

Paradigm Shift around 1600

*How a millennium-old, approximate inheritance became a precise, mathematised universe —
and why, unlike Alexandria's, this revolution never went into reverse*

FRAMING THE CHAPTER

What made c. 1600 a hinge, not just another handover?

The previous two chapters followed a body of knowledge — Greek in origin, transmitted and re-housed across the Islamic world and medieval Europe — that stayed remarkably stable for well over a thousand years. This chapter asks what made the early seventeenth century a genuine turning point rather than one more redistribution of the same inheritance, in three stages.

1

What changed

Three simultaneous shifts crystallise in the same few decades: mathematics applied to reality, corpuscularism, and new modes of study.

§3.1

2

How it changed

A three-stage transmission — Islamic world, medieval Europe, Renaissance — carries the Greek inheritance to the threshold of fusion.

§3.2

3

Why it lasted

Kepler and Galileo close a gap that Alexandria's own mathematised nature had left open — and this time it does not reopen.

§3.3

The throughline: from an “approximate whole” — a philosophy describing everything but loosely — to a “universe of precision,” in which description is expected to be both exact and predictive.

3.1
CHAPTER 3 · PARADIGM SHIFT AROUND 1600

What Changed: Three Simultaneous Shifts

*Mathematics turns onto the physical world, matter theory turns mechanist, and method itself turns practical
— all in the same few decades.*

3.1 • THREE SHIFTS

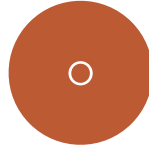
All crystallising in the first decades of the 1600s



Mathematics applied to reality

Never before systematically used to describe and unify real physical behaviour with predictive precision — Galileo and Kepler embody the change.

Falling bodies, projectiles, orbits



A corpuscularist turn

Aristotelian substantial forms give way to an explosive revival of corpuscular and atomist matter theory — no occult qualities, no purposes.

Descartes is the emblematic figure



New modes of study

Systematic observation, precise description, and — the point worth dwelling on — deliberate practical application.

Carries science to a non-scholarly public

First shift, embodied

It is Galileo and Kepler who embody the first shift: both apply mathematics not as an abstract, self-contained discipline but as a tool for describing — and unifying — real physical phenomena previously treated as belonging to unrelated domains (§3.3).

3.1 · CORPUSCULARISM

One mechanist wave, two different theories

“Corpuscularism” and “atomism” are related but not identical — a distinction worth keeping straight. Both currents count as part of the same anti-Aristotelian, mechanist revival; they are not the same theory.

Descartes — corpuscular, not atomist

Explicitly denies any void: for Descartes, extension and matter are the same thing, so empty space is a contradiction in terms. Matter is infinitely divisible — no ultimate, indivisible particles.

Gassendi — a deliberate atomist revival

Pierre Gassendi goes the other way, reviving the genuinely atomist physics of Epicurus (Chapter 1): indivisible atoms moving in a real void — and tries to reconcile it with Christian doctrine.

Why the distinction matters

Reading “corpuscularism” and “atomism” as interchangeable erases a live, contemporary disagreement — over the void, and over divisibility — inside the very movement that displaced Aristotelian substantial forms. Descartes and Gassendi agree on rejecting occult qualities; they disagree on what physically fills space.

3.1 · NEW MODES OF STUDY

Application, not argument, wins the public

- **Systematic observation and precise description** become a practice in their own right, alongside — not instead of — argument from principles.
- **Deliberate practical application** is not incidental: it is applications, more than any abstract argument, that carry the new science to a wide, non-scholarly public.
- **A popular constituency** instrument-makers, sailors, gunners, and surveyors see for themselves that the new mathematical methods produce results that work.

A genuinely new notion: progress

Tied to this popular constituency is a new idea — progress, understood as concrete, cumulative improvement in ordinary life, rather than the recovery of a fixed ancient wisdom. This is a departure from the humanist ideal that dominates the Renaissance's own self-image (§3.2, Stage Three): restoring the past, rather than surpassing it.

