

Medieval knowledge

Science across cultures

Lecture 3 · ENG 151

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In 425, Theodosius II organized higher teaching in Constantinople with 31 publicly supported chairs.

Greek and Latin grammar and rhetoric stood alongside law and philosophy. Education served an empire that needed trained officials.

The Pandidakterion connects the history of higher learning with a city whose streets and monuments we can still visit.



A manuscript scene of learned discussion

425: education and public service

The teaching programme joined the study of language with rhetoric, law and philosophy.

Rhetoric trained students to construct and present an argument. Law and advanced literacy mattered in government and administration.

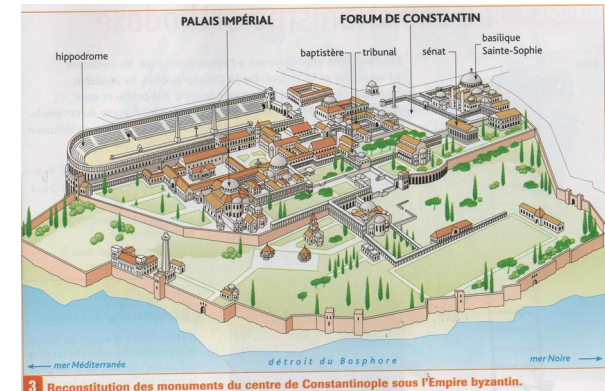
A government that supports teachers helps determine which knowledge becomes available to the next generation.

Constantinople: the imperial city

The maps place the palace district within the historic peninsula of Istanbul.

Higher learning operated close to the demands and resources of imperial government.

The city makes our opening question concrete: how does political power create conditions in which learning can prosper?



Historic peninsula map and reconstruction

The city beneath Sultanahmet

Around Sultanahmet, the imperial city survives among later buildings and everyday streets.

These views bring an apparently distant history into a place close to us.

What remains visible of a society's investment in learning? Buildings are one trace; texts and teaching traditions are others.



Photographs of structures in Sultanahmet

The palace and its surroundings

The Great Palace complex helps us picture the imperial setting of the Magnaura school.

Court support could bring teachers and pupils together and make specialist study possible.

A reconstruction helps us imagine that setting, while surviving evidence limits what we can know about each building.



Two reconstructions of the imperial setting

9th–11th centuries: higher learning

In the ninth century, Bardas supported teaching at the Magnaura, associated with Leo the Mathematician.

In 1045, new arrangements supported law and philosophy under Constantine IX.

These renewals show how leadership could strengthen learning. Sustained education also needed teachers and successors.



Reconstruction of Constantinople around 1200

Istanbul around 1200

Imagine the city as an active capital, with administrators, teachers, craftspeople and students.

The urban reconstruction and surviving objects connect intellectual life with the wealth and activity of the capital.

Learning belonged to this wider society. It depended on people and resources as well as books.



Bronze horses and a reconstruction of Constantinople

University of Constantinople: continuity

Greek literature and philosophy continued to supply material for advanced study in a Christian empire.

Teaching took several forms: imperial and private schools, church settings and individual scholars.

This was a long educational tradition, with interruptions and renewals, rather than one unchanged institution.



Architectural details in reused structures

1204 and 1453: changes in the city

The conquest of 1204 disrupted the imperial capital. Later Byzantine scholars continued higher learning in changed conditions.

The Ottoman conquest of 1453 opened another chapter in the city's institutional history.

A place can remain a centre of learning even while its government and educational institutions change.



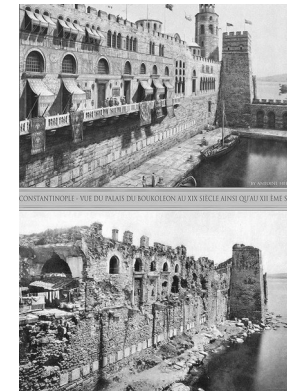
Masonry detail and a historical urban photograph

Historic places and later uses

The hotel view and historical Boukoleon images connect the Byzantine city with later Istanbul.

The same urban area can acquire very different uses. Its earlier story may become difficult to recognize.

Remembering that story is part of understanding our own city's relationship with knowledge and institutions.



