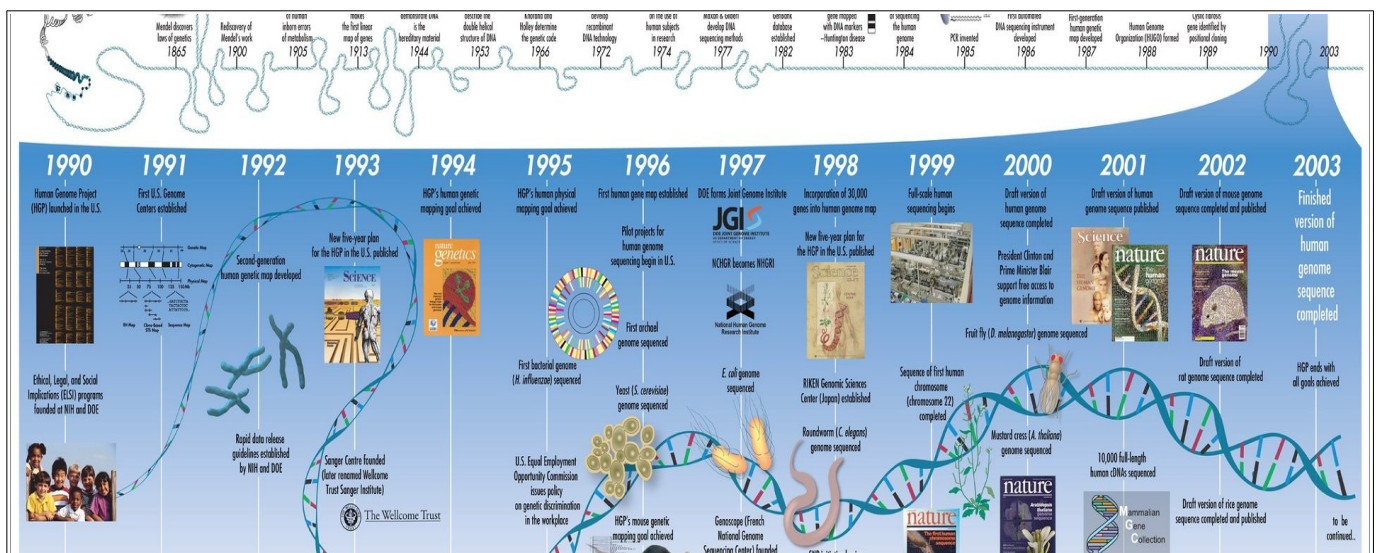


Course: Handout

UNIVERSAL HISTORY OF BIOLOGICAL SCIENCES

U.H.B.S

Intended for first-year students in the core curriculum of Natural and Life Sciences



Presented by:

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PREFACE

This course, Global History of Biological Sciences, is designed to introduce first-year undergraduate students in the Natural and Life Sciences to the foundational ideas, milestones, and cultural contexts that have shaped biological inquiry across human civilizations. Rather than presenting science as a linear progression of Western discoveries, this course adopts a global and interdisciplinary perspective, highlighting contributions from Mesopotamia, Egypt, India, China, the Greco-Roman world, the Islamic Golden Age, and modern Europe. The primary objective is to foster historical awareness, critical thinking, and an appreciation for the interplay between science, philosophy, religion, and society. By tracing the evolution of biological thought from prehistoric observations to 21st century genomics students will understand that science is not merely a collection of facts, but a dynamic, culturally embedded human endeavor.

SYLLABUS

This course is intended for first-year students enrolled in the common core curriculum of the Nature and Life Sciences field during the first semester of the bachelor's cycle.

Interdisciplinary Teaching Unit	SHV	Weekly Teaching Hours				Coef	Credit	Assessment
Course Title		Course	PW	DW	Other			Exam
Universal History of Biological Sciences	22h30	01h30	/	/	22h30	1	1	100%

Course Content

1. Prehistory
2. Antiquity
3. Middle Ages
 - 3.1. In the West
 - 3.2. In the East (Islamic civilization)
4. Sixteenth and Seventeenth Centuries
5. Eighteenth Century: Darwin
6. Nineteenth Century: Cell Theory (Microscopy), Sexuality, Embryology, Molecular Biology (DNA), Genetics
7. Twentieth Century: Gene Therapy and Cloning

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1. INTRODUCTION: What Is Science?

1.1. Defining Science

Science, from the Latin **scientia** (“knowledge”), refers to the systematic body of knowledge acquired through observation, experimentation, logical reasoning, and empirical inquiry, and accepted as provisionally true within a broad epistemological framework. It is defined by a clearly delineated subject matter, a rigorous and reproducible methodology, and the establishment of objective, verifiable relationships grounded in empirical evidence.

Guided by a scholarly community that upholds standards of epistemic integrity, science aims to generate scientific knowledge—knowledge that emerges from systematic, transparent, and peer-reviewed investigative practices. A central objective of science is to understand natural, social, and formal phenomena; to formulate explanatory laws or theoretical models; and to derive reliable predictions and functional applications. Scientific knowledge is inherently provisional: it is continuously tested against empirical reality, refined in light of new evidence, and integrated into an evolving, self-correcting corpus.

Moreover, scientific advances serve as the foundation for countless technological and technical innovations, profoundly shaping contemporary societies—from everyday practices and public policies to cultural worldviews and ethical frameworks.

Science is not a monolithic enterprise but is organized into specialized disciplines, each addressing a distinct domain of inquiry. Examples include mathematics, physics, chemistry, biology, astronomy, mechanics, optics, pharmacology, archaeology, economics, and sociology. This classification is neither fixed nor absolute; disciplinary boundaries are often fluid, and novel interdisciplinary fields such as bioinformatics, neuroeconomics, and agroecology frequently emerge at the intersections of established domains. Each discipline, whether fundamental or applied, constitutes a distinct scientific field, characterized by its own conceptual frameworks, methodological conventions, and epistemological traditions.

In its strictest sense, science is characterized by :

- A defined **object of study** (e.g., living organisms in biology),
- A rigorous **methodology** (e.g., hypothesis testing, reproducibility),
- **Verifiable and falsifiable** claims about the natural world.

Science aims not only to explain phenomena but also to predict outcomes and develop practical applications that benefit society.

- **The three Conceptions of Science are :**

- **Broad Definition:** Knowledge gained through experience or study.
- **Organized Knowledge:** Structured understanding through theories and laws.
- **Strict (Modern) Definition:** A discipline grounded in empirical evidence, logical reasoning, and peer-reviewed validation.

- **Branches of Science :**

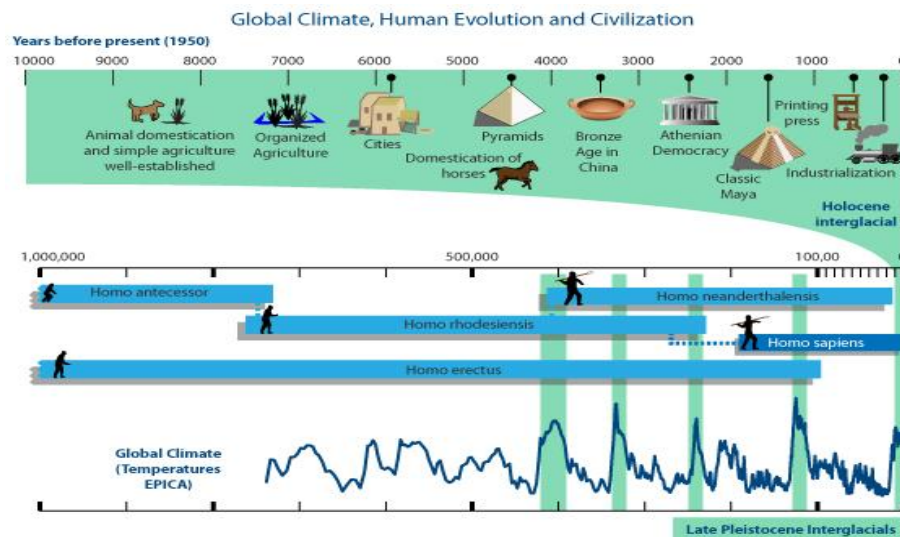
- **Formal Sciences:** Mathematics, logic (based on abstract reasoning).
- **Natural Sciences:** Physics, chemistry, biology, astronomy (study of nature).
- **Human & Social Sciences:** Psychology, sociology, anthropology (study of human behavior).
- **Applied Sciences:** Engineering, medicine, agronomy (practical implementation).

Key Insight: Science is not monolithic. Its methods and goals vary across disciplines, yet all share a commitment to evidence-based inquiry.

1.2. Science in Historical Context: From Philosophical Inquiry to Modern Rationality :

The history of science cannot be disentangled from the evolution of societies, systems of thought, and cultural contexts that have shaped it. Although science today constitutes an epistemologically autonomous enterprise grounded in experimentation, modeling, and empirical validation it was for centuries deeply embedded within philosophical, theological, or cosmological frameworks. In Greco-Roman antiquity, for instance, the search for natural causes was conducted within a speculative tradition inherited from pre-Socratic and later Aristotelian philosophy, wherein the observation of nature aimed less at transforming the world than at comprehending its rational order. During the Middle Ages particularly in the Byzantine, Islamic, and Latin worlds natural knowledge was often preserved, transmitted, and expanded within religious or scholarly institutions, where understanding the cosmos was regarded as a path toward divine wisdom.

It was only between the Renaissance and the Enlightenment that a slow yet profound transformation occurred: science gradually emancipated itself from metaphysics and emerged as an autonomous practice, guided by experimental method, quantification, and rational critique. This shift marked the rise of a distinct “scientific rationality,” capable not merely of explaining natural phenomena but also of predicting and controlling them.



Interplay of Global Climate, Human Evolution, and Civilization Development Over the Past 10,000 Years, Image by John Garrett.

