Course Companion

GAC Science

Every topic handout in one volume

全部专题讲义合集

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GAC013 Science II: Scientific Principles

GAC Science

What this module is, and how it is marked

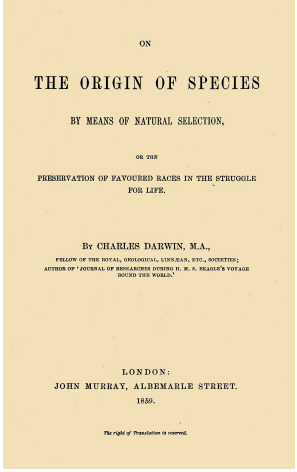
Two paper samples retain different amounts of water. Does that mean one is best for every cleaning task? To answer well, a scientist asks how the comparison was made, which properties were tested and what remains unknown.

This guide supports GAC013: the development of scientific ideas, investigation, scientific language, the organisation of research and scientific issues. Science includes evidence, methods, explanations and a growing body of knowledge. Its questions connect physics, chemistry, biology and other fields.

A **practical investigation** 探究实验 needs a safe, permitted method that fits its question. An **investigation report** 实验报告 records that method, the actual observations and a conclusion limited by the evidence. Follow your teacher's current brief for assessment criteria, structure and deadlines. The original companion sheets are practice, not official assessment papers. No result or phrase guarantees a mark. Never replace an unexpected observation with a predicted answer.

The history of science

A **paradigm** 范式 is a broad framework shaping explanations and questions. A **paradigm shift** 范式转换 is a substantial change in that framework. Not every revised number or new observation is a shift of this scale.


ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

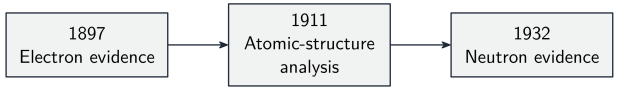
By CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNEAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

The first edition of On the Origin of Species, 1859: a single book that changed how science explains life

Scientific explanations are **provisional** 暂定的: they remain open to evidence-led revision. This does not mean that every explanation is equally uncertain. A model represents selected features of a system; observations test how well its predictions and explanations work within a stated scope.



Selected evidence about electrons, atomic structure and neutrons contributed to changing atomic ideas.

■ Worked example: separate event dates from award dates

Thomson identified the electron in 1897. Rutherford's 1911 atomic-structure analysis drew on scattering measurements, including work by Geiger and Marsden. Chadwick established evidence for the neutron in 1932. These are selected developments, not a complete history of science. A scientist's award year is not automatically the discovery or publication year.

Sources checked 2 October 2026: Nobel atomic-history timeline, electron discovery, and Chadwick facts.

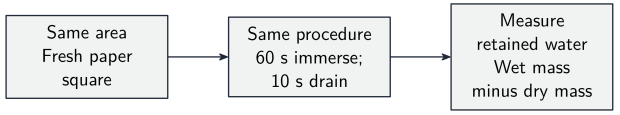
Physics studies matter and energy. Chemistry studies substances and their changes. Biology studies living systems. A plant-growth investigation can be biological while using physical measurements of light and chemical ideas about materials. Naming its main field does not supply its result.

The scientific method

A **hypothesis** 假设 is a testable proposed explanation or prediction. Identify what observations would support or challenge it. Research can involve controlled experiments, observation, modelling and revision; it does not always follow one straight sequence.

In a controlled experiment, the **independent variable** 自变量 is deliberately changed, the **dependent variable** 因变量 is the measured response, and **control variables** 控制变量 are kept comparable. A **control group** 对照组 can provide a comparison without the treatment where the design requires it. Comparing two materials is not automatically a treatment-versus-no-treatment design.

Repeat 重复 trials to examine variation and reduce dependence on one reading. Repeats do not repair a systematically unequal procedure, and a single careful observation is not automatically worthless. Report what the evidence permits and what further checking would help.



The paper comparison holds area and timing comparable before measuring wet-minus-dry mass.

