

# Late Medieval Philosophy

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# What the Middle Ages knew

- Before the Scholastics
  - The Bible is infallible, therefore there is no need for scientific investigation or for the laws of logic
  - Conflict between science and religion due to the Christian dogma that the Bible is the truth
  - 1. Dangerous to claim otherwise
  - 2. Pointless to search for additional truths
  - Tertullian (3rd c AD): curiosity no longer necessary because we know the meaning of the world and what is going to happen next ("Liber de Praescriptione Haereticorum")

# What the Middle Ages knew

- Before the Scholastics
  - Decline of scientific knowledge
    - Lactantius (4th c AD) ridicules the notion that the Earth could be a sphere ("Divinae Institutiones III De Falsa Sapientia Philosophorum")
    - Cosmas Indicopleustes' "Topographia Cristiana" (6th c AD): the Earth is a disc

# What the Middle Ages knew

- Before the Scholastics
  - Plato's creation by the demiurge in the Timaeus very similar to the biblical "Genesis"
  - Christian thinkers are raised by neoplatonists
    - Origen was a pupil of Ammonius Sacca (Plotinus' teacher)
    - Augustine studied Plotinus

# What the Middle Ages knew

- Preservation of classical knowledge
  - Boethius (6th c AD) translates part of Aristotle's "Organon" and his "Arithmetica" preserves knowledge of Greek mathematics
  - Cassiodorus (6th c AD) popularizes scientific studies among monks and formalizes education ("De Institutione Divinarum" and "De artibus ac disciplinis liberalium litterarum") with the division of disciplines into trivium (grammar, rhetoric, dialectic), which are all about words, and quadrivium (arithmetic, geometry, music, astronomy), which are all about numbers
  - Isidore of Sevilla (7th c AD) preserves Graeco-Roman knowledge in "De Natura Rerum" and "Etymologiae" (an encyclopedia in 20 volumes)

# What the Middle Ages knew

- Preservation of classical knowledge
  - Bede (8th c AD) compiles an encyclopedia, "De Natura Rerum"
  - St Peter's at Canterbury under Benedict Biscop (7th c AD) becomes a center of learning
  - Episcopal school of York: arithmetic, geometry, natural history, astronomy.
  - York's pupil Alcuin in 780 hired by Charlemagne and in 796 retires to the abbey of St Martin of Tours
  - Alcuin's pupil Hrabanus Maurus (9th c) becomes archbishop of Mainz and writes the encyclopedia "De Universo" (based on Isidore and Bede)
  - Isidore and Hrabanus defend atomism

# What the Middle Ages knew

- Preservation of classical knowledge
  - Gerbert of Aurillac (10th c) improves the abacus according to the Arabic numerals, introduces mathematics and astronomy at the school of Rheims, and becomes Pope Sylvester II
  - Gerbert's pupil Fulbert moves to the School of Chartres, which becomes a center of learning (peaking with Bernard and Thierry in the 12th c) (“De Sex Dierum Operibus” reconciles Platonic philosophy and Bible)
  - 12th c: Plato revered as a pioneer of Christian thought, Aristotle only known as a logician (“Organon”)
  - 13th c: Aristotle completely translated from Arabic

# What the Middle Ages knew

- The Aristotelian dogma
  - Initially the Church doesn't like Aristotle because he preaches an uncreated eternal universe (Honorarius III, Gregory IX and Urban IV forbid the teaching of his metaphysics)
  - Franciscan and Dominican intellectuals bridge Christian dogma and Aristotle's metaphysics: Alexander of Hales (Franciscan), Albert von Bollstadt/ Albertus Magnus (Dominican)
  - Thomas Aquinas (Dominican): A fully Christianized Aristotle
  - Adopting Aristotle allows them to harmonize theology/philosophy and science
  - When the Church adopts Aristotle, Aristotle becomes a dogma too, as much as the scriptures

# What the Middle Ages knew

- Influence on Persian philosophy
  - Nestorians found a school of learning at Edessa (5th c), moved in 489 to Nisibis under Persian rule
  - Expelled Greek philosophers move to Persia (Gundi-Sapur Univ) under Persian emperor Chosroes
  - Nestorians and Monophysites found schools of learning in Persia (eg Sergius of Resaina who translates Greek classics into Syriac)

# What the Middle Ages knew

- Center of transmission of Arabic knowledge
  - Sicily: West meets Arab and Byzantine civilizations and Frederik II opens school of translation
  - Notably: Henricus Aristippus commissions and/or provides the first Latin translation of Ptolemy's "Almagest" from the Greek original in 116# and the first Latin translation of Plato's "Phaedo" in 1160
  - Salerno's medical school (10<sup>th</sup> c)
  - Montecassino: Constantinus Africanus (11<sup>th</sup> c) travels, collects and translates Arabic and Greek manuscripts into Latin

# What the Middle Ages knew

- Center of transmission of Arabic knowledge
  - Adelard of Bath translates Euclid's "Elements" from Arabic into Latin (1120) and translates Al-Huwarizmi's "Arithmetica" that uses the "Arabic" numerals
  - Toledo (conquered by Christians in 1085): archbishop Raymond sets up a college of translators, notably Gerardus Cremonensis translates Ptolemy's "Almagest" into Latin (1175)