Hotel setting and historical views of Boukoleon

Boukoleon and the memory of a city

The palace remains make the passage of time visible. The photographs record different conditions around them.

Physical remains can survive after the institutions around them have changed.

Our opening question stays with us: what must a society sustain if its learning is to outlive a generation?



Two views of Boukoleon; photograph dates unspecified

Knowledge across cultures

How did people preserve knowledge while also changing it?

Our focus is roughly 500–1500, across connected regions with different political histories.

Follow people, books and techniques. Ask who supported their work and who could gain access.



Geometrical learning in a manuscript illustration

The route through this lecture

After our opening visit to Constantinople, we return to the chronological history of knowledge across cultures.

We follow Indian mathematics and Arabic scholarship century by century, including later examples and a deliberate eighteenth-century pause.

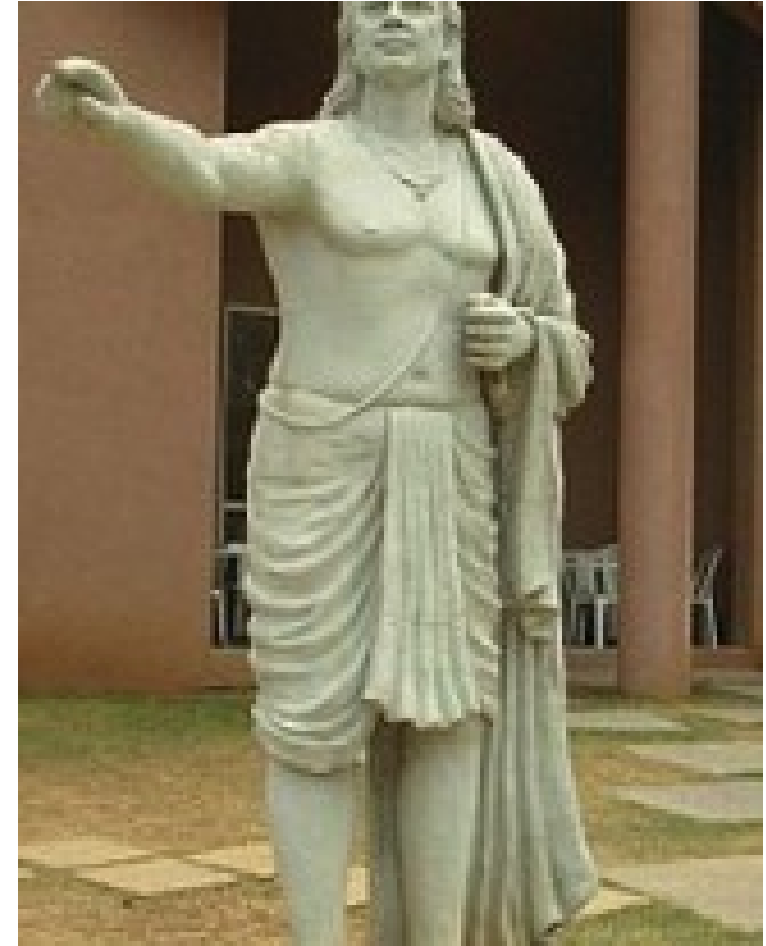
We then follow the overlapping medieval story in Latin Europe before connecting it with the Renaissance.

Aryabhata and Brahmagupta

Aryabhata's Aryabhatiya (499) joins mathematical calculation with astronomy.

Brahmagupta's work of 628 gives rules involving zero and negative quantities. Some rules differ from modern arithmetic.

Indian mathematical traditions became important sources for later Arabic scholarship.



Modern statue commemorating Aryabhata

A numeral is more than a symbol

In a place-value system, the position of a digit contributes to its value. Compare 52 and 502.

Zero can mark an empty position. Treating zero as a number raises further questions about operations.

Notation becomes useful through teaching and reliable calculation methods, not through symbol shapes alone.

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Different written forms for numbers

Practical knowledge in Byzantium

Medicine, engineering and military techniques existed beside the study of authoritative texts.

Greek fire illustrates a technology whose preparation and use depended on specialist knowledge.

