.
- **conventions** (from 6A) — the things the reader of a format expects to find. Meeting them is part of communicating clearly; breaking them costs the audience's trust.
- **infographic** — one message on one screen or page, mostly visual, for an audience that gives it seconds: a title that is the claim, a few numbers with units, one graph, one takeaway sentence, and the source of every number.
- **interactive presentation** — a presentation the audience changes (a slider, a button) and watches respond, so the user discovers the pattern instead of being told it.
- **campaign** — a run of short posts repeating one message to one audience until it lands — not a single post, and never a claim bigger than the data.
- **call to action** — one small thing the audience is asked to do; every campaign post ends in one.
- **carbon footprint** — a way of adding up the greenhouse gases a household's choices produce.
- **honest scales** (from 4C) — graph axes with no trick that makes a small difference look big; one of the two things (with units) that may never be dropped for any audience.

Chapter 7 words

7A — Reproductive cells and organs: structure related to function

- **gamete** — a reproductive cell (a sex cell); in animals, a sperm cell or an egg cell. Gametes join at fertilisation.

- **fertilisation** — the joining of a sperm cell and an egg cell to form one new cell.
- **reproductive organs** — the larger structures that make gametes, carry them, and bring them together; they work collectively as organ systems, with no single organ doing the whole job.
- **testes** (singular: testis) — the two glands that make sperm cells; each is packed with fine tubes in which sperm develop.
- **scrotum** — the sac of skin that holds the testes outside the body, keeping them a little cooler than body temperature — the condition in which sperm develop best.
- **ovaries** — the two glands that make egg cells and release them, usually one at a time.
- **oviduct** (also called fallopian tube) — the tube that carries an egg from an ovary toward the uterus; fertilisation happens here, not in the uterus — the fertilised egg then travels on to the uterus to settle and grow.
- **uterus** — the organ where the fertilised egg settles and a baby grows; its wall is thick and has a rich blood supply, protecting the growing baby and bringing it food and oxygen.
- **stamen** — the male part of a flower: a filament (stalk) holding up an anther, which makes pollen grains.
- **carpel** — the female part of a flower: a sticky stigma on top of a style, with an ovary at the base that contains the ovules.
- **pollen grain** — the structure that carries a plant's male gametes (its sperm cells); each ovule holds the plant's female gamete, an egg cell.
- **pollen tube** — the tube a pollen grain grows down through the style toward the ovary after landing on the stigma; it carries the sperm cells to an ovule, since a plant's gametes cannot swim through the air.
- **mitochondria** — the small structures inside cells that release energy; the sperm cell's midpiece is packed with them to power the swimming tail.

7B — Sexual and asexual reproduction, variation and survival of the species

- **offspring** — the new individuals produced by reproduction.
- **survival of the species** — a species continuing through time, generation after generation; not about any one organism staying alive. Reproduction makes it possible.
- **asexual reproduction** — reproduction with one parent and no joining of sex cells; the offspring are genetically identical to the parent and to each other. It is fast and suits stable, favourable conditions.
- **sexual reproduction** — reproduction usually involving two parents, whose gametes (from 7A) join at fertilisation; the offspring are genetically different from the parents and from each other. It is slower but produces variation.
- **fertilisation** (from 7A) — the joining of a male gamete and a female gamete; the key event of sexual reproduction.
- **variation** — the differences between individuals of the same species. When the environment changes, variation means some individuals are more likely to survive and keep the species going.
- **clone** — an organism that is genetically identical to its parent.
- **binary fission** — a form of asexual reproduction in bacteria: the cell copies its instructions and splits into two identical cells; numbers double at each division.
- **budding** — a form of asexual reproduction in which a small outgrowth (a bud) forms on the parent, grows, and separates to live on its own as a clone; seen in yeast and the hydra.
- **vegetative propagation** — asexual reproduction in plants, where new plants grow from a stem, bud or storage organ of one parent (using structures such as runners, tubers and bulbs) and so are clones.
- **external fertilisation** — fertilisation outside the body: eggs and sperm are released into the water, which keeps the gametes moist and carries the sperm to the eggs; used by most fish and frogs, usually with very large numbers released.
- **internal fertilisation** — fertilisation inside the female's body, where the gametes stay moist; used by land animals, because gametes released into air would dry out. The developing embryo is then protected inside a shelled egg or inside the mother's body.
- **embryo** — the early stage of the new organism, formed after fertilisation.
- **reproduction** — the process by which organisms produce new individuals (offspring), replacing those that die and so enabling the species to survive.

7C — DNA, chromosomes, genes and alleles; mitosis and meiosis

- **genetic information** — the instructions carried in the DNA of an organism, passed from a cell to the cells that come from it when the cell divides, and from parents to offspring at reproduction.
- **DNA** (deoxyribonucleic acid) — the chemical that stores genetic information in humans and almost all other living things; the order of its four bases (A, T, G, C) is the information, like letters spelling different words.
- **double helix** — the shape of DNA: two long strands twisted around each other like a twisted ladder, with a sugar–phosphate backbone and bases joining the strands as rungs.
- **base pair** — one matching pair of bases joining the two DNA strands; A always pairs with T, and C always pairs with G, so one strand lets you work out the other.
- **gene** — one stretch of DNA that carries one set of instructions, for example instructions that help to set a feature of the organism. A gene is not the same as an allele (one *version* of the gene) or a chromosome (a packed DNA molecule carrying many genes).
- **allele** — one version of a gene; different alleles of the one gene sit in the same position on matched chromosomes. A body cell carries two alleles of every gene — one on each chromosome of the pair.
- **chromosome** — one long DNA molecule tightly packed into a short, thick package so it can be moved safely when a cell divides; it carries many genes. A human body cell has 46 chromosomes in 23 matched pairs; a gamete (from 7A) has 23 single chromosomes.
- **genome** — the complete set of genetic information in an organism; in humans it is carried on the chromosomes and holds about 3 billion bases and about 20 000 genes.
- **heredity** — the passing on of instructions from parents to offspring; **genetics** is the study of heredity.
- **mitosis** — the cell division that copies a body cell exactly: one division makes two daughter cells, each genetically identical to the original cell, with the same full set of chromosomes. Its roles are growth, repair and replacement.
- **meiosis** — the cell division in the reproductive organs that makes gametes: one cell divides twice to make four gametes, each with half the chromosome number (one chromosome from each matched pair), and the mix of chromosomes is random. Meiosis halves the number so that fertilisation can restore it.
- **fertilisation** (from 7A) — the joining of a sperm cell and an egg cell to form one new cell; the two half-sets join, restoring the full number of chromosomes — 46 in 23 matched pairs in humans, half from the mother and half from the father.
- **variation** (from 7B) — the differences between individuals of a species; meiosis shuffles the chromosomes into gametes and fertilisation combines one set from each parent, so offspring are similar to their parents but not identical to them or to each other.
- **mutation** — a change in the base sequence of the DNA; it can change the instructions a gene carries. A harmful mutation in a gene can cause a **genetic disorder** — a condition a person is born with, such as cystic fibrosis or sickle cell disease. If a mutation switches off the controls on mitosis, cells divide out of control and form a tumour — the basis of **cancer**.

7D — Mendelian inheritance: monohybrid crosses, ratios, pedigrees

- **trait** — a feature of an organism, such as flower colour, plant height, or the way a person's blood clots.
- **gene** (from 7C) — a section of DNA that controls a trait.
- **allele** (from 7C) — one version of a gene; each gamete carries one allele of each gene, and fertilisation puts a pair back together — one allele from each parent.
- **genotype** — the pair of alleles an organism carries for a gene, written as two letters (for example *Tt*).
- **phenotype** — the trait you can actually observe; what the genotype, plus the organism's development, produces.
- **homozygous** — having two identical alleles for a gene (*TT* or *tt*).
- **heterozygous** — having two different alleles for a gene (*Tt*).
- **carrier** — an organism that is heterozygous for a recessive allele: it does not show the recessive trait, but it can pass the allele on to its offspring.