# What the Middle Ages knew

- Aristotelian-Ptolemaic model of the universe:
  - Earth at rest in the center
  - Ultimate sphere also at rest
  - Concentric circles in motion
  - Hierarchically organized spheres

# What the Middle Ages knew

- Scholasticism (1050)
  - Reason can prove the Christian revelation
  - Philosophy and science of Aristotle
  - Systematic understanding of Nature and Christianity
  - Monasteries
  - God is the source of both scientific and religious phenomena
  - God is truth
  - Therefore science must be consistent with religion
  - Averroes: two truths, one the approximation of the other
  - Scholastics: only one truth

# What the Middle Ages knew

- Scholasticism (1050)
  - Reconciling the teachings of Aristotle with Christian theology
  - Problems with Aristotle:
    - Matter pre-existed the prime mover (“Physics”)
      - Ibn Rushd: the universe is both eternal and created by God
    - The mind dies when the body dies (“Ethics”)
    - “Physics” and “Ethics” are banned by the Pope in 1210
    - Only the “Logic” can be taught
    - 1277: The bishop of Paris, Stephen Tempier, issues the 219 condemnations: prohibits the teaching of 219 philosophical and theological theses

# What the Middle Ages knew

- Scholasticism (1050)
  - Peter Lombard’s five fundamental topics of scholasticism:
    - God
    - Creation
    - Incarnation
    - Redemption
    - Sacraments (seven) by which divine grace is transmitted to humans
      - Baptism removes the original sin
      - Confession removes this life’s sins
      - Eucharist
      - Sacraments can only be administered by priests

# What the Middle Ages knew

- Universities
  - 9th c: Charlemagne orders that all churches must provide schools for clerics (reading, writing, music, arithmetic)
  - Until the 11th c the intellectual life of Europe was relegated to monasteries
  - Reform movements downplay education in monasteries
  - They are not founded but formed spontaneously by networks of students and teachers
  - There is no building
  - “Universitas” means an association/guild
  - 11th c: cathedral schools (Canterbury, Chartres, Orleans, Notre Dame) created around the newly built cathedrals to teach more practical topics

# What the Middle Ages knew

- Universities
  - Original mission: training not research (train doctors and theologians), not creation of new knowledge but transmission of canonical knowledge
  - Needs of 11th century Europe: medicine (no guild for doctors) and law (investiture controversy)
  - Loose control of authorities turns them into places for debate, not training (unlike China and Islam)
  - The high mobility of the age (pilgrims, traders, troubadours, soldiers) transfers to education and students travel just to learn
  - The scholarly equivalent of a pilgrimage site

# What the Middle Ages knew

- Universities
  - In the 13th c, monasteries lose the monopoly on spiritual perfection
  - Secularization of the mystical experience (lay people can also achieve unity with God while remaining in the world)

# What the Middle Ages knew

- Universities
  - Al Azhar, Cairo (988)
  - Medical school: Salerno (11th c)
  - Law school: Bologna (1088)
  - University
    - Paris (1150): the French kings encourage education among clerics
    - Oxford (1167): benefits from Paris' 1229 student riots

# What the Middle Ages knew

- Universities
  - Cathedral schools
    - Several liberal arts
      - Boethium’s Quadrivium (“mathematical” disciplines to conduct scientific research): Arithmetic, Geometry, Music, Astronomy
      - Trivium (“verbal” disciplines to express the results of such research): Grammar, Rhetoric, Logic (recently discovered Aristotelian logic)
    - Chartres: mostly liberal arts
    - Orleans: mostly law

# What the Middle Ages knew

- Universities
  - 1200: University (“studium generale”) of Paris recognized by Philip Augustus
  - 13th c: the University of Paris replaces the cathedral schools as center of learning, and students flock from all over Europe

# What the Middle Ages knew

- Universities
  - Medieval universities conferred degrees that included the right to teach in any Christian country
  - International body of students and teacher
  - Latin is the lingua franca of education
  - The new wealthy bourgeoisie created by the revival of trade can afford to send their children to a foreign university

# What the Middle Ages knew

- Universities
  - Bologna
    - A university controlled by the students who are basically “customers”: students elect their teachers, rate their teachers and even punish underperforming teachers
    - Irnerius (1087) rediscovers and teaches the Codex Justinianus (Justinian’s law code)
    - Trains legal specialists who stand outside the government (the beginning of the rule of law by which even the ruler has to abide)
    - Several alumni of its law school become popes

# What the Middle Ages knew

- Universities
  - Paris
    - Controlled by teachers, not students
    - Protected by Pope and Emperor
    - Four faculties
      - Arts
      - Medicine
      - Law
      - Theology (dominant specialty)

# What the Middle Ages knew

- Universities
  - Oxford
    - Controlled by teachers, not students
    - Main specialties: mathematics and natural science (especially after papal ban against Aristoteles in Paris)

