

Science

Development, Methods &
Achievements

科學的發展、方法與成就

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Some of the materials presented are from talks of

Ismail Serageldin

Director of the Library of Alexandria



Bibliotheca Alexandria (3rd C BC to 4th C AD) rebuild in 2002 with \$600 Millions contributions from UNESCO, France, German, Japan etc.

Science: Western History

Egyptians 埃及人

Greeks 希臘人

Why No Romans? 爲什麼沒有羅馬人？

Arabs 阿拉伯人

Europeans 歐洲人

Spread to the Entire World 擴散至全世界

Imhotep (~2600 BC)

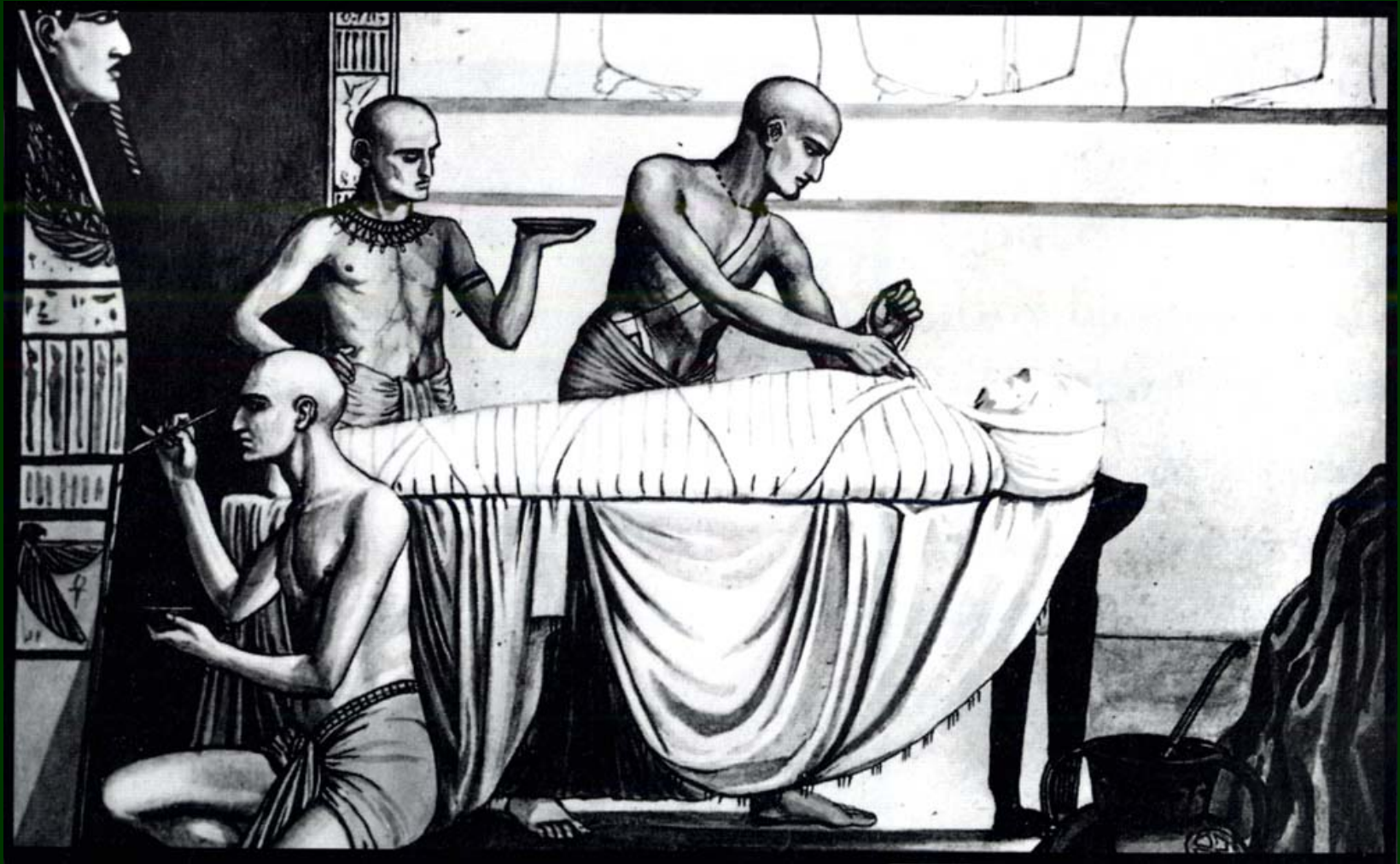


- Builder of the Saqqara Pyramid
- God of Medicine



2630 BC

Great Engineering: 100,000 workers, 2,300,000 blocks of stones, each weighs 2-4 tons



Source: *Science in Ancient Egypt*, by Geraldine Woods, 1998.

Mummy 木乃伊

Tien T. Tsong



4500 year old false teeth
held together by gold wire

古埃及以金線固定假牙



埃及未有拔牙技術，牙痛吃草藥，但
巴基斯坦古代墓地發現九副9000年前
前頭顱，有11顆白齒上有鑽洞痕跡。

Photo of Time Magazine

(好相片勝過千言萬語)

中國農村 (Time 03/06)



現在城鄉差距嚴重，但鄉下
也有拔牙技術



Source: *Science in Ancient Egypt*, by Geraldine Woods, 1998.

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The Great Pyramid (~140 m in height, 2551 bc-2528 BC)



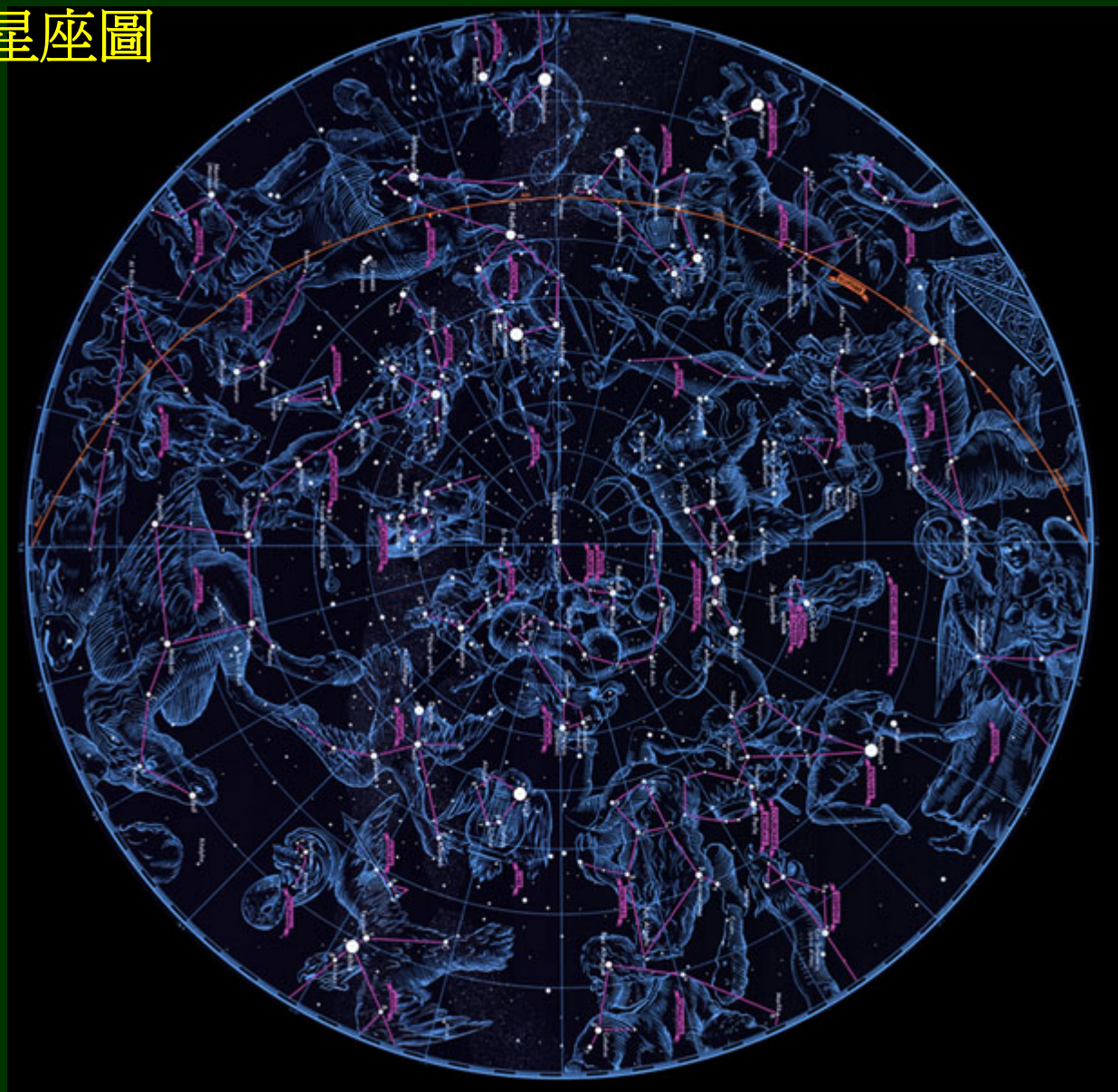


The Great Pyramid was built during Khufu's reign.