- **dominant allele** — an allele whose trait shows when it is paired with a recessive allele; one copy is enough for its effect. Dominant does not mean stronger, better, or more common — the words describe only a pattern of inheritance in a pair.
- **recessive allele** — an allele whose trait shows only when no dominant allele is present (that is, when both copies are that allele).
- **Punnett square** — a grid that lists every possible fertilisation of a cross: one parent's gamete alleles along the top, the other's down the side, each cell one equally likely outcome. The cells give the genotype ratio (for *Tt* × *Tt*: 1 : 2 : 1) and the phenotype ratio (3 : 1), which are also the probabilities for each offspring.
- **monohybrid cross** — a cross that follows just one gene at a time, with two alleles (mono = one; hybrid = the parents carry different alleles).
- **test cross** — a cross that reveals a hidden genotype: cross the plant showing the dominant trait (which could be *TT* or *Tt*) with the recessive form (*tt*) and read the offspring — any recessive offspring prove a hidden recessive allele.
- **pedigree** — a family tree drawn with symbols (squares for males, circles for females, filled shapes for individuals with the trait, a centre dot for carriers) to show how a trait is inherited across generations.
- **X-linked** (sex-linked) — describing a gene carried on the X chromosome. A male has only one copy of any X-linked gene, so a recessive X-linked allele shows in males with no partner allele — and an affected father never passes an X-linked trait to his sons, because sons receive his Y, not his X.

Chapter 8 words

8A — The nervous and endocrine systems

- **stimulus** (plural **stimuli**) — a change in a condition the body can detect. External stimuli (light, sound, temperature, danger) are outside the body; internal stimuli (hunger, thirst, a rising body temperature) are inside it.
- **response** — the action that follows a stimulus, such as a muscle contracting or a gland releasing a chemical.
- **receptor** — a structure that detects one kind of stimulus and turns it into a message the body can act on.
- **effector** — the muscle or gland that carries out the response.
- **control centre** — the part that receives the message, decides what is needed and sends the command; usually the brain or spinal cord (also called the command centre).
- **central nervous system (CNS)** — the brain and spinal cord; the control centre that receives messages and decides the response.
- **neuron** — a cell that makes up a nerve; the message it carries is an **impulse**, a fast electrical signal that travels along the cell.
- **sensory neuron** — the neuron that carries the message from a receptor to the CNS.
- **relay neuron** — the neuron that connects sensory and motor neurons inside the CNS.
- **motor neuron** — the neuron that carries the command from the CNS to an effector.
- **reflex** — a fast, automatic response to a stimulus, produced by a pathway called the **reflex arc**; the decision is made in the spinal cord, not the thinking part of the brain, which is why it is so fast.
- **endocrine system** — the set of glands, organs that release chemical messengers straight into the blood; slower than the nervous route, but its effects last longer.
- **hormone** — a chemical messenger released by a gland into the blood that changes the activity of the organs that can detect it.
- **adrenaline** — a hormone released by the adrenal glands when danger is detected, preparing the body for urgent action; it rises within seconds but is slow to clear, so the heart keeps pounding after the danger is over.

8B — Homeostasis and negative feedback

- **homeostasis** — the body's keeping of its internal conditions, such as temperature, water content and blood sugar, within narrow limits around a target value, even while conditions outside the body change.
- **set point** — the target value a condition is held around; conditions are kept within a narrow range, balanced but always being adjusted, not frozen at one exact value.

- **stimulus** (from 8A) — the change that a receptor detects in a feedback loop.
- **receptor** (from 8A) — the part of a feedback loop that detects a change and sends information about it to the control centre.
- **control centre** (from 8A) — the part that compares the reported level with the set point and decides what response is needed; usually the brain or a gland.
- **effector** (from 8A) — the muscle or gland that carries out the response the control centre orders, such as sweat glands, muscles or the liver.
- **hormone** (from 8A) — the chemical messenger of the endocrine route, carried in the blood; slower to arrive than a nerve impulse but suited to responses kept going for minutes or hours.
- **negative feedback** — a loop in which the response acts in the opposite direction to the change that started it, returning the condition toward the set point; "negative" does not mean bad. When describing a loop, say whether you mean the level (where the value is now) or the change (which way it is moving).
- **hypothalamus** — a small region deep in the brain that acts as the body's thermostat — the control centre of the temperature loop.
- **pancreas** (from 8A) — the gland that detects the blood glucose level and releases hormones; it is both receptor and control centre of the glucose loop.
- **insulin** (from 8A) — the hormone the pancreas releases when blood glucose rises; it tells liver and muscle cells to take glucose out of the blood. It is a protein, so it must be injected, not swallowed.
- **glycogen** — the substance the liver stores extra glucose as, to be converted back into glucose when the blood level falls.
- **type 1 diabetes** — a condition in which the pancreas produces little or no insulin, so blood glucose stays high after meals; treated with injected insulin matched to food and activity.
- **hypothermia** — the condition in which core body temperature falls below about 35 °C because the loop is overwhelmed; shivering stops and thinking becomes slow and confused.

8C — Infectious and non-infectious disease

- **disease** — a condition that disrupts the normal working of the body; the most useful first question to ask is what causes it, not how bad it is.
- **infectious disease** — a disease caused by a pathogen; because pathogens can move between hosts, it can spread from one host to another.
- **non-infectious disease** — a disease not caused by a pathogen; its cause lies in the person's genes, age, diet, surroundings or habits, and it cannot spread between people.
- **pathogen** — an organism, or agent, that causes disease: a bacterium, virus, fungus or parasite. Most bacteria and fungi do not cause disease.
- **host** — the living thing a pathogen lives in or on.
- **bacterium** (plural **bacteria**) — a single-celled organism whose cell has no nucleus; it can grow and multiply on its own (e.g. tuberculosis).
- **virus** — not a cell, but genetic material in a protein coat; it can only multiply inside a living cell by taking over the cell's machinery, so it is called an agent rather than a fully living organism.
- **fungus** (plural **fungi**) — a pathogen whose cells have a nucleus; some fungi are single-celled yeasts, such as *Candida*, which reproduce by budding.
- **parasite** — an organism that lives on or in a host and takes what it needs from it, such as a tapeworm in the gut.
- **vector** — an animal that carries a pathogen from one host to another, such as a mosquito.
- **malnutrition** — disease caused by a diet missing what the body needs or badly out of balance; scurvy, caused by a lack of vitamin C, is the classic example.
- **risk factor** — a factor that raises the chance of a disease but does not guarantee it; factors add, and two people with the same factor can have different outcomes.
- **cholesterol** — a fatty substance; when too much settles in an artery wall it forms a build-up called a **plaque**, which narrows the channel so less blood reaches the heart muscle.

- **type 2 diabetes** (from 8B) — a non-infectious disease whose risk factors include genetics, age and lifestyle; it clusters in families through shared genes and habits, not by spreading.

8D — Controlling transmission

- **pathogen** (from 8C) — an organism or agent that causes disease, such as a bacterium, virus, fungus or other parasite like tapeworm.
- **chain of infection** — the links a pathogen must complete to reach a new host — pathogen, source, exit, spread, entry, new host; breaking any one link stops the chain, which is why measures are combined.
- **personal hygiene** — everyday measures such as washing hands with soap for at least 20 seconds, coughing into the elbow and wearing a mask when sick; they mainly break the exit and spread links and depend on every person, every time.
- **disinfection** — destroying pathogens on surfaces with cleaning agents; breaks the contaminated-surface route.
- **colony** — a visible cluster of bacteria grown on an agar plate from microbes left there (in the handwashing investigation, by fingertips).
- **isolation** — separating people who are sick and infectious so they cannot pass the pathogen on; breaks the chain at the source link.
- **quarantine** — separating and watching people, animals or goods that may have been exposed but are not yet showing symptoms, for the longest time the disease can take to show; at Australia's borders it is applied under the Biosecurity Act 2015 (Cth).
- **exclusion zone** — a pest-free growing region into which carrying fruit is illegal — quarantine applied to pests, because one infested fruit can start an outbreak.
- **antibiotic** — a medicine that kills bacteria or stops them dividing; it treats bacterial infections only and does not work on viruses such as colds and flu.
- **antiviral** — a medicine that slows a virus down; not every virus has one.
- **antifungal** — a medicine that kills fungi or stops their growth.
- **resistance** — the build-up of bacteria that survive an antibiotic: a misused course (stopped early, or taken for a viral illness) kills only the susceptible bacteria, leaving the resistant few to divide and take over.
- **vaccination** — a vaccine prepares the body to fight one specific disease; when most people are vaccinated, chains of spread keep hitting protected people and stop, shielding those who cannot be vaccinated.
- **public education** — campaigns that change the behaviour of thousands of people at once; a message that works gives a clear action, a reason that matters, an audience it is aimed at and a trusted, named source — a measure people do not follow is a link left unbroken.