■ Worked example: controlled conditions and a mean

In the written task, fresh squares of two paper types have the same area. Each is immersed for 60 seconds, drained for 10 seconds without squeezing, and weighed using the same checked balance. Retained-water mass is wet mass minus dry mass. Type A records 3.0, 3.2 and 2.8 grams; B records 4.2, 4.0 and 4.4 grams.

The mean summarises the three trials:

$$\bar{m} = \frac{m_1 + m_2 + m_3}{3}$$

$$\bar{m}_A = \frac{3.0 + 3.2 + 2.8}{3} = 3.0 \text{ g}$$

$$\bar{m}_B = \frac{4.2 + 4.0 + 4.4}{3} = 4.2 \text{ g}$$

The difference between means is 1.2 grams. Individual trials vary. Squeezing only A adds another changed condition and undermines a comparison of paper type. Strength, price and other uses were not tested, so "B is always best" is unsupported. Any real practical activity requires the teacher's approved procedure and supervision.

The language of science

Units 单位 identify the scale of a physical quantity. Some quantities, such as a count or a ratio, are dimensionless but still need a clear definition. A unit conversion changes representation, not the physical quantity. For area, square the length conversion factor.

Accuracy 准确度 concerns closeness to a suitable reference or true value. **Precision** 精密度 concerns closeness of repeated readings. An instrument can give close repeats with a systematic offset. Significant figures help communicate the supported numerical precision; calculator output is not evidence for extra digits.

Uncertainty 不确定度 describes limitations on a measurement or estimate. Instrument resolution, procedure and variation can contribute. Do not invent an uncertainty range or confidence level that was never established.

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Distance and elapsed time define average speed; repeat precision still needs an accuracy check.

■ Worked example: average speed is not constant speed

For the supplied trolley record, travelled distance is 3.60 metres and elapsed time is 48.0 seconds. Average speed is distance per elapsed time:

$$v_{\text{avg}} = \frac{d}{t}$$

$$v_{\text{avg}} = \frac{3.60\ \text{m}}{48.0\ \text{s}} = 0.0750\ \frac{\text{m}}{\text{s}}$$

This is an interval average, not a speed at every moment. Separately, timer repeats of 10.1, 10.1 and 10.2 seconds are close, but they disagree with a supplied 12.0-second reference. Investigate the timing procedure instead of claiming accuracy from closeness alone.

The organization of science

Peer review 同行评审 asks relevant specialists to examine a study's methods and reasoning. It can identify weaknesses, but is not automatic product certification. **Replication** 可重复性 obtains new observations using an appropriately comparable procedure to investigate a finding. Checking calculations on the same readings is useful, but does not supply a new independent experiment.

Research **institutions** 机构 provide people, resources and rules. Disclose funding and relevant interests. Examine whether they affect design, analysis or reporting; funding alone proves neither honesty nor dishonesty. Transparent records and independent scrutiny help readers judge a claim.



The original study, specialist review and planned independent test have different evidential roles.

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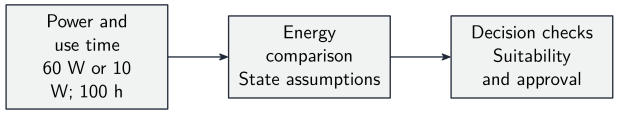
■ Worked example: a review finds a condition that matters

An insulating-sleeve report compares cups starting at different temperatures. A reviewer flags that difference. A second calculation cannot remove the unequal starting condition. A second school's independent experiment could improve checking, but it supplies no confirmation until performed. Keep the original record and explain its limit rather than inventing a successful replication.

Scientific issues

Scientific work can inform decisions about technologies and their effects. Evidence does not by itself decide every value, cost or acceptable trade-off. A **risk** 风险 concerns both the chance and seriousness of harm; a possible harm is not automatically frequent, and uncertainty is not proof of zero risk.

Communicating uncertainty 传达不确定性 means describing the assumptions, scope and unknowns accurately. Use an established range where available, but do not invent one because a single number looks insufficient. A bounded estimate can still be useful.



A power-and-time estimate informs a lamp comparison before suitability and approval decisions.

