

History of Science — Exam Study Guide

Rosie Gartner | T00757818 | All Four Units

Exam format: short essay (written). All four units weighted equally. Read Lindberg closely.

UNIT 1 — Ancient and Greek Science (Lindberg)

The Big Argument for This Unit

Science did not begin with the Greeks — but the Greeks transformed something practical and embedded in religion into something theoretical, argued, and open to criticism. The key shift is from "know-how without theoretical knowledge" (prehistoric) to causal explanation through the natures of things (Milesian). That shift is what Lindberg means by the beginning of Western science.

Prehistoric and Near Eastern Science

Prehistoric science: practical orientation, knowledge embedded in cultural/religious tradition, no theoretical framework, no openness to criticism or debate. Egypt: practical mathematics, medicine with some naturalistic elements. Babylonian astronomy: began as celestial divination (reading divine messages), became computational — clay tablets, planetary tables, eclipse prediction. Lindberg calls this "the beginning of computational astronomy" but notes it lacked physical/geometrical models to explain why the heavens moved as they did.

The Milesians — The Critical Break

Thales, Anaximander, Anaximenes: first thinkers to seek causes only in the natures of things, not divine will. Lindberg: "the capricious world of divine intervention was being pushed aside, making room for order and regularity; chaos was yielding to kosmos." Writing in argued prose opened knowledge to inspection, comparison, and criticism — the key institutional precondition for science. Aristotle called

them physikoi (nature thinkers). The problem they debated: what is the fundamental stuff of reality, and how does change occur?

Plato

Two-realm metaphysics: perfect eternal Forms vs. imperfect material world. The Demiurge constructed the cosmos as an imperfect replica of the Forms. Knowledge of the physical world yields only probable opinion, not true knowledge. Mathematics is the language of nature's structure. Astronomy should reveal mathematical harmonies, not study actual celestial motions. Legacy: strong in theology, cosmology, mathematics; weak for empirical investigation.

Aristotle — The Most Important Thinker in This Unit

Reversed Plato: forms exist in individual things, not separately. Reality is the sensible material world. Knowledge begins with sense experience. His four causes (material, formal, efficient, final) gave natural philosophy a complete vocabulary for causal explanation. Cosmology: eternal spherical universe, celestial region made of aether (incorruptible fifth element), circular motion. Biology: 500+ species described, History of Animals, dogfish placenta described accurately (not confirmed until 19th century). Lindberg: "almost single-handedly, he created entirely new disciplines." His dominance through the Renaissance was "not from intellectual subservience... but from the overwhelming explanatory power" of his system. "Aristotle prevailed through persuasion, not coercion."

Greek Mathematics and Optics

Mathematics was epistemologically inferior to natural philosophy (dealt with accidents, not essences) until the Scientific Revolution elevated it. Euclid's Optica applied geometry to vision: rays emerge from the eye in a cone, apparent size is a function of the angle of perception. Lindberg calls this "an impressive piece of mathematical analysis" — important as a model for applying mathematics to natural phenomena.

Greek Medicine

Hippocratic tradition: rejected supernatural causation, committed to naturalistic explanation. On the Sacred Disease: epilepsy called sacred by "witch-doctors, faith-healers, quacks." "Nature acts uniformly; whatever the causes may be, they are not capricious, but uniform and universal." Clinical observation: face, eyes, hands, posture, breathing, sleep, stool, urine, vomit, sputum. Case histories "remarkable for precision and clarity." Distinction: prognosis through observation, not divination. Galen: systematic anatomy ("only systematic account of human anatomy until the Renaissance"), three pneuma system (psychic/vital/natural through nerves/arteries/veins). Caveat: learned medicine coexisted with rivals; it did not drive them out.

Key Essay Angles for Unit 1

Compare Plato and Aristotle: metaphysics determines method — Plato's two realms produce abstraction; Aristotle's immanent forms produce empiricism. Explain the Milesian revolution: from divine causation to natural causation, from oral tradition to argued prose. Evaluate Aristotle's greatest contribution: not any single discovery but the creation of a systematic empirical framework for multiple disciplines.

UNIT 2 — Medieval and Islamic Science (Lindberg)

The Big Argument for This Unit

Greek science did not die when Rome declined. It was preserved, transmitted, and transformed — first eastward into Islam, then back westward into medieval Europe via the translation movement. The continuity question asks whether this transmission constitutes a genuine scientific tradition or merely preservation. Lindberg argues for substantial continuity alongside genuine transformation.