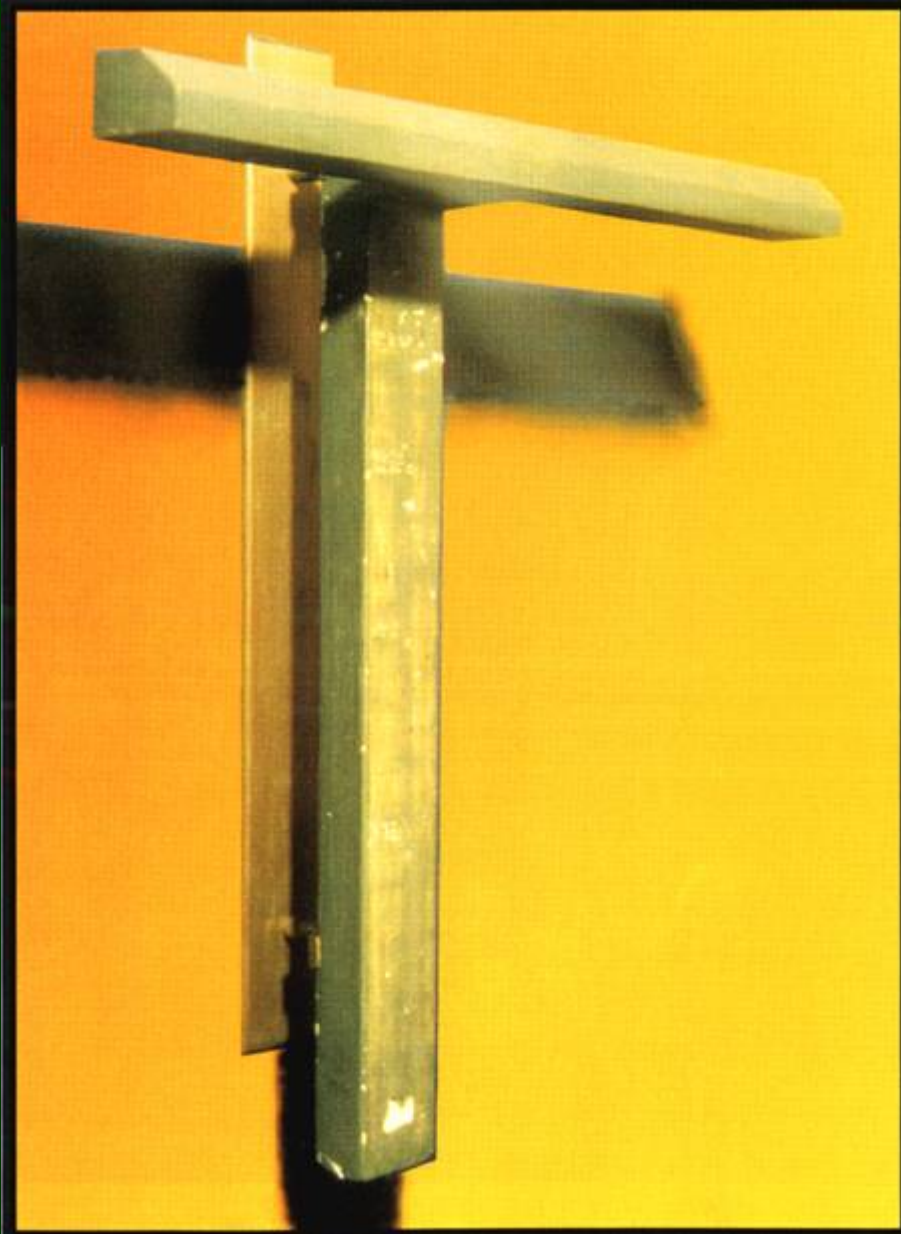


埃及古墓

星座圖



House Clocks



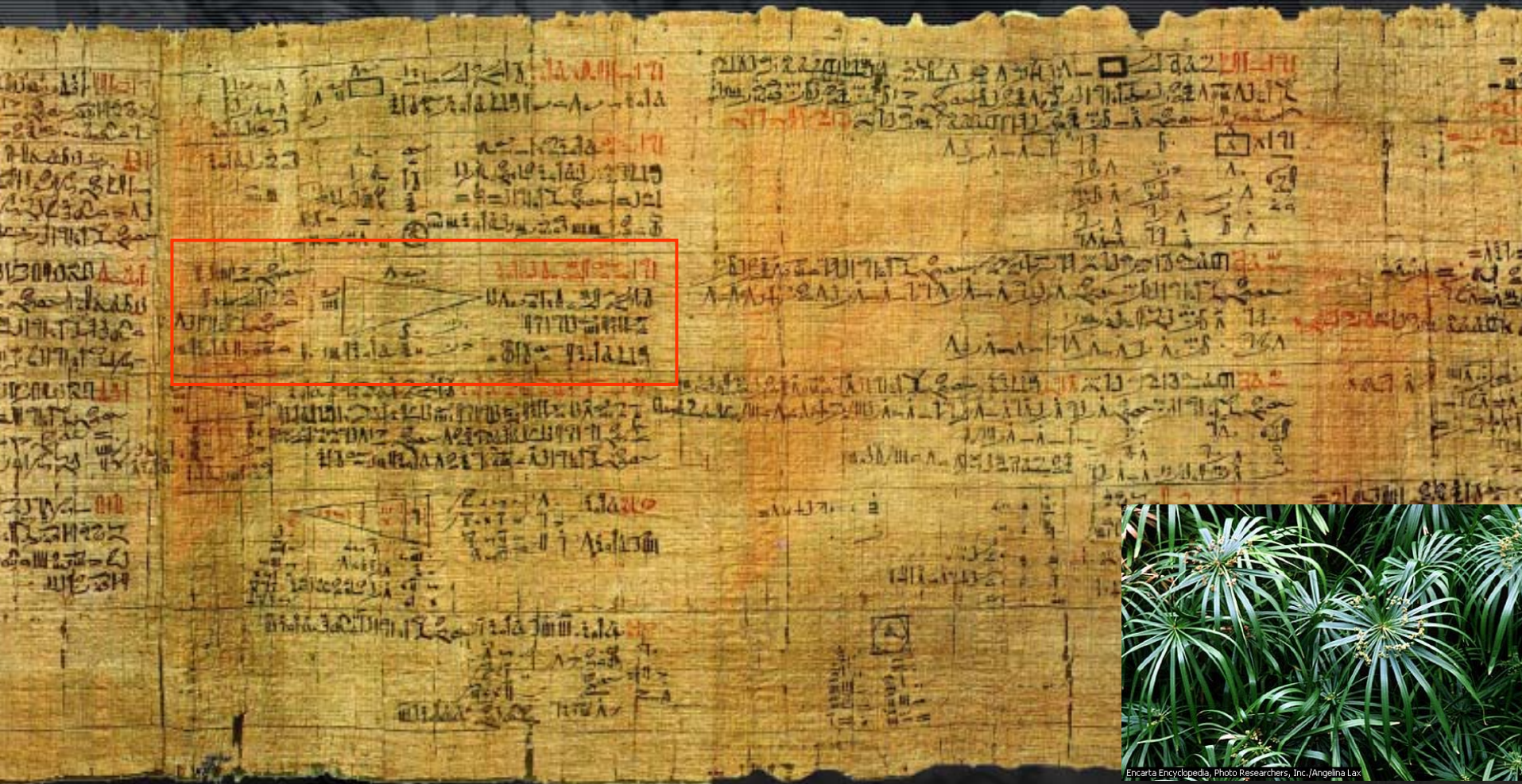
For Night and Day

1	I	10	 (head)
2	II	100	 (coiled rope)
3	III	1,000	 (flower)
4	IIII	10,000	 (pointing finger)
5	IIII II	100,000	 (tadpole)
6	IIII IIII	1,000,000	 (surprised man)
7	IIII IIII II		
8	IIII IIII IIII		
9	IIII IIII IIII II		

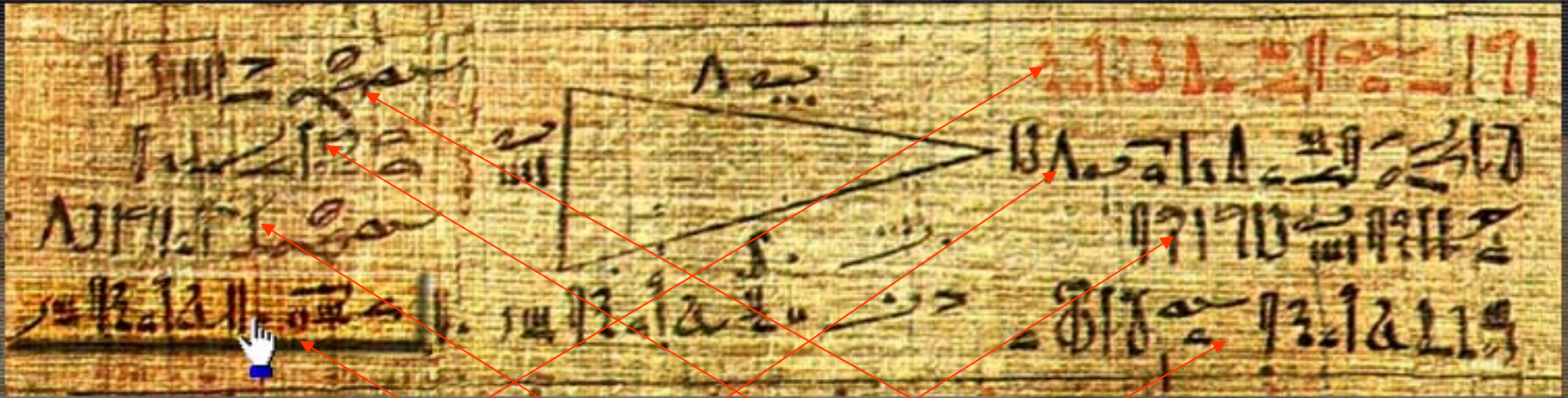
古埃及已有十進制和數目字

The Rhind Papyrus 紙（莎）草紙書

1650 BC, Mathematical Puzzle 數學難題，數學謎題



Written some 3650 years ago, copied from a work about 400 years older



Example of calculating the area of a triangular land

Assume you have a triangle of height 10 khet

And a base of 4 khet

What is its area?