■ Worked example: an energy benefit is one decision input

Assume a lamp operates 5 hours daily for 20 days: 100 hours. Compare constant powers of 60 watts and 10 watts. Convert to kilowatts because the requested energy unit is kilowatt-hours:

$$E = Pt$$

$$E_{old} = 0.060\ \text{kW} \times 100\ \text{h} = 6.0\ \text{kWh}$$

$$E_{new} = 0.010\ \text{kW} \times 100\ \text{h} = 1.0\ \text{kWh}$$

The estimated reduction is 5.0 kilowatt-hours under those assumptions. No tariff establishes a monetary saving, and no lighting measurement establishes equal brightness. Check required performance, purchase and installation costs, compatibility and reliability. Replacement needs school approval and authorised personnel. Students should analyse the supplied data, not carry out electrical installation.

GAC023 Science III: General Science

GAC Science

What this module is, and how it is marked

A pond contains organisms, water, minerals and energy transfers. Understanding it needs several kinds of science, and no single observation answers every question. A plant can be present without proving drinking-water safety. A lower chemical concentration can be useful without proving that a substance has been destroyed.

This guide supports GAC023: biology, classification, ecosystems, Earth resources, chemistry, environmental chemistry and waves. A **collaborative investigation** 合作探究 assigns clear roles and uses a safe, approved procedure. Its report connects recorded observations with a question, method and bounded conclusion. Follow your actual assignment brief; the companion exercise sheets are original practice, not official assessment papers. Case data are labelled separately from cited background facts.

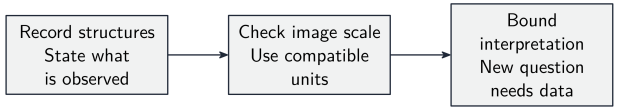
The history, nature and practice of biology

Biology 生物学 studies living systems, including structure, function and change. A **cell** 细胞 is the basic structural and functional unit of organisms. **Prokaryotic** 原核 cells have DNA without a membrane-bound nucleus. **Eukaryotic** 真核 cells typically contain a nucleus and other membrane-bound structures, with specialised exceptions. Do not infer that a structure is absent simply because one poor image does not show it.

Homeostasis 稳态 is regulation of internal conditions within suitable limits as external conditions vary. It does not mean every internal value stays exactly constant. Biological observations should distinguish what is seen, what is inferred and what would need another method.

■ Historical context and a scale check

Hooke's *Micrographia*, published in 1665, used "cell" for the tiny spaces observed in cork. This is a selected historical development, not the whole history of cell theory. Sources checked 2 October 2026: Royal Society account and digitised Micrographia.



Recorded structures and a scale check support interpretation, while new questions require new evidence.

In the supplied case, a printed cell is 30.0 millimetres long and its stated actual length is 0.0500 millimetres. Use the same units in the ratio:

$$M = \frac{L_{image}}{L_{actual}}$$

$$M = \frac{30.0\ \text{mm}}{0.0500\ \text{mm}} = 600$$

The magnification is ×600, not a length. Shape and scale alone do not establish growth rate. A permitted growth study needs a specified measure, comparable organisms, conditions and observation period.

The classification of living things

Classification 分类 organises organisms using evidence about relationships, including inherited traits and molecular information. A traditional hierarchy is kingdom, phylum, class, order, family, genus and **species** 物种. Broader groups can contain several groups at the next level. A visible feature helps identification but does not alone establish ancestry.

Binomial nomenclature 双名法 gives a species a genus name and a specific epithet. Capitalise the genus, use lower case for the epithet and italicise both words in print. When handwriting, underline both as required by the task. The epithet alone is not the full species name.



A family can contain several genera, each of which can contain several species.

■ Worked example: one genus, different species

The supplied table places lion, tiger and domestic cat in Felidae. Lion and tiger share Panthera, but their species names are *Panthera leo* and *Panthera tigris*. The domestic cat is *Felis catus*, a different genus within that family. Names checked 2 October 2026 against ITIS records.

A classroom leaf key can separate needle-like leaves from broad leaves, then smooth margins from toothed margins. This identifies prepared cards from stated features. The key's branch order is not evidence that plants evolved in that order.