Chapter 9 words

9A — Evolution by natural selection

- **species** — a group of organisms that can interbreed with each other under natural conditions and produce fertile offspring.
- **population** — the individuals of one species living in one area at one time.
- **variation** — the differences between individuals of the same species; the raw material natural selection works on. Only inherited variation is passed to offspring — changes gained during life cannot cause evolution.
- **natural selection** — the process in which individuals with inherited features that suit their environment are more likely to survive and reproduce than individuals without those features. It has no goal; it only sorts the variation already present.
- **evolution** — the change in the inherited features of a population over generations. Evolution is something populations do, not organisms: no individual changes its own features within its lifetime and passes them on.
- **adaptation** — an inherited feature — in structure, behaviour or body function — that helps an organism survive and reproduce in its environment.
- **structural adaptation** — an adaptation that is a feature of body structure, such as a cactus's spines and swollen water-storing stem.

- **behavioural adaptation** — an adaptation that is something an organism does, such as a desert mouse resting in its burrow by day and feeding at night.
- **functional adaptation** — an adaptation that is a process inside the body, such as the water-holding frog storing water in its body through years of drought.
- **isolation** — a barrier splitting one population into two groups that no longer interbreed; with different conditions on each side, selection can drive the groups apart until they become two species.
- **artificial selection** — breeding in which people choose which individuals reproduce; it shares variation, selection and inheritance with natural selection and differs only in who selects.
- **mutation** (from 7C) — a change in the genetic instructions; it makes new alleles and, with the mixing of sexual reproduction, is the source of inherited variation.

9B — The evidence: fossil record, biogeography, comparative embryology

- **fossil** — the preserved remain or trace of a once-living organism; most fossils form in sedimentary rock, rock built up from layers of sediment laid down over time.
- **law of superposition** — in an undisturbed stack of rock layers, each layer is younger than the one below it, so fossils in lower layers are older; the rule gives order, not a number of years.
- **transitional form** — a fossil organism with a mix of features from an older group and a younger one, such as the whale series from land mammal to fully aquatic whale.
- **biogeography** — the study of where species live and why; patterns such as Wallace's Line and Australia's marsupials reflect shared ancestry and long isolation.
- **marsupial** — a mammal whose young are born very undeveloped and finish growing in a pouch; almost all of Australia's native large land mammals are marsupials, while other continents' are placental mammals, which grow their young longer inside the body.
- **comparative embryology** — comparing the early stages of development (embryos) across species; early vertebrate embryos share a post-anal tail and pharyngeal pouches, evidence of shared ancestry.
- **pentadactyl limb** — a limb built on five digits — one upper bone, two lower bones, wrist bones and digits — as in the human arm, bat wing, whale flipper and horse leg.
- **homologous structures** — body parts in different species that share the same underlying build but do different jobs.
- **genetic code** — the chemical dictionary that turns a DNA sequence into a body; the same in all known life, and the fewer the DNA differences between two species, the more recently they share a common ancestor.
- **common ancestor** — the ancestral species at each branch point of the tree of life; relatedness is a branching tree, not a ladder of progress — no living species is the ancestor of another, and every living species is equally modern.
- **biodiversity** — the variety of life, past and present: about 1.2 million species described and about 8.7 million estimated, produced by branching descent, isolation and extinction over deep time.
- **megafauna** — giant versions of more familiar animals, such as *Diprotodon* and *Genyornis*, that lived in Australia until most disappeared about 40 000–50 000 years ago; human impact and climate change are both debated as the cause.
- **isolation** (from 9A) — populations kept apart so they no longer interbreed; Australia's long isolation as an island continent is why its mammals evolved separately from those of other continents.

Chapter 10 words

10A — How the model of the atom changed

- **atom** — the smallest particle of an element that keeps the properties of that element.
- **electron** — a negatively charged particle, far lighter than the lightest atom, that Thomson showed comes from inside the atoms of every element; electrons move in the space around the nucleus.
- **plum pudding model** — Thomson's model of the atom: a sphere of spread-out positive charge with the electrons stuck through it like plums in a pudding; replaced after the gold foil experiment.
- **alpha particle** — a fast, positively charged particle given off by certain unstable substances; fired at thin gold foil to probe the atom's structure.

- **nucleus** — the dense, positively charged centre of the atom, holding nearly all its mass and all its positive charge; the rest of the atom is mostly empty space.
- **proton** — a particle in the nucleus with charge +1 and a mass about 1836 times the electron's mass.
- **neutron** — a particle in the nucleus with no charge and about the mass of a proton; it supplies the extra mass in nuclei that protons alone could not account for.
- **atomic number** — the number of protons in a nucleus; it decides which element the atom is.
- **shell** — in Bohr's model, a fixed path around the nucleus holding a set number of electrons (2 in the first, 8 in the next for the first twenty elements) and a fixed amount of energy.
- **emission spectrum** — an element's own pattern of sharp bright lines of light given out when its atoms are given extra energy; the sharp lines show electrons can hold only certain fixed amounts of energy.

10B — Isotopes, natural radioactive decay and half-life

- **nucleus** (from 10A) — the dense centre of the atom, made of protons and neutrons; radioactive decay is a change in the nucleus, from unstable to stable.
- **mass number** — the total number of protons and neutrons in a nucleus.
- **isotope** — one of two or more forms of an element whose atoms have the same number of protons but different numbers of neutrons, written as the element's name plus mass number, e.g. carbon-12, carbon-14; isotopes behave almost exactly alike in chemical reactions.
- **radioisotope** — an unstable isotope whose nucleus changes by itself into a more stable arrangement.
- **radioactive decay** — the spontaneous change of an unstable nucleus into a more stable one, giving out radiation; it is spontaneous (cannot be sped up, slowed or switched off) and random (no one can say which atom will decay next). Natural radioactive decay happens without any human cause.
- **radiation** — energy travelling outward; in this subtopic, the particles and rays (alpha, beta, gamma) released by decaying nuclei.
- **alpha particle** (from 10A) — a cluster of 2 protons and 2 neutrons, identical to a helium nucleus; emitting one makes the atom a different element. Stopped by paper, but the most ionising of the three radiations.
- **beta particle** — a fast-moving electron thrown out of the nucleus, created at the moment of decay when one neutron changes into a proton; a different element forms. Stopped by a few millimetres of aluminium.
- **gamma ray** — not a particle but a burst of energy, a very high-energy electromagnetic wave; no protons or neutrons are lost, so the element does not change. Reduced by thick lead but never completely stopped.
- **ionising radiation** — radiation carrying enough energy to knock electrons out of the atoms it passes through, leaving charged atoms (ions); this is why it can damage living cells.
- **half-life** — the time taken for half of the nuclei in a sample to decay, or for the count rate to fall to half its value. Not half the total time: the amount halves every half-life and is never all gone at once, and it predicts large samples only, never one particular atom.
- **count rate** — the number of decays detected per minute (counts/min); corrected count rate = measured count rate − background count rate.
- **background radiation** — the radiation always present in the environment, from rocks, soil, space, food and our own bodies; its count rate must be subtracted to find the count rate due to a sample alone.
- **tracer** — a radioisotope attached to a substance the body uses so that its path through the body can be followed from outside with a detector, e.g. technetium-99m for imaging organs.