Take half of the base 4, this gives 2

So that you can square the triangle

Then you multiply 10

Times 2, this will give you the area

圓周： $\pi = 3.16049$

Passing the torch to Greece

- Many of the great Greeks (e.g. Plato, Pythagoras) visited Egypt to learn from its temples, and soon they built the great edifice of learning in ancient Greece that we all admire to this day.
- 火炬傳至希臘：
很多偉大希臘學者如 Plato，Pythagoras 曾經訪問埃及，學自廟宇，他們很快建立至今我們推崇的古希臘文明。



Pythagoras

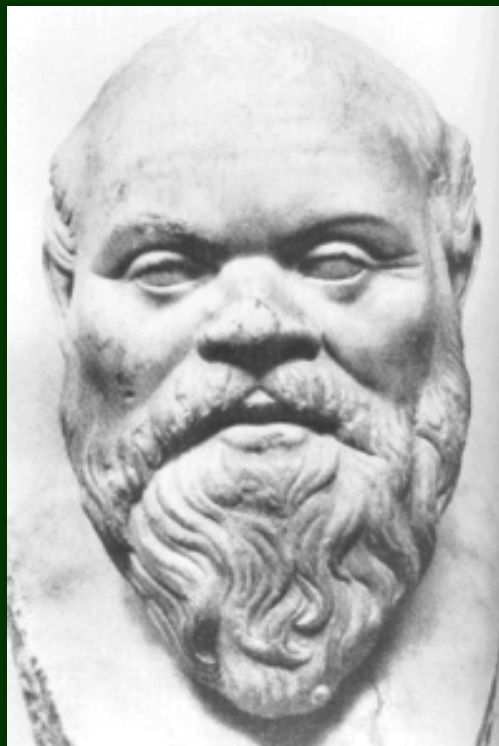
582-500 BC

Source: Milestones of Science, Curt Supplee – National Geographic society, 2000.

陽曆，365天6小
時，幾何



Eudoxus
(~380 BC)



Thales
(~600 BC)



Confucius
(~500 BC)
Socrates
(~440 BC)



人際和社會倫理

Source: *Milestones of Science*, Curt Supplee – National Geographic society, 2000.



Democritus (~460 BC)

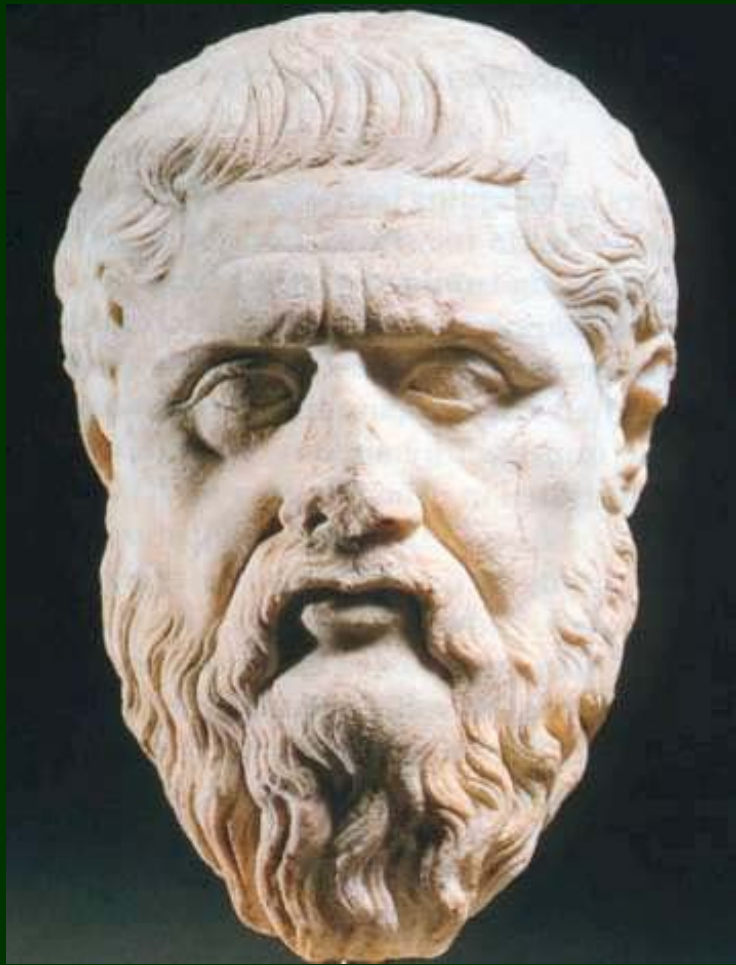
Leucippus (~5C BC) Epicurus (341-271 BC)

原子論: 宇宙除了原子之外只有虛無一物的空間

Fifty Years of Seeing Atoms

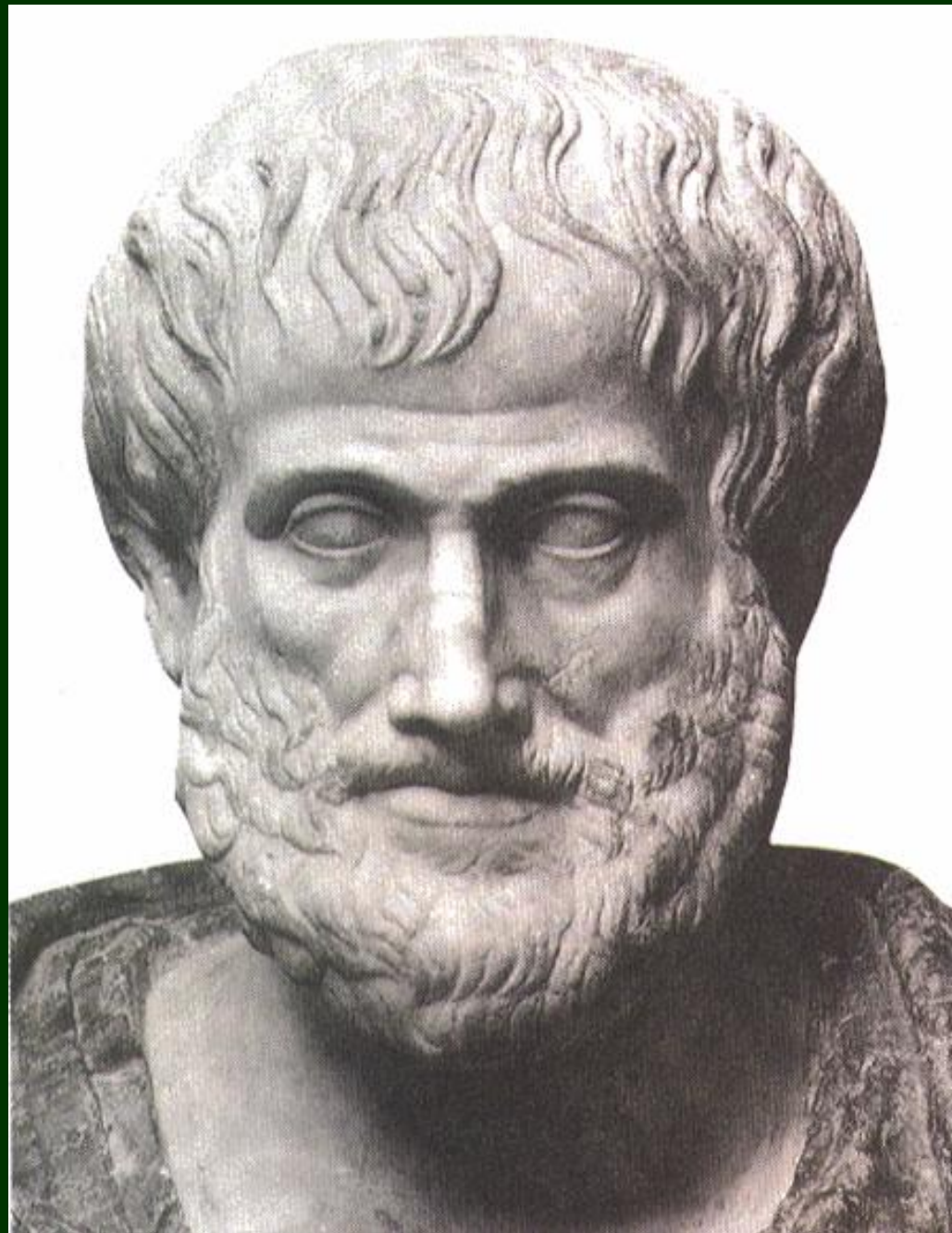
Tien T. Tsong March 2006 Physics Today 31

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Plato (428-347 BC)

Aristotle (384-322 BC)



**Love of Creating New Knowledge
Greek Philosophers and Scientists
Propose, discuss, debate, teach & learn**



Source: *Milestones of Science*, Curt Supplee – National Geographic society, 2000.