Contemporary historiography of science is structured around two complementary though sometimes tension-filled approaches. The first, often termed the “internalist” perspective, focuses on the history of discoveries, theories, instruments, and concepts—that is, on the genesis and development of scientific content itself. The second, known as the “externalist” approach, situates scientific thought within its social, institutional, political, and cultural dimensions, interrogating how epistemic norms, validation practices, dominant paradigms, and the interplay between science and power have evolved over time. Far from being mutually exclusive, these two perspectives together reveal science not as a linear accumulation of truths, but as a complex, historically situated human endeavor, in constant dialogue with its historical moment.

2. From Empirical Knowledge to Early Rationality: Prehistory and Antiquity

2.1. Prehistory: The Genesis of Technical Knowledge and the Emergence of Rational Thought

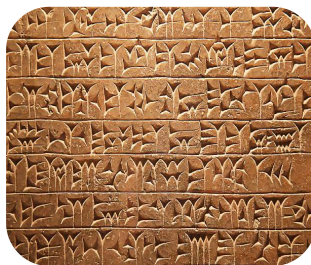
Long before the advent of formalized science, prehistoric societies developed technical know-how grounded in observation, empirical experimentation, and oral transmission. As early as the Paleolithic period, “Homo sapiens” and likely earlier hominins such as “Homo erectus” mastered the knapping of stone, followed by the working of bone and ivory, demonstrating an ability to conceptualize the functional purpose of tools. A pivotal milestone in this techno-cognitive evolution was the domestication of fire, generally dated between 300,000 and 250,000 years ago. This mastery was far from merely utilitarian; it implied an implicit understanding of the physical properties of matter such as combustion and thermal transformation thereby constituting an early form of causal reasoning. Although science in the modern sense did not yet exist, certain prehistoric practices exhibit what may be termed “proto-rationality”, foreshadowing later scientific methodologies. Systematic observation of lunar and solar cycles, evidenced by artifacts such as the Ishango bone (c. 20,000 BCE), suggests the use of rudimentary counting systems and an awareness of natural periodicities. Similarly, the orientation of dwellings, ritual burials, and parietal art reflect attempts to symbolically model the world, perhaps even giving rise to an embryonic cosmogony.

The anthropologist and prehistorian André Leroi-Gourhan emphasized that human evolution unfolds through a tight dialectic between biological and technical development: tools function as “extensions of the body,” while collective memory gradually shifts toward external supports. This cognitive externalization constitutes a necessary precondition for the formalization of knowledge.

It was during the Neolithic period (c. 10,000 BCE), with the advent of sedentism, agriculture, urbanization, and long-distance trade, that the first organized systems of knowledge emerged. According to the philosopher of science André Pichot in (*La Naissance de la science*, 1991), true science originated in Mesopotamia particularly in the Sumerian and Elamite city-states. The practical demands of agricultural management, irrigation planning, commercial accounting, and flood prediction along the Tigris and Euphrates rivers spurred the development of measurement systems, arithmetic, and celestial observation. Concurrently, early metallurgical experiments first with copper smelting and later with bronze production laid the groundwork for

what may be regarded as the earliest forms of chemistry, albeit still embedded within ritual or artisanal frameworks. The production of vitreous glazes by c. 2000 BCE stands as a testament to this technological sophistication.

Nevertheless, the most decisive innovation was the invention of cuneiform writing in Mesopotamia around 3300 BCE. Initially composed of pictograms impressed onto clay tablets using a wedge-shaped stylus, this script enabled not only the durable recording of knowledge but also its reproduction, transmission, and cumulative refinement beyond the constraints of individual memory. It is precisely this capacity to objectify and accumulate knowledge that marks the transition from empirical rationality to the first institutionalized forms of science a legacy that classical antiquity would inherit and systematically develop.

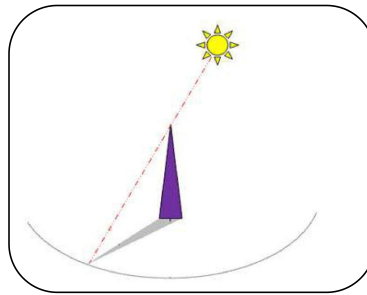


Cuneiform writing



Pictograms or pictographs (Egypt)

Mesopotamia thus pioneered the development of the earliest instruments for measuring time and space such as the gnomon laying foundational groundwork for systematic observation and quantification in the ancient world.

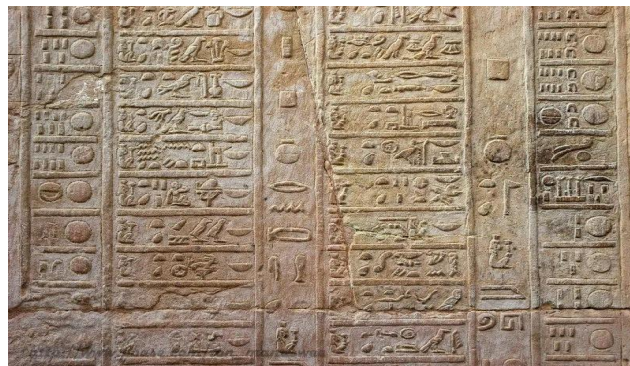


Gnomon

3. Antiquity

3.1. Pharaonic Egypt: Foundations of Mathematical and Astronomical Knowledge

In Pharaonic Egypt, scientific inquiry though embedded within administrative, religious, and practical contexts laid crucial groundwork for later developments in mathematics and astronomy. Egyptian scribes demonstrated a sophisticated command of applied geometry, accurately computing the areas of rectangles and triangles, as evidenced in key documentary sources such as the Rhind Mathematical Papyrus (c. 1550 BCE), the Moscow Mathematical Papyrus (c. 1850 BCE), the Kahun Papyri, and the enigmatic Leather Roll. These texts reveal a problem-oriented mathematical tradition focused on practical challenges: equitable division of goods, land surveying after Nile inundations, and volume calculations for granaries and pyramids. While lacking formal algebraic notation, Egyptian mathematics employed proto-algebraic methods particularly in solving linear equations and performing fractional arithmetic with remarkable precision.



Ancient Egyptian calendar

Notably, the Rhind Papyrus contains an approximation of the mathematical constant π (pi) through a geometric procedure for squaring the circle: by equating the area of a circle to that of a square with side length $\frac{8}{9}$ of the circle's diameter, the Egyptians effectively used a value of $\pi \approx 3.1605$ a remarkably close estimate given the absence of theoretical geometry as later developed in Greece.

In parallel, Egyptian astronomy achieved significant advances driven by both ritual and agricultural needs. The civil calendar, consisting of 365 days organized into 12 months of 30 days plus 5 epagomenal days, represents one of the earliest solar calendars in human history. Timekeeping relied on stellar clocks diagonal star tables inscribed in tomb ceilings (e.g., at the Valley of the Kings) which tracked the heliacal risings of decanal stars to divide the night into hours. These observations not only regulated temple rituals and nocturnal activities but also enabled the systematic cataloging of visible stars, forming the basis of a celestial framework that would influence later Hellenistic and Babylonian astronomy.

Thus, while Egyptian science remained largely utilitarian and non-theoretical, its empirical rigor and systematic record-keeping constituted a vital intellectual legacy that prefigured the formalized scientific traditions of subsequent civilizations.

In medicine, surgery took its first steps during ancient Egyptian times, marking the emergence of a systematic approach to health and disease. As early as 2300 BCE, a genuine medical theory began to take shape, grounded in clinical observation, symptom analysis, and the implementation of standardized treatments. This body of medical knowledge simultaneously empirical and ritualistic—was recorded in remarkably sophisticated medical texts. The Ebers Papyrus, dated to approximately 1550 BCE but likely compiled from earlier sources originating in the third millennium BCE, stands as one of the most comprehensive records of pre-Hippocratic medicine. Spanning over 20 meters in length, this document lists nearly 700 remedies and 877 prescriptions, addressing a wide spectrum of pathologies from gastrointestinal disorders and gynecological conditions to traumatic injuries and minor surgical procedures such as suturing, abscess drainage, and fracture reduction. Although closely intertwined with magic and religion, the Ebers Papyrus reflects a growing effort to rationalize medical practice: it distinguishes symptoms, classifies diseases, and evaluates the relative efficacy of treatments hallmarks that foreshadow the emergence of a proto-scientific medical tradition.

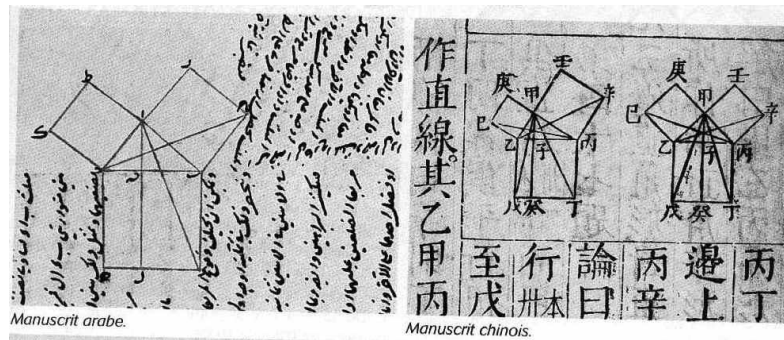
3.2. Ancient China: Advancements in Mathematics and Astronomy

Long before the formalization of mathematical and astronomical knowledge in the Greco-Roman world, ancient Chinese scholars made significant contributions to both fields through empirical observation and systematic record-keeping. Notably, the Gougu theorem functionally equivalent to the Pythagorean theorem was articulated in the *Zhoubi Suanjing* (c. 2nd century BCE), demonstrating a sophisticated understanding of right-angled triangles.