CHAPTER 3 · PARADIGM SHIFT AROUND 1600

How It Changed: From an Approximate Whole to a Precise Universe

Three stages of transmission — Islamic world, medieval Europe, Renaissance — carry the Greek inheritance to the threshold this chapter is about.

3.2 • THE FRAMEWORK

Two sources of knowledge, not yet fused

Summarising the whole of Chapters 1 and 2 in a single claim: essentially everything that happened in the Islamic world, medieval Europe, and the early Renaissance still operates within the frame the Greeks originally set, in which knowledge comes from two quite different sources.

Philosophy — approximate, but whole

Describes the whole of nature coherently and, in principle, completely — a genuine theory of everything, in the sense of the Hellenistic schools (Chapter 1, §1.4). But only approximately: not especially precise, and not reliably predictive.

Mathematics — precise, but narrow

A bubble of real precision, but not, over this whole period, systematically applied to the physical world. Too abstract, too simplified, to serve as a general description of reality — and developing on a track largely separate from natural philosophy.

The seventeenth century moves this course from that “approximate” way of thinking to the “universe of precision” we now take for granted — the three stages below carry the Greek starting point to that threshold.

3.2 · STAGE ONE — ISLAMIC WORLD

Refinement and correction, with one major exception

As Chapter 2 described, the Graeco-Arabic translation movement transmitted and substantially extended Greek mathematics and astronomy, but — with one major exception — introduced comparatively few conceptual novelties: refinement, extension, and correction of detail, rather than a new kind of mathematics.

- **The exception: algebra itself** The systematic treatment of equations developed by al-Khwārizmī and his successors has no close Greek precedent — a genuine Islamic-world innovation. Both the word “algebra” and the word “algorithm” descend from his treatise and his name.
- **Philosophy: syncretism, not new systems** The period is characterised more by combining and harmonising existing schools — above all Platonism and Aristotelianism — than by new philosophical systems; Aristotelianism retains clear overall dominance.
- **Mathematics and religion stay separated** Little integration of the one into the other, beyond a handful of bounded applications — see the noteCard alongside.

‘Ilm al-mīqāt

The mature discipline of “the science of timekeeping” used spherical astronomy and trigonometry to determine correct prayer times and the qibla (direction of Mecca) from any given location — genuinely sophisticated applied mathematics, but one whose scope stayed narrowly tied to specific religious observances, rather than expanding into a general programme of mathematising nature.

3.2 · STAGE TWO — MEDIEVAL EUROPE

A bounded academic freedom

Medieval Europe, as Chapter 2 detailed, inherits a similar dominance of Aristotelian philosophy, which tends to constrain rather than encourage new empirical or mathematical discovery; the Alexandrian mathematical tradition is, on the whole, neglected.

Augustine's two-tier division (Chapter 2, §2.2)

Faith and revelation hold final authority, while reason and the empirical study of nature occupy their own bounded, subordinate domain. The study of nature is not, as such, a religious matter — and this separation, precisely because it keeps nature outside the domain that could be charged with heresy, secures European natural philosophy a real, if bounded, academic freedom — markedly greater than the Islamic world's narrower, more strictly separated arrangement.

That freedom had limits — and the limit is worth illustrating together with the freedom, not only the freedom alone.

Next: the limit, in two trials

Giordano Bruno (1548–1600), a former Dominican friar, developed a radical cosmology and was burned at the stake in Rome — the first of two cases that show this freedom right up against its limit (following slides).

3.2 · STAGE TWO — MEDIEVAL EUROPE

Giordano Bruno: trial, execution, and a popular myth



A former Dominican friar, Bruno developed a radical cosmology — an infinite universe containing countlessly many worlds — and was tried by the Roman Inquisition and burned at the stake in February 1600.