A picture of a weapon tells us about its representation. It cannot by itself establish an exact chemical recipe.



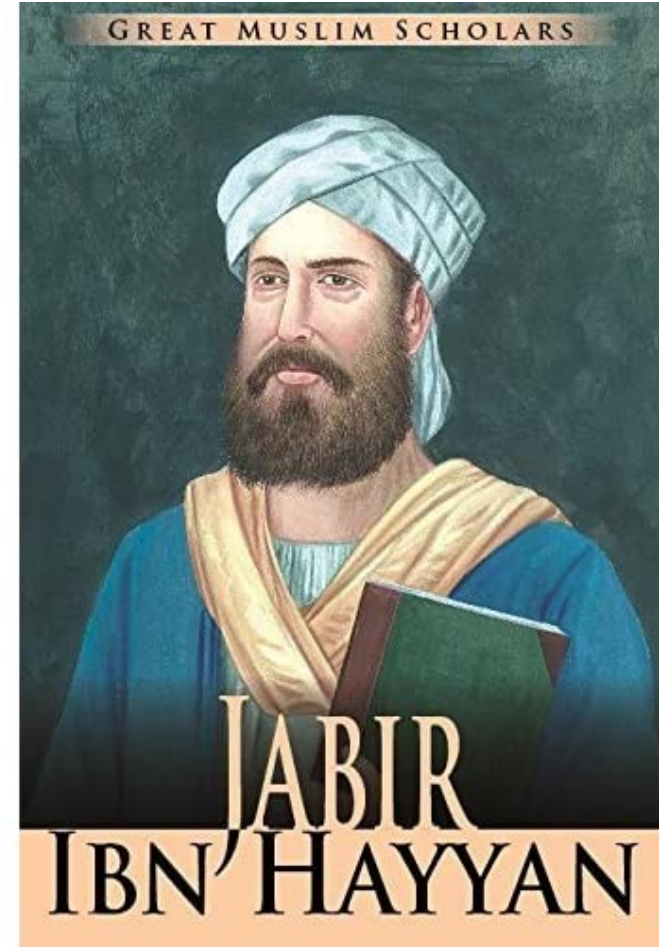
Manuscript depiction of an incendiary weapon at sea

8th century: Jabir and alchemy

Heating, distillation and work with minerals supported practical experience with substances.

The writings attributed to Jabir ibn Hayyan form a complicated textual tradition, with disputed authorship and dates.

Alchemy helped develop techniques while also pursuing goals and explanations different from modern chemistry.



Later imagined portrait of Jabir ibn Hayyan

8th–9th centuries: Arabic scholarship

The Islamic world included many regions, dynasties and languages. It was never a single unchanging research institution.

Muslim, Christian, Jewish and other scholars contributed to work written in Arabic.

Greek, Syriac, Persian and Indian traditions entered new settings through translation, teaching and debate.

9th century: translation

A translator must understand the subject as well as the languages. Technical words rarely match perfectly.

Scholars compared manuscripts, explained difficult passages and made texts useful to new readers.

Hunayn ibn Ishaq and his collaborators helped make Greek medicine accessible through Syriac and Arabic.

9th century: patronage and books

Abbasid Baghdad became an important centre for translation and scholarship. Patrons commissioned useful and prestigious work.

Libraries mattered, but so did households, teachers and professional networks.

“House of Wisdom” is a useful historical name. It should not make us imagine that all scholarship occurred in one modern-style university.

9th century: al-Khwarizmi

Al-Khwarizmi's ninth-century work organized procedures for solving equations.

His algebra used verbal reasoning and geometrical justification, rather than our modern symbolic notation.

Practical concerns included inheritance and measurement. A reusable method could serve many problems.



Modern monument to al-Khwarizmi

An algebra example

In modern notation: $x^2 + 10x = 39$. We seek a positive length.

Add 25 to both sides: $(x + 5)^2 = 64$. Then $x + 5 = 8$, so $x = 3$.

Check: $9 + 30 = 39$. The example shows a repeatable procedure. Modern symbols here explain a historical verbal method.