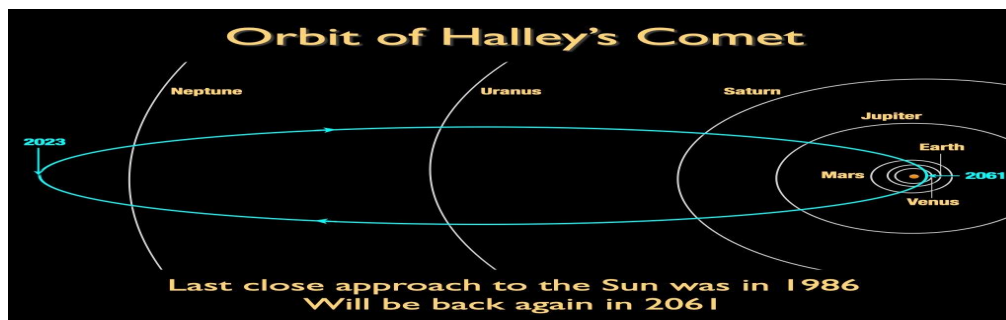
While often attributed to Pythagoras in the Western tradition, this geometric principle had already been applied by Babylonian mathematicians as early as the 18th century BCE, underscoring the independent yet parallel development of mathematical thought across early civilizations.

In astronomy, Chinese astronomers distinguished themselves through meticulous celestial documentation. As early as 240 BCE, they recorded the appearance of what is now known as Halley's Comet, providing the oldest confirmed sighting of this periodic comet a record later corroborated by modern orbital calculations. Furthermore, Chinese scholars recognized the cyclical nature of lunar and solar eclipses, developing predictive models based on the Saros cycle long before similar methods emerged in the Mediterranean world.

A landmark achievement in this domain was the promulgation of the Taichu Calendar in 104 BCE under Emperor Wu of the Han dynasty. This reform replaced earlier lunisolar systems with a more accurate framework that integrated precise measurements of the solar year (365.25 days) and the lunar month, while also aligning calendrical calculations with cosmological and ritual imperatives. The Taichu Calendar is widely regarded as the first standardized and scientifically grounded calendar in Chinese history, reflecting the state's growing institutionalization of astronomical knowledge for agricultural, administrative, and ceremonial purposes. Together, these developments illustrate how ancient Chinese science, though rooted in practical and cosmological concerns, achieved a high degree of technical sophistication and empirical rigor laying foundations that would influence East Asian scientific traditions for centuries.

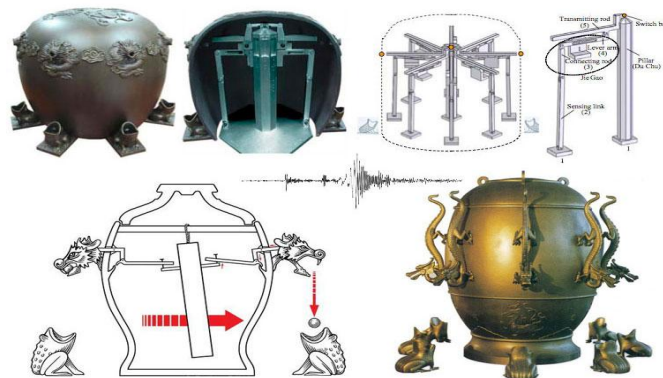


Pythagorean Theorem



Halley's Comet

In 132 CE, Zhang Heng invented the world's first seismoscope an instrument capable of detecting distant earthquakes—and became the first person in China to construct a rotating celestial globe. He also devised an early form of the odometer, a mechanical device for measuring the distance traveled by a vehicle.

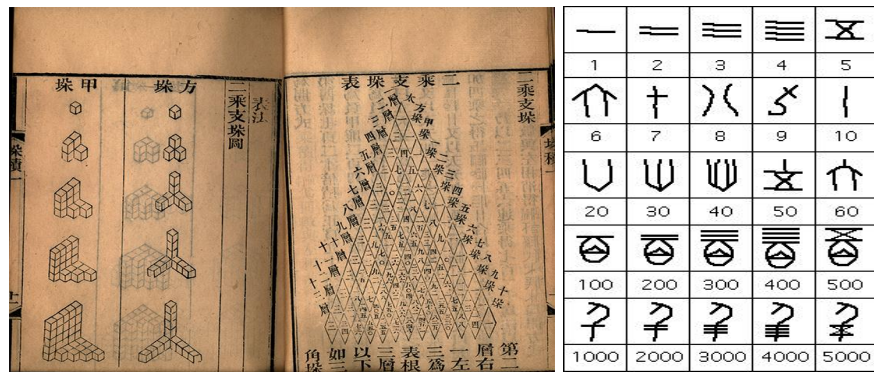


Chinese ancient seismoscope

During the Eastern Han dynasty, Chinese medicine advanced significantly through the contributions of Zhang Zhongjing and Hua Tuo. Notably, Hua Tuo is credited with performing the first recorded use of general anesthesia, marking a pioneering milestone in the history of surgery.

In mathematics, Sun Zi and Qin Jiushao made significant contributions to the study of systems of linear congruences and linear equations, laying foundational work for what

would later be recognized in the West as the Chinese Remainder Theorem and methods for solving simultaneous linear equations.



3.3. Scientific Thought in Ancient India

The Indus Valley Civilization (c. 3300–1500 BCE), one of the earliest urban cultures of the ancient world, laid foundational groundwork for later intellectual developments in South Asia, particularly in the realm of mathematics. Although its script remains undeciphered, archaeological evidence such as standardized weights, calibrated rulers, and geometrically precise urban planning suggests a sophisticated grasp of measurement, proportion, and spatial organization.

It was during the subsequent Vedic and post-Vedic periods, however, that Indian scholars formalized a distinct mathematical tradition known as “gaṇita” (the science of calculation). This tradition emphasized algorithmic problem-solving, arithmetic, algebra, and geometry, often in service of ritual, astronomy “jyotiṣa”, and commerce. A landmark achievement of this intellectual milieu was the development of the “decimal place-value numeral system”, complete with a symbol for zero “śūnya”. This system, which emerged between the 3rd century BCE and the 5th century CE, represented a radical conceptual leap: it enabled efficient representation and manipulation of large numbers, forming the basis of modern arithmetic.

By the early medieval period, Indian mathematical and astronomical texts—most notably the “Āryabhaṭīya” (499 CE) by Āryabhaṭa and the “Brāhmasphuṭasiddhānta” (628 CE) by Brahmagupta had achieved remarkable sophistication, including rules for operations with zero, negative numbers, and quadratic equations. These works were transmitted westward through cultural and scholarly exchanges along trade and intellectual networks.

A pivotal moment in the global dissemination of Indian science occurred in the 9th century CE, when scholars at the “Bayt al-Ḥikma” (House of Wisdom) in Baghdad,

under the Abbasid Caliphate, undertook systematic translations of Sanskrit scientific texts into Arabic. Among them, the mathematician “Muḥammad ibn Mūsā al-Khwārizmī” often regarded as the “father of algebra” and the eponym of the term “algorithm” drew extensively on Indian sources. His seminal work “Kitāb al-Ḥisāb al-Hindī” (“On the Calculation with Hindu Numerals”) introduced the Indian decimal system to the Islamic world. From there, these numerals later mislabeled in Europe as “Arabic numerals” spread across the Mediterranean and eventually revolutionized mathematical practice in medieval and Renaissance Europe.

Thus, the Indian contribution to the history of science extends far beyond regional boundaries: its numerical innovations became the universal language of mathematics, underpinning scientific, technological, and commercial progress across civilizations.

Indian mathematicians made groundbreaking contributions to the development of advanced mathematical concepts, including the formalization of **zero** as a number, the systematic use of **negative numbers**, and early formulations of principles that anticipate **differential and integral calculus** notably in the work of scholars such as Aryabhata (5th century CE) and Bhāskara II (12th century CE), who explored instantaneous motion and infinitesimal increments centuries before the advent of modern calculus in Europe.



4. Science in the Middle Ages: A Transcultural Foundation for Modern Knowledge

Although the term “Middle Ages” is often associated narrowly with European history conventionally spanning from the early 6th century (e.g., the reign of Justinian I, c. 527–565 CE) to the late 15th century (marked symbolically by the fall of Constantinople in 1453 or Columbus’s voyage in 1492) the scientific and technological dynamism of this era was profoundly transregional. Far from being a period of intellectual stagnation, as popularized by Enlightenment-era narratives and outdated textbook accounts, the medieval world witnessed a vibrant circulation of

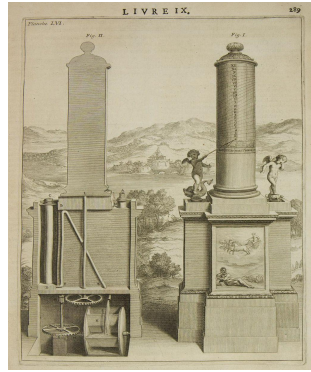
knowledge across Byzantine, Islamic, and East Asian civilizations. These interconnected traditions played a decisive role in shaping the epistemological and methodological foundations of what would later be termed “modern science” a systematic, institutionalized, and internationally collaborative enterprise grounded in empirical observation, logical reasoning, and reproducible experimentation.

4.1. Byzantium and the Transmission of Technical Knowledge to the Islamic World

The Byzantine Empire, heir to the Greco-Roman intellectual legacy, served as a crucial repository and innovator of scientific and engineering knowledge during late antiquity and the early medieval period. Byzantine scholars preserved and expanded upon classical texts in mathematics, astronomy, medicine, and mechanics, while engineers developed sophisticated urban infrastructure. Notably, they achieved remarkable mastery in hydraulic engineering, designing complex systems for municipal water supply, sewage management, and public fountains in cities such as Constantinople. They also refined water clocks (clepsydrae) for timekeeping in both civic and monastic contexts and constructed large-scale noria wheels undershot waterwheels used for irrigation and lifting water from rivers to elevated aqueducts.