The Ancient Library of Alexandria

古亞歷山大古圖書館

**Love of
Conquest**

**Alexander
the Great**

356-323 BC

**King of
Macedonia**

**Founded Port of
Alexandria**

建立亞歷山大港

**population of
~300,000**

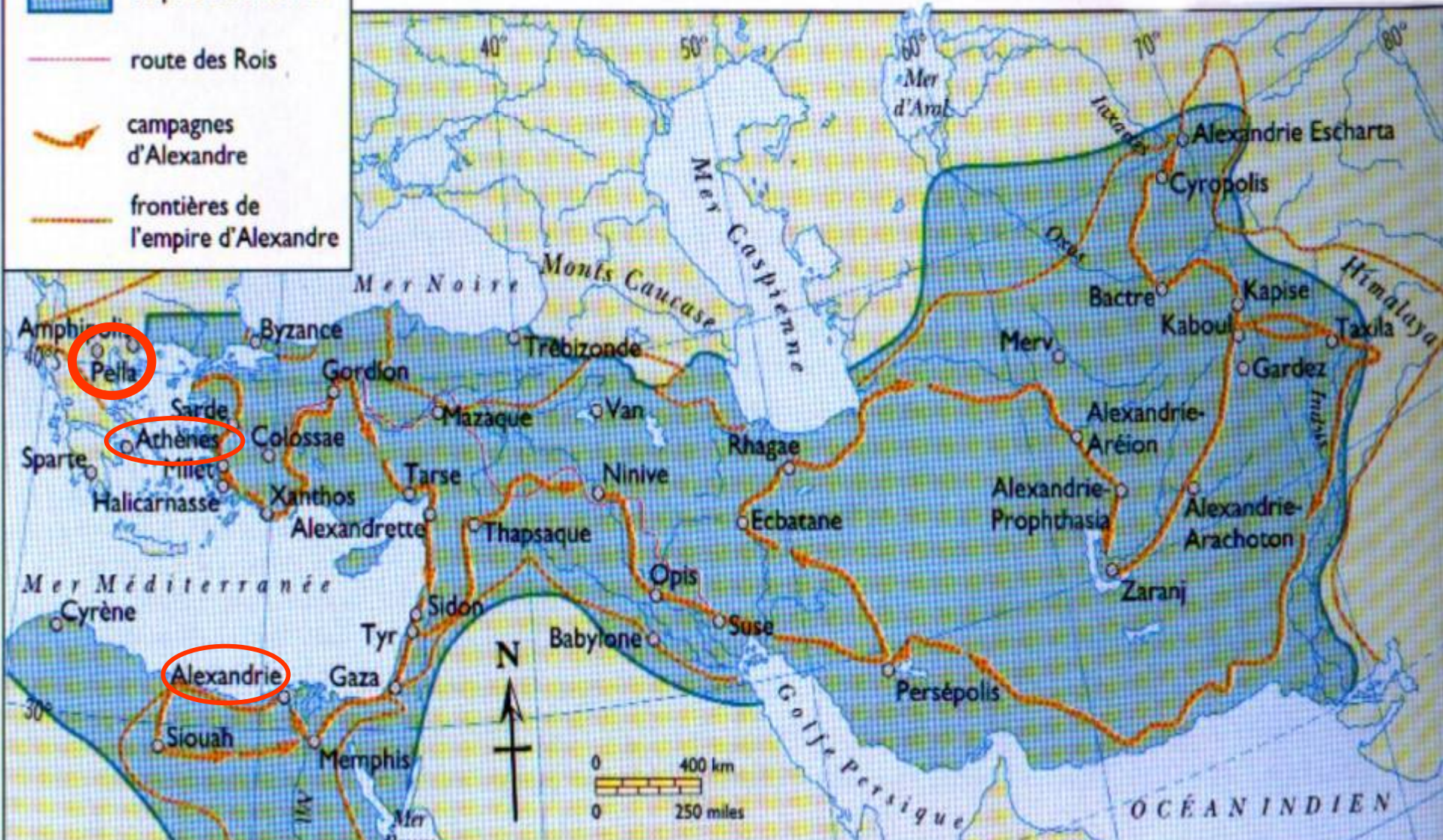


Empire achéménide

route des Rois

campagnes d'Alexandre

frontières de l'empire d'Alexandre



Modern Map of the Ancient Western World



280 BC

Population:
~300,000

Light house:
143 m tall

One of the 7
wonders of
the world

Destroyed by
earthquake in
14th C.

亞帝扶植了
Ptolemy 王朝

Von Erlach 1721



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Library of Alexandria

Founded by Ptolemy I Soter, king of Egypt around ~3rd CBC

Love of Learning



The library held about 700,000 scrolls, arranged in storage racks



700,000 Scrolls
7- 8 scrolls = 1 book of 300
octavo pages



猶太福音
3 or 4 AD

Love of Knowledge:
Incoming ships are
searched for books
and copied.

來船要先被搜查，書
本先抄下後才歸還



ΑΡΧΙΜΗΔΟΥΣ
ΠΑΝΤΑ ΣΩΖΟΜΕΝΑ.
ARCHIMEDIS OPERA
QVAE EXTANT.
NOVIS DEMONSTRATIONIBVS
COMMENTARIISQVE ILLUSTRATA.
Per DAVIDEM RIVALTYM a FLVRANTIA Coenomanum, è Regia Turma sacri Cubiculi, sanctioribusque regni Consiliis & à literarum pictatisque studiis Christianissimi Gallorum & Navarrae Regis

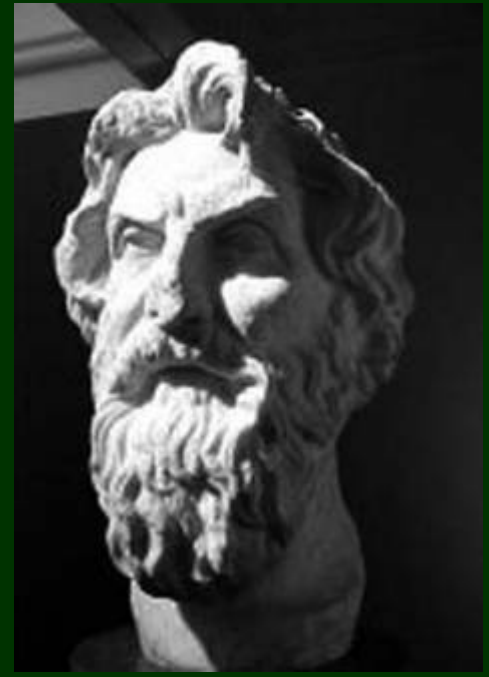
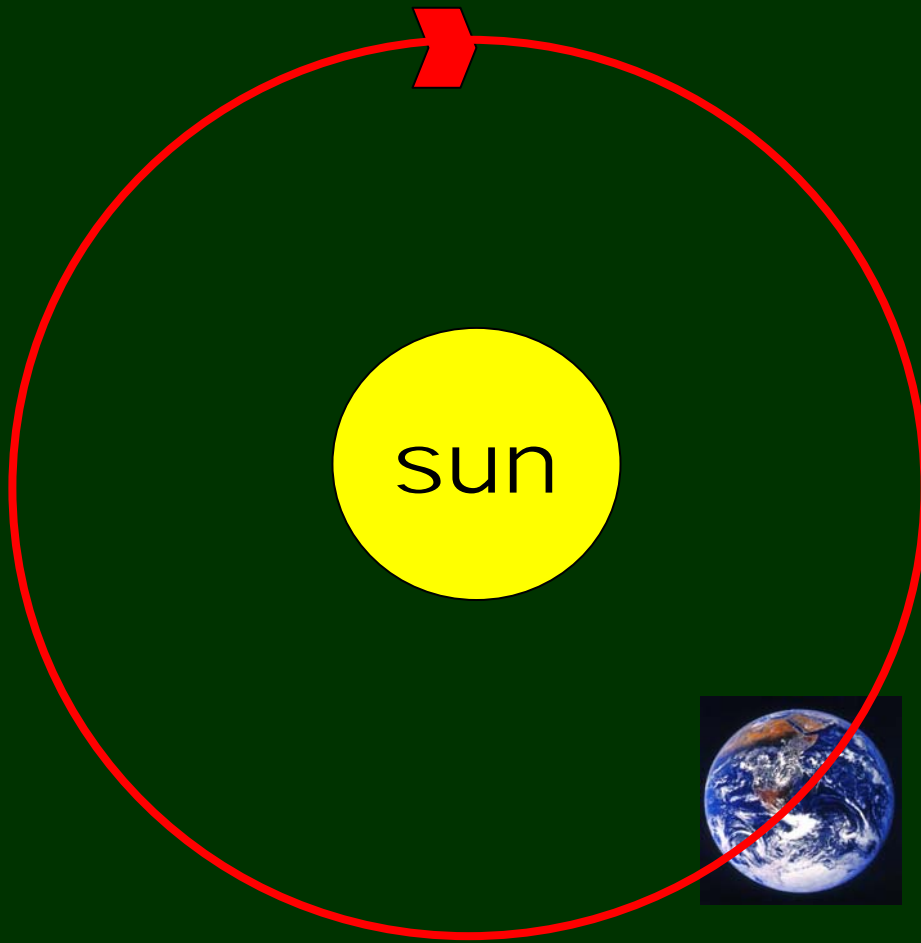
1st library & multiversity of the world