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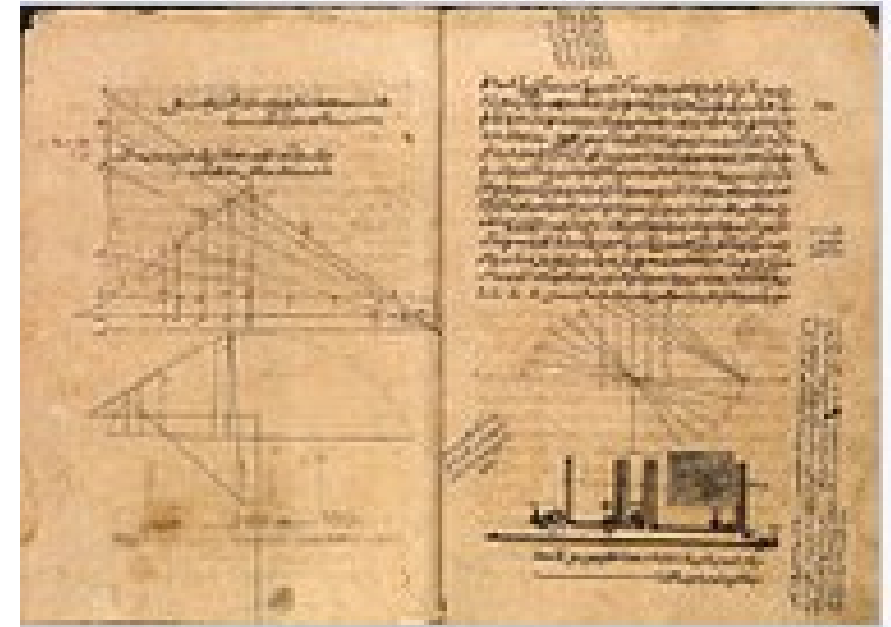
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9th century: Thabit ibn Qurra

Thabit, from Harran, worked on translations and mathematical problems in Baghdad.

Editing a Greek work required mathematical judgment. Translation and original investigation could reinforce each other.

His work on amicable numbers offers an example of interest in relationships within arithmetic.



Pages from Thābit's
Arabic translation of
Apollonius' *Conics*

Pages identified as Thabit's translation of Apollonius

An arithmetic curiosity

The proper divisors of 220 sum to 284. The proper divisors of 284 sum to 220.

For 284: $1 + 2 + 4 + 71 + 142 = 220$. These are called amicable numbers.

This pair was known before Thabit. His contribution involved a method for finding pairs, not inventing this example.

9th–11th centuries: medicine

Al-Razi drew on earlier medical learning and clinical observations. Ibn Sina's Canon organized medical knowledge systematically.

Texts travelled, but effective care also depended on practitioners, training and local institutions.

Historical importance does not make every old treatment effective. We distinguish influence from modern medical validation.

10th century: calculation systems

Finger reckoning, sexagesimal calculation and Indian place-value arithmetic coexisted.

Different users needed different tools. Base 60 remained useful in astronomy and angles.

Al-Uqlidisi adapted Indian arithmetic for written work on paper in the tenth century. Adoption involved changes in practice.