# What the Middle Ages knew

- Universities

- Cambridge (England, 1209)
- Salamanca (Spain, 1218)
- Padova (Italy, 1222)
- Napoli (Italy, 1224), first university created by the emperor
- Toulouse (France, 1229), first papal university
- Siena (Italy, 1240)
- Sorbonne, Paris (France, 1257)
- Montpellier (France, 1289)
- Coimbra (Portugal, 1290)
- Pisa (Italy, 1343)
- Prague (Czech, 1347), first northern university
- Krakow (Poland, 1364)
- Wien/ Vienna (Austria, 1365)
- Pecs (Hungary, 1367)
- Erfurt (1379), first in Germany
- Heidelberg (1385)
- Cologne (1388)
- Leipzig (1409)
- Roma (1431)
- Barcelona (1450)
- Venezia/Venice (1470)
- Copenhagen: 1475

# What the Middle Ages knew

- Universities
  - Johannes Gratian: “Concordantia discordantium canonum” or “Decretum” (114x), father of canon law
  - Peter Lombard: “Liber Sententiarum” (1151), father of theology
  - Peter Comestor “Historia Scholastica” (117x) father of Biblical history
  - Full Latin translation of Aristotle from the Arabic (12th c), translation of Al-Khwarizmi’s algebra book (“Arabic” numerals) and translation of other classics
    - Toledo (Arabic to Latin)
    - Sicily (Greek to Latin)

# What the Middle Ages knew

- Universities
  - Logic as the main subject in the trivium
  - The scholars of the urban centers demand formal demonstrations of God's attributes

# What the Middle Ages knew

- Universities
  - Universities create an expanding market for books
  - Books also spread to private libraries (eg the Duc de Berry in 1408 owned 155 books)

# What the Middle Ages knew

- Christian vs Muslim Universities
  - Christian universities are modeled after Muslim universities but with one key difference:
  - The priority of Muslim universities is to interpret the Muslim scriptures, because the interpretation determines the law of the country
  - In the Christian world the Pope has a monopoly on the interpretation of the Christian scriptures, so the universities (the scholastics) focus not on God's words but on God's creation, i.e. on nature

# What the Middle Ages knew

- Christian vs Muslim Universities
  - Indirectly, the fact that the Christian world had a spiritual dictator (the Pope) encouraged thinkers to study nature, a secondary subject, instead of the most important subject, whereas Muslim thinkers were more encouraged to study the scriptures than nature.
  - Eventually, the study of nature led to science.
  - Muslims had scientists but they were mostly bibliophiles summarizing knowledge imported from ancient Greek texts and Indian texts.
  - Christians had all sort of creative thinking even without access to those ancient Greek texts and Indian texts.

# What the Middle Ages Knew

- Johannes Scotus Erigena (870, Ireland)
  - Nature is divided into
    - that which creates but is not created (God as creator)
    - that which creates and is created (the ideas, or Logos)
    - that which is created but does not create (the objects in space and time)
    - that which which does not create nor is created (God as supreme end)

# What the Middle Ages Knew

- Johannes Scotus Erigena (870)
  - The uncreated creator (God) originates...
  - ...the created creators (the ideas) from which originate...
  - ...the created non-creators (the objects), i.e. according to which Nature is formed, which returns to the...
  - ...uncreated non-creator (God again)
  - Only God truly exists (God is the beginning, the substance and the end of the universe)
  - Nature is a dynamic process of emanation from God
  - Pantheism

# What the Middle Ages Knew

- Johannes Scotus Erigena (870)
  - Extreme realism: universals have a real and independent existence of their own (e.g., the Church is not just a community of individuals but a real entity)

# What the Middle Ages Knew

- Walafrid Strabo (9th c)
  - Commentary on the Bible
  - Man is composed of body, soul and spirit
  - The Bible contains three levels of meaning: literal, moral and mystical
- Gerbert (10<sup>th</sup> c)
  - Introduces Arab science and mathematics to Christian Europe

# What the Middle Ages Knew

- Anselm (1070)
  - Ontological argument to prove the existence of God
    - God is the greatest possible thing
- Peter Abelard (1079)
  - Most influential of Parisian intellectuals
  - Aristotle rather than Plato
  - Reason: we can discover truth through systematic reason
  - Moderate realism (conceptualism): the universal is an attribute of an entity, not an entity in itself

# What the Middle Ages Knew

- **William of Saint-Thierry (1085)**
  - Progress from the body (center of animal life) to the soul (center of reason) to the spirit (center of ecstasy)
  - Focus on love: “De natura amoris”
- **St. Bernard of Clairvaux (1090)**
  - Against dialectics and logic: “Quia amare dei est deus” (what causes us to love god is god)
  - The Virgin Mary, mother of God, as a symbol of love
  - Focus on love: “De amore Dei”

# What the Middle Ages Knew

- **Hugh of Saint-Victor (1096)**
  - **Every visible thing is a sign of the invisible truth that the soul will discover after death**
  - **Cogitatio to penetrate the secrets of the material world**
  - **Meditatio to penetrate the secrets of one's soul**
  - **Contemplatio to intuit the real essence of the universe**

# What the Middle Ages Knew

- Jean Roscelin (1100)
  - Nominalism: forms and concepts only exist in our minds (first major nominalist)
- Realism: forms and concepts exist independently of our mind (supports the feudal and clerical order)
- Realism prevails in early medieval times, Nominalism prevails in late medieval times

# What the Middle Ages Knew

- Adelard of Bath (12th c): celestial bodies are divine living beings ("Quaestiones Naturales", "De Eoden et Diverso")
- William of Conches (France, 12th c): Plato's idea that celestial bodies determine events on Earth ("Philosophia Mundi")
- Bernard Sylvester (France, 12th c): the study of the stars explains present and future of people and natural phenomena ("De Mundi Universitate")
- Alain de Lille/ Alanus de Insulis (France, 12th c): God created Nature and Nature now runs the world