Rome and the Transmission of Greek Science

Rome valued practical application over theoretical inquiry. Popularizers and encyclopedists (Pliny, Cicero) transmitted Greek knowledge in simplified form. Rise of Christianity initially complicated relationship with classical learning but did not simply destroy it — many early Christian scholars engaged seriously with Greek philosophy. Medieval education structured around the seven liberal arts (trivium + quadrivium). Greek East (Byzantine) preserved texts that would later return to the West.

Islamic Science — The Translation Movement

Nestorian Christians transmitted Greek texts into Syriac before Islam. Abbasid caliphs in Baghdad (from 750 AD) funded translation for political legitimacy and practical needs (astronomy for prayer times, medicine at court). Paper from China accelerated copying. Hunayn ibn Ishaq: translated 95 Galen works Greek→Syriac, 34 Greek→Arabic. His method: not word-for-word but meaning-for-meaning. By year 1000: "nearly the entire corpus of Greek medicine, natural philosophy, and mathematical science had been rendered into usable Arabic versions" (Lindberg). Sabra's three stages: invited guest → original achievement → naturalization.

Islamic Scientific Achievement

Al-Khwarizmi: Algebra (Euclidean geometry applied to algebraic problems — contributed to symbolic algebra in Europe). Ibn al-Haytham: Book of Optics (became Europe's principal authority until 17th century). Al-Battani: corrected Ptolemy's solar/lunar parameters (cited by Copernicus and Kepler). Ibn al-Nafis: pulmonary transit of blood (anticipated Harvey). Maragha observatory. Tusi-couple (later used by Copernicus). Why did Islamic science fade? Lindberg challenges the assumption of decline: "not the product of research in manuscript archives, but an assumption." Mongol sack of Baghdad 1258 but conquerors became patrons. Astronomy flourished into 16th century. Thousands of manuscripts remain unexamined.

Medieval Europe — Carolingian Reforms and Universities

Charlemagne mandated cathedral/monastery schools; Alcuin collected classical texts. "Earliest known copies of most Roman scientific and literary texts date from the Carolingian period." 12th-century translation movement: Toledo fell 1085, library exploited. Gerard of Cremona translated 70-80 books including *Almagest*, Euclid's *Elements*, Avicenna's *Canon*, Aristotle's *Physics*. Universities: *universitas* = voluntary guild of scholars. Bologna by 1150, Paris by 1200, Oxford by 1220. "For the first time in history, there was an educational effort of international scope." By 1255: lectures on all known works of Aristotle mandatory at Paris.

1277 Condemnations

Bishop Tempier condemned 219 propositions targeting: eternity of world, monopsychism, denial of personal immortality, determinism, philosophical autonomy. "A ringing declaration of the subordination of philosophy to theology." Also opened space for non-Aristotelian speculation. Targeted Siger of Brabant and radical Aristotelians. Conservative backlash — but paradoxically productive for later science.

Mathematical Astronomy and the Continuity Question

Two traditions: cosmological (Aristotle, Sacrobosco's *Sphere*) vs. mathematical astronomy (Ptolemy's *Almagest*). Realist vs. instrumentalist debate: do the models describe physical reality or just save the appearances? Continuity question: Duhem argued 14th-century Oxford/Paris scholars anticipated Galileo. Lindberg's position: "no informed historian of science would now support the extreme negative opinions" of the anti-medieval view; but few medievalists now defend strong continuity either.

Lindberg: "Revolution does not demand total rupture with the past."

Key Essay Angles for Unit 2

Importance of the translation movement: not just preservation but transformation — Islamic scholars corrected, extended, and applied Greek science. Origins of universities: institutional rather than purely

intellectual story — guild model, patronage, mobility. Continuity question: use specific examples (Copernicus drew on Ptolemaic data; Galileo drew on Oxford/Paris kinematics; mechanical philosophy = revived Epicurean atomism).

UNIT 3 — Scientific Revolution through Darwin (Bowler & Morus)

The Big Argument for This Unit

The Scientific Revolution was not a single event but a transformation in what counted as scientific knowledge and who had the authority to produce it. Key shifts: experience over authority, mathematics as the language of nature, new institutional homes for science. The Chemical Revolution and Conservation of Energy show similar patterns — theoretical crisis, new framework, generational resistance. Darwin's theory is the culmination of several converging lines of inquiry, none of which was sufficient alone.