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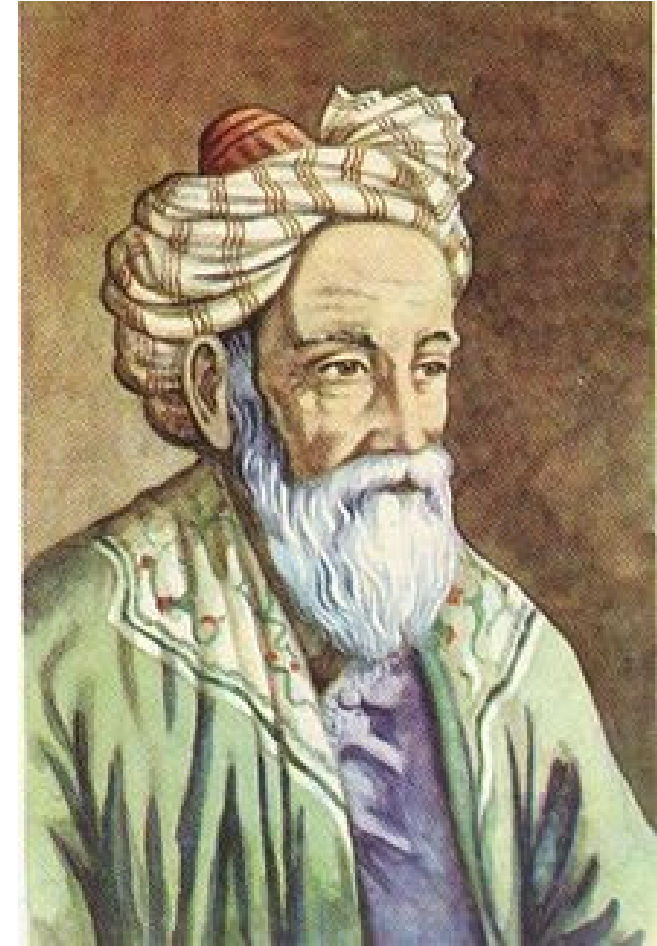
Babylonian numerals: a base-60 comparison

11th century: Omar Khayyam

Omar Khayyam studied cubic equations through geometry and worked on calendar reform.

An observatory needed patronage, instruments and sustained observations, as well as skilled individuals.

Poetry and mathematics were parts of a broader learned culture. Present-day disciplinary boundaries fit it imperfectly.



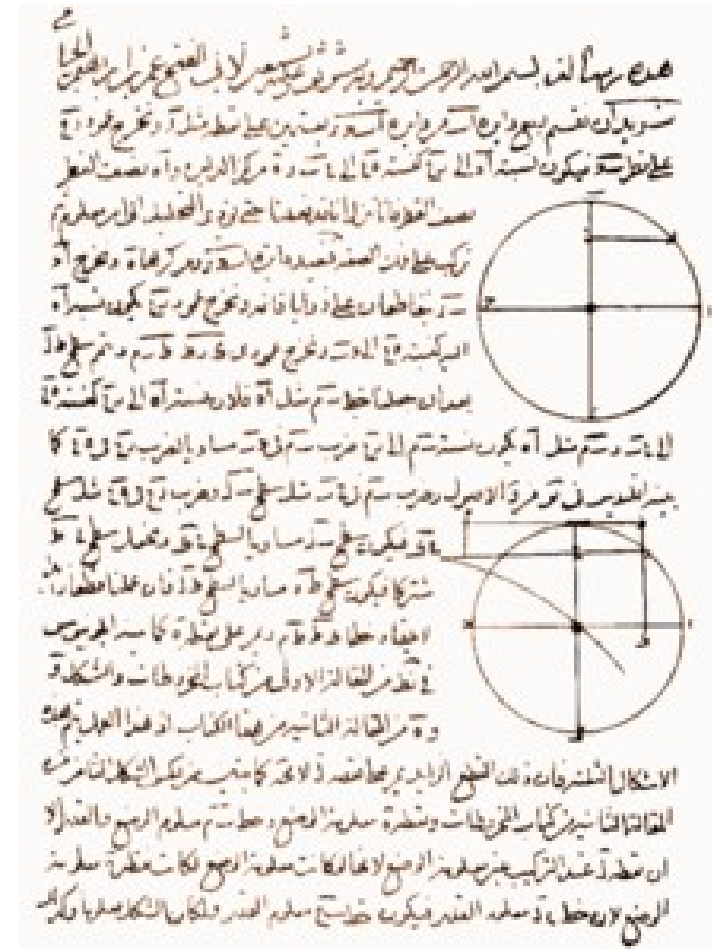
Later representation of Omar Khayyam

11th–12th centuries: geometry

Conic sections offered geometrical methods for investigating cubic equations.

The accompanying manuscript image recalls the close connection between a written argument and its diagram.

Detailed methods are optional depth here. The main idea is that problem solving developed within several mathematical traditions.



Manuscript image associated with Khayyam's geometrical work

Astronomical knowledge served calendars, timekeeping and the determination of directions.

Tables expressed calculations in a form that other people could consult and use.

An instrument joins a mathematical model with skilled construction. Its usefulness depends on observation and correct operation.