10C — The periodic table: groups, periods, electron shells and trends

- **periodic table** — the organised table of all the elements, arranged in order of increasing atomic number; an element's position tells you the structure of its atoms, and that structure tells you how the element behaves.
- **atomic number** (from 10A) — the number of protons in an atom; it decides which element the atom is.
- **period** — a row of the periodic table (seven in all); the period number tells you the number of occupied electron shells.
- **group** — a column of the periodic table (eighteen in all, numbered 1–18); elements in the same group have the same number of outer-shell electrons, so they react in similar ways.

- **shell** (from 10A) — a region at a certain distance from the nucleus that can hold up to a fixed number of electrons (2, 8, 8 for the first twenty elements); shells fill from the inside out.
- **metal** — the family of elements filling the left side and centre of the table; typically shiny, good conductors and malleable, and metals tend to lose their outer electrons when they react.
- **non-metal** — the family of elements on the right of the table; typically dull and brittle if solid, and poor conductors, and non-metals tend to gain or share electrons when they react.
- **metalloid** — an element whose properties sit between those of metals and non-metals, such as silicon; metalloids touch the zigzag line between the two families.
- **metallic character** — how strongly an element shows the properties of metals; it increases down a group and decreases across a period.
- **reactivity** — how easily an element reacts; it increases down Group 1 (the outer electron is further from the nucleus and lost more easily) and decreases down Group 17 (an incoming electron is attracted less strongly).
- **alkali metals** — the Group 1 metals (lithium, sodium, potassium), soft metals that react with water to form the metal hydroxide and hydrogen, more vigorously going down the group.
- **halogens** — the Group 17 non-metals (fluorine, chlorine, bromine, iodine) with seven outer electrons; they get less reactive going down the group.
- **noble gases** — the Group 18 elements (helium, neon, argon) with full outer shells; a full outer shell is a very stable arrangement, so they are almost completely unreactive.
- **emission spectrum** (from 10A) — the element's own set of colours released as light when heated electrons fall back toward the nucleus; it acts like a fingerprint, since no two elements share the same one.

Chapter 11 words

11A — Conservation of mass and the rearrangement of atoms

- **chemical reaction** — a change in which the starting substances are changed into new substances with different properties.
- **reactant** — a substance that is taken apart or used up during a chemical reaction.
- **product** — a new substance made by a chemical reaction.
- **bond** — a link that holds atoms together inside a molecule; in a reaction some bonds break and new bonds form.
- **molecule** — a group of atoms joined together by bonds, acting as one particle.
- **rearrangement of atoms** — how every chemical reaction works: the reactants are taken apart and their atoms rejoin in new combinations to form the products. Atoms are never created or destroyed in a chemical reaction — they are only regrouped.
- **Law of Conservation of Mass** — the rule that the total mass of the products of a chemical reaction equals the total mass of the reactants, because no atoms are created or destroyed.
- **closed system** — a setup in which no matter can enter or leave, such as a stoppered flask.
- **open system** — a setup in which matter can enter or leave, such as an open beaker. Mass can seem to fall (gas escapes) or rise (gas from the air joins in), but the law still holds once every particle, including invisible gases, is counted.
- **element** — a substance made of only one kind of atom.
- **compound** — a substance in which atoms of different elements are bonded together in fixed combinations.
- **green chemistry** — designing chemical processes so that they harm the environment as little as possible, for example by arranging the reaction so most atoms end up in the useful product.

11B — Writing and balancing word and symbol equations

- **reactant** (from 11A) — the starting substances; in an equation they are written on the left of the arrow.
- **product** (from 11A) — the new substances made; in an equation they are written on the right of the arrow, where the arrow points.
- **word equation** — an equation that writes a reaction using the names of the substances: reactants on the left, products on the right, with plus signs read as "reacts with" and the arrow read as "produces" or "forms".

- **symbol equation** — an equation that replaces every name in a word equation with its chemical formula (also called a chemical equation or formula equation).
- **chemical formula** — the shorthand for a substance, built from element symbols and small numbers, that tells you what it is made of.
- **subscript** — the small number written low after an element symbol, telling how many atoms of that element are in one molecule or formula unit; it belongs to the element directly before it only. Changing a subscript changes the substance itself (H_2O_2 is hydrogen peroxide, not water), so subscripts are never changed to balance an equation.
- **coefficient** — the big number written in front of a formula, telling how many molecules or formula units there are; it multiplies everything in the formula behind it. Coefficients are counts, not labels, and can be read as ratios that scale to any size batch.
- **diatomic elements** — the seven elements whose atoms never live singly in ordinary conditions but always in pairs: hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine and iodine. Their formulas always carry the subscript 2 — oxygen is O_2, never a lone O.
- **unbalanced (skeleton) equation** — an equation with correct formulas but atom counts that do not yet match on both sides. An unbalanced equation is not a rough version of the truth — it is false, because no reaction can make an atom vanish.
- **balance** — to put coefficients in front of the formulas so that the number of atoms of each element is the same on both sides. Only the big numbers in front may change — never the formulas or their subscripts — and the coefficients should be the smallest whole numbers that work.
- **state symbols** — short symbols written in brackets after each formula to record its physical state: (s) solid, (l) liquid, (g) gas, (aq) dissolved in water. They do not change the balancing.
- **Law of Conservation of Mass** (from 11A) — the reason equations must balance: mass is conserved because atoms are conserved, so every balanced equation shows the same number of atoms of each element on both sides.

11C — Reaction types: synthesis, decomposition and displacement

- **reactant** (from 11A) — a starting substance in a reaction; counting the reactants is the first step in sorting a reaction into its family.
- **product** (from 11A) — a new substance made by a reaction; counting the products helps identify the reaction family.
- **synthesis reaction** — a reaction in which two or more substances join to form a single new substance ($A + B \rightarrow AB$), such as a metal joining with oxygen to form a metal oxide.
- **decomposition reaction** — a reaction in which a single compound splits into two or more simpler substances ($AB \rightarrow A + B$). It usually needs a continuous supply of energy to keep going, delivered as heat, electricity or light.
- **displacement reaction** — a reaction in which one element takes the place of another element in a compound ($A + BC \rightarrow AC + B$), pushing the other element out on its own.
- **reactivity** — how easily a substance reacts. In displacement, the more reactive element wins the place; a less reactive element cannot displace a more reactive one.
- **ion** — a charged particle, such as the charged sodium and chlorine particles packed into solid sodium chloride.
- **lattice** — the regular crystal arrangement of ions, as in sodium chloride.
- **thermal decomposition** — decomposition driven by strong heating, such as a metal carbonate breaking down into a metal oxide plus carbon dioxide.
- **electrolysis** — decomposition driven by electricity, such as splitting water into hydrogen and oxygen.
- **neutralisation** — a reaction of an acid and an alkali in which the ions swap partners: each hydrogen ion (H^+) joins a hydroxide ion (OH^-) to form water, while the other ions remain dissolved as a salt. This book sorts neutralisation into the displacement family.
- **alkali** — a base that dissolves in water.
- **precipitate** — an insoluble solid that forms and falls out of the mixture when two solutions are mixed.