**The Ancient Library
Married Greek and Egyptian
Science with Asian Elements Added**

亞歷山大古圖書館結合古希臘和埃及科學，並具東方色彩

The Ancient Library
Then Produced An Explosion Of
Knowledge Unmatched in History

亞歷山大港古圖書館激發了史上
無可比擬的知識遽增

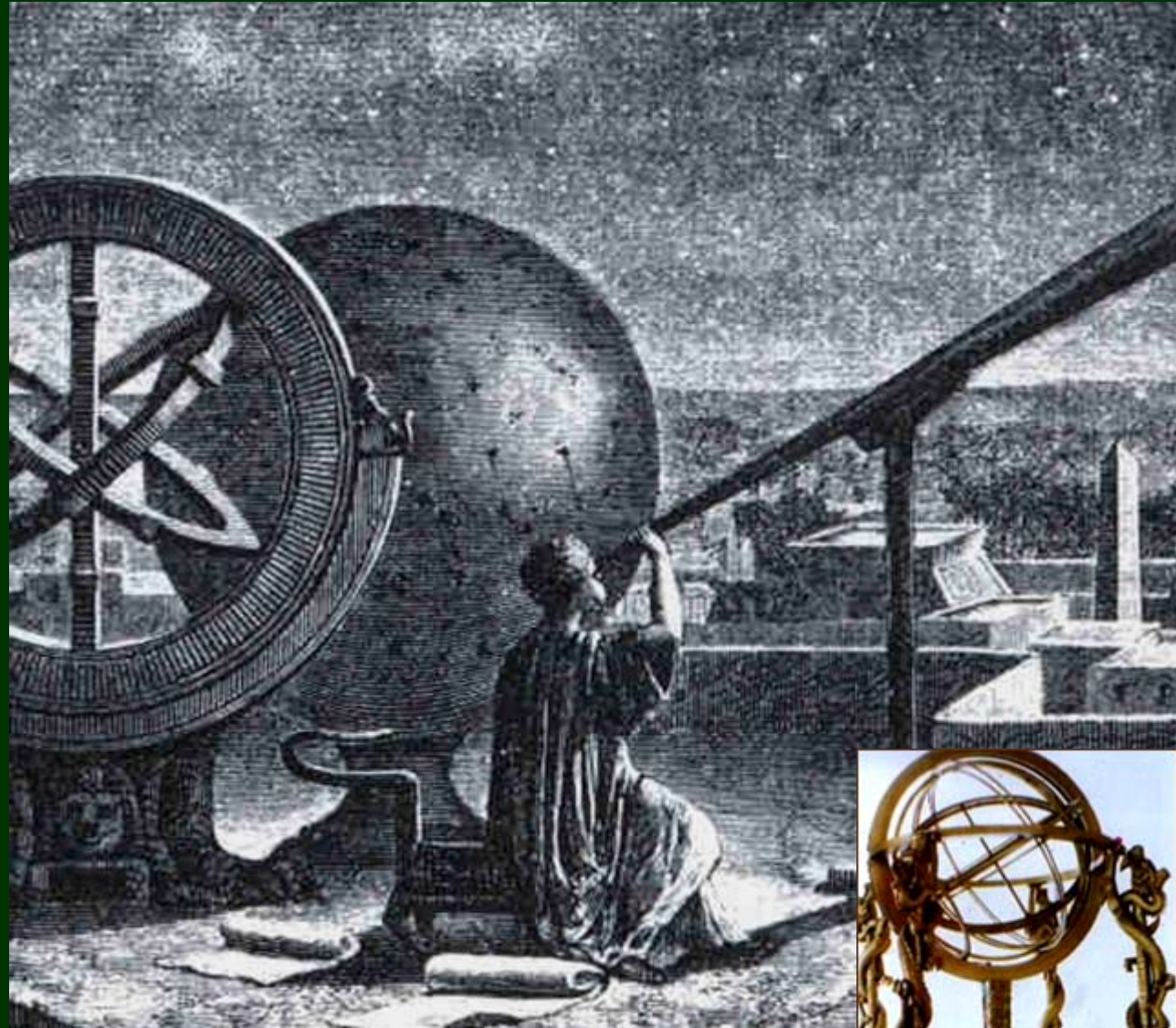


ARISTARCHUS
(310 BC – 230 BC)

地球繞著太陽轉學說

Hipparchus

2nd Century BC, calculated the length of the year to within 6 1/2 minutes, compiled the first known star catalog, and made an early formulation of trigonometry (計算一年天數，紀錄星譜，創造三角).



張衡（東漢，78-139 AD），地震儀，渾天儀 ~130 A

Eratosthenes

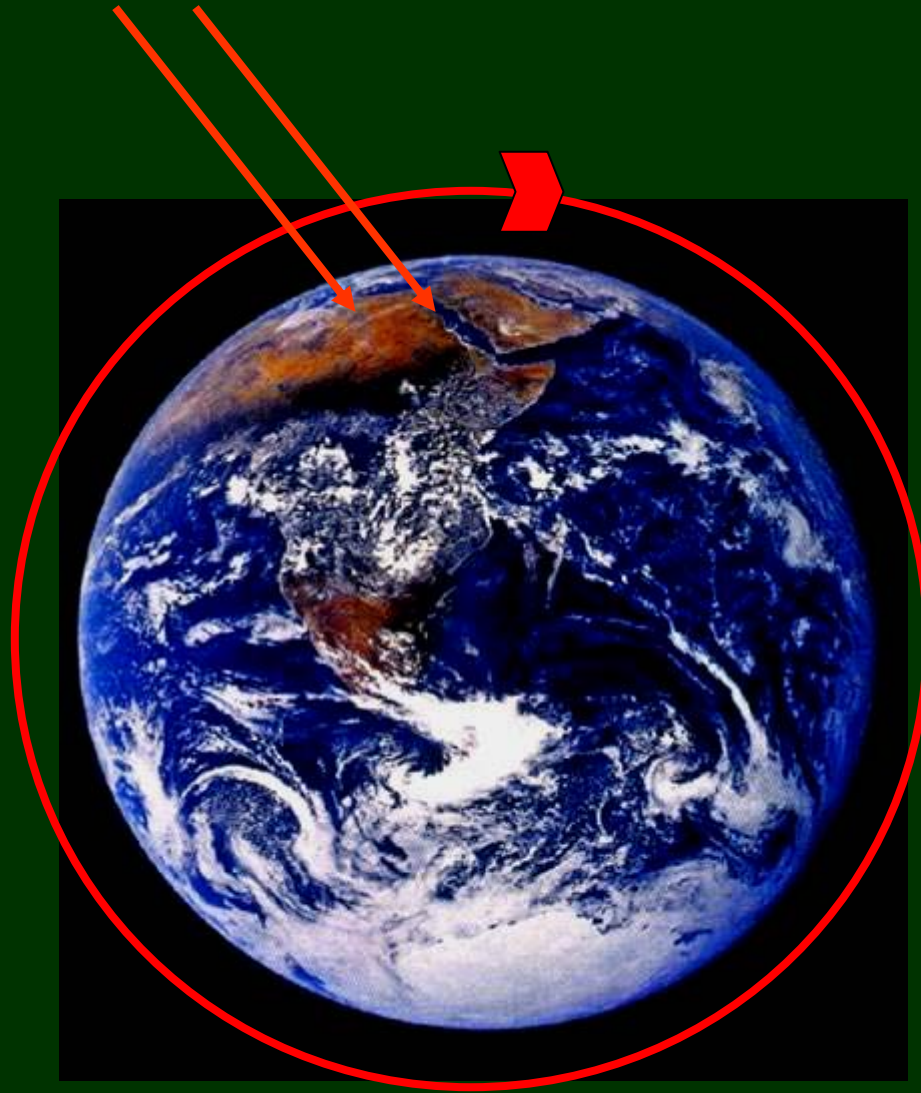
(276 BC-194BC)



- Third Director of the Library
- Brought Archimedes
- 錯誤：鍊金術
- Tasked Callimachus
- Beta Scholar
- Father of Geography
- Grammarian

Eratosthenes As Astronomer

- Measured the distance to the sun as 804,000,000 stadia (測量地球到太陽之距離)
- Measured the distance to the Moon as 780,000 stadia. (測量地球到月球之距離)
- He computed these distances using data obtained during lunar eclipses. (從月蝕時得到的數據計算而得這些距離)
- Measured the tilt of the Earth's axis with great accuracy obtaining the value of $\frac{11}{83}$ of 180, namely 23° 51' 15". (測量地球自旋角度)



Eratosthenes

Tien T. Tsong



Illumination from the Sun

Alexandria

(short shadow on solstice)




Eratosthenes
240 BC

Calculates diameter
of the Earth

Illumination from the Sun

Syene

(no shadow on solstice)

 Curved surface of Earth

How accurate?

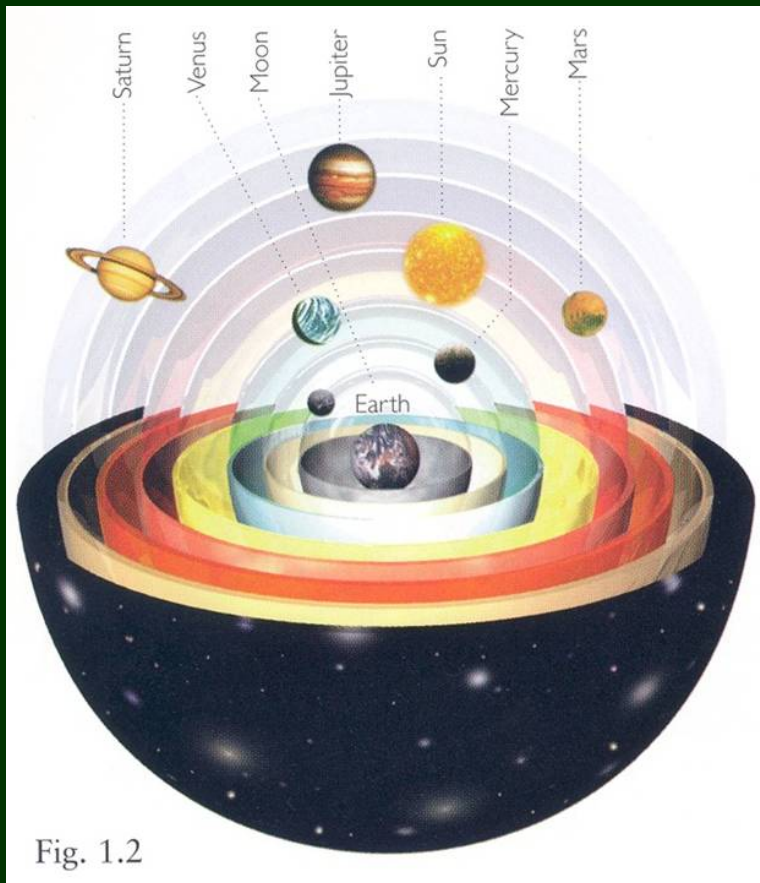
- Circumference of the earth: 250,000 stadia
@ 157.2 m = 39,300 Km
98.25 % of present value
- Distance to the sun: 804,000,000 stadia @
157.2 m = 126 million Kms
84.25% of present value

Eratosthenes Maps The world



Claudius Ptolemy

(65-125 AD)



地球中心論

The Earth At The Center Of The Cosmos



Established the calendar

- The year 365.25 days long
- Leap years
- Became the basis for the Julian calendar

Euclid

(~300 BC)

Greek, but taught
geometry in
Alexandria.