# What the Middle Ages Knew

- Pre-Aristotelian Christian thought: St Augustine (mostly neo-Platonic)
  - Sensory knowledge is illusory
  - Direct mystical knowledge
- Robert Grosseteste (1175)
  - Commentary on the "Physics" of Aristoteles
  - Treatises on Geometry, Meteorology, and Optics
  - All science must be based on Mathematics
  - Scientific inquiry based on reductionism
  - The universe is light, and everything radiates from light
- Dominicans adopt Aristotelianism
- Franciscans stick to St Augustine
- Condemnation of Aristotelianism in 1277

# What the Middle Ages Knew

- Cross-pollination of civilizations
  - Barlaam and Josaphat, a novel written in Greek by Euthymius in the 1020s
    - Which was a translation of a book from Georgia titled "Balavariani"
      - Which was a summary of an Arab book titled "Kitab Bilawhar wa-Yudasaf"
        - » Which was a rewrite of the sanskrit Buddhist hagiography "Buddhacarita" (2nd c AD)

# What the Middle Ages Knew

- Thierry of Chartres (12th c)
  - Physical explanation of the Genesis
- Albertus Magnus (1206)
  - Compendium of living creatures
  - The first “summist”
  - Albertus Magnus collects empirical facts
  - Albertus Magnus encourages empirical scientific inquiry into the working of Nature
- Amaury of Bene (13th c)
  - Pantheism: Everything is one, everything is god

# What the Middle Ages Knew

- **Francesco d'Assisi (b 1181)**
  - **God is in nature**
  - **Intuitive knowledge of God**

# What the Middle Ages Knew

- Art of Memory
  - Dominicans and Franciscans rediscover the art of memory
  - Ramon Lull: "Ars Magna" (1305)
    - a combinatorial system ("ars combinatoria") of letters and revolving wheels that would allow missionaries to prove systematically the truth of the Christian faith
    - A system to solve any theoretical problem
    - the mechanical production of truth
  - "De Memoria Artificiali" (Anonymous, 14th c)

# What the Middle Ages Knew

- **Islamic philosophy**
  - **Avicenna**
  - **Al-Ghazali**
  - **Averroes**

# What the Middle Ages Knew

- **Siger de Brabant (Averroism):**
  - **Philosophy is independent of revelation**

# What the Middle Ages Knew

- Thomas Aquinas (1264)
  - There is no separation between reason and faith
  - Finally reconciles Aristoteles and Christianity
  - 631 topics for discussion and 10,000 objections and counterobjections

# What the Middle Ages Knew

- Thomas Aquinas (1264)
  - There is only one truth, not two (logic can prove religion true)
  - Attributes of God can be proven logically
    - God is the mover that does not move (the first cause)
    - God is omniscient, omnipotent and perfect
    - Creation ex nihilo
  - In God, essence and existence are the same ("the essence of God is his existence", "existence is the substance of God", "God is in all things")
  - God is the ultimate process of self-realization

# What the Middle Ages Knew

- Thomas Aquinas (1264)
  - Aristotelian view of mind
    - Vegetative life (reproduction, metabolism)
    - Sensory-motor life (perception, locomotion)
    - Sentient life (reason, free will)
    - The soul is the form of the body
    - God creates the soul (that did not pre-exist) and the soul is then immortal
    - All living beings have souls, but only humans have spiritual souls
    - The mind (intellect) is the device by which spiritual souls perceive other forms
    - Knowledge comes not from divine illumination but from sensory experience plus intellect

# What the Middle Ages Knew

- Thomas Aquinas (1264)
  - Aristotelian view of mind
    - The mind does not perceive matter but form, not individuals but universals
    - Forms perceived by the mind become concepts (no innate ideas)
    - The soul is the form of the body and uses it to acquire knowledge
    - The quest for happiness is a quest for knowledge (the human essence is to understand)
    - True happiness can only be achieved in the afterlife (the "vision of the divine essence")
    - Reason can never attain full knowledge of God

# What the Middle Ages Knew

- Thomas Aquinas (1264)
  - Ethics: Greek virtues plus theological virtues (faith, hope, charity, love)

# What the Middle Ages Knew

- John of Fidenza/Bonaventura (126x)
  - The soul is the form of the body, and sensations are changes caused by an object to the body, but we also judge (not only perceive) the objects, and that judgement is made according to a timeless standard created by God
  - Knowledge presupposes divine illumination, otherwise it would remain pure sensation
  - Proofs of the existence of God
  - Coincidentia oppositorum: God is infinite and finite, eternal and actual, transcendent and active, etc
  - There is a path to God that we can ascend

# What the Middle Ages Knew

- Optics (13th c): Dietrich of Freiberg (who explains the rainbow), Grosseteste, Bacon, John Peckham and Witelo, mostly derived from Greeks (Ptolemy) and Arabs (Alhazen)
- Optics (13th c): Grosseteste believes that God is light, and light is the primordial substance that, combined with matter, creates the objects of the visible universe