11D — Energy changes and reaction rate: exothermic/endothermic; temperature, concentration, surface area, catalysts

- **reaction mixture** — the chemicals that are actually reacting.
- **surroundings** — everything else around the reaction mixture: the container, the thermometer, the bench, the air, your hands.
- **exothermic reaction** — a reaction that releases energy from the reaction mixture out into the surroundings; the surroundings warm up, and the products store less energy than the reactants did.
- **endothermic reaction** — a reaction that takes in energy from the surroundings into the reaction mixture; the surroundings cool down, and the products store more energy than the reactants did.
- **combustion** — the burning of any fuel: reacting with oxygen and releasing energy, mostly as heat and light.
- **thermal decomposition** (from 11C) — a decomposition that only happens while strong heating is continued; take the heat away and it stops. It is classified as endothermic.
- **rate of reaction** — how fast a reaction goes: how quickly the reactants are used up or the products form. It is measured as an amount divided by a time, such as cm^3/s or g/min.
- **collide (collision)** — to run into each other. Reactant particles must collide before a reaction can happen, and anything that makes collisions happen more often makes the reaction go faster.
- **solute** — the substance that dissolves in a liquid to form a solution.
- **solvent** — the liquid that dissolves the solute.
- **concentration** — how much solute is dissolved in a given volume of solution: a concentrated solution has more solute in the same volume than a dilute one. More crowded particles collide more often, so the reaction is faster.
- **surface area** — how much of a solid is open for another substance to touch; a solid can only react at its surface. Grinding a solid to powder exposes far more surface, so more collisions can happen at once and the reaction is faster.
- **catalyst** — a substance that speeds up a reaction without being used up by it: at the end it is still there, unchanged in mass. A catalyst does not change how much product forms, or how much energy is released or taken in — it only changes how fast.
- **enzyme** — a catalyst in living things that speeds up the reactions that keep cells alive.

Chapter 12 words

12A — Earth's four interrelated systems and the carbon cycle

- **atmosphere** — the layer of gases wrapped around the Earth; the air you breathe, including its carbon dioxide (CO_2).
- **hydrosphere** — all the water on Earth: oceans, rivers, lakes, ice and groundwater; the ocean is by far the largest part.
- **lithosphere** — the rocky outer part of the Earth: the crust, the rocks, and the soils formed from them.
- **biosphere** — every living thing on Earth (plants, animals, algae, fungi, microscopic organisms) together with the places they live.
- **store (stock)** — any place where carbon sits for a while, such as the air, the ocean, rock or living things; sizes are measured in gigatonnes of carbon (GtC), where one gigatonne is one billion tonnes. A small store changes a lot from a small flow; the same flow barely shifts a big store.
- **flow** — a movement of carbon from one store to another.
- **carbon cycle** — the loop in which carbon moves between the air, the water, living things and rock, never staying in one system.
- **photosynthesis** — the process in which plants, algae and phytoplankton use light energy to make glucose (a sugar that stores chemical energy) from carbon dioxide and water, releasing oxygen.
- **respiration** — the process in which cells break down glucose with oxygen to release energy for life, producing carbon dioxide and water. It is not breathing, and every living organism respires — plants too, day and night.

- **chloroplast and chlorophyll** — chloroplasts are the tiny structures in plant cells where photosynthesis happens; they contain chlorophyll, the green pigment that captures light energy.
- **stomata** — tiny pores, mostly on the underside of a leaf, that open and close to let gases in and out: CO_2 enters, oxygen and water vapour leave.
- **decomposers** — organisms such as bacteria and fungi that break down dead remains and waste, releasing CO_2 back to the air.
- **phytoplankton** — microscopic drifting organisms that photosynthesise, suspended in sunlit surface water like plants on land.
- **stock-and-flow** — a way of reading a store as a tank with flows in and flows out: the store grows when flows in exceed flows out. A level (the size of the store) is not a rate (how fast it changes) — "emissions fell" does not mean "the CO_2 level fell"; the level falls only when flows out exceed flows in.

12B — Fire, weathering, vulcanism and fossil-fuel combustion

- **source** — a process that adds carbon dioxide to the atmosphere.
- **sink** — a process that removes carbon dioxide from the atmosphere.
- **fire triangle** — the three things that must be present together for a fire to burn: fuel, oxygen and heat; taking any one away puts the fire out.
- **combustion** (from 11D) — an exothermic reaction in which a fuel burns with oxygen, releasing energy: fuel + oxygen → carbon dioxide + water. Fire is combustion running out in the open.
- **fossil fuels** — coal, oil and natural gas formed from buried remains of plants and tiny sea organisms that heat and pressure turned into fuel over about 300 000 000 years; carbon locked in the lithosphere. Burning them is a one-way addition of CO_2 to the atmosphere.
- **sediment** (from 12A) — sand, mud and silt carried by rivers and the sea; layers of it bury dead remains and, over deep time, help form fossil fuels and rock.
- **weathering** — a very slow sink: rainwater dissolves CO_2 and becomes a weak acid that slowly attacks rock, moving carbon into dissolved form that ends up locked in limestone, over tens of thousands to hundreds of thousands of years.
- **calcium carbonate** — the compound that seashells are made of; rocks built of it include limestone, chalk and marble.
- **vulcanism** — a slow source: magma (melted rock) carries dissolved CO_2 that escapes into the atmosphere during eruptions, and heated carbonate rocks release CO_2 too — the mirror image of weathering.
- **parts per million (ppm)** — the number of carbon dioxide molecules in every million molecules of air; the unit used for CO_2 concentrations.
- **ice cores** — long cylinders of ice drilled from the Antarctic ice sheet, whose bubbles of trapped ancient air let scientists measure the CO_2 of hundreds of thousands of years ago.
- **infrared radiation** — energy that travels like light but is felt as heat; the warm Earth's surface sends energy back out this way.
- **greenhouse effect** — greenhouse gases (carbon dioxide, water vapour, methane) let most sunlight through but absorb some outgoing infrared radiation and send part back down, keeping the surface about +15 °C instead of −18 °C. The natural effect is not a problem to fix — it makes the planet liveable.
- **carbon capture and storage** — a technology that takes CO_2 from the waste gases of a factory or power station before it reaches the atmosphere, compresses it and pumps it deep underground into rock layers where it is trapped.

12C — Climate dynamics

- **weather** — what the atmosphere does over hours to days; a single hot or cold day tells you almost nothing about climate.
- **climate** — the pattern of weather averaged over a long period, conventionally about 30 years; a single cold winter does not erase a warming trend.
- **albedo** — the share of arriving sunlight a surface reflects, a number between 0 and 1: fresh snow and ice up to about 0.85, open ocean about 0.07.

- **greenhouse gases** (from 12B) — trace gases in the air — water vapour, CO_2, methane and nitrous oxide — that let incoming visible light pass through but absorb the outgoing infrared radiation from the warmed surface and re-emit it in all directions, sending a share back down.
- **greenhouse effect** (from 12B) — the warming that results: without any greenhouse gases the Earth would average about −18 °C; with the natural mix, about 15 °C. It is natural and life-saving.
- **enhanced greenhouse effect** — the same mechanism with extra gas added by burning fossil fuels, clearing forests and farming, so more infrared is re-emitted back down and the planet warms. Keep the two effects separate: the natural one makes the planet liveable; the enhanced one is the human addition changing the climate.
- **trend** — the long-term direction of a record. In the CO_2 record the trend is sharply upward and is what changes the energy budget; on top of it sits a small yearly cycle (forest growth and decay), and a cycle of a few ppm does not change the climate the way the 141 ppm trend does.
- **global warming potential (GWP) and carbon dioxide equivalent (CO_2-e)** — GWP is how much heat one tonne of a gas traps over 100 years compared with one tonne of CO_2 (methane about 28, nitrous oxide about 265); tonnes of gas × GWP = CO_2-e, the tonnes of CO_2 that would trap the same heat.
- **salinity** — how salty the water is; cold, salty water is denser, so where surface water becomes cold and salty enough it sinks and drives the deep ocean circulation.
- **upwelling** — the rising of deep water where wind pushes surface water away from a coast; it carries nutrients that feed plankton and fish, supporting a large share of fisheries.
- **indicators** — independent measurements of climate change; the six standard ones (atmospheric and ocean temperature, sea level, sea ice, permafrost, species distributions) all point the same way, which makes the conclusion robust.
- **feedback** — a loop in which a change causes further change: a positive feedback amplifies (melting ice lowers the albedo, more sunlight is absorbed, more ice melts); a negative feedback damps. Feedbacks cause most of the spread between model projections.
- **stock and flow** (from 12A) — a stock (level) is an amount that accumulates, like the CO_2 in the air; a flow (rate) enters or leaves it per unit time, like tonnes emitted per year. Cutting emissions shrinks the inflow, but while inflow exceeds outflow the concentration keeps rising: "emissions fell" is not "concentration fell".
- **climate model** — a supercomputer program that divides the atmosphere, ocean and land into a three-dimensional grid of cells and computes the physics of radiation, clouds, winds and currents step by step; only runs that include human emissions reproduce the observed warming, and projections depend on the emissions scenario (a storyline of high or low future emissions).