The Scientific Revolution — Causes

Social/institutional cause: barrier between astronomy (appearances) and natural philosophy (real causes) broke down. Patronage shifted from universities to courts — Galileo lobbied to become court philosopher, not mathematician. This allowed astronomers to make philosophical claims. Empirical cause: Francis Bacon's program — experience over authority, collaborative fact-gathering, Solomon's House model. Led to Royal Society and Paris Academy. Mathematics elevated: Galileo's argument that nature is written in mathematical language. Tension: mathematics was inaccessible and could not easily be publicly verified (Boyle's concern).

Newton

Principia (1687): three laws of motion + universal law of gravitation. Demonstrated that force maintaining moon's orbit = force causing bodies to fall at earth's surface. Book 3 "System of the World"

established universal gravitation. Opticks (1704): prism experiments showed white light is compound of all colors — rejected prevailing modification theory. Added Queries speculating on active powers, nature of light, ether. Also pursued alchemy and scriptural research — sought to recover ancient knowledge. Hypotheses non fingo (I do not feign hypotheses) — yet Queries were frankly speculative. Legacy: Principia followers did mathematical physics; Opticks followers did experimental investigation of active powers.

Chemical Revolution

Phlogiston theory (Stahl): combustion releases phlogiston (principle of fire in metals). Metal = calx + phlogiston. Sophisticated and versatile — used by Priestley and Cavendish even after Lavoisier. Not simply wrong. Lavoisier: oxygen (principle of acidity) is the key to combustion. Reformed chemical nomenclature (*Méthode de nomenclature chimique*, 1787): elements named systematically, calxes renamed oxides. Made the language itself carry the theory. Success in France partly because it fit broader French philosophical emphasis on quantification and systematic reform (Laplace, Condillac). Priestley and Cavendish never accepted it. Key point: Lavoisier's system still had caloric (immaterial heat) and misidentified oxygen as the principle of acidity — not fully modern.

Conservation of Energy

British approach (Joule, Thomson, Maxwell): practical, industrial, theological. Thomson: nothing God created can be destroyed. First law of thermodynamics = conservation of energy. Second law = in any irreversible process there is "an absolute loss of mechanical energy available to man." Energy as the unifying concept for all physical phenomena including electricity and magnetism (Maxwell). Ether as the medium for energy storage. Physics of the steam engine and the telegraph. German approach (Helmholtz, Clausius): abstract, rationalist, mathematical. Helmholtz: conservation based on denial of perpetual motion. Applied to physiology — animal heat = oxidation of nutrition. Clausius: introduced

entropy; second law = entropy of universe tends to maximum. Key difference: British wanted energy to be physically real and practically applicable; Germans regarded mathematical theorizing as autonomous.

Age of the Earth and Geology

Stratigraphy: principle of superposition (newer rocks deposited on older). Werner's Neptunism: failed because same rock types appear at different periods. Solution: fossil record. Smith (England), Cuvier and Brongniart (France): fossils characteristic of each stratum whatever the rock type. Cuvier: established reality of extinction. By 1840s: Paleozoic, Mesozoic, Cenozoic named. Catastrophism (Cuvier, Buckland): abrupt boundaries between formations = catastrophic upheavals. Some linked to Noah's flood (Buckland's *Reliquiae diluvianae*). Not anti-scientific — based on cooling-earth physics (Elie de Beaumont). Uniformitarianism (Hutton, Lyell): only observable causes at observable intensities. Lyell's *Principles of Geology* (1830-33). Demands vast time. Problem: cyclic model, no directionality, could not accept progressive development of life.

Darwin

Four converging inputs: (1) Lyell: uniformitarian method + deep time. (2) Fossil record: succession and extinction make species change a live problem; South American succession most direct. (3) Galapagos: finches and tortoises diversified on different islands — branching model, not linear ladder. Gould confirmed distinct species. (4) Malthus (1838): struggle for existence → natural selection of favorable variations. Animal breeders taught Darwin that selection works. Wallace 1858: independent arrival at similar mechanism forced publication. *Origin of Species* 1859. Key features of Darwin's theory: branching not linear, no predetermined direction, adaptation to local conditions drives divergence, imperfect fossil record explained by incompleteness not disproof.

Key Essay Angles for Unit 3

Two causes of the Scientific Revolution: social repositioning of practitioners + institutionalization of empiricism. Stratigraphy and fossil record: mutually reinforcing — stratigraphy provides framework, fossils provide the key. Events leading to Darwin: argue that no single input was sufficient — method (Lyell), problem (fossil record), observation (Galapagos), mechanism (Malthus) all required. Phlogiston vs oxygen: phlogiston was not simply wrong but was a functioning framework — its persistence shows scientific revolutions are not automatic.