13 volumes

Elements

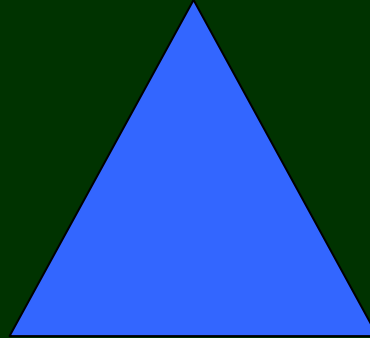
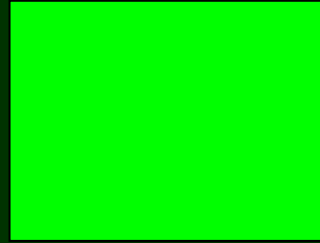
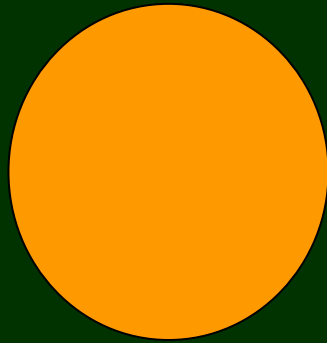
mathematics

books



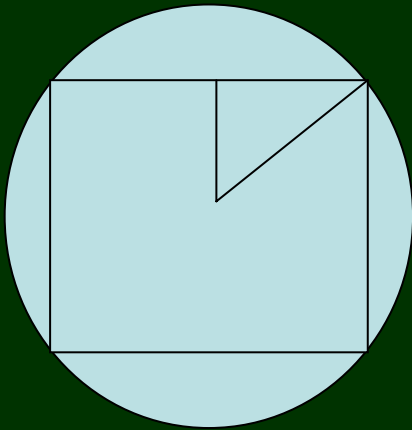
Source: *Milestones of Science*, Curt Suplee – National Geographic Society, 2006