These hydraulic technologies did not remain confined to the Eastern Roman world. Through diplomatic exchanges, trade, and scholarly translation movements particularly during the Umayyad and Abbasid caliphates they were systematically adopted, improved, and disseminated by the Arabo-Islamic civilization. In cities like Baghdad, Damascus, and Cordoba, Muslim engineers integrated Byzantine hydraulic principles with Persian and Indian innovations, creating advanced irrigation networks, automata, and astronomical instruments. This cross-cultural synthesis not only sustained agricultural productivity across arid regions but also laid the groundwork for later European technological developments during the Renaissance.

Thus, the medieval period emerges not as an “age of darkness,” but as a critical bridge a dynamic era of knowledge transfer and innovation in which Byzantine, Islamic, and Chinese scientific traditions collectively nurtured the seeds of modern scientific practice.



Water clocks.

During the early medieval period, the Byzantine Empire played a pivotal role as a custodian of classical learning. Imperial and ecclesiastical institutions—often functioning as proto-universities and extensive monastic libraries systematically preserved, copied, and annotated a vast corpus of ancient texts encompassing philosophy, mathematics, astronomy, and natural philosophy. Scholars in Constantinople and other Byzantine centers not only safeguarded the works of Aristotle, Ptolemy, Galen, and Euclid but also produced commentaries and syntheses that would later prove instrumental in the intellectual revival of Western Europe.

Central to this evolution was the reconceptualization of natural philosophy (*philosophia naturalis*) as the disciplined study of nature understood as an ordered system of phenomena (*pragmata*) governed by intelligible principles what would later be termed “laws of nature.” In the Late Middle Ages (13th–15th centuries), scholars associated with the University of Paris and the Oxford Calculators (e.g., Robert Grosseteste, Roger Bacon, Jean Buridan) began to advocate for observation, measurement, and mathematical modeling as essential tools for understanding physical reality. Although the Port-Royal des Champs academy emerged much later (17th century) and thus does not belong to the medieval period, its emphasis on clear logic and methodological rigor reflects a long-standing trajectory that originated in these earlier scholastic efforts.

Thus, the medieval period, far from being an intellectual void, constituted a dynamic and multifaceted era of preservation, transmission, and innovation that laid the essential epistemological and institutional foundations for the Scientific Revolution.

4.2. The Arabo-Islamic World: A Golden Age of Scientific Synthesis and Innovation

Between the 8th and 14th centuries CE, the Arabo-Islamic world experienced an unprecedented intellectual flourishing often referred to as the Islamic Golden Age that laid the groundwork for a distinctive and highly influential scientific tradition. This era of scholarly dynamism emerged first in Damascus under the late Umayyad caliphs but reached its zenith in Baghdad following the Abbasid Revolution (750 CE), particularly under the patronage of caliphs such as al-Ma'mūn and his illustrious predecessor Hārūn al-Rashīd.

Central to this scientific renaissance was a systematic program of translation, commentary, and critical engagement with the intellectual heritage of antiquity. Through institutions like the famed Bayt al-Ḥikma (House of Wisdom), established in Baghdad in the early 9th century, scholars Muslim, Christian, Jewish, and Zoroastrian alike translated into Arabic a vast corpus of Greek, Persian, Indian, and Syriac texts in philosophy, medicine, astronomy, mathematics, and optics. Far from passive transmission, this process involved rigorous critique, correction, and expansion of classical knowledge, often integrating it with empirical observation and original theoretical insights.

The geographical expansion of the Islamic empire played a pivotal role in facilitating this cross-cultural exchange. As Arab armies and traders traversed from the Iberian Peninsula to Central Asia and the Indian subcontinent, they encountered and assimilated scientific traditions from diverse civilizations. Notably, contact with Tang China following the Battle of Talas (751 CE) led to the adoption of papermaking technology, which rapidly supplanted parchment and papyrus across the Islamic world. This technological shift dramatically lowered the cost of book production, enabling the widespread dissemination of knowledge and the growth of libraries, madrasas, and scholarly networks from Cordoba to Samarkand.

Astronomy, in particular, received exceptional state support due to its religious, navigational, and calendrical importance. Caliph Hārūn al-Rashīd (r. 786–809), himself a devoted patron of the sciences, commissioned astronomical tables (zījēs) and sponsored the construction of instruments. His successors institutionalized this commitment: in 829 CE, the first permanent observatory in the Islamic world was established in Baghdad under the direction of astronomers such as Yaḥyā ibn Abī Maṣṣūr. Equipped with armillary spheres, astrolabes, and quadrants, this observatory

enabled systematic, long-term recording of celestial phenomena, leading to refined models of planetary motion and more accurate predictions of eclipses and solstices. Thus, the scientific culture of the Arabo-Islamic world was not merely derivative but synthetic and generative a dynamic fusion of inherited knowledge and original inquiry that preserved, transformed, and ultimately transmitted the foundations of classical science to both the medieval Latin West and later global scientific traditions.

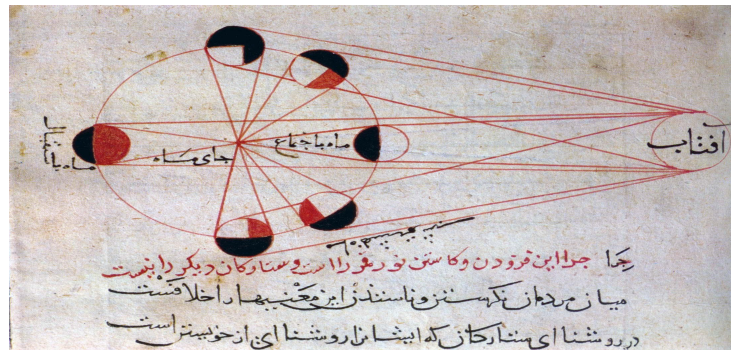


Page from al-Khwarizmi's *Algebra*. Photo credit: Al-Khwarizmi - Esposito, John L., ed. (1999) *The Oxford History of Islam*, Oxford University Press.

Long before the Copernican revolution, the Persian polymath Abū Rayḥān al-Bīrūnī (973–1048 CE) made remarkable contributions to geodesy and cosmology by building upon the foundational work of Eratosthenes of Alexandria (3rd century BCE). Using an innovative trigonometric method based on the measurement of the dip angle of the horizon from a mountain of known height al-Bīrūnī calculated the Earth's radius with striking accuracy, arriving at a value within 1% of the modern figure. Moreover, he critically examined the motion of celestial bodies and explicitly argued that the Earth rotates on its axis, a hypothesis he supported through physical reasoning and astronomical observation, centuries before Galileo's advocacy of heliocentrism.

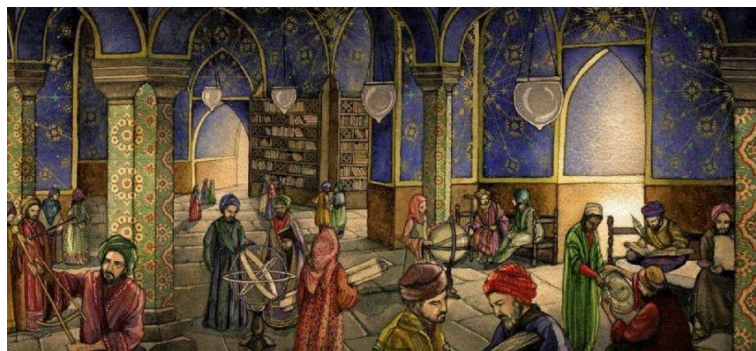
This intellectual breakthrough was made possible by the vibrant scholarly ecosystem of the Islamic Golden Age, epitomized by institutions such as the Bayt al-Ḥikma (House of Wisdom), formally established in Baghdad in 832 CE under the Abbasid Caliph al-Ma'mūn. Far more than mere libraries, these centers functioned as dynamic academies where scholars from diverse religious and cultural backgrounds Muslim, Christian, Jewish, and Zoroastrian translated, debated, and expanded upon the scientific heritage of Greece, Persia, and India. It was within this collaborative and cosmopolitan environment that ancient

knowledge was not only preserved but critically reinterpreted, laying essential groundwork for the later development of modern science.



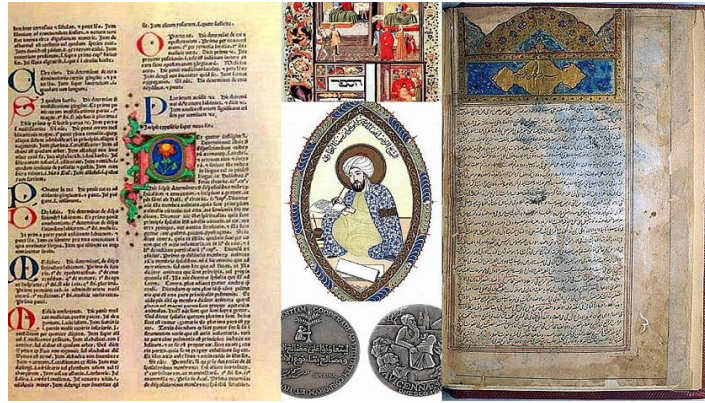
An illustration from al-Biruni's astronomical works, explains the different phases of the Moon, with respect to the position of the Sun

In 832, the Houses of Wisdom “Bayt al-Ḥikma” were established, a prestigious institutions dedicated to the exchange, translation, and dissemination of scientific and philosophical knowledge across civilizations.



Scholars in an house of wisdom “Bayt al-Ḥikma”

In medicine, Avicenna (980–1037) authored a monumental encyclopedia the Canon of Medicine which synthesized Greco-Roman, Persian, and Indian medical knowledge into a comprehensive and systematic treatise that would dominate medical education in both the Islamic world and Europe for over six centuries.