12D — Mitigation

- **mitigation** — acting on the causes of climate change: reducing greenhouse gas emissions at their sources, or strengthening the sinks (such as forests and oceans) that remove them from the air.
- **adaptation** — adjusting to the effects of climate change already happening, such as designing drains for heavier rainfall; it copes with the trend rather than changing it.
- **sink** (from 12B) — a process or place that removes greenhouse gases from the air; in Australia's emissions inventory the land-use and forestry bar is negative because forests and soils take up more CO_2 than they release.
- **rate and level** (from 12A) — emissions are a rate (CO_2 added per year, the tap); the CO_2 already in the atmosphere is a level (the water in the bath). "Emissions fell" is not "the CO_2 level fell": the level keeps rising while adding exceeds removing, steadies at net zero, and falls only when removing exceeds adding.
- **net zero** — the point at which emissions added equal removal by sinks; the level stops rising but does not fall. Net negative means removal exceeds adding.
- **deforestation** — clearing forest: a double hit, because burning and decay release the carbon stored in wood, leaves and soil while the uptake a living forest provides stops. Protecting, replanting and regrowing forests is mitigation.
- **ruminant** — an animal such as a cattle or sheep whose stomachs produce methane as they digest grass, which is why ruminant meat sits at the top of food emissions charts.

- **carbon footprint** — the total mass of greenhouse gases, expressed as CO_2-e, released by a person's activities over a period: the flows from power, travel, food and waste added together.
- **emission factor** — the kg of CO_2-e released per unit of activity (per kWh, per km, per kg of food); a footprint is built by multiplying each activity by its factor.
- **percentage change** — a trend measured against its starting value: (new − starting) ÷ starting × 100. A fall matters more against a small starting value.
- **emissions per person** — a total divided by the population (per-capita normalisation); fair comparisons between countries are per person, not per country, since totals mostly reflect population size.

Chapter 13 words

13A — Features of the universe and their scales

- **star** — a huge ball of hot gas that gives out its own light and energy, powered by fusion in its core. The Sun is an ordinary star.
- **solar system** — a star together with everything held to it by gravity: planets, moons, asteroids and comets.
- **galaxy** — a huge collection of billions of stars, together with gas and dust, all held together by gravity. The Milky Way is a spiral galaxy.
- **black hole** — a region of space where gravity is so strong that nothing, not even light, can escape once it crosses the boundary. The hole itself is invisible; what can be seen is the glowing accretion disc of gas spiralling in and heating up.
- **event horizon** — the boundary of a black hole, beyond which nothing can ever escape, not even light.
- **order of magnitude** — a step of ten times. Each extra power of ten is one order of magnitude (10^9 m is three orders of magnitude bigger than 10^6 m).
- **astronomical unit** — (AU) the average distance from the Earth to the Sun, about 149.6 million km (1.496×10^8 km). The handy ruler for distances inside the solar system.
- **light-year** — (ly) the distance light travels in one year, about 9.46×10^{12} km. A light-year is a distance, not a time; it is the handy ruler for distances between stars.
- **fusion** — the process in which hydrogen nuclei deep in a star's core join together to form helium nuclei, releasing the energy that powers the star.
- **supernova** — the catastrophic explosion that ends the life of a high-mass star, leaving behind a neutron star or, if the core is massive enough, a black hole.
- **absorption line** — a dark line at a particular wavelength in a star's spectrum, where the cooler outer layers of the star have absorbed light. Every element makes its own pattern of lines — a fingerprint used to identify it.
- **Hertzsprung–Russell diagram** — a chart plotting each star's luminosity (the total energy it radiates per second) against its surface temperature. Most stars lie on the diagonal band called the main sequence.
- **electromagnetic spectrum** — the family of waves arranged by wavelength: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays. Different telescopes collect different bands.
- **inverse-square law** — the rule that a star's apparent brightness falls off with the square of its distance: double the distance and it looks 1/4 as bright; triple the distance and 1/9 as bright.

13B — The big bang theory and its evidence

- **big bang theory** — the scientific model in which the universe began about 13.8 billion years ago extremely hot and extremely dense, and has been expanding and cooling ever since. It was not an explosion at one place into space — space itself stretches everywhere at once, so there is no centre and no edge.
- **theory** — in the scientific sense, a model that ties together many independent lines of evidence and makes testable predictions — the opposite of a guess.
- **Hubble's law** — the pattern Hubble measured: the further the galaxy, the faster it moves away. On a graph of speed against distance the points fall close to a straight line through the origin.
- **Hubble constant** — H_0, the gradient of the line in Hubble's law. In this book's units it is about 22 km/s per million light-years.

- **redshift** — the shift of the dark lines in a galaxy's spectrum towards the red end, showing the galaxy is moving away. In an expanding universe the light's wavelengths are stretched by the stretching of space itself.
- **blueshift** — the shift of spectral lines towards the violet end, showing the source is moving towards us. The nearby Andromeda galaxy is blueshifted because gravity wins over the stretching of space at close range.
- **cosmic microwave background** — (CMB) the leftover glow of the big bang, released about 380 000 years after it when the first atoms formed. Stretched by the expansion, it now arrives from every direction as microwaves at about 2.7 K — the strongest single evidence for the theory.
- **dark matter** — matter that gives gravity but gives out no light; about 27 parts in 100 of the universe. It is the extra gravity that holds galaxies together.
- **dark energy** — the name given to whatever is making the expansion of the universe speed up; about 68 parts in 100 of the universe. It names something the evidence forces us to accept but does not yet fully explain.
- **gravitational wave** — a ripple in space itself, sent out when massive objects such as two merging black holes shake space, travelling at the speed of light. First detected in 2015 — a completely new kind of signal.
- **fast radio burst** — a flash of radio waves from a distant galaxy that lasts only milliseconds.
- **light-year** (from 13A) — the distance light travels in one year; used here in millions of light-years for the distances between galaxies.
- **supernova** (from 13A) — the explosion of a dying star, bright enough to see across billions of light-years. Distant supernovae showed in 1998 that the expansion is accelerating.

13C — Space exploration

- **interstellar space** — the space between the stars. Voyager 1 became the first human-made object to reach it, in 2012.
- **propellant** — what a rocket burns: fuel together with an oxidiser, thrown out of the back as hot gas at high speed.
- **oxidiser** — the oxygen supply a rocket must carry because there is no air in space to burn its fuel with.
- **thrust** — the forward push on a rocket, produced by throwing exhaust gas backwards at high speed; the two pushes are equal and opposite.
- **orbit** — the path of a craft going sideways so fast that it keeps missing the Earth as it falls. Reaching orbit is a speed problem (about 7.8 km/s), not a height problem.
- **microgravity** — the state of feeling almost weightless inside a freely falling craft. It is not the absence of gravity: at the ISS's height gravity is still about 90% as strong as at the surface.
- **vacuum** — a space with no air at all, so nothing to breathe and no air pressure, and no air to carry heat in or out.
- **micrometeoroids** — tiny grains of rock and metal, often smaller than a grain of sand, moving at many km/s and striking like bullets.
- **convection** — the carrying of heat by a moving fluid, as when hot air rises. In microgravity there is no up, so a flame stays small and dome-shaped instead of stretching into a teardrop.
- **surface tension** — the skin-like pull that holds a liquid's surface together. In microgravity it pulls water into floating spheres.
- **sol** — a day on Mars, about 24.6 hours, about 36 minutes longer than an Earth day.
- **spinoff** — a technology first developed for space missions and now in everyday use, such as water filters, memory foam and infrared ear thermometers.
- **astronomical unit** (from 13A) — the average Earth–Sun distance, about 1.496×10^8 km. Earth orbits at 1.00 AU and Mars at 1.52 AU, so the gap between the planets — and the radio delay — keeps changing.