Euclid --



Elements of Geometry

n 角形



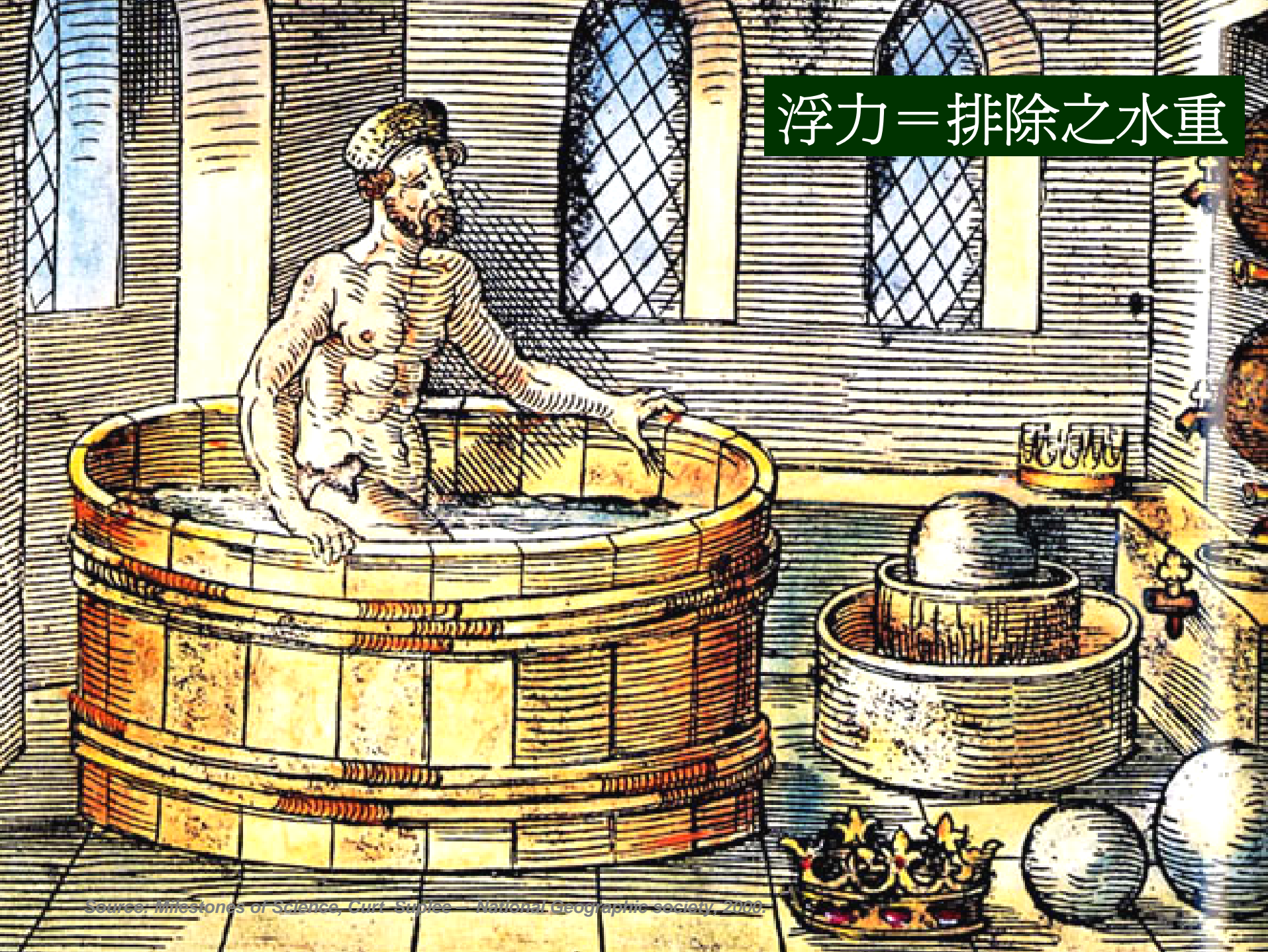
讓 n 趨於無限大，可求 π 值

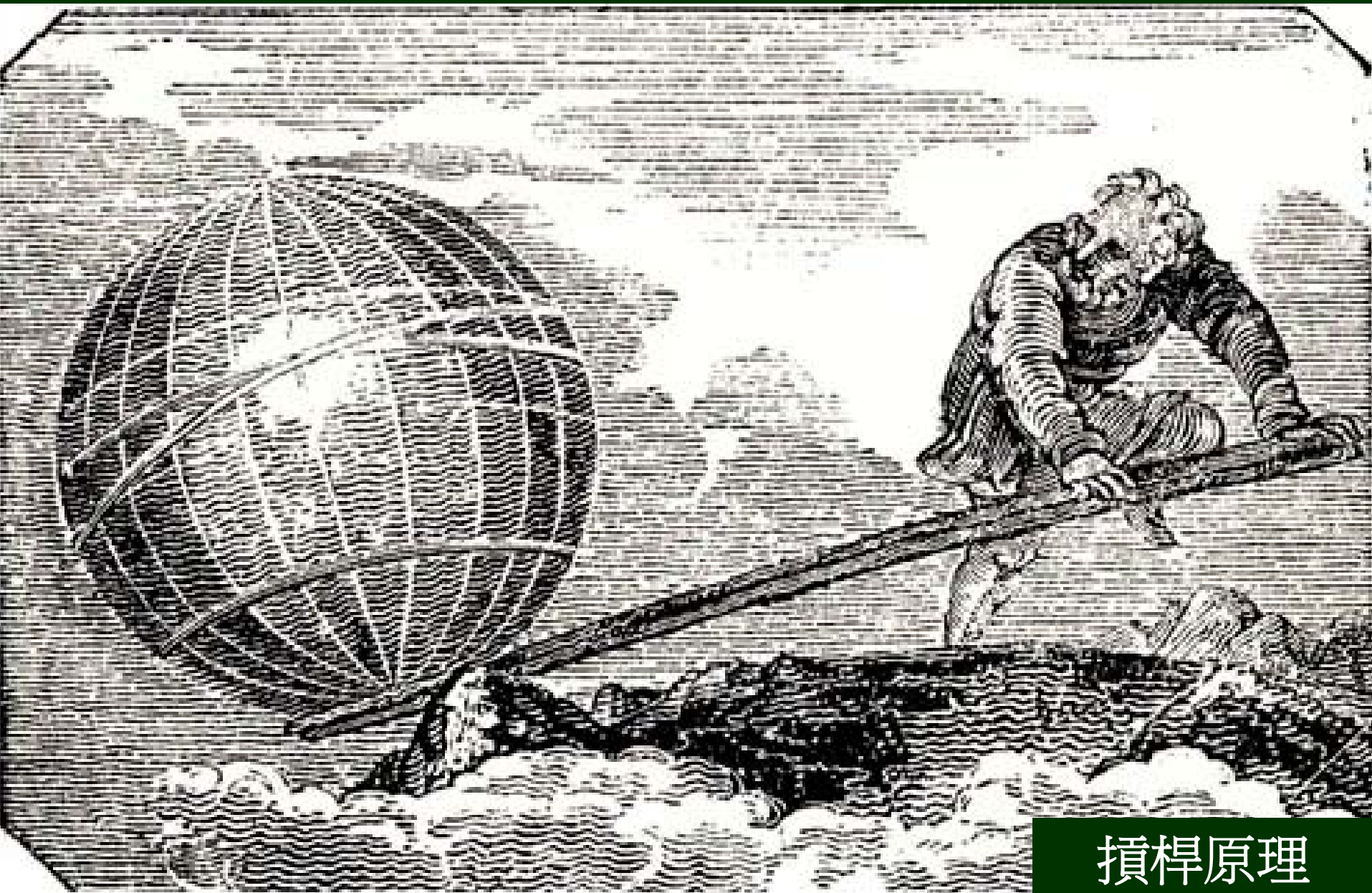
π 是希臘文圓周的第一字母



Archimedes (287-212 BC)
Educated in Alexandria

浮力 = 排除之水重

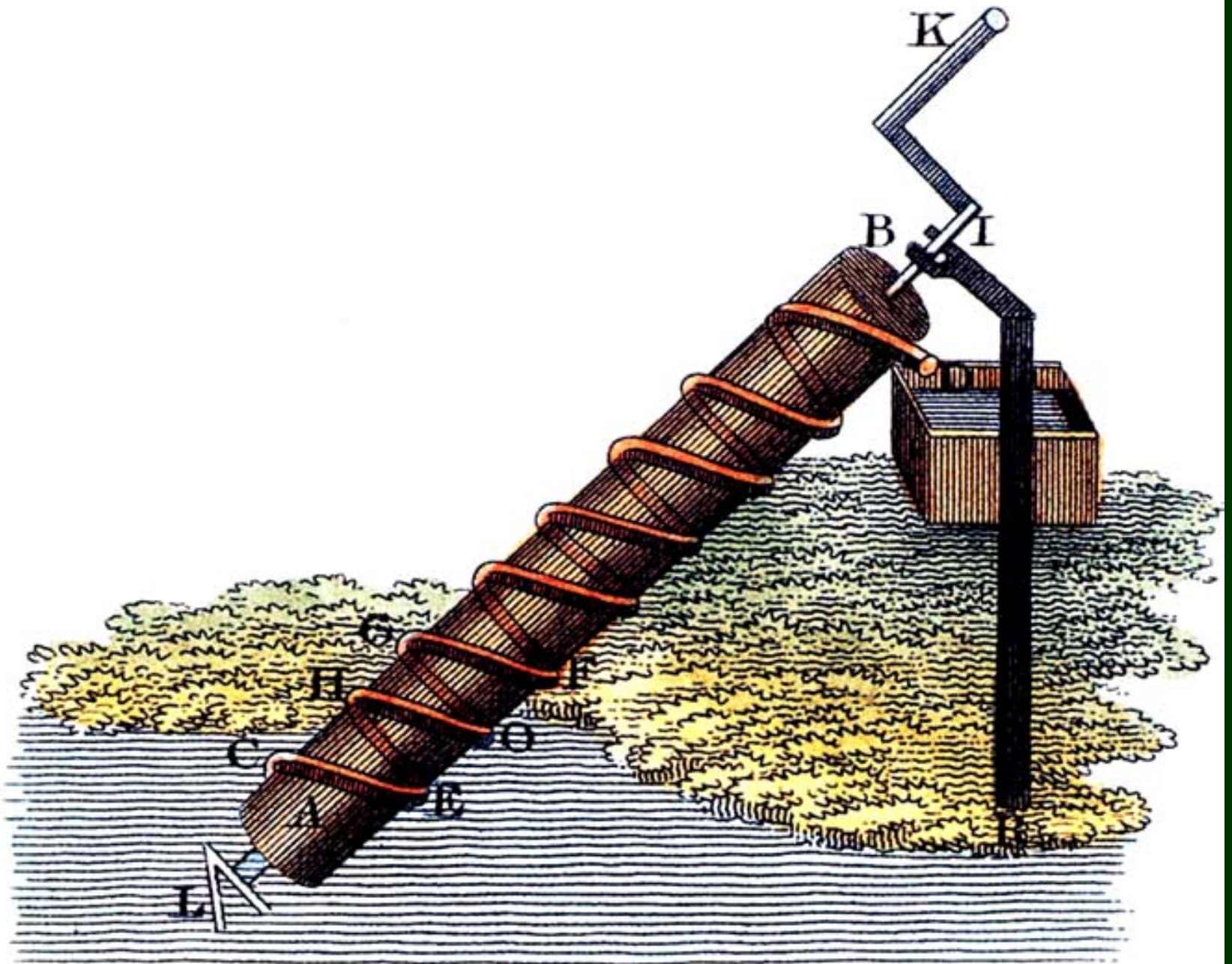




槓桿原理

Source: *Milestones of Science*, Curt Supplee – National Geographic society, 2000.

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Source: *Milestones of Science*, Curt Supplee – National Geographic society, 2000.