12th century: mathematical inquiry

Al-Samawal developed algebraic methods, including work with polynomials and powers.

Sharaf al-Din al-Tusi investigated cubic equations and the conditions under which solutions exist.

These examples continue the mathematical story after Khayyam. Different approaches could illuminate the same kind of problem.

13th century: al-Jazari's mechanisms

The Banu Musa and al-Jazari described ingenious devices involving water, moving parts and controlled sequences.

Al-Jazari completed his book in 1206 in the Artuqid setting of northern Mesopotamia.

An automatic action follows an arranged mechanism. Calling a device a “robot” can help comparison, but needs historical care.

14th–15th centuries: Ulugh Beg

Ulugh Beg (1394–1449) supported an observatory and mathematical scholarship at Samarkand.

Born in the fourteenth century, he carried out this programme in the fifteenth. Accurate astronomical tables required sustained collective effort.

His career also reveals the vulnerability of scholarship tied to political power.



Ulugh Beg memorial and monumental architecture in Samarkand

15th century: al-Kashi

Al-Kashi worked on arithmetic and demanding astronomical calculations in the fifteenth century.

His writings include decimal-fraction methods and a highly accurate calculation of pi.

Precision required a procedure that others could follow and check. Instruments alone could not supply it.



A mathematical manuscript associated with al-Kashi

15th century: algebraic notation

Al-Qalasadi (1412–1486) used abbreviated signs in mathematical writing.

These practices developed within an existing tradition. A useful notation did not appear fully formed in one person's work.

Abbreviations make repeated operations easier to write, but readers must learn their meaning.

17th century: Muhammad Baqir Yazdi

Muhammad Baqir Yazdi completed his arithmetic work ‘Uyun al-hisab in 1637.

His work includes the amicable pair 9,363,584 and 9,437,056, extending the number-theory thread we met with Thabit.

A long mathematical tradition could still produce results. This makes the question of changing scientific activity more specific.

18th Century

Decline: what changed?

The sack of Baghdad in 1258 caused destruction and disrupted institutions.

Yet mathematical and astronomical work continued in other centres. One city's catastrophe is not an end date for an entire scientific tradition.

Maragha and later Samarkand help us ask where support and expertise moved.



Historical depiction of conflict

Discussion: why does science prosper?

We have followed a long sequence of achievements, then reached an empty century marker.

What could explain a change in the pace, visibility or support of scientific work?

Consider institutions, political decisions, conflict and education. Test each explanation against particular places and periods.



Historical representation of warfare

Paper and the circulation of knowledge

Papermaking developed in China and spread across connected regions over centuries.

Copyists needed materials, skill and time. More available paper could support the production and circulation of books.

A route on a map is only a beginning: people had to learn production methods and establish workshops.

Craft knowledge and useful objects

Mills used flowing water or wind to perform work. Their operation depended on local conditions and maintenance.

Spinning, clocks and spectacles changed particular tasks. Technical improvement did not always begin with a new scientific theory.

The spinning-wheel photograph shows how hand skills and a mechanism work together. It does not date the invention.



A person operating a spinning wheel

12th century: translation into Latin

From the twelfth century, translation in places such as Toledo widened access to Arabic and Greek scholarship.

Translators worked across religious and linguistic boundaries, often with local collaborators.

The texts included new Arabic scholarship as well as ancient works. Europe received an enlarged body of knowledge.