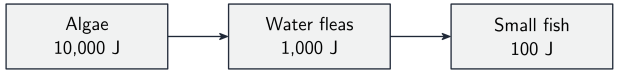
Ecosystems

An **ecosystem** 生态系统 includes organisms and nonliving conditions. **Producers** 生产者 make organic material using an energy source. **Consumers** 消费者 obtain it from other organisms. **Decomposers** 分解者 break down dead material and waste, helping return nutrients to available forms.

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Food-chain arrows point from food to consumer. Energy enters and transfers through the system, with dissipation through respiration and other pathways. It does not disappear from existence or cycle indefinitely back to the producer. Matter can cycle through living and nonliving parts, although a local system can also gain or lose matter across its boundary.

Biodiversity 生物多样性 concerns the variety of life. Species richness and distributions of abundance are possible measures, depending on the question. Counting only one species does not describe all this variety. Diversity may affect ecosystem responses, but it does not guarantee resistance to every disturbance.



An algae chain uses its supplied energy values, not a universal transfer rule.

■ **Worked example: transfer percentages are case-specific**

For the separate meadow record, grass has 5,000 joules in its defined level, grasshoppers receive 600 and frogs receive 60. The efficiency relation is:

$$\eta = \frac{E_{next}}{E_{previous}} \times 100\%$$

$$\eta_1 = \frac{600}{5000} \times 100\% = 12\%$$

$$\eta_2 = \frac{60}{600} \times 100\% = 10\%$$

Neither result makes ten percent a universal law. Not all material is eaten or assimilated, and energy is used and dissipated. This period's budget contains no population trend, so it cannot predict an exact frog decline the next week.

Earth resources

The **rock cycle** 岩石循环 connects formation and change. Cooling and solidification form igneous rock; sediment deposition, compaction and cementation can form sedimentary rock; heat and pressure can alter rock into metamorphic rock without melting it. Weathering and erosion produce sediment, while melting and later cooling form another route. These processes are not one compulsory circular sequence for every rock.

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An oil refinery separates crude oil, a finite Earth resource, into fuels and raw materials

Renewable 可再生 resources can be replenished on a relevant timescale. **Non-renewable** 不可再生 resources are not replenished fast enough on human-use timescales. Renewable does not mean unlimited: demand can exceed replacement, and ecosystem needs also matter.

The **water cycle** 水循环 includes evaporation, condensation, precipitation and movement or storage through runoff, infiltration and groundwater. A local pond is open to inputs and losses. A report should combine physical layout, dated chemical measurements and non-destructive biological records, citing their sources and methods.



A local pond budget records inputs, storage and losses within a stated boundary and period.

■ **Worked example: renewal versus extraction**

In the simplified supplied budget, inputs are 30 cubic metres, outlet loss is 18 and evaporation is 7. Other changes are excluded by assumption:

$$\Delta S = I - O - E$$

$$\Delta S = 30 - 18 - 7 = 5 \text{ m}^3$$

With a proposed additional extraction of 12 cubic metres:

$$\Delta S = I - O - E - X$$

$$\Delta S = 30 - 18 - 7 - 12 = -7 \text{ m}^3$$

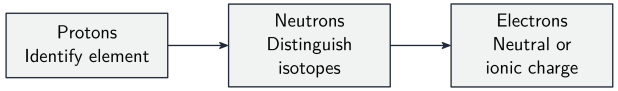
That period's estimate does not establish long-term sustainability, initial storage or permission to extract. Reeds do not prove drinking-water safety. A rock photograph does not establish every rock's type or exact age.

Chemistry

An **atom** 原子 has a nucleus and electrons. Its **atomic number** 原子序数 is its proton count, while its **mass number** 质量数 counts protons and neutrons. Most nuclei contain both, but hydrogen-1 has one proton and no neutron. **Isotopes** 同位素 of an element have the same proton count and different neutron counts.

The **periodic table** 元素周期表 orders elements by atomic number. In an introductory main-group model, outer electron arrangements help explain similarities within groups. The elements are not identical, and the simplified rule should not be extended without care to every element.