# What the Middle Ages Knew

- Scientific speculation takes place in a monastery cell, not in laboratory
- Petrus of Maricourt/Peregrinus, based on experiments, shows that magnetism is not magic - "Epistola de Magnete" (1269)
- Jordanus of Nemore: mathematical mechanics - "Elementa Jordani super demonstrationem ponderis/ Elements of Jordanus on the Demonstration of Weights" (1260)

# What the Middle Ages Knew

- Astrology officially banned by the Church but still very popular, eg Bartholomeus Anglicus (a Franciscan) publishes "De Proprietatibus Rerum" (1240)
- Alchemy allowed and popular: philosophers' stone capable of turning metals into gold or silver; elixir of immortality
- Paolo di Taranto (13<sup>th</sup> c) aka Pseudo-Geber: "Summa perfectionis magisterii/ The Height of the Perfection of Mastery" (1309)

# What the Middle Ages Knew

- Roger Bacon (1269)
  - Robert Grosseteste's pupil Roger Bacon: the Bible contains all knowledge but it requires allegorical interpretation
  - Bacon encourages sensory experience ("scientia experimentalis" but it doesn't mean with actual laboratory experiments, just observation)
  - Bacon believes that astrology, magic and alchemy are as much science as natural science
  - Bacon believes that mathematics should be the foundation of science

# What the Middle Ages Knew

- Roger Bacon (1269)
  - Encyclopedia of logic, mathematics, physics, ethics, etc
  - Logic and observation allow an understanding of nature
  - Science to be founded on logic and observation
  - The Earth is round
  - Founder of science fiction (in his letters)

It is possible that great ships and sea-going vessels shall be made which can be guided by one man and will move with greater swiftness than if they were full of oarsmen.

It is possible that a car shall be made which will move with inestimable speed, and the motion will be without the help of any living creature. . . .

It is possible that a device for flying shall be made such that a man sitting in the middle of it and turning a crank shall cause artificial wings to beat the air after the manner of a bird's flight. . . .

# What the Middle Ages knew

- 14th Century Science
  - The cause of the motion of falling bodies
  - The structure of matter
  - Does the Earth move?
  - Gerardus Cremonensis translates the Arabic version of Ptolemy's "Almagest" into Latin (1175)
  - Michael Scot's Latin translation of Al-Bitruji's "Kitab al-Hay'ah" in 1217
  - Latin version of Aristotle's "De Coelo"
  - Astronomy (via Latin translations in Spain of Al-Fargani, Al-Battani and Al-Huwarizmi)

# What the Middle Ages knew

- Johannes Eckhart (Dominican, 1308)
  - God is being, and being is God
  - Anything that "is" is God
  - Everything emanates from God
  - God is One, and brings the many into One
  - God is the being of all things
  - The soul can know God by forgetting itself, by renouncing its self-consciousness
  - The soul can do God's will by renouncing its self-will
  - Self-will causes inner conflict

# What the Middle Ages knew

- Johannes Eckhart (1308)
  - The soul becomes divine
    - “I was the cause of myself and of everything else”
  - Negative theology
    - We cannot say anything about God
    - “God is without name”
    - “God is a being above being and a superessential negation”

# What the Middle Ages knew

- Johannes Eckhart (1308)
  - The Christian stories are merely metaphors for higher truths
  - Influenced by Vedanta

# What the Middle Ages knew

- John Duns Scotus (1300)
  - Human reason cannot grasp the nature of God (God is infinite, the human mind is finite)
  - One can only prove a few truths (limit of the scholastic program)
  - Truth via reason AND divine revelation
  - Theology and philosophy are distinct: Theology is the (practical) discipline of the nature of God, Philosophy is the (theoretical) discipline of the “first cause”
  - Theology is concerned with saving souls
  - The scholastic program of proving faith by reason is doomed to failure (beginning of the decline of scholasticism)

# What the Middle Ages knew

- John Duns Scotus (1300)
  - The world is a set of individual entities
  - No overarching unity or order
  - The forces that keep the world together are beyond human understanding
  - His philosophy mirrors the breakdown of the medieval worldview

# What the Middle Ages knew

- Theory of impetus
  - Aristoteles: nothing moves unless it is moved
  - Things can move if they are impressed with an original force, *vis impressa*
  - Nicholas Oresmus (XIV): metaphor of the universe as a vast mechanical clock built by God
  - Franciscus of Marchia (14th c): “*virtus derelicta*” propels the projectile
  - John Buridan

# What the Middle Ages knew

- Jean Buridan (1300)
  - “Buridan's ass”: the ass starves to death between two equally alluring and equidistant bundles of hay because it has no rational basis for preferring one bundle over the other
  - Appearance of motion is relative: there is no way to determine if it is the Earth or the universe that moves (Galilean invariance ante-litteram)
  - Movement is due to an internal impulse
  - Movement continues unless disturbed by external forces
  - Celestial bodies are governed by the same natural laws that govern Earthly bodies

# What the Middle Ages knew

- Jean Buridan (1300)
  - Theory of the impetus: a body set in motion has impetus, contrasted by the resistance of the matter in which it moves and contrasted by the force of gravity that wants to pull it to its natural place. Gravity itself imparts an impetus to falling bodies.