Myth corrected: “executed for heliocentrism”

Bruno is very often presented as a scientific martyr executed for defending Copernican heliocentrism or the plurality of worlds. The surviving trial documentation does not clearly support this: the reconstructable charges are overwhelmingly theological — denial of the Trinity, of Christ's divinity, of the virgin birth, and, repeatedly, of transubstantiation. No formal Church ruling against heliocentrism as such yet existed in 1600 — the first dates to 1616, in connection with Galileo. His cosmological speculations were almost certainly discussed and may have counted among the charges, but treating them as the central or sole cause is considerably weaker than the popular legend suggests.

Monument, Campo de' Fiori, Rome (erected 1889) — itself a piece of the later, partly mythologised reception of Bruno.

3.2 · STAGE TWO — MEDIEVAL EUROPE

Two trials, a generation apart

Bruno, 1600

Theological charges, almost certainly discussed alongside cosmological speculation the trial record does not clearly foreground. Outcome: execution by burning.

Galileo, 1633

For advocating heliocentrism as physically, not merely hypothetically, true — after a 1616 Inquisition ruling against teaching it as established fact. Outcome: forced recantation and lifelong house arrest.

Galileo's trial is the much clearer instance of natural philosophy running directly into the limit of Augustinian academic freedom. Read together, the two trials show a real freedom to study nature operating right up against a real, and sometimes lethal, limit — not a simple age of faith with no space for inquiry, nor a simple war of science against religion.

A second popular myth, briefly flagged

A widely circulated claim holds Bruno was homosexual and that this played some unacknowledged part in his condemnation. Neither the 1576 Naples proceedings nor the surviving 1592–1600 trial charges anything of the kind — the reconstructable charges are exclusively the theological ones above.

3.2 · STAGE THREE — RENAISSANCE

Restoration in name, novelty in practice



Title page of Niccolò Tartaglia's *Nova Scientia* (1537) — a mathematical treatise on projectile motion, written in Italian rather than Latin, already announcing itself as new.

The Renaissance rediscovers the full range of Greek philosophical schools — not only Aristotle, but Platonism, Stoicism, Epicureanism, and, crucially, the Alexandrian mathematical and empirical tradition — restoring something closer to antiquity's own balance (Chapter 1, §1.4) after Aristotelianism's long medieval dominance.

The stated goal was restoration, not discovery. Humanist scholarship overwhelmingly aimed to restore lost or corrupted ancient knowledge; genuine discoveries, where they occurred, were often understood as a by-product of successful restoration.

And yet the word new keeps appearing. Nova / nuovo begins conspicuously to appear in book titles — and books increasingly appear in vernacular languages, not the Latin that had been the medieval university's single scholarly medium (Chapter 2, §2.1).

A stated programme of pure restoration and a genuinely new, vernacular, application-oriented science coexist — often in the very same books.

3.2 · STAGE THREE — RENAISSANCE

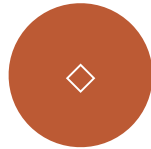
Renewed mathematical applications

This renewed, better-balanced access to the Alexandrian tradition drives a fresh search for mathematical applications:



Perspective

Worked out for painting — Brunelleschi's demonstrations, formalised in Leon Battista Alberti's treatise *Della Pittura* (1435).



Fortification

Geometry applied to military design — the trace-italienne bastion system, an explicitly mathematical response to cannon warfare.