UNIT 4 — Modern Science: Genetics through Cosmology (Bowler & Morus)

The Big Argument for This Unit

Twentieth-century science repeatedly forced practitioners to abandon assumptions they had previously treated as self-evident. Quantum mechanics dismantled determinism; plate tectonics displaced traditional geology; genetics revealed that inheritance is discrete, not blended. In each case the revolution involved both new empirical evidence and a new conceptual framework — and in each case it met resistance from the generation most committed to the older view, as Planck's observation predicts.

Genetics — Preformation vs Epigenesis

Preformationism: complete organism preformed in miniature within egg or sperm, needing only to be filled out. Epigenesis: embryo develops gradually by sequential addition of parts from undifferentiated matter. By start of 19th century preformationism was dead — but the core insight (that future structure is preordained by information in the fertilized ovum) was reformulated as the gene. Haeckel's recapitulation theory (ontogeny recapitulates phylogeny) dominated late 19th century — left no room for discrete heritable units.

Mendel and Classical Genetics

Mendel (1865, rediscovered 1900): discrete non-blending units, dominant/recessive, 3:1 ratio, independent assortment of different characters. Crucially: Mendel made no proposal about material particles. His discussion was entirely in terms of character differences. The rediscoverers read their own ideas into his work. Historians now question whether Mendel was testing a law of heredity at all — possibly testing hybridization as an alternative to Darwinian evolution. Classical genetics (Morgan, 1910-15): genes as sections of chromosomes. *Drosophila* as model organism. Gene mapping. Genetic linkage. *The Mechanism of Mendelian Inheritance* (1915). Indifferent to how gene is decoded in development — this divided biology and contributed to eugenics. Key difference from Mendelian: classical genetics supplied the material mechanism (chromosome) that Mendel had left open.

Continental Drift and Plate Tectonics

Crisis in geology: cooling-earth theory could not account for scale of mountain building; contraction insufficient; radioactive heating undermined the timescale. Wegener (1912/1915): Pangaea, fit of coastlines, continuity of formations, fossil evidence, paleoclimatology. But: no convincing mechanism; geophysicist outsider rejected by geological community. Holmes (1927): convection currents in crust — hot spots, seafloor spreading — but untestable, ignored. Plate tectonics (1960s): Cold War military technology → ocean floor mapping → magnetic striping (Vine & Matthews 1963) → seafloor spreading confirmed → Morgan, McKenzie, Le Pichon (mid-1960s). Six major plates. Continental drift vindicated. Disciplinary revolution: geophysics displaced traditional geology. Uniformitarianism rehabilitated. Universities renamed departments "earth sciences."

Twentieth-Century Physics — The Atom

Classical assumption: atom is indivisible, properties are definite. Thomson (1897): electron discovered via cathode rays — atom is composite. Röntgen: X-rays. Becquerel, Curies: radioactivity — energy from inside the atom. Rutherford (1911): nuclear model — dense positive nucleus, orbiting electrons. Problem: classical electromagnetism predicts electrons should spiral in. Should not exist. Bohr (1913):

electrons occupy specific orbits defined by Planck's constant, emit energy only in discrete quanta when jumping between orbits. Explained spectral lines. But violated classical physics — accepted a working inconsistency. Quantum mechanics (1920s, Heisenberg, Schrodinger): replaced defined orbits with probability distributions. Heisenberg uncertainty principle: position and momentum cannot both be precisely determined simultaneously — not an instrumental limitation but a feature of physical reality. Determinism replaced by irreducible probability. Einstein never accepted Copenhagen interpretation. Mid-century: particle proliferation, big physics, kilometer-scale accelerators.

Relativity

Special relativity (Einstein, 1905): no privileged frame of reference, velocity of light constant in all frames, time is relative to frame of reference, $E = mc^2$. General relativity (1915): gravity as curvature of spacetime. Light bends under gravity. Redshift in gravitational fields. Confirmed by Eddington's 1919 eclipse observations. Led to cosmological models of an expanding universe.

Cosmology — Shape of the Universe

Newton's universe: infinite, static, uniform. 20th century: Milky Way one of many galaxies. Hubble (1923): Cepheid variable in Andromeda Nebula — calculated distance far beyond Milky Way boundaries. Island universe hypothesis confirmed. Hubble (1929): galaxies receding, recession velocity proportional to distance — expanding universe. Einstein's field equations (without cosmological constant) predicted expansion. Big Bang theory: extrapolate expansion backward → all matter at single point → Lemaître (1927), Gamow et al. (1948 $\alpha\beta\gamma$ paper). Steady state theory (Bondi, Gold, Hoyle, 1948): universe always existed, new matter continuously created to maintain constant density (wide/perfect cosmological principle). Hoyle coined "Big Bang" as dismissive term in 1949 BBC broadcasts. Steady state marginalized by 1960s: radio source surveys, quasars (only at great distances — contradicts homogeneity in time), cosmic background radiation. Big Bang now consensus.