# What the Middle Ages knew

- William Occam/Ockham (1320, England)
  - Empiricism
    - Sensations are the source of knowledge: “Nothing can be the object of the interior sense without having been an object of the exterior sense”
    - Sensation revived: memory
    - Sensation interpreted through memory: perception
    - Memories combined: imagination
    - Memory projected: Anticipation
    - Memories compared: Thought
    - Memories interpreted through thought: Experience

# What the Middle Ages knew

- William Occam/Ockham (1320, England)
  - Nominalism
    - Universals (concepts) only exist in the mind: they are symbols devoid of reality
    - Only individual objects/facts are real
    - Human knowledge is limited to individuals, which truly exist and are open to observation.
    - Anything beyond the realm of sensory experience is a matter of faith
    - Philosophy and science are fragile generalizations prone to error
    - Our knowledge is limited by our senses
    - The truths of religion cannot be proven by reason

# What the Middle Ages knew

- William Occam/Ockham (1320, England)
  - Nominalism
    - Note: indirectly, nominalism allows science to separate from religion and pursue its own quest for truth

# What the Middle Ages knew

- William Occam/Ockham (1320, England)
  - Logic
    - Logic is processing symbols for the sake of the mind
    - Abstract reasoning does not lead to certain knowledge
  - Science
    - Action at a distance is possible
    - Celestial and terrestrial matter obey the same laws

# What the Middle Ages knew

- William Occam (1320)
  - Separation of Logic and Metaphysics
  - Separation of the profane and the sacred
  - Separation of Science and Church
  - Metaphysics
    - Knowledge of God is possible only through revelation
    - The existence of God, the immortality of the soul, etc cannot be deduced logically but requires a profession of faith

# What the Middle Ages knew

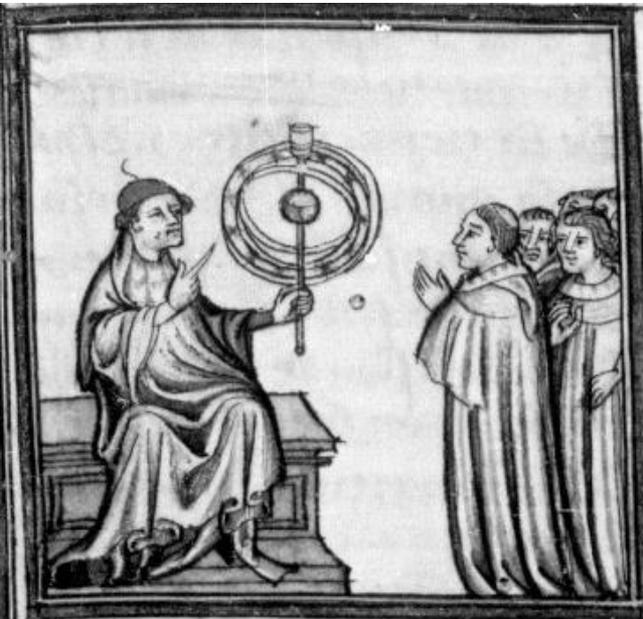
- Nicholas of Autrecourt (1346)
  - We can never know anything with absolute certainty
  - Democritus' atomic theory

# What the Middle Ages knew

- Knowledge of the Earth
  - Giovanni Carpini: “Historia Mongalorum” (1248)
  - Marco Polo: “Il Milione” (1298)
  - Odorico Mattiuzzi da Pordenone: “De Rebus Incognito” (14th c)
  - Pierre d’Ailly: “Imago Mundi” (14th c)
  - Albertus Magnus (13th c): the Earth is a sphere

# What the Middle Ages knew

- Knowledge of the Earth
  - Nicolas Oresme (14th c): the rotation of the Earth on an axis explains the daily motion of the universe



Livre du ciel et du monde, 1377

# What the Middle Ages knew

- Nicole Oresme (137#)
- Graphical representation of quantities: the first graphs
- Kinematics
- If the Earth were moving and not the celestial spheres, all the movements that we see in the heavens that are computed by the astronomers would appear exactly the same as if the spheres were rotating around the Earth
- "Livre du Ciel et du Monde" (1377), a French translation and commentary on Aristotle's "De Coelo": the Earth rotates, not the sky
- "Traite' de l'Esperance" (1368), a French translation and commentary of John of Sacrobosco's "De Sphaera"

# What the Middle Ages knew

- Scientific investigation
  - Leonardo Fibonacci
  - Roger Bacon
  - Benefactors of science: Alfonso of Castille and Frederick II (13th c)
  - Nichole d'Oresme (1360s): the graph to represent functions

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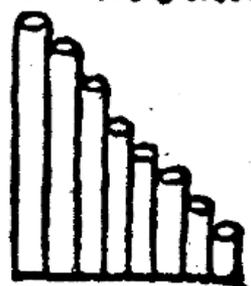
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# What the Middle Ages knew

- Leonardo Fibonacci (Leonardo Bigollo, 1202)
  - Indian (“Arab”) numerals
  - Fibonacci sequence (first recursive number sequence)
  - Golden ratio



# What the Middle Ages knew

- Scientific investigation
  - Plus and minus signs (15th c)
  - Richard of Wallingford (14th c): Trigonometry
  - Guillaume St Cloud (14th c): Astronomy