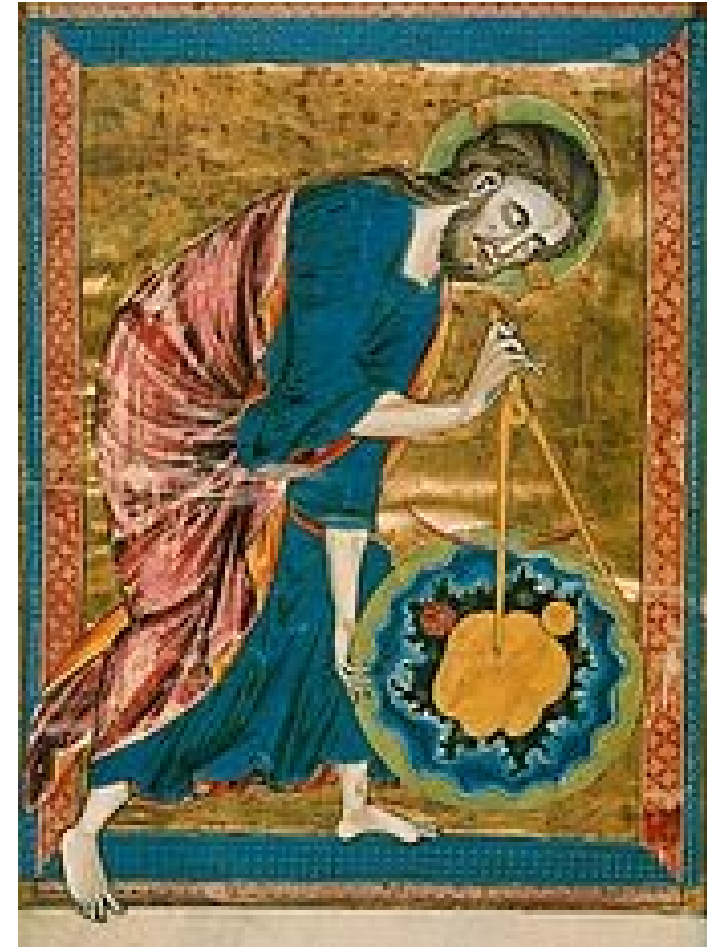
Toledo Cathedral: an institutional setting for learning

12th–13th centuries: universities

Bologna, Paris and Oxford developed as communities with teaching practices and recognized qualifications.

Natural philosophy, logic and medicine gave students structured ways to study and debate authoritative works.

Different forms of higher learning existed elsewhere. “First university” depends on what institutional features we mean.



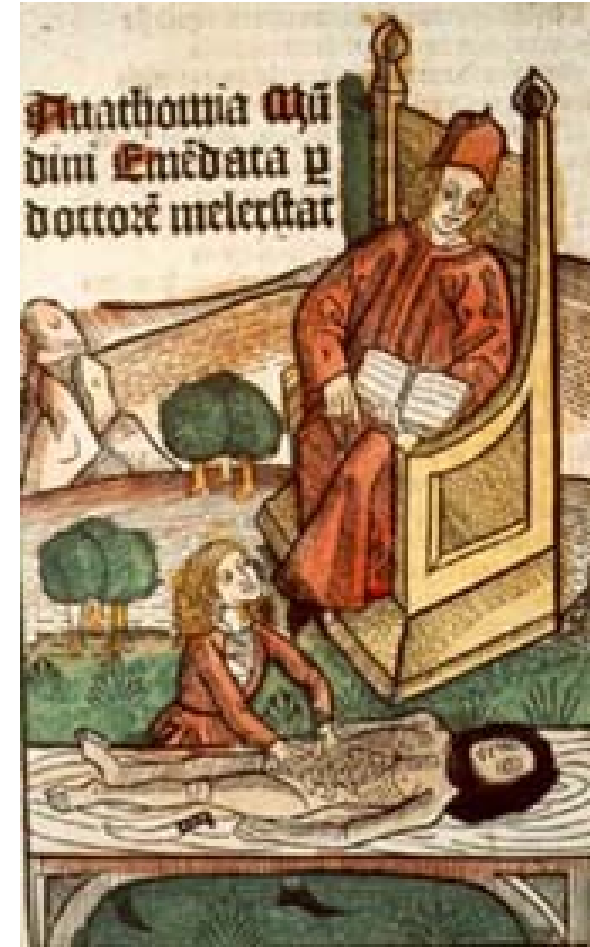
A medieval image of creation through geometry

14th century: anatomy teaching

Medieval medicine combined written authorities with teaching and practical encounters with patients.

Anatomical dissection became part of teaching in settings such as Bologna. Mondino's fourteenth-century text became influential.

The picture stages a lesson: readers, demonstrators and observers may perform different roles.



An illustrated anatomy lesson

14th century: Buridan and motion

Scholastic commentary could include criticism of an authority, not simply agreement.