Ionic bonds 离子键 are attractions between oppositely charged ions. Electron transfer can explain their formation; it is not the attraction itself. **Covalent bonds** 共价键 involve shared electron pairs. These are explanatory models, not instructions to handle reactive materials.



Protons identify the element, neutrons distinguish isotopes, and electron changes determine ionic charge.

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■ **Worked example: keep proton number unchanged**

Sodium-23 has 11 protons and mass number 23:

$$N = A - Z$$

$$N = 23 - 11 = 12$$

Its neutral atom has 11 electrons. Losing one gives Na^+ with ten electrons and the same eleven protons. Sodium-24 has thirteen neutrons but remains sodium. Neutral chlorine has seventeen electrons; gaining one gives Cl^- with eighteen. Their opposite charges explain attraction.

Chemistry and the environment

Combustion 燃烧 of carbon-containing fuels can release carbon dioxide. The **greenhouse effect** 温室效应 involves absorption and emission of thermal infrared by gases including carbon dioxide. **Acid rain** 酸雨 involves atmospheric reactions of sulfur dioxide and nitrogen oxides forming acidic compounds. These are different mechanisms, with different evidence and responses.

Pollution 污染 depends on a substance or agent, its amount, pathway and effects. Chemistry can help monitor and treat it, but moving material into another output is not necessarily destroying it. Assess benefits alongside energy use, residual material and appropriate waste handling. Sources checked 2 October 2026: EPA acid-rain explanation and NASA radiation budget.



The supplied treatment has liquid and filter-waste outputs, both of which remain in the substance accounting.

■ Worked example: a reduction can still miss a target

A 10-litre treatment record falls from 12.0 to 3.0 milligrams per litre. At unchanged volume:

$$m = CV$$

$$m_{remaining} = 3.0\ \frac{\text{mg}}{\text{L}} \times 10.0\ \text{L} = 30\ \text{mg}$$

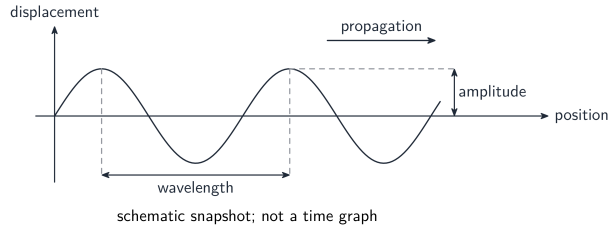
The initial mass was 120 milligrams, so ninety are retained on the filter under the stated assumptions. The concentration reduction is seventy-five percent, but the final 3.0 still exceeds the task target of 2.0 milligrams per litre. This is not a real safety standard. Students analyse the supplied data and do not discharge chemicals.

Physics

A **wave** 波 transfers energy through a travelling disturbance without carrying each medium particle along with it. **Frequency** 频率 counts complete oscillations per second. **Wavelength** 波长 is the spacing of successive points in the same phase. **Speed** 波速 relates them through the wave equation. Amplitude is maximum displacement from equilibrium, not crest-to-trough height.

Transverse waves 横波 oscillate perpendicular to propagation; **longitudinal waves** 纵波 oscillate parallel to it. The direction drawn on a page alone does not decide the type. A string point may oscillate vertically while the disturbance moves horizontally.

The **electromagnetic spectrum** 电磁波谱 runs through radio, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays. Electromagnetic waves do not require a material medium. They share the same vacuum speed while differing in frequency and wavelength; mechanical waves do not all have that speed.



A schematic transverse-wave snapshot separates wavelength and amplitude from propagation direction.

■ Worked example: choose the equation for the question

The supplied string wave has frequency 5.0 hertz and wavelength 0.40 metres:

$$v = f\lambda$$

$$v = 5.0\ \text{Hz} \times 0.40\ \text{m} = 2.0\ \frac{\text{m}}{\text{s}}$$

Its period is the time per complete oscillation:

$$T = \frac{1}{f}$$

$$T = \frac{1}{5.0} = 0.20\ \text{s}$$

An amplitude of 0.030 metres gives a crest-to-trough height of 0.060 metres. Neither is the 0.40-metre wavelength. A marked point oscillates about equilibrium; no supplied observation establishes that changing amplitude changes frequency.

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