# What the Middle Ages knew

- **Effects of the victory of Nominalism**
  - **Breakdown of the hierarchical order of medieval society (feudalism and church)**
  - **Devaluation of the Church (individual faith is real, the abstraction of the Church is just a human invention)**
  - **Personal experience of God as opposed to the public rituals of organized religion**
  - **Rise of individualism**
  - **Prelude of the Reformation**

# What the Middle Ages knew

- **Bestiary**
  - **Hugo of St. Victor: "Tractatus de bestiis et aliis rebus" (12th c, Germany)**
  - **Richard de Fournival: "Bestiaire d'Amour" (13th c, France)**
  - **Albertus Magnus: "De animalibus" (13th c, Germany)**
  - **Vincent de Beauvais: "Speculum naturale" (13th c, France)**

# What the Middle Ages knew



- Ramon Llull (Spain, 1275)
  - A combinatorial system of letters and revolving wheels that would allow missionaries to prove systematically the truth of the Christian faith to
  - "Ars Magna" (1305) = Leibniz's ars combinatoria
  - Invented the first computers (for the purpose of converting Muslims to Christianity)
  - The volvelle



# What the Middle Ages knew

- **Medicine**
  - **Henri de Mondeville's "Chirurgia" (1320)**
  - **Guy de Chauliac's "Chirurgia Magna" (1363)**
  - **1365: There are 40 barber surgeons in Paris**

# What the Middle Ages knew

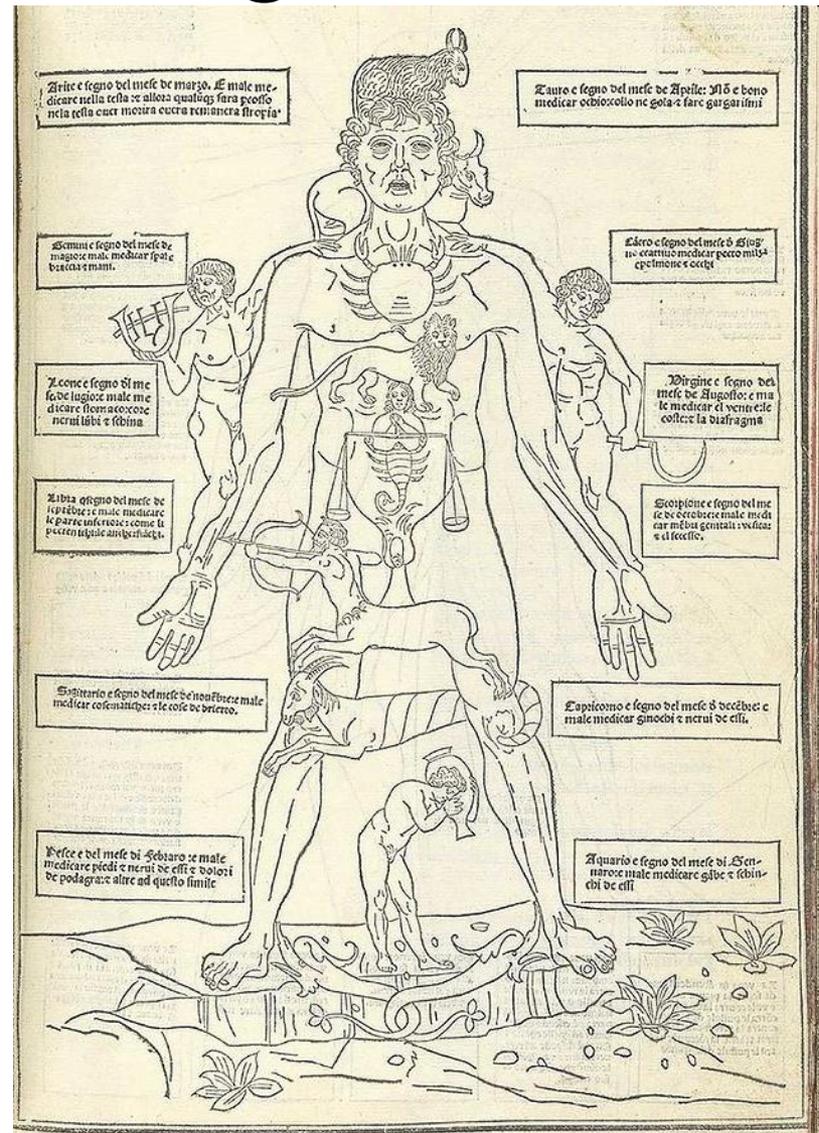
- Mondino de Luzzi's *Anathomia* (1316)
  - A guide to dissection of cadavers



(A printed version of 1493)

# What the Middle Ages knew

- **Mondino's *Anathomia* (1316)**
  - Zodiac man linking the zodiacal signs to bodily organs



# What the Middle Ages knew

- Political science
  - Marsilio da Padova's "Defensor Paci" (1324)
    - National state above the Church

# What the Middle Ages knew

- Pierre d'Ailly (1410)
  - The Atlantic is traversable in a few days



“Imago Mundi” (1410)

# What the Middle Ages knew

- Humanism
  - Francesco Petrarca rediscovers Cicero's letters (1345)
  - Poggio Bracciolini, former secretary of many popes, rediscovers Lucretius' "De Rerum Natura" (1417), Quintilian's treatise on law, Vitruvius' treatise on architecture