Buridan used the idea of impetus to explain why a projectile continues after leaving the thrower.

This theory belongs to its own framework. It should not be treated as identical to Newton's later account of motion.

14th century: the Oxford Calculators

Fourteenth-century scholars associated with Merton used mathematical reasoning to investigate change and motion.

They explored how quantities could vary, even when direct measurement remained difficult.

This made motion a subject for mathematical comparison before the later experimental mechanics of the Scientific Revolution.



A printed mathematical text associated with this tradition

A motion example

Illustrative modern example: a speed rises uniformly from 0 to 10 metres per second over 4 seconds.

Its average is 5 metres per second. Distance = $5 \times 4 = 20$ metres.

The result depends on uniform change. The same starting and ending speeds alone do not determine the distance.

Travellers and routes

Trade routes connected communities across Eurasia.
Travellers carried information alongside goods.

Mongol rule facilitated some long-distance movement, while conquest also caused severe destruction.

A travel report provides evidence of contact, but it needs scrutiny about what the traveller saw, heard or repeated.



Travellers represented in a historical map

13th–14th centuries: exchange

Byzantine scholars did more than preserve texts that later travelled west.

Gregory Chioniades studied Persian astronomy and translated material into Greek around the turn of the fourteenth century.

Knowledge moved in several directions. Translators changed which traditions readers could use.

After 1453: a longer transition

Greek scholars and manuscripts contributed to Italian learned culture before and after Constantinople fell in 1453.

Migration was one process among others, including earlier translations and the growth of institutions.

The Renaissance did not begin suddenly when a single city fell. Lecture 4 follows these overlapping developments.



Eastern Mediterranean political map, labelled 1450

What sustains learning?

Consider a ruler who funds an observatory but restricts the circulation of its results.

What might improve immediately? What might remain vulnerable?

Compare money and equipment with trained successors, freedom to question and access to records.

Funding can support instruments, salaries and time for careful work. It may produce useful observations.

Restricted circulation makes independent checking and wider teaching harder. Reliance on one patron can leave a fragile institution.

Durable support combines resources with practices that allow knowledge to survive people and political changes.

Review questions

How can translation create knowledge rather than merely transport it? Give one example.

Why did several numeral systems coexist? Explain a connection between a method and its users.

How does Samarkand challenge a simple “science ended in 1258” story?

Translation can require correcting a text and explaining a method. Thabit's mathematical work illustrates this active role.

Astronomers could use base 60 while other users adopted decimal arithmetic. Familiar tools and tasks shaped choices.

Fifteenth-century Samarkand supported significant astronomy. We must distinguish local disruption from the history of an entire region.

The medieval contribution

Knowledge survived through repeated work: copying, teaching, criticism and practical use.

Scholars developed new mathematics and techniques while drawing on earlier traditions.

The next lecture follows printing, new observations and debates over authority into the early modern world.

Reference: scholars and representations

Later portraits help communities remember scholars. They do not necessarily preserve a contemporary likeness.

The Harran location map places Thabit's background in a recognizable region.

A manuscript page is a different kind of evidence: its text and diagrams can be examined directly.



Later portrait of al-Kindi and a map locating Harran

Reference: buildings and craft

Vaults and other structural forms required practical geometrical judgment and skilled building work.

Religious institutions could also organize labour and economic activity.

These photographs illustrate architecture. They do not directly show a medieval furnace or establish an invention date.



Church ruins and a vaulted interior

Reference: an attempted flight

A medieval account describes Eilmer of Malmesbury attempting to fly with attached wings and suffering injuries.

The story survives through a later written account. The stained glass is a representation of remembrance.

We can discuss curiosity and failed trials without treating the reported flight distance as a modern measurement.



Stained-glass representation of Eilmer

Sources for further study

MacTutor, University of St Andrews: Indian and Arabic mathematics, Khayyam, Ulugh Beg and al-Kashi.

US National Library of Medicine and the Metropolitan Museum of Art: manuscripts, medicine, astronomy and mechanical devices.

Cambridge, Stanford Encyclopedia of Philosophy and university histories: institutions, translation and medieval natural philosophy.