A picture of Avicenna's Canon of medicine which was the main source of medicine in Europe



Ibn al-Nafis and Al-Razi old manuscripts

Scholars such as Ibn al-Nafis and al-Razi played pivotal roles in the advancement of medical knowledge: Ibn al-Nafis provided the first accurate description of pulmonary circulation, while al-Razi pioneered the use of alcohol as a disinfectant in medical practice.

In the late 10th to early 11th century, the Andalusian physician and surgeon Abū al-Qāsim al-Zahrāwī (known in Latin Europe as Abulcasis) authored the “Kitāb al-Taṣrīf li-man ‘ajaza ‘an al-ta’līf” (The Method of Medicine for Those Unable to Compose), a thirty-volume medical encyclopedia that would become one of the most influential surgical texts of the medieval world. The final volume, dedicated entirely to surgery, broke new ground by systematically describing over 200 surgical instruments many of which he designed or refined and detailing procedures ranging from cauterization and wound management to cataract extraction, lithotomy, and dental surgery. Crucially, al-Zahrāwī emphasized empirical observation, technical precision, and ethical responsibility, rejecting speculative theory in favor of practical, experience-based instruction. Translated into Latin by Gerard of Cremona in the 12th century, the Taṣrīf served as the standard surgical reference in European universities for more than five

centuries, profoundly shaping the development of Western medical practice and establishing al-Zahrāwī as a foundational figure in the history of surgery.



Some of the surgical instruments designed by Al-Zahrāwī

During the medieval period, the scientific and mathematical legacy of antiquity particularly the works of Greek, Indian, and Persian scholars was not only preserved but significantly expanded upon within the Arabo-Islamic intellectual tradition. This synthesis laid the groundwork for the emergence of algebra as a distinct mathematical discipline, most notably through the systematic treatises of scholars such as Al-Khwārizmī in the 9th century. A pivotal innovation of this era was the adoption and refinement of the Indian decimal numeral system, including the concept of zero as both a placeholder and a number in its own right. These numerals later transmitted to Europe via Latin translations and mislabeled as “Arabic numerals” revolutionized computation, enabling more efficient arithmetic, algebraic manipulation, and the eventual development of advanced mathematical sciences.

4.3. Scientific and Technological Innovation in Medieval China

While ancient and medieval China is often celebrated for its philosophical and administrative sophistication, its most enduring global legacy lies in a series of transformative technological breakthroughs. Among these, four innovations stand out as foundational to the development of modern civilization: paper, movable-type printing, gunpowder, and the magnetic compass.

Paper making, traditionally attributed to Cai Lun in the Eastern Han dynasty (c. 105 CE), though with earlier archaeological evidence dating to the 2nd century BCE, revolutionized record-keeping, education, and bureaucratic administration. By the 9th century CE, Chinese artisans had developed movable-type printing centuries before Gutenberg enabling the mass reproduction of texts. Gunpowder, first documented in the Wujing Zongyao (Complete Essentials from the Military Classics), a military

compendium compiled around 1044 CE during the Northern Song dynasty, was initially used for incendiary devices and ceremonial fireworks before evolving into a pivotal element of warfare.

The magnetic compass, originally employed in the 11th century for feng shui (geomancy) to align buildings harmoniously with cosmic forces, was soon adapted for navigation. The polymath Shen Kuo (1031–1095), a statesman, astronomer, and scientist of the Song dynasty, provided one of the earliest known descriptions of the magnetic needle compass as a navigational instrument in his Dream Pool Essays (Mengxi Bitan, 1088). He not only documented magnetic declination but also emphasized empirical observation and experimental reasoning hallmarks of an incipient scientific methodology. Together, these innovations illustrate how medieval Chinese science, though often embedded in practical, administrative, or cosmological frameworks, generated technologies of profound global consequence, many of which would later catalyze scientific and industrial transformations in other parts of the world.



Han Dynasty loadstone compass, called Nainan of the time (206 BC - 220 AD).

In his monumental 17-volume work *Science and Civilisation in China*, the historian Joseph Needham argued that Chinese society developed a highly innovative scientific tradition from its earliest periods challenging the Eurocentric narrative that modern science originated exclusively in the West. He emphasized that, long before the emergence of European universities, China pursued knowledge with a spirit of systematic, disinterested inquiry. This is evident in mathematical treatises such as *The Nine Chapters on the Mathematical Art* a foundational text containing 246 problems, later annotated by Liu Hui (3rd century CE) and Li Chunfeng (7th century CE) as well as Li Ye's *Ceyuan Haijing* (1248), which explores advanced topics including fractions, square and cube root extraction, area of the circle, and volume of pyramids. Historian Karine Chemla has demonstrated that the widespread belief that rigorous mathematical proof is uniquely Greek is historically incomplete. Chinese

mathematicians engaged with comparable epistemological questions, developing their own forms of demonstration and validation. As Chemla asserts, “One cannot remain Western-centric; the history of science demands an international perspective that recognizes the plurality of knowledge traditions.”

4.5. Medieval Indian Mathematics: Abstraction, Innovation, and the Foundations of Calculus

Unlike the pragmatic, application-oriented mathematics of ancient Egypt, classical Indian mathematics was characterized by a high degree of abstraction and theoretical sophistication. A pivotal figure in this tradition was Brahmagupta (598–668 CE), whose seminal work, the *Brāhmasphuṭasiddhānta* (628 CE), provided the first comprehensive treatment of zero not merely as a placeholder but as a full-fledged number and formalized the rules for arithmetic operations involving negative numbers and square roots. This text also completed the development of the decimal place-value numeral system, which would later revolutionize global mathematics.

Remarkably, Brahmagupta described what 17th-century European mathematicians would later call the “chakravala method” a cyclic algorithm for solving indeterminate quadratic equations (Pell’s equation) demonstrating advanced algebraic insight centuries ahead of its time.

The tradition culminated with Bhāskara II (1114–1185), whose treatises, especially the *Siddhānta Shiromani*, contain sophisticated results in polynomial algebra, trigonometry (including angle-addition formulas), and early concepts of differential calculus. Bhāskara explicitly discussed instantaneous motion (*tat-kāla*), introduced notions akin to the derivative, and described methods resembling differentiation, earning him recognition as a forerunner of mathematical analysis.

Earlier, Āryabhaṭa (476–550) had already laid crucial groundwork in his *Āryabhaṭīya* (c. 499 CE) a concise astronomical treatise in verse that presents 66 mathematical propositions spanning arithmetic, algebra, and both plane and spherical trigonometry. Notably, Āryabhaṭa devised a phonetic numeral system using Sanskrit consonants to encode numbers a remarkable innovation in symbolic representation.

These advances were further refined from the 14th to 16th centuries by the Kerala School of Astronomy and Mathematics, including scholars such as Mādhava of and Jyeṣṭhadeva. This lineage developed infinite series expansions for trigonometric

functions and proto-calculus techniques anticipating key elements of European analysis by over two centuries.

5. Sciences in the Sixteenth, Seventeenth and Eighteenth centuries

5.1. The Renaissance and the Origins of Modern Science (c. 1450–1600)

The Renaissance marks a pivotal era in the history of science, widely regarded as the period in which the foundations of modern experimental science were laid. Far from being confined to the realm of ideas, this intellectual shift was embedded within a broader cultural, social, and artistic transformation that redefined European thought. During the 16th and early 17th centuries, a profound epistemological transition took place, characterized by:

- **The emergence of a new scientific mindset**, grounded in reason and empirical inquiry;
- **A critical reassessment of classical and medieval doctrines** particularly in natural philosophy and biology that had long gone unchallenged;
- **The systematic adoption of observation**, controlled experimentation, and mathematical quantification as essential methods for investigating nature;
- In the life sciences, **the invention of the microscope toward the end of the 16th century** and its progressive refinement throughout the 17th century, which opened entirely new dimensions of biological investigation by revealing the previously invisible world of cells and microorganisms.

5.1.1. The Sixteenth Century: Foundations of Modern Life Sciences

The 16th century marked a transformative era in the biological and medical sciences, characterized by a shift toward empirical observation and systematic documentation. Two major developments defined this period:

- **Advancements in human anatomy**, driven by direct dissection and meticulous illustration, most notably exemplified by Andreas Vesalius's *De humani corporis fabrica* (1543), which challenged centuries-old Galenic doctrines and established anatomy as a discipline grounded in firsthand observation.
- **The proliferation of richly illustrated works in botany and zoology**, which reflected a growing interest in the natural world. Scholars such as Leonhart Fuchs, Conrad Gessner, and Ulisse Aldrovandi produced detailed compendia that cataloged plants and animals with unprecedented accuracy, laying the groundwork for modern taxonomy and comparative biology.

Together, these innovations signaled the emergence of a new scientific ethos one that privileged visual evidence, empirical inquiry, and the systematic classification of living organisms.

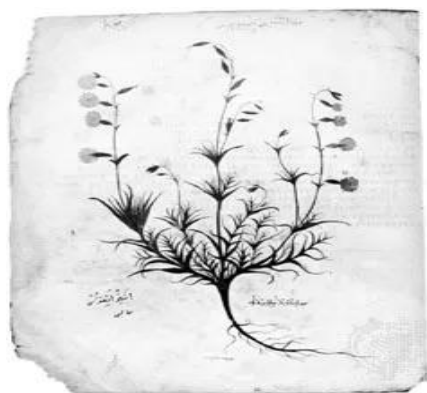


Illustration of an aster (*Silene linoides*) in the 6th-century codex of the *De materia medica* of Pedanius Dioscorides

5.1.2. The Seventeenth Century and the Scientific Revolution

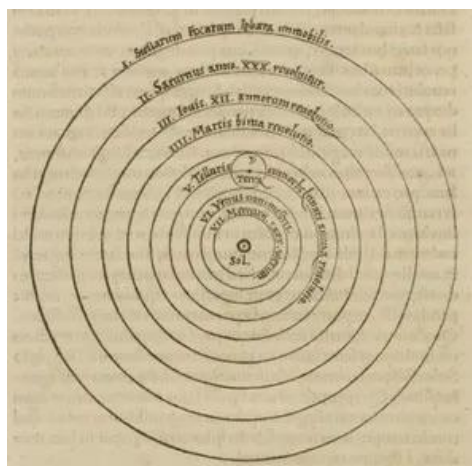
The 17th century stands as a defining era in the history of science, often referred to as the period of the Scientific Revolution. This transformation was driven by the mathematization of natural philosophy, the systematic adoption of experimental methods, and the rise of mechanistic explanations of natural phenomena—including those of the living world.