Black Holes and Modern Cosmology

Schwarzschild (1916): mathematical solution to Einstein's equations with points of infinite spacetime curvature — no light can escape. Regarded as curiosity for decades. Wheeler (1968): coined "black hole," investigated conditions for real existence. Pulsars (1967, Jocelyn Bell): rapidly rotating neutron stars — theoretical objects proven real. Hawking: black holes emit radiation (1973). *Brief History of Time* (1988) brought cosmology to mass audience. Hubble Space Telescope (1990, corrected later) — public spectacle of deep cosmos.

Psychology as Science

Origins in philosophy and introspection. Locke: tabula rasa, association of ideas. Spencer: Lamarckian evolutionary psychology — acquired mental habits inherited as instincts. Wundt (1879): Leipzig laboratory, mechanical apparatus, controlled stimuli — first experimental psychology. Claimed psychology was now a science. Watson (1913): behaviorism — exclude consciousness, study only observable behavior. Publicly verifiable evidence only. Left instincts and ethology to field naturalists (Lorenz, Huxley). Freud: analytical psychology — unconscious, free association, no experiment. Claimed science based on confronting unpleasant truths rather than experiment. Whether it is science remains debated.

Key Essay Angles for Unit 4

Most radical 20th-century break: quantum mechanics — not just new theory but abandoned determinism, the philosophical backbone of science since Descartes. Both empirical (radioactivity, electron, spectra) and conceptual (willingness to accept working inconsistency) required. Generational argument (Planck): Einstein's resistance is the clearest example. Plate tectonics: disciplinary revolution not just theoretical one — geophysics displaced geology; Cold War technology enabled it. Classical vs Mendelian genetics: Mendel provided observations, Morgan provided the material mechanism; the narrowness of transmission genetics had real-world consequences. Big Bang vs steady state: case study

in how scientific controversies are resolved — not by single decisive refutation but by accumulating evidence and community consensus.

Exam Strategy

What the Professor Is Looking For

Short essay format means you need a thesis, evidence, and a conclusion — not just a list of facts. The professor emphasized reading Lindberg closely, which means Units 1 and 2 answers should include specific Lindberg quotes or arguments (the "know-how without theoretical knowledge" distinction, Sabra's three stages, the continuity question framing, "Aristotle prevailed through persuasion not coercion"). Units 3 and 4 draw on Bowler and Morus.

The Core Themes That Run Across All Units

1. What counts as science? The boundary shifts constantly — from know-how to theoretical explanation, from authority to experience, from natural philosophy to experimental science, from philosophy to experimental psychology. 2. The role of institutions: science has never existed in a vacuum. Courts, monasteries, universities, scientific societies, military funding, Cold War competition all shaped what science was done and how. 3. Continuity and rupture: this is Lindberg's central question for Units 1-2 and Bowler & Morus's implicit question throughout Units 3-4. The answer is always both — revolutions build on what came before. 4. Resistance to new ideas: phlogiston persisted, Wegener was ridiculed, Einstein rejected quantum indeterminism, steady state advocates never fully conceded. Planck's generational argument explains why.

Likely Essay Question Types

Unit 1: Compare Plato and Aristotle. Explain the significance of the Milesian revolution. Evaluate Aristotle's contribution to science. Describe early Greek medicine and what distinguished it. Unit 2:

Explain the importance of the translation movement. Describe the origins of universities. Explain what happened in 1277 and why it mattered. Evaluate the continuity question. Unit 3: Name and explain two causes of the Scientific Revolution. Explain the relationship between stratigraphy and the fossil record. Outline the events leading to Darwin's theory. Compare phlogiston and oxygen theories. Explain British vs German approaches to energy. Unit 4: Which 20th-century discovery was the most radical break? Compare Mendelian and classical genetics. Explain the importance of plate tectonics. Differentiate Big Bang from steady state.

Time Management

The professor specifically warned about time. If there are four questions (one per unit), budget equal time for each. Write your thesis first, then two or three pieces of evidence, then a conclusion that returns to the thesis. Do not spend all your time on Unit 1 just because it feels most familiar from Assignment 1. The units are equally weighted.