# What the Middle Ages knew

- Humanism
  - Classical humanism: a literary movement aimed at recovering and restoring the cultural heritage of Greek and Roman antiquity
  - Republican humanism: the political movement towards republican city-states
  - Virtue humanism: a moral movement to revive virtue through education and establish a meritocratic style of government (eg Francesco Patrizi)

# What the Middle Ages knew

- Oxford Calculators (14th c, Merton College at Oxford): numerical calculation of qualities, including philosophical concepts
  - - Thomas Bradwardine, William Heytesbury, Richard Swineshead and John Dumbleton
- Thomas Bradwardine
  - - "Tractatus de Proportionibus" (1328)
  - - Exponential function which describes the relationship between forces, resistances, and velocities in motions

# What the Middle Ages knew

- Oxford Calculators (14th c, Merton College at Oxford): numerical calculation of qualities, including philosophical concepts
  - Richard Swineshead: "Liber Calculationum" (1350)
  - William Heytesbury: "Regulae Solvendi Sophismata" (1335)

# What the Middle Ages knew

- Oxford Calculators
  - William of Auvergne: "De Universo/ The Universe of Creatures" (1240)
    - Endorses Nur ad-Din Al-Bitruji/ Alpetragius' astronomical theory
    - The motion of the universe is due to the world-soul of Plato's "Timaeus"
  - Nicholas Cusanus

# What the Middle Ages knew

- Nicholas Krebs “Nicolaus Cusanus” (1440)
  - Truth is simple and infinite
  - Human knowledge can only be complex and finite
  - Truth is beyond human reason
  - The infinitely small and the infinitely large are one and the same in God (the “complicatio” coincides with the “explicatio”) but appear like opposites to humans
  - God is the synthesis of opposites

# What the Middle Ages knew

- Nicholas Krebs “Nicolaus Cusanus” (1440)
  - The universe is a sphere with its center everywhere and its circumference nowhere (proto-cosmological principle)
  - The Earth is a star just like all other stars
  - There are many other worlds and they are all inhabited
  - His 800-page book was titled “Learned ignorance” (“Apologia doctae ignorantiae”)

# What the Middle Ages knew

- Nicholas Krebs “Nicolaus Cusanus” (1440)
  - The universe is infinite
  - The Earth moves
  - The Earth is not the center of the universe
  - Mathematics is the foundation of Science
  - Earth and Heavens obey the same laws
  - God is both the center of the concentric circles and the circumference of the outer one

# What the Middle Ages knew

- Nicholas Krebs “Nicolaus Cusanus” (1440)
  - Anything new is defined relative to how similar and how different it is to things we know
  - Nothing is identical to something else: there are only degrees of resemblance
  - Nothing is perfect: there are only approximations to perfection (e.g. the Earth is not a perfect sphere)
  - All knowledge is based on ratios (and therefore numbers)
  - The infinite is unknowable (it has no ratio)

# What the Middle Ages knew

- Nicholas Krebs “Nicolaus Cusanus” (1440)
  - God is the complicatio of the universe and the universe is the explicatio of God
  - "Idiota De Staticis Experimentis/ The Layman on Experiments done with Weight-Scales" (1450): importance of quantitative experimental research

# What the Middle Ages knew

- Bernardino Albizzeschi da Siena (1470)
  - Scholastic economics
  - Defense of the entrepreneur
  - Justification of private property
  - Ethics of trade

# What the Middle Ages knew

- Astronomy
  - School of Vienna
    - 1383: Heinrich von Langenstein founds the astronomical school of Vienna
    - Georg von Peuerbach: "Tabulae Eclipsium" (1457)  
- eclipse tables
    - Regiomontanus/ Ioannes de Montereio (Johannes von Koenigsberg)

# What the Middle Ages knew

- Johann “Regiomontanus” Muller (1474)
  - De Triangulis omnimodis" (1464): trigonometry
  - "Algorithmus Demonstratus" (14??): symbolic algebra
  - Portable sundial for Pope Paul II (1465)

# What the Middle Ages knew

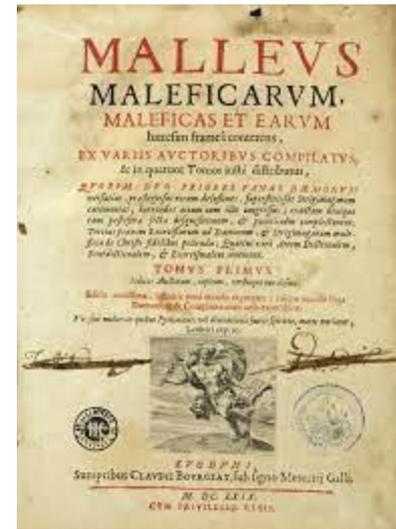
- Johann “Regiomontanus” Muller (1474)
  - Almanac predicting the position of planets
  - Observation of Halley’s comet

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# What the Middle Ages knew

- 1486 "Malleus Maleficarum" a bestseller for two centuries (a manual of witchcraft)



# What the Middle Ages knew

- End of the Middle Ages 15th c
  - Philosophy: Aristotle
  - Astronomy: Ptolemy
  - Medicine: Hippocrates and Galen
  - Law: Justinian

What the Middle Ages knew

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