Chapter 14 words

14A — Particle and wave models of energy transfer

- **conduction** — the transfer of energy through a material without the material itself moving: vibrating particles hand energy along from particle to particle. Most important in solids, where particles are close together.

- **convection** (from 13C) — the transfer of energy by the movement of the heated material itself; it can only happen in fluids. Warmed fluid expands, becomes less dense and rises while cooler, denser fluid sinks, setting up a circulating convection current.
- **radiation** — the transfer of energy by electromagnetic waves, including light and infrared radiation (felt as warmth). It needs no material — no medium — so it can cross the vacuum of space.
- **particle model** — the model in which all matter is made of extremely small particles, and heating gives the particles more energy of motion: vibrating more strongly in a solid, moving faster in a liquid or gas.
- **medium** — the material through which energy is transferred. Radiation needs no medium at all.
- **conductor** — a material that transfers energy well by conduction. Metals are the best conductors because some of their electrons are free to move and carry energy quickly.
- **insulator** — a material that does not transfer energy well by conduction, such as wood, plastic, glass, wool or trapped air.
- **photon** — a tiny packet of energy that radiation arrives in — the particle model of radiation. A brighter beam delivers more photons each second, and the energy of one photon depends on the kind of radiation: an ultraviolet photon carries more energy than an infrared photon.
- **static electricity** — electric charge at rest: electrons transferred from one material to another by rubbing, so nothing new is made. The charged object then attracts opposite charges nearby.
- **electric current** — electric charge on the move: free electrons drifting along a metal wire, carrying energy from the cell to whatever the circuit powers.
- **voltage** — the push from a cell (battery) that drives the electrons around a circuit.
- **vacuum** (from 13C) — a region containing no matter. With no particles, neither conduction nor convection can cross a vacuum, but radiation can.

14B — Waves

- **wave** — a repeating disturbance that travels through a material or through space, carrying energy with it. A wave carries energy, not matter: particles of the medium only oscillate about fixed positions.
- **medium** (from 14A) — the material a wave travels through, such as air or water for sound. Some waves need no medium at all.
- **mechanical wave** — a wave that needs a medium in order to travel, such as sound, water waves, and waves on ropes or springs. Remove the medium and the wave stops.
- **electromagnetic wave** (from 14A) — a wave that does not need a medium and can travel through a vacuum. All electromagnetic waves are transverse and all travel through a vacuum at the speed of light, $c = 3.0 \times 10^8$ m/s.
- **transverse wave** — a wave whose oscillations are at right angles to the direction of travel. The highest point is the crest and the lowest the trough; all electromagnetic waves are transverse.
- **longitudinal wave** — a wave whose oscillations are along (parallel to) the direction of travel, such as sound. It is made of compressions, where particles are pushed close together, and rarefactions, where they are spread further apart.
- **amplitude** — the maximum distance a particle of the medium moves from its fixed (rest) position as the wave passes. A wave with a larger amplitude carries more energy; in sound, amplitude sets the loudness.
- **wavelength** — λ, the distance from one point on a wave to the next point at exactly the same stage of the cycle, such as crest to crest. Measured in metres (m).
- **frequency** — f, the number of complete waves that pass a fixed point each second, measured in hertz (Hz); one hertz is one wave per second. In sound, frequency sets the pitch. The related period, T, is the time for one complete wave to pass: $T = 1/f$.
- **wave equation** — the relation $v = f\lambda$ linking wave speed v (the distance the wave travels each second, in m/s), frequency and wavelength. At a fixed speed, frequency and wavelength are inversely proportional.
- **ultrasound** — sound with a frequency above the range of human hearing (above about 20 000 Hz). Used in medicine to image organs and in sonar to measure depths.
- **echo** — a reflection of sound from a surface. Timing an echo gives speed or distance ($v = 2d/t$) — the principle behind sonar and medical ultrasound scans.

- **electromagnetic spectrum** (from 13A) — the continuous range of electromagnetic waves in order of increasing frequency: radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays.
- **vacuum** (from 13C) — a region containing no matter. Mechanical waves such as sound cannot travel through a vacuum, but electromagnetic waves can.

14C — Conservation of energy in systems

- **joule** — (J) the unit in which energy is measured. Larger amounts are measured in megajoules (1 MJ = 1 000 000 J).
- **kinetic energy** — the energy of a moving object, such as a rolling ball, a running athlete or moving air.
- **gravitational potential energy** — the energy stored in an object because of its height above the ground; the higher the object, the more it has.
- **elastic potential energy** — the energy stored when an object is stretched, bent or squashed, such as a drawn bow or a compressed spring.
- **chemical energy** — the energy stored in food, fuels (coal, gas, petrol, wood) and batteries.
- **thermal energy** — the energy an object has because it is hot; the hotter the object, the more thermal energy it holds.
- **electrical energy** — the energy carried by an electric current in a circuit.
- **system** — the part of the world you have decided to watch, from a bouncing ball to the whole Earth. Energy crossing its boundary in is an input; energy leaving is an output.
- **transfer** — moving energy from one place or object to another without changing its form, such as thermal energy moving from a flame to a kettle.
- **transformation** — changing energy from one form into another, such as a solar cell transforming light energy into electrical energy.
- **Law of Conservation of Energy** — energy cannot be created or destroyed, only transferred or transformed; the total amount stays the same. So a system's energy input always equals its output, and no device can ever give out more energy than it takes in.
- **dissipated** — energy that has spread out into the surroundings where it cannot easily be used for the job in hand. It has not been destroyed — the total still adds up — but it is no longer available.
- **efficiency** — the ratio useful energy output ÷ total energy input: how much of the input energy comes out where you want it, in the form you want it. Usually written as a decimal or fraction, or multiplied by 100 as a percentage; since energy cannot be created, it can never be greater than 1 (100%).
- **Sankey diagram** — a drawing of the energy flow through a system in which the width of each arrow is proportional to the energy it carries. The total width of the arrows leaving equals the width of the arrow coming in, because energy is conserved.

Chapter 15 words

15A — Generating electricity

- **alternating current (AC)** — a current in which the direction of charge flow reverses regularly, again and again; produced by magnet-and-coil generators spun by turbines. The mains supply is AC.
- **direct current (DC)** — a current in which charge flows in one direction the whole time; produced by batteries and photovoltaic cells — the sources with no turbine.
- **polarity** — which terminal of a source is positive (+) and which is negative (−). A DC source keeps a fixed polarity; an AC source swaps + and − each half cycle.
- **mains supply** — the AC delivered to homes and schools through the grid, the network of wires and cables that carries electricity from generators to users. In Australia it is 230 V, 50 Hz AC.
- **frequency** — the number of complete cycles an AC supply makes each second, measured in hertz (Hz); 1 Hz means one cycle each second.
- **period** — the time taken for one complete cycle, linked to frequency by $T = 1/f$; for the 50 Hz mains supply it is 0.02 s. The current reverses direction twice in each cycle.