Several key developments laid the groundwork for this intellectual shift:

- **Anatomical Science:** The practice of human dissection, pioneered in the Renaissance by figures such as Andreas Vesalius, became increasingly central to medical education, enabling accurate descriptions of human physiology and challenging long-standing Galenic doctrines.
- **The Printing Press:** Although invented around 1450 by Johannes Gutenberg, the printing press with movable type reached its full scholarly impact in the 17th century. By enabling the mass production and wide dissemination of scientific texts, it facilitated the rapid exchange of ideas across Europe.
- **Heliocentrism:** In 1543, Nicolaus Copernicus published *De revolutionibus orbium coelestium*, proposing a heliocentric model of the cosmos in which the Earth and other planets revolve around the Sun. This revolutionary idea dismantled the geocentric worldview that had dominated medieval thought.
- **Advancement of the Life Sciences:** The 17th century witnessed the flourishing of botany, zoology, anatomy, and medicine, all increasingly grounded in direct observation and empirical evidence.

A pivotal technological innovation of this era was the **microscope**. First developed around 1595 by the Dutch spectacle-maker **Zacharias Janssen** who combined two lenses in sliding tubes to magnify small objects it remained a curiosity until the late 17th century. It was then refined and put to groundbreaking scientific use by **Robert Hooke** and **Antonie van Leeuwenhoek**. Hooke's *Micrographia* (1665) revealed the cellular structure of cork, coining the term "cell," while Leeuwenhoek, using superior single-lens microscopes of his own design, became the first to observe living microorganisms, including bacteria and protozoa. These discoveries unveiled an entirely new dimension of the natural world, invisible to the naked eye, and laid the foundations for modern biology and microbiology.

Together, these advances exemplify how the integration of instrumentation, empirical observation, and mathematical reasoning redefined the scope and methods of scientific inquiry during the Scientific Revolution.



Engraving of the solar system from Nicolaus Copernicus's *De revolutionibus orbium coelestium libri*



The first compound microscope

5.2. The Eighteenth Century and the Foundations of Evolutionary Thought

5.2.1. The Enlightenment and the Scientific Study of Life

The 18th century often termed the **Age of Enlightenment** was a transformative era in European and transatlantic intellectual history. Marked by a profound faith in reason, empirical inquiry, and human progress, this period witnessed an unprecedented expansion of scientific knowledge, particularly in the natural sciences.

Scholars of the time turned their attention to the systematic study of the living world. Botany, zoology, ornithology, and the classification of exotic species became central pursuits, fueled by global exploration and colonial expansion. Figures such as Jean-Baptiste Lamarck began to investigate invertebrates and propose early theories of biological change, laying conceptual groundwork for later evolutionary thought.

A landmark intellectual achievement of the century was the publication of the **Encyclopédie**, ou “**Dictionnaire raisonné des sciences, des arts et des métiers**” (1751–1772), edited by Denis Diderot and Jean le Rond d’Alembert. This monumental work sought to compile and critically assess the totality of human knowledge, championing empirical science, technological innovation, and secular reasoning. It stood as both a product and a catalyst of Enlightenment ideals, celebrating scientific progress as a driving force of societal advancement.



View of the spines of multiple volumes of the Encyclopédia

5.2.2. Charles Darwin and the Theory of Evolution by Natural Selection

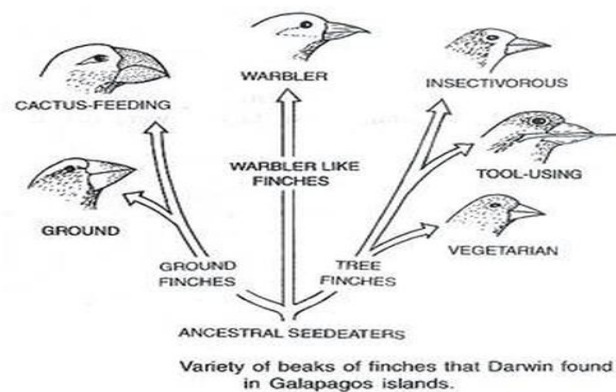
Although Charles Robert Darwin (1809–1882) lived primarily in the 19th century, his revolutionary ideas were deeply rooted in the empirical and taxonomic traditions forged during the Enlightenment. Darwin is widely regarded as one of the most influential biologists in history. His seminal work, *On the Origin of Species* (published on 24 November 1859), introduced a unifying explanation for the diversity of life: evolution through natural selection. According to Darwin’s theory, all living

organisms descend from common ancestors and undergo gradual morphological and genetic change across generations.

This process is driven by natural selection a mechanism whereby individuals possessing heritable traits better suited to their environment are more likely to survive, reproduce, and pass those advantageous traits to offspring. Over time, this differential reproduction can lead to the emergence of new species and the extinction of others.

Darwin's theory fundamentally redefined biology, replacing static conceptions of nature with a dynamic, historical framework. It provided a scientific explanation for the observed variation, adaptation, and complexity of life, and remains the cornerstone of modern biological science.

***Note for students:** While Darwin's major contributions belong to the 19th century, they emerged from the Enlightenment's legacy of observation, classification, and rational inquiry making the 18th century essential to understanding the origins of evolutionary biology.*



Species evolution example according to Darwin's theory of evolution

6. Nineteenth century: cell theory (microscopy), Sexuality, Embryology, and Genetics

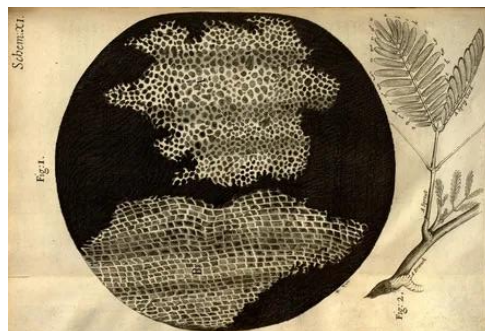
6.1. Cell Theory: Foundations of Modern Biology

Cell theory is a cornerstone of biological science, formalized in the 19th century but rooted in discoveries spanning from the 17th to the mid-1800s.

It rests on three fundamental principles:

- All living organisms are composed of one or more cells;
- The cell is the basic structural and functional unit of life;
- All cells arise from pre-existing cells through division.

The development of cell theory was made possible by advances in microscopy. In 1665, **Robert Hooke** English scientist and architect coined the term “**cell**” after observing box-like cavities in a thin slice of cork using a self-built compound microscope. He published these findings in “**Micrographia**”, likening the structures to small rooms “**cellulae** in Latin”.



Robert Hooke's drawings of the cellular structure of cork and a sprig of sensitive plant from Micrographia (1665).

A major conceptual leap came with **Antonie van Leeuwenhoek** commonly known as the "**father of microbiology**", a Dutch tradesman and skilled lens grinder, who crafted single-lens microscopes capable of over 200× magnification. In the 1670s, he became the first to observe and describe living microscopic organisms, which he called “animalcules” including protozoa from pond water and bacteria from dental plaque. His work revealed that life existed at scales invisible to the naked eye, laying the groundwork for microbiology and affirming the cell as a living entity, not merely an empty compartment. Although the cell is the smallest unit of life, it is itself organized into specialized sub-cellular structures organelles that carry out essential functions. Thus, while cells are the foundational units of organisms, they are not the smallest biological structures.

Cell theory ultimately unified biology by providing a common framework for understanding growth, reproduction, disease, and evolution across all forms of life.

In 1838, the German botanist **Matthias Schleiden** concluded that all plants are composed of cells, emphasizing the role of the nucleus in cell formation. The following year, physiologist Theodor Schwann extended this idea to animals, proposing that all living things are cellular. Together, Schleiden and Schwann are regarded as the co-founders of classical cell theory.

Finally, in 1855, the pathologist **Rudolf Virchow** articulated the principle “*omnis cellula e cellula*” (“**every cell comes from a cell**”), rejecting spontaneous generation and establishing cell division as the basis of growth, repair, and reproduction.

While the cell is the smallest unit considered independently alive, it is itself organized into sub-cellular structures organelles that carry out specialized functions. Thus, cell theory not only unified the diversity of life under a common biological framework but also laid the groundwork for modern disciplines such as histology, microbiology, and molecular biology.

6.2. Embryology: From Ancient Speculation to Scientific Foundations

Embryology is the branch of biology that studies the development of organisms from fertilization through to birth or hatching, focusing on the processes, mechanisms, and causes that govern embryonic formation.

Its origins trace back to Antiquity, where philosophers and physicians most notably Aristotle sought to understand generation and development. Lacking advanced observational tools, they relied largely on the dissection of animal eggs (especially chicken eggs) and philosophical reasoning. Aristotle’s *Historia Animalium* included the first known classification of animals into **oviparous**, **viviparous**, and **ovoviviparous** groups and proposed a systematic account of **embryogenesis**. However, his explanations were deeply rooted in teleological (finalist) thinking, which often prioritized purpose over mechanism and hindered empirical progress for centuries.