Musical temperament

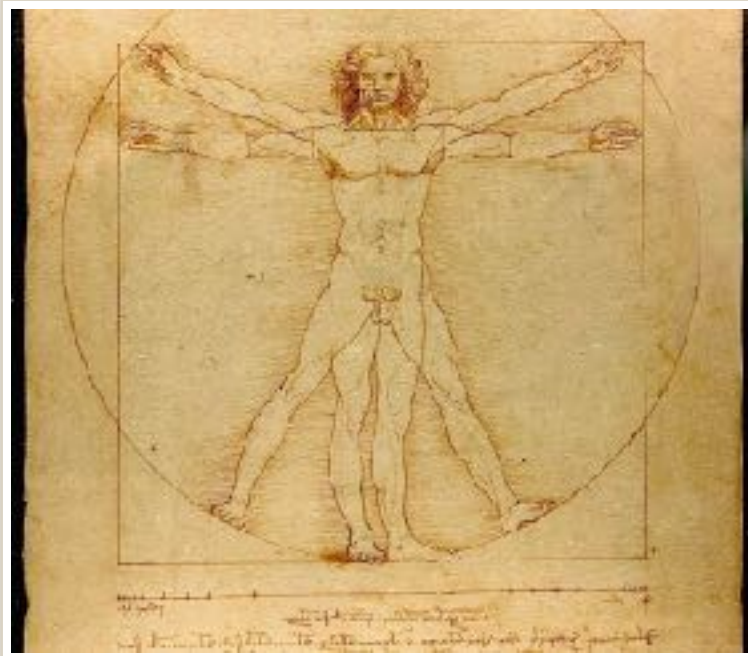
A live technical dispute — debated between Gioseffo Zarlino and Vincenzo Galilei, Galileo's own father.

Not a European invention of the idea itself

Comparable stirrings of mathematised, applied, empirically minded inquiry can be found in other times and places — this course does not claim Renaissance Europe invented the idea. What is distinctive is scale: nowhere else does this combination of restored learning, vernacular publication, and applied mathematics occur with anything like this density.

3.2 • STAGE THREE — RENAISSANCE

Three further, independently reinforcing developments



Leonardo da Vinci's Vitruvian Man (c. 1490): scientific proportion and artistic representation as a single act.



Martin Waldseemüller's world map (1507), the first to name "America" — the cartographic response to the discovery of the New World.

Cartography

Waldseemüller (1507) and Mercator's 1569 projection, designed for practical navigation.

Artistic revolution

The boundary between scientific and artistic representation blurs — Leonardo's drawings, and Brunfels's illustrated herbal (1530), with woodcuts drawn from living specimens.

Mechanics for labour

Mining, lifting, milling machinery — Agricola's *De Re Metallica* (1556), Ramelli's *Le Diverse et Artificiose Machine* (1588).

3.2 · STAGE THREE — RENAISSANCE

A genuine democratisation of science

The cumulative social effect: artisans, instrument-makers, gunners, and navigators — people with no stake in the learned, Latinate culture of the universities — directly experience the gains these applications deliver, creating broad, popular support the learned culture alone could never have generated.

In turn, this restores something like the balance between science and religion so heavily tilted since Europe's Christianisation (Chapter 2, §2.1): natural philosophy regains real social standing, not by winning an abstract argument, but because it visibly worked for a wide cross-section of the population.

Closing the transmission story

By the end of the Renaissance, all three stages of §3.2 converge: an enlarged mathematical corpus (Stage One), a bounded but real academic freedom (Stage Two), and a rediscovered, better-balanced, vernacular and applied learning culture with a genuinely popular constituency (Stage Three). What remains missing — and what §3.3 turns to — is the decisive fusion of exact mathematics with the whole of physical reality, not merely a handful of applications.

CHAPTER 3 · PARADIGM SHIFT AROUND 1600

Why Did This Revolution Never Reverse? Kepler, Galileo, and the Turn to Precision

Alexandria already had mathematical applications to nature — and that episode still receded. This time, the fusion holds.

3.3 · THE ALEXANDRIAN LIMIT

Exact mathematics, idealised objects

Alexandria, after all, already had real mathematical applications to nature — planetary astronomy, the geometry of mirrors, the law of the lever — and that episode did not lead to a lasting, self-sustaining scientific culture; it eventually receded (Chapter 1, §1.8). Why has the seventeenth-century shift, by contrast, never gone into comparable reverse?

The answer turns on the quality of the link to reality in each case:



Planetary models represent orbits with combinations of perfect circles, without reference to the planets' actual physical shape, size, or the play of forces between them.



Geometrical optics analyses idealised mirrors, not the imperfections of any mirror actually ground and polished.



The law of the lever holds exactly for an idealised rigid, weightless beam, not for any real lever with mass, flex, and friction.