- **electromagnetic induction** — a current produced in a wire when the magnetic effect around it changes, caused by movement between a magnet and a coil. Movement is the key requirement: a still magnet gives no current; faster movement gives a larger current.
- **AC generator** — a coil (or magnet) spinning past the north and south poles of a magnet, so the induced current reverses every half turn and the output is AC. One full turn gives one cycle; spinning faster raises the frequency.
- **turbine** — a wheel with blades designed to spin when wind, water, tides or steam pushes against the blades; its shaft drives the generator.
- **fission** — the splitting of a large nucleus, such as a uranium nucleus, releasing energy and able to set off further splits in a chain reaction. Used in all nuclear power stations today; it does not involve burning.
- **fusion** — the joining together of small nuclei, such as hydrogen nuclei, to make a larger nucleus, releasing even more energy than fission. It powers the Sun and stars but is not yet used to generate electricity on Earth.
- **photovoltaic cell** — a device that transforms light energy directly into electrical energy, with no moving parts and no turbine; light pushes charge one way only, so the output is DC.
- **battery** — a device that transforms stored chemical energy into electrical energy. Its terminals keep a fixed polarity, so it can only deliver DC.
- **rechargeable battery** — a battery that can be restored: connecting it to a supply pushes charge back through the other way, reversing the chemical reactions so it can deliver energy again.

15B — Newton's laws and the relationship between force, mass and acceleration

- **force** — a push or a pull, measured in newtons (N). Forces can change an object's motion; some act only when objects touch, others (gravity, magnetism) act at a distance.
- **friction** — a contact force that opposes motion between two surfaces; the reason a rolled ball slows down and stops.
- **net force** — the overall force when all the forces on an object are combined; along a straight line, forces in one direction add and forces in the opposite direction subtract. If it is zero (balanced forces) the motion does not change; if it is not zero (unbalanced forces) the object speeds up, slows down or changes direction.
- **Newton's first law** — an object stays at rest, or keeps moving in a straight line at a steady speed, unless an unbalanced force acts on it.
- **inertia** — the tendency of an object to resist any change to its motion; the more mass an object has, the more inertia it has.
- **Newton's second law** — net force = mass × acceleration ($F = ma$). A bigger net force gives a bigger acceleration; for the same net force, a bigger mass gives a smaller acceleration.
- **acceleration** — how quickly an object's velocity changes: $a = (v - u)/t$, measured in m/s². Speeding up, slowing down and changing direction all count — slowing down is a negative acceleration, opposite to the motion.
- **velocity** — an object's speed together with the direction it is moving in.
- **mass** — the amount of matter in an object, measured in kilograms; the same everywhere. Not the same thing as weight.
- **weight** — the force of gravity on an object, measured in newtons: $W = mg$ (g = 9.8 m/s² near Earth's surface). Unlike mass, weight depends on where the object is.
- **Newton's third law** — whenever one object exerts a force on a second object, the second exerts an equal force back on the first, in the opposite direction. The pair act on different objects, so they do not cancel each other out.
- **newton (N)** — the unit of force; 1 N is exactly the force needed to give a mass of 1 kg an acceleration of 1 m/s².

15C — Analysing motion quantitatively

- **speed** — how quickly distance is covered: $v = d/t$, measured in m/s. To convert km/h to m/s divide by 3.6; to convert m/s to km/h multiply by 3.6.

- **average speed** — total distance ÷ total time for a whole journey; a summary of the whole trip, not the speed at any one moment.
- **line of good fit** (from 15B) — a line drawn through plotted points that smooths out the small timing errors in individual readings.
- **distance–time graph** — a graph whose shape tells the motion story: a flat line means at rest, a straight climbing line means steady speed, a steeper line means faster, and a curved line means changing speed.
- **gradient** — the steepness of a line: rise ÷ run. The gradient of a distance–time graph IS the speed; the gradient of a speed–time graph IS the acceleration.
- **speed–time graph** — a graph whose value is the speed itself: a flat line means steady speed (acceleration = 0), a climbing line means positive acceleration, and a falling line means negative acceleration.
- **deceleration** — slowing down; a negative acceleration, opposite to the motion.
- **acceleration** (from 15B) — the change in speed per second; on a speed–time graph it is the gradient — the same calculation as the formula $a = (v - u)/t$.
- **area under a speed–time graph** — the area between the line and the time axis is the distance travelled (m/s × s = m): a rectangle at steady speed, a triangle when speeding up from rest.
- **reaction time** — the time a driver takes to see a hazard, decide and move a foot to the brake — about 1 s for an alert driver. The car keeps moving at full speed during it.
- **thinking distance** — the distance travelled during the reaction time, before the brake is pressed: speed × reaction time, so it is proportional to speed.
- **braking distance** — the distance travelled while the car slows to rest once the brake is pressed; it grows with the square of the speed, so doubling the speed gives about four times the braking distance.
- **stopping distance** — thinking distance + braking distance.

Chapter 16 words

16A — Socio-scientific issues

- **socio-scientific issue** — a question about what people should do, where scientific knowledge matters but people's values matter too. Sensible people who agree about the facts can still disagree about what to do — that disagreement is part of the issue, not a failure to understand the science.
- **projected outcome** — a result a person or group expects when they picture a practice being adopted — for their health, environment, money or way of life. How widely a practice is adopted follows those projections.
- **empirical claim** — a claim about what is true or what will happen — it can be checked against evidence, at least in principle.
- **value claim** — a claim about what matters or what ought to happen — evidence can inform it, but evidence alone cannot settle it.
- **steelman** — to put each side's case — especially the view you disagree with — in its strongest form before you judge it.
- **denominator** (from 5B) — the "out of how many" behind a count. A count on its own can reverse the truth, so compare rates (such as injuries per 1 000 riders) and always ask who was counted.
- **meta-analysis** — a study that combines the results of many earlier studies.
- **carbon sequestration** — the locking of carbon in soil and plants instead of leaving it in the air as carbon dioxide.
- **citizen science** — scientific work that members of the public take part in. Volunteers choose themselves, so their data are used alongside hospital and laboratory data, not instead of them.
- **genetically engineered (GM)** — a crop whose DNA scientists have changed to give it a trait it did not have (also called genetically modified).
- **payback time** — the time it takes for savings to equal the upfront cost, so a system has paid for itself.

16B — Interpretation, misinformation and the values that set research priorities

- **interpretation** — a reading of what scientific knowledge means for you. Different groups may honestly weigh the same knowledge differently, but every fair reading stays inside what was actually measured.

- **misinformation** — information that is false or misleading, whether by accident or on purpose. Unlike a bent interpretation, which starts from real data, misinformation has no evidence leaning behind it at all.
- **bias** — a tilt in how data is analysed or presented that pushes the reading one way; the numbers never change, only what you are shown of them.
- **truncated axis** — a graph axis that starts above zero so a small change looks like a big one. A zoomed axis is honest only when the caption says so.
- **cherry-picked window** (from 5A) — showing only the part of a data series that happens to suit the story and presenting it as the whole picture; the numbers are real, but the bias is in the chosen frame.
- **relative statement** — a comparison of one risk with another, such as "doubles the risk"; true, but it hides how small both risks are.
- **absolute statement** — a comparison of the risk with the people taking it, such as "one extra case per 10 000 patients"; the number a decision actually runs on.
- **manufactured doubt** — doubt used as a strategy to keep a debate running and delay action after the evidence has already answered the question — the oldest form of misinformation on record. Genuine doubt is a question about evidence (how strong is it, what would change it?) and is healthy.
- **priority loop** — the way society's values and needs set the focus of research: values and needs → funding choices → research focus → new knowledge and technology reaching society. Financial support from governments and commercial organisations is needed for scientific developments and can determine what research is undertaken.
- **regenerative braking** — making a vehicle's motor run backwards as a generator whenever it slows, turning motion energy into electrical energy that is stored or fed back to the grid, instead of being lost as heat.
- **green chemistry** — designing chemical processes so they make less hazardous waste, use less energy and recycle what they use.
- **supercritical carbon dioxide** — carbon dioxide held under high pressure in a state between gas and liquid that dissolves caffeine well; it is cooled and run through the next batch, so the solvent never becomes waste.
- **decision ladder** — the four steps from a claim to a decision: what is my decision, trace the claim to its source, check who paid and whether independent sources agree, and check the wording is fair — ending in one of three verdicts: change it, keep it, or wait and find out what is missing.