A decisive turning point came in 1651 with the publication of **William Harvey**’s *Exercitationes de generatione animalium* (On the Generation of Animals). Challenging preformationist ideas, Harvey asserted the principle “*ex ovo omnia*” (“**all living things arise from an egg**”) and, through careful observation of chick development, demonstrated that the embryo forms progressively structure by structure. This supported the theory of **epigenesis**, which holds that complex forms emerge gradually from an initially undifferentiated state, laying the groundwork for modern developmental biology.

The discovery of **spermatozoa** by **Antonie van Leeuwenhoek** (1677) and the identification of ovarian follicles by **Regnier de Graaf** led to the rise of **preformationism** a theory that temporarily replaced epigenesis as the dominant explanation for embryonic development. Preformationism held that a complete, miniature organism (a homunculus) existed preformed from the moment of

conception, and that development consisted merely of its gradual enlargement, not the formation of new structures. This idea split into two competing schools:

- **Ovism:** championed by scientists such as **Marcello Malpighi**, **Charles Bonnet**, and **Nicolas Malebranche**, who argued that the preformed individual resided in the egg. Bonnet famously proposed the “**encasement of germs**” (emboîtement des germes), suggesting that all future generations were nested within the ovaries of Eve, like a series of Russian dolls.

Animalculism: supported by Leeuwenhoek, **Nicolas Hartsoeker**, **Gottfried Leibniz**, and others, who believed the homunculus was contained within the spermatozoon, with the egg serving only as a nourishing environment.

Though imaginative and influential in its time, preformationism was eventually refuted in the 19th century by advances in microscopy and cell theory, which reaffirmed the epigenetic view that organisms develop progressively from undifferentiated material.

6.3. Immunology: Foundations of the Science of Immunity

Immunology is the scientific study of immunity a term derived from the Latin **immunitas**, meaning “exemption” or “protection.” In biological terms, immunity refers to an organism’s ability to resist or eliminate pathogenic agents such as bacteria, viruses, and other foreign substances.

Although forms of empirical immunization existed earlier (e.g., variolation), immunology emerged as a rigorous scientific discipline in the 19th century, driven by three pioneering figures:

- **Edward Jenner** (1749–1823, England) pioneered the concept of **vaccination** by demonstrating that inoculation with cowpox (*Vaccinia virus*) conferred protection against smallpox a breakthrough that laid the groundwork for preventive medicine.
- **Louis Pasteur** (1822–1895, France) expanded the principle of vaccination beyond smallpox. He developed laboratory methods to **attenuate or inactivate pathogens** (e.g., for rabies and anthrax) and introduced the term “vaccination” in its modern, generalized sense.
- **Robert Koch** (1843–1910, Germany) established the **germ theory of disease**, proving that specific microorganisms cause specific illnesses. His postulates

provided a systematic framework for linking pathogens to disease, cementing microbiology as a cornerstone of immunology.

Together, these advances transformed immunization from a folk practice into a scientific, reproducible, and scalable public health strategy, ultimately enabling the control—and in some cases, eradication—of deadly infectious diseases.

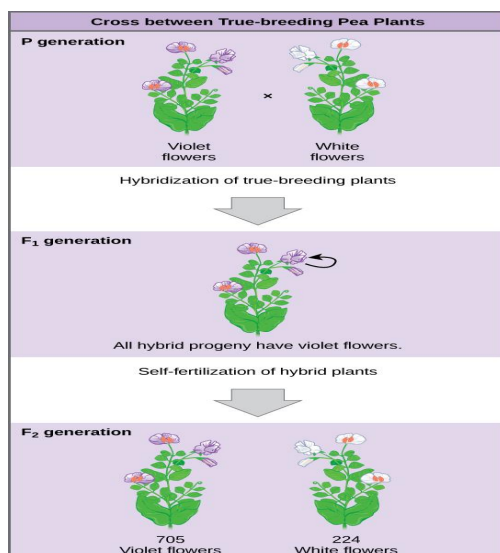
6.4. Genetics: From Mendel's Experiments to a Foundational Science

Although genetics emerged as a formal scientific discipline only in the early 20th century, its conceptual foundations were laid in the mid-19th century by **George Mendel**. Through meticulous **hybridization** experiments with pea plants (*Pisum sativum*), Mendel investigated the inheritance of clearly defined traits such as seed color and shape and established that **hereditary factors** (now called **genes**) are transmitted in discrete units.

His work revealed three key principles:

1. Traits are determined by paired hereditary factors;
2. These factors segregate during gamete formation;
3. Some traits are **dominant** while others are **recessive**, explaining patterns of **phenotypic** expression.

Despite its rigor, Mendel's research remained largely unrecognized until its rediscovery around 1900 a period marked by growing demands in agriculture due to industrialization, urbanization, and population growth. The need to develop higher-yielding, disease-resistant, and climate-resilient crop varieties created a practical impetus for understanding heredity, catalyzing the birth of modern genetics as both a theoretical and applied science.



Mendel's process for performing crosses included examining flower color.

7. Twentieth century: molecular biology, gene therapy, and cloning

7.1. Molecular Biology: Foundations of Modern Life Sciences

Molecular biology emerged in the mid-20th century as a revolutionary synthesis of biology, chemistry, and physics. The field was conceptually anticipated by physicist **Erwin Schrödinger** in his 1944 book **What Is Life?**, which inspired a generation of scientists to seek the physical basis of heredity.

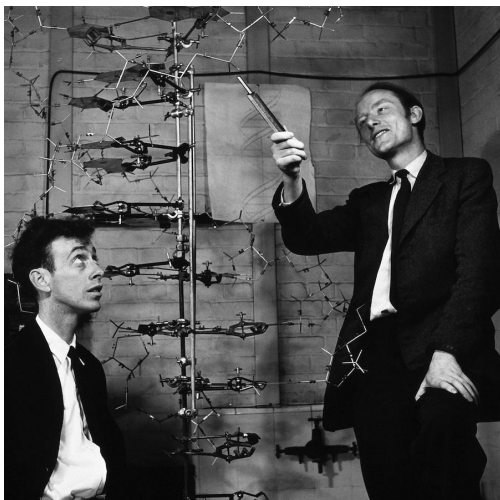
Two landmark discoveries catalyzed the birth of molecular biology:

1. In 1944, **Oswald Avery** and colleagues demonstrated that the **DNA** is the molecular carrier of genetic information.
2. In 1953, **James Watson** and **Francis Crick**, using **Rosalind Franklin**'s X-ray diffraction data, proposed the **double-helix structure** of DNA, revealing how genetic information is stored and replicated.

This molecular framework built upon three foundational pillars of biological thought:

1. **Charles Darwin**'s **theory of evolution** by **natural selection** (1859), which explained the diversity and adaptation of life through gradual change over generations.
2. **Gregor Mendel**'s laws of inheritance (1866), which established the principles of **dominant** and **recessive** traits though his work remained unrecognized until its rediscovery around 1900.
3. **August Weismann**'s "**germ plasm theory**" (1885), which distinguished germ cells (responsible for heredity) from somatic cells (the mortal body), laying the conceptual groundwork for genetics.

The convergence of these ideas evolution, heredity, and molecular structure transformed biology into a unified, mechanistic science capable of explaining life from the level of molecules to ecosystems.



**James Watson and Francis Crick with
their DNA model at the Cavendish
Laboratory in 1953.**

7.2. Gene Therapy: Principles and Therapeutic Applications

Gene therapy is a **biomedical** strategy that involves the targeted delivery of functional genetic material into a patient's cells to correct or compensate for a disease-causing genetic defect. Originally developed to treat monogenic disorders conditions resulting from mutations in a single gene it aims to restore normal cellular function by introducing a functional copy of the affected gene.

The therapeutic objectives of gene therapy include:

- **Restoring metabolic pathways** disrupted by enzyme deficiencies (e.g., inborn errors of metabolism);
- **Mitigating pathological effects** of genetic mutations (e.g., stabilizing red blood cell membranes in hereditary spherocytosis);
- **Providing essential diffusible factors** (such as hormones or enzymes) whose absence underlies clinical symptoms;
- **Targeting cancer** by enabling localized expression of anti-tumor agents, such as cytokines or pro-apoptotic proteins, directly within tumor tissue.

While early efforts focused on inherited diseases, advances in vector design and genome editing have expanded gene therapy's potential to acquired conditions, including oncological and degenerative disorders.

7.3. Molecular Cloning: Principles and Procedure

Molecular cloning is a foundational technique in **genetic engineering** that enables the isolation, amplification, and propagation of a specific DNA sequence within a host organism. This is achieved by constructing a recombinant DNA molecule typically by inserting the target DNA fragment into a plasmid vector and introducing it into a host cell (e.g., *E. coli*), where it is replicated autonomously.

7.3.1. Key Steps of the molecular cloning:

1. Preparation of the Insert:

The DNA fragment of interest (e.g., a gene, promoter, or operon) is isolated using methods such as restriction enzyme digestion, PCR amplification, or chemical synthesis of oligonucleotides.

2. Vector Preparation:

A plasmid vector a small, circular, double-stranded DNA molecule capable of autonomous replication is linearized using restriction enzymes or PCR. It contains

essential elements including an origin of replication, a selectable marker (e.g., antibiotic resistance), and a multiple cloning site (MCS).