The mathematics itself was flawless — the derivations perfectly valid — but it was a mathematics of idealised objects standing at one remove from messy physical reality, applied narrowly, and never extended into a general method.

3.3 • KEPLER

Putting objects onto mathematics



Johannes Kepler (1571–1630). Traditional portrait.

Kepler's three laws of planetary motion (1609 and 1619) replace circular, idealised orbital models with a mathematical description — the ellipse, the equal-area law, the relation between orbital period and orbital size.

An ontological claim, not just a calculating device

Kepler insisted this was not merely a convenient calculating device but a literally true description of how the planets actually move: the mathematics is asserted to describe what really exists and really happens — not simply to reproduce observed appearances (“saving the phenomena,” the older, more modest astronomical tradition Kepler was explicitly breaking with).

Real astronomical bodies, and their actual behaviour, is what a precise mathematical law now describes.

3.3 • GALILEO

Putting mathematics onto objects — all objects



Galileo Galilei (1564–1642). Traditional portrait.

“Philosophy is written in this grand book — I mean the universe — which stands continually open to our gaze, but it cannot be understood unless one first learns to comprehend the language in which it is written. It is written in the language of mathematics...”

— Galileo Galilei, *Il Saggiatore* (The Assayer), 1623

Not necessarily the first to hold this view, but its decisive populariser, Galileo takes the further, sweeping step of declaring mathematics the language of absolutely everything in nature — decisively including ordinary terrestrial motion (falling bodies, projectiles, pendulums) that Aristotelian physics had always treated as governed by entirely different principles from the celestial realm.

This same precise, predictive mathematical description is owed to every corner of nature, not to a privileged few.

3.3 · WHY IT NEVER REVERSED

A fusion, not one more redistribution

Kepler puts objects onto mathematics — takes real astronomical bodies and insists their actual behaviour is what a precise law describes — while **Galileo puts mathematics onto objects, and onto all objects** — insists this same description is owed to every corner of nature.

Once both moves are made together, the earlier, Alexandrian pattern — exact mathematics confined to a small number of idealised, narrowly applied cases — is no longer a stable resting point: either mathematics describes nature everywhere and exactly, or the mathematics that manifestly does work for the planets and for falling bodies alike demands an explanation for why it should stop working anywhere else.



Kepler (1571–1630) — objects onto mathematics.



Galileo (1564–1642) — mathematics onto all objects.



Descartes (1596–1650) — the corpuscular philosophy behind them (§3.1).

LOOKING AHEAD

A gap closed, and a programme still to build

This chapter has argued that the early seventeenth century's real novelty was not any single discovery but the closing of a gap that had stood open since Alexandria: between mathematics precise enough to be trusted and a natural philosophy ambitious enough to describe everything. Kepler and Galileo, backed by a corpuscular philosophy of matter and a newly practical, applied, and popularly supported culture of inquiry, fused the two.

The chapters that follow ask:

what this fusion built next — an experimental and institutional programme (Bacon, the learned societies) and a mechanical philosophy of the whole cosmos (Newton) that between them turn Kepler's and Galileo's initial moves into a durable, self-sustaining science.

FURTHER READING

- Alexandre Koyré, *From the Closed World to the Infinite Universe* (1957)
- Alexandre Koyré, *The Astronomical Revolution: Copernicus, Kepler, Borelli* (1973)
- David C. Lindberg & Robert S. Westman (eds.), *Reappraisals of the Scientific Revolution* (1990)
- Steven Shapin, *The Scientific Revolution* (1996)
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- Maurice A. Finocchiaro, *The Trial of Galileo: Essential Documents* (2014)
- David A. King, *Astronomy in the Service of Islam* (1993)
- William R. Shea & Mariano Artigas, *Galileo in Rome* (2003)
- Stephen Gaukroger, *Descartes: An Intellectual Biography* (1995)

Chapter 3

Questions?

Next: the experimental and institutional turn — Bacon, the learned societies, and Newton