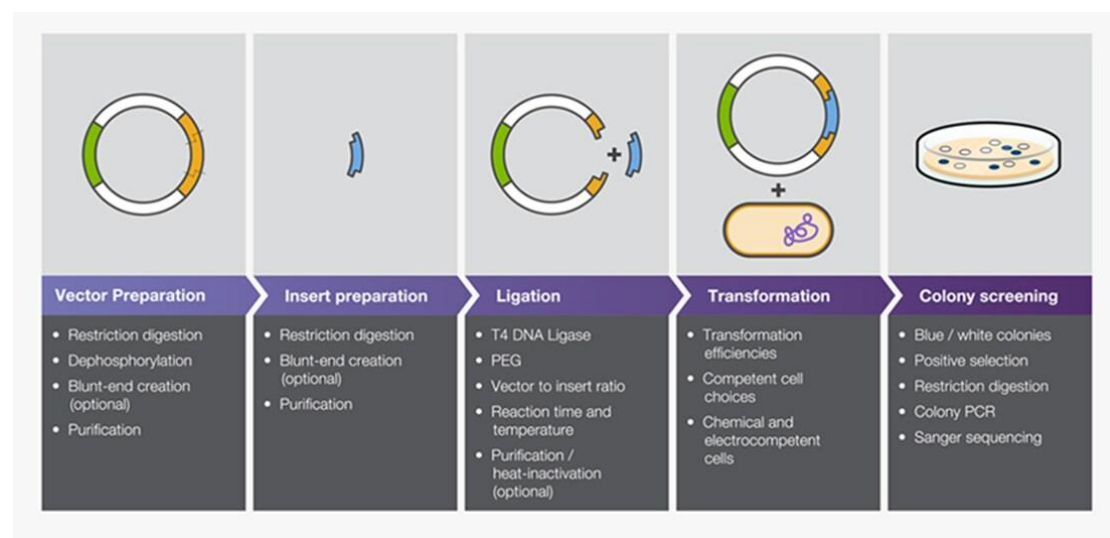
3. Ligation and Recombination:

The insert and linearized vector are enzymatically modified (e.g., with kinases, phosphatases, or compatible cohesive/blunt ends) to ensure compatibility. They are then joined via phosphodiester bonds using DNA ligase, forming a recombinant plasmid.

4. Transformation and Amplification:

The recombinant plasmid is introduced into host cells through transformation. Successfully transformed cells are selected and cultured, allowing the recombinant DNA to be replicated in large quantities.

Modern cloning strategies including **TA cloning**, **Gibson assembly**, and **commercial cloning kits** have streamlined these steps, enhancing efficiency, precision, and accessibility in molecular biology research.



A general workflow for traditional cloning



THE SCIENTIFIC REVOLUTION IN EUROPE c. 1500 - 1700

1558 Urdaneta discovers the sea route from Asia to the Americas

1614
S. SANTORIO
METABOLISM,
MEDICAL DEVICES



1637
R. DESCARTES
"COGITO, ERGO SUM"
DEDUCTIVE REASONING



1673
A. VAN LEEUWENHOEK
MICROBIOLOGY



1618-1648 Thirty Years' War

1556
G. AGRICOLA
MINERALOGY,
MINING SCIENCES



1594
J. NAPIER
LOGARITHMS



1630
G. GALILEI
REFUTES
ARISTOTELIAN SYSTEM



1660
M. MALPIGHI
MICROSCOPICAL
ANATOMY



1690
J. HEVELIUS
STARS
CATALOGUE



1562-1598 French Wars of Religion

1530-1537
O. BRUNFELS
BOTANICAL WRITINGS
ON OBSERVATIONS



1558 Elizabeth I is crowned
1557 Spain declares bankruptcy

1600
W. GILBERT
MAGNETISM
STATIC ELECTRICITY



1620
F. BACON
SCIENTIFIC
METHOD



1647
J. HEVELIUS
MOON MAP



1665
R. HOOKE
MICROBES



1704
I. NEWTON
SPEED OF SOUND,
INFINITESIMAL CALCULUS



1521 Edict of Worms

1547 Ivan the Terrible becomes the first Russian tsar

1543
N. COPERNICUS
HELIOCENTRIC
SOLAR SYSTEM



1577
T. BRAHE
VS. ARISTOTELIAN
COSMOLOGY



1600
G. BRUNO
COSMIC PLURALISM
INFINITE UNIVERSE



1609-1619
J. KEPLER
LAWS OF
PLANETARY MOTION



1660
ROYAL SOCIETY



1687
I. NEWTON
LAWS OF MOTION,
UNIVERSAL GRAVITATION



1669 first steam engine by T. Savery

1525

1550

1575

1600

1625

1650

1675

1700

1725

1543
A. VESALIUS
BOOKS ON
HUMAN ANATOMY



1582
POPE GREGORY XIII
GREGORIAN CALENDAR



1610
G. GALILEI
OBSERVATIONAL
ASTRONOMY



1661
R. BOYLE
MODERN
CHEMISTRY



1677
E. HALLEY
SOUTHERN STARS
MAPPED



1524-1525 German Peasants' War

1569 Mercator 1569 world map

1580-1640 Spanish and Portuguese crowns are united

1589 Bill of Rights

1542
L. FUCHS
PLANTS' USES
AS MEDICINES



1591
F. VIETA
ALGEBRA NOVA



1608
H. LIPERSHEY
REFRACTING
OPTICAL TELESCOPE



1657
C. HUYGENS
PENDULUM
CLOCK



1680
G. BORELLI
BIOMECHANICS



1520-1566 reign of Suleiman the Magnificent

1527 Rome sacked by mutinous troops of Charles V

1532 Church of England breaks away from the Catholic Church

1585
A. PARE
FIELD SURGERY
FORENSIC PATHOLOGY



1619
C. DREBBEL
COMPOUND
MICROSCOPE



1653
B. PASCAL
TRANSMISSION OF
FLUID-PRESSURE



1657
O. VON GUERICKE
VACUUM PUMP



1705
E. HALLEY
COMET
PERIODICITY



1683 the Ottomans are defeated in the siege of Vienna.

1550-1551 Valladolid debate on rights of the indigenous people of the Americas

1621 the Mayflower reaches North America

References

Berche P. (2016). Histoire de la biologie moléculaire. Biologie et Histoire Biologie moléculaire. feuillets de Biologie/N° 333

Cavazzana-Calvo M, Hacein-Bey S, de Saint Basile G, Gross F, Yvon E, Nusbaum P, et al. (2000). Gene therapy of human severe combined immunodeficiency (SCID)-X1 disease. Science; 288 : 669-72.

Corrick, James A. (1998). The Renaissance. San Diego, CA: Lucent Books

Darwin C. (1859). On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life. John Murray, London.

Djebbar Ahmed. (2013). l'âge d'or des sciences arabes le pommier Edit, France
<https://www.a2schools.org/cms/lib/MI01907933/Centricity/domain/2403/humpdf/medieval.pdf> <https://plato.stanford.edu/entries/albert-great/>

Ernest Babelon. (2015). Manual of Oriental Antiquities 1854-1924 Evetts, B. T. A. (Basil Thomas Alfred), 1858- Public domain in the USA.

Gibbons Ann. (2006). The First Human: The Race to Discover Our Earliest Ancestors Hardcover – April 18, 336 pages, illustrations. Publisher: Anchor Books

Guthrie R Dale. (2006). The Nature of Paleolithic Art © 520 pages, 20 halftones, 847 line drawings, published by the University of Chicago Press

Holt Rosa Belle. (1901). Rugs, Oriental and Occidental, Antique and Modern. ED by A. C. McClurg & Company, l'Université du Michigan
<https://www.a2schools.org/cms/lib/MI01907933/Centricity/domain/2403/humpdf/medieval.pdf>

Jean SCHOWING : professeur à la faculté des sciences de Fribourg, Institut de biologie animale M. Moulin (ed.). (1996a). L'Aventure de la vaccination et Le Dernier langage de la médecine. Histoire de l'immunologie de Pasteur au Sida (1991, p. 19 à 22).

Johnson, Paul. (2000). The Renaissance: A Short History. New York: Modern Library
<https://www.encyclopedia.com/fashion/encyclopedias-almanacs-transcripts-and-maps/sixteenth-century>

Josselyne SALAÛN : docteur ès sciences, chargée de recherche au C.N.R.S.
<https://www.universalis.fr/encyclopedie/embryologie/>

Kuhn Thomas. (2014) Chapter 9 « The History of Science » in Philosophy, Science, And History A Guide and Reader. Edited by Lydia Patton

Le Gall Jean-Yves. (2015). La génétique : une brève histoire en pleine expansion. Bull. Acad. Natle Méd., 2015, 199, nos 8-9, 1485-1492

Mason C.P and Hodgson C.R. (1884). Educational Times, and Journal of the college of Preceptors. Vol. XXXVII. New Series, No :273. Fellow of Univ, Coll., London

Murray John and Strret Albemarle, (1859). The origin of species by means of natural selection, on the preservation of favoured races in the struggle for life by Charles Darwin, London.

Ornstein De Martha. (1913). The role of the scientific societies in the seventeenth century
University of Chicago Press,
https://books.google.dz/books?id=F_gvABlClDgC&printsec=frontcover&hl=fr#v=onepage&q&f=false

Philippe Schuwer, Véronique Herbold Mémo Benjamin, Sous la direction de Martine et Daniel Sssier et Marie-Pierre Perdrizet (1991-1994). La Rousse l'Encyclopédie des 7-9 ans. ISSN : 1248-7139. ISBN : 2-03-601-231-0

Raven, Johnson, Mason, Losos, Singer. (2017). Biology, 11th edition Published by McGraw-Hill Educations Original edition copyright © 2017 by McGraw-Hill Educations. All rights reserved. French edition copyright © by De Boeck Supérieur. All rights reserved

Robert S. (2009). Boston Studies in the Philosophy of Science, Springer Edit, France.

Senta German. The Neolithic Revolution. <https://www.khanacademy.org/humanities/ap-art-history/global-prehistory-ap/paleolithic-mesolithic-neolithic-apah/a/the-neolithic-revolution>

Gros Francois and Walker R. Scott. (1988). View all authors and affiliations. Developments in Contemporary Biology. Volume 36, Issue 142. First published June 1988
<https://doi.org/10.1177/039219218803614201>

Yuval Noah Harari. (2016). Sapiens: A Brief History of Humankind Paperback – June 10, 2018 Publisher: Signal