五結鄉利澤國中從書
中記載，委託廠商重
製**2000**多年前希臘科
學家阿基米德抽水
機，引水灌溉農園。



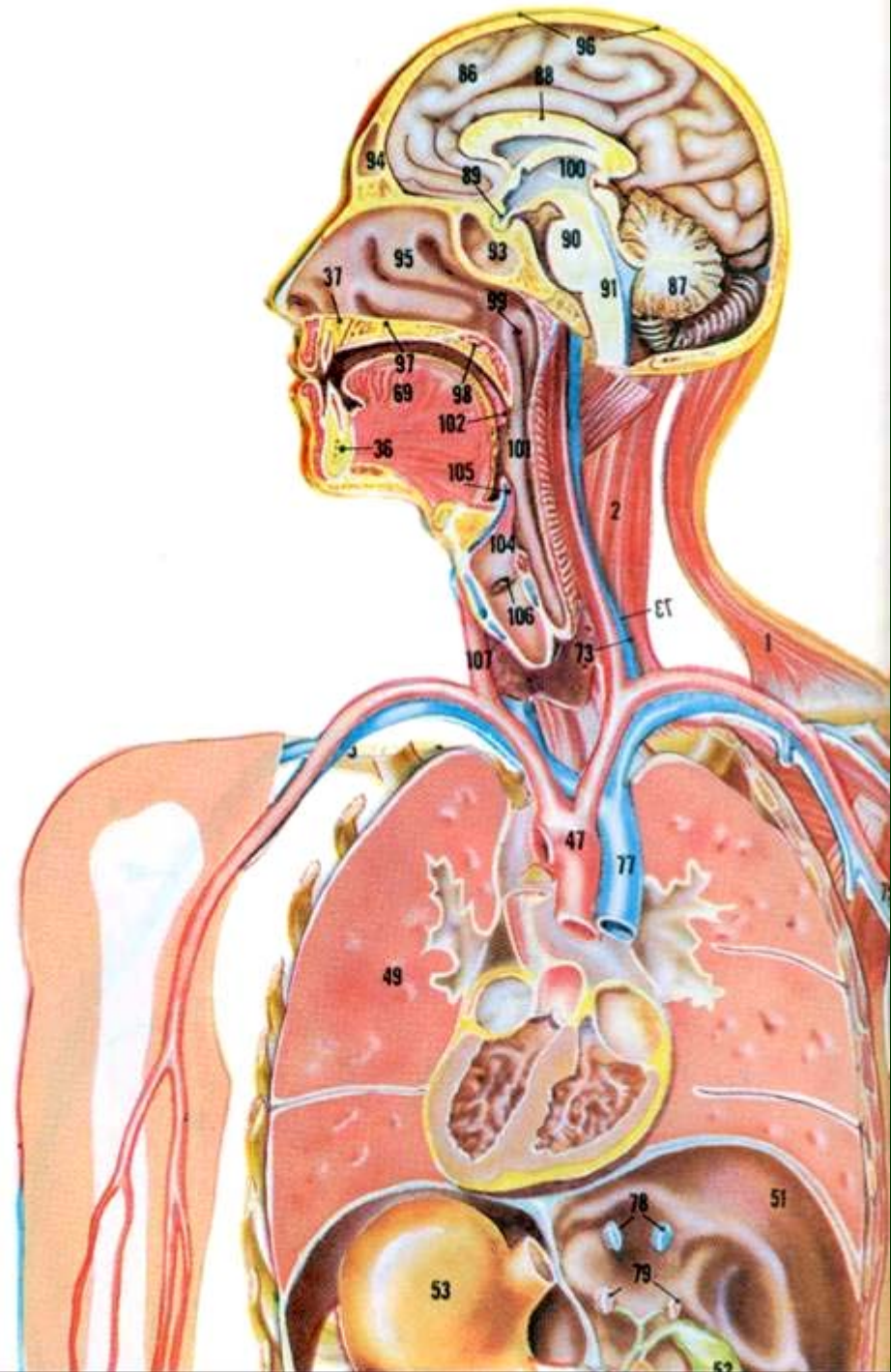
Herophilus

335-280 BC

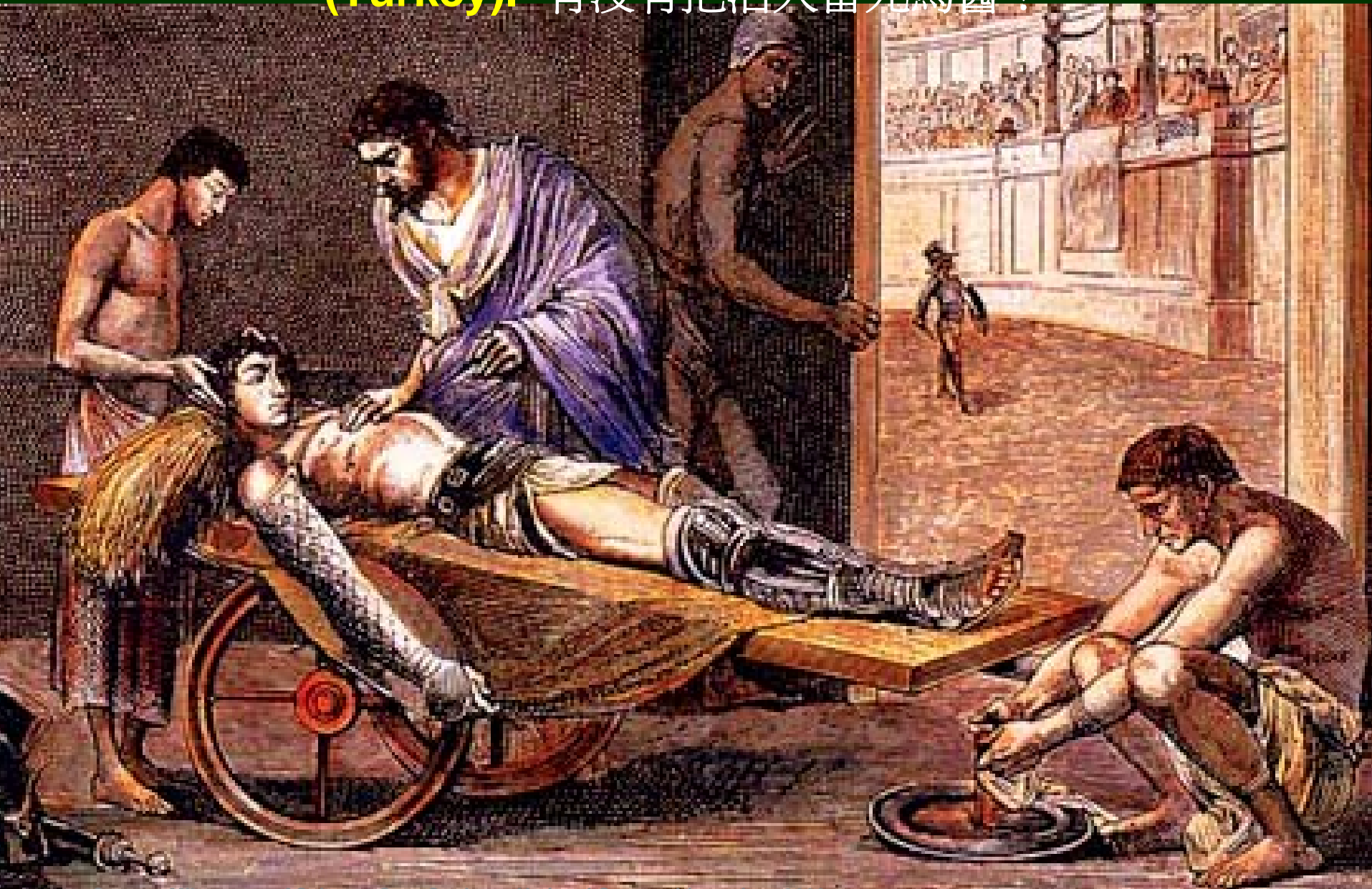
**Father of
Science
Anatomy**

Conducted
detailed post-
mortems and
identified parts of
the brain and the
circulatory
system

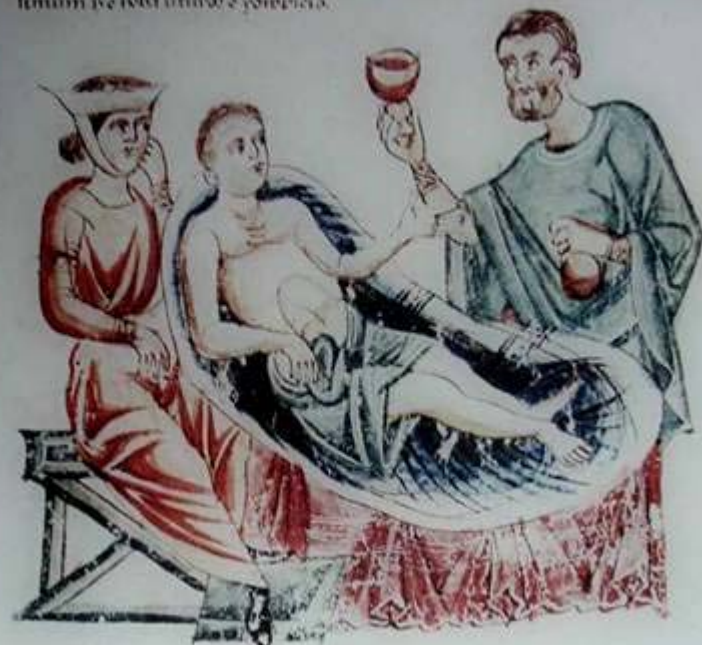
屍體解剖學，腦
與循環系統



Galen served as a doctor to gladiators in Pergamom (Turkey). 有沒有把活人當死馬醫？



are ficut iohda. i. uba cura et ad...
 Tote emydantie ad grana m. fiet coloris aneth grana m. in uno fenoie
 tra exco uno oved umi adpripa ut miter e parna qm ante de uncoed pes
 flumim hie idit univo e qmencia.



Dioscorides Herbarium

- Eminent figures relied for centuries on this catalogue of herbal treatments

Stagena Oxlinga

Cyrenomon dese

Jurat stomachu qm x.

7 dactily

menten.



A gress or

hyrcinon

中草藥或漢藥
 動物生病也會找草藥

真正歷史比小說或戲劇有趣



Julius Caesar 凱撒

100-44 BC

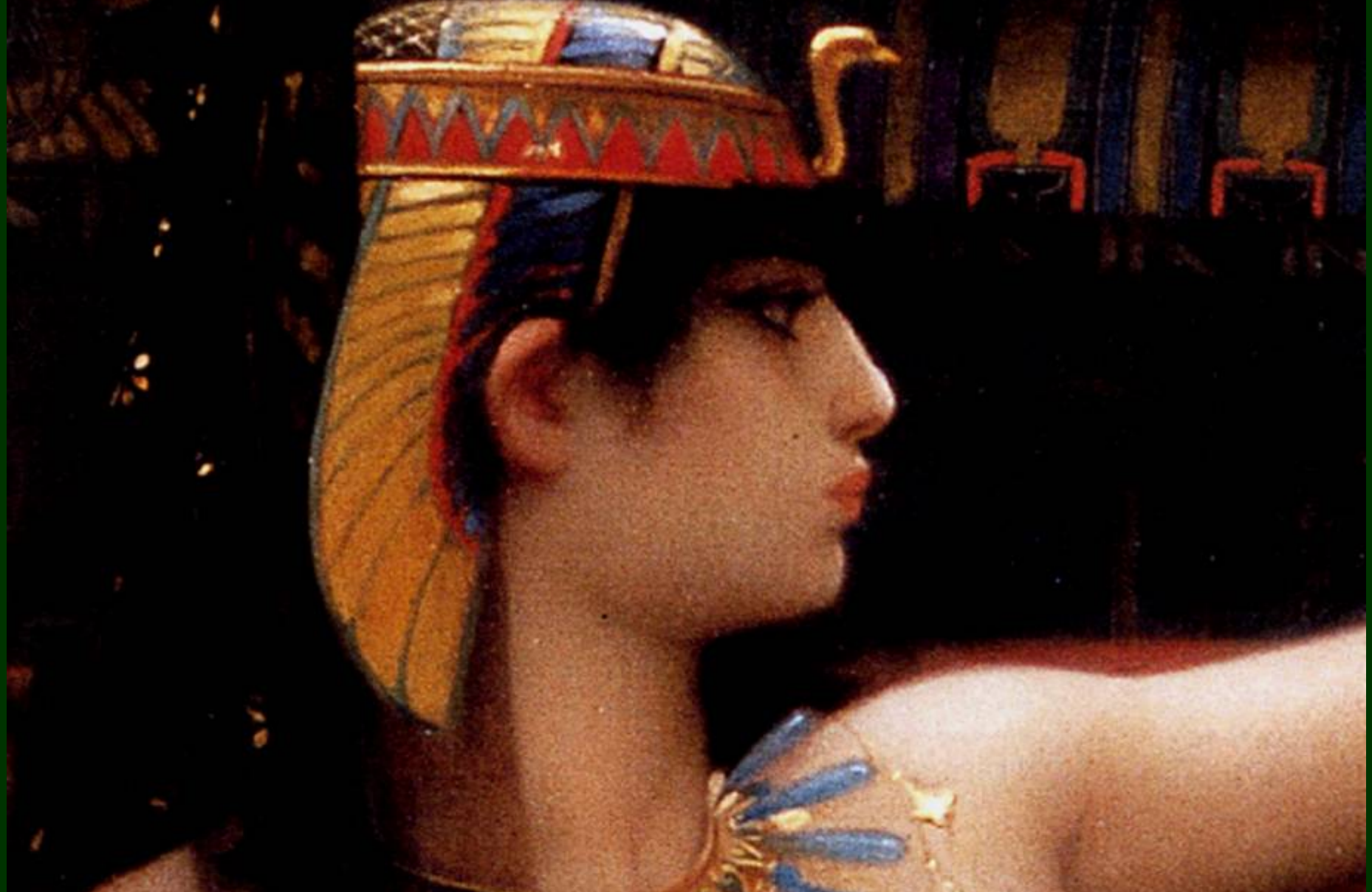
Cleopatra 埃及豔后

69-30 BC

Love of Power



Assassination of Caesar (100-44 BC) by Cassius & Brutus Tsong



**Love of Books & Knowledge:
Mark Antony Gives Cleopatra a Gift
of 200,000 Scrolls from Pergamom**



Die for Love?: Mark Anthony (83-30 BC) & Cleopatra (39 yr old)
Ptolemy 王朝從此滅亡

30 BC-200 AD

- Egypt becomes a Roman Province (Octavian/Augustus 30 BC) 成爲羅馬帝國一省
- Emergence of Christianity, St. Marc preaches in Alexandria mid 1st C AD 基督教的進入
- Persecution of Christians in Egypt 基督徒被迫害
- Riots, fires, civil strife in late second and early third centuries 動亂與大火
- Arab influence & rule 阿拉伯勢力的引入與統治



Reassembling The Lost Knowledge

重新尋找收集遺失的知識

- Al-Ma'amun and Beit Al Hikma
- Enormous support for learning
- Huge translation program
- In 70 years, Arabic would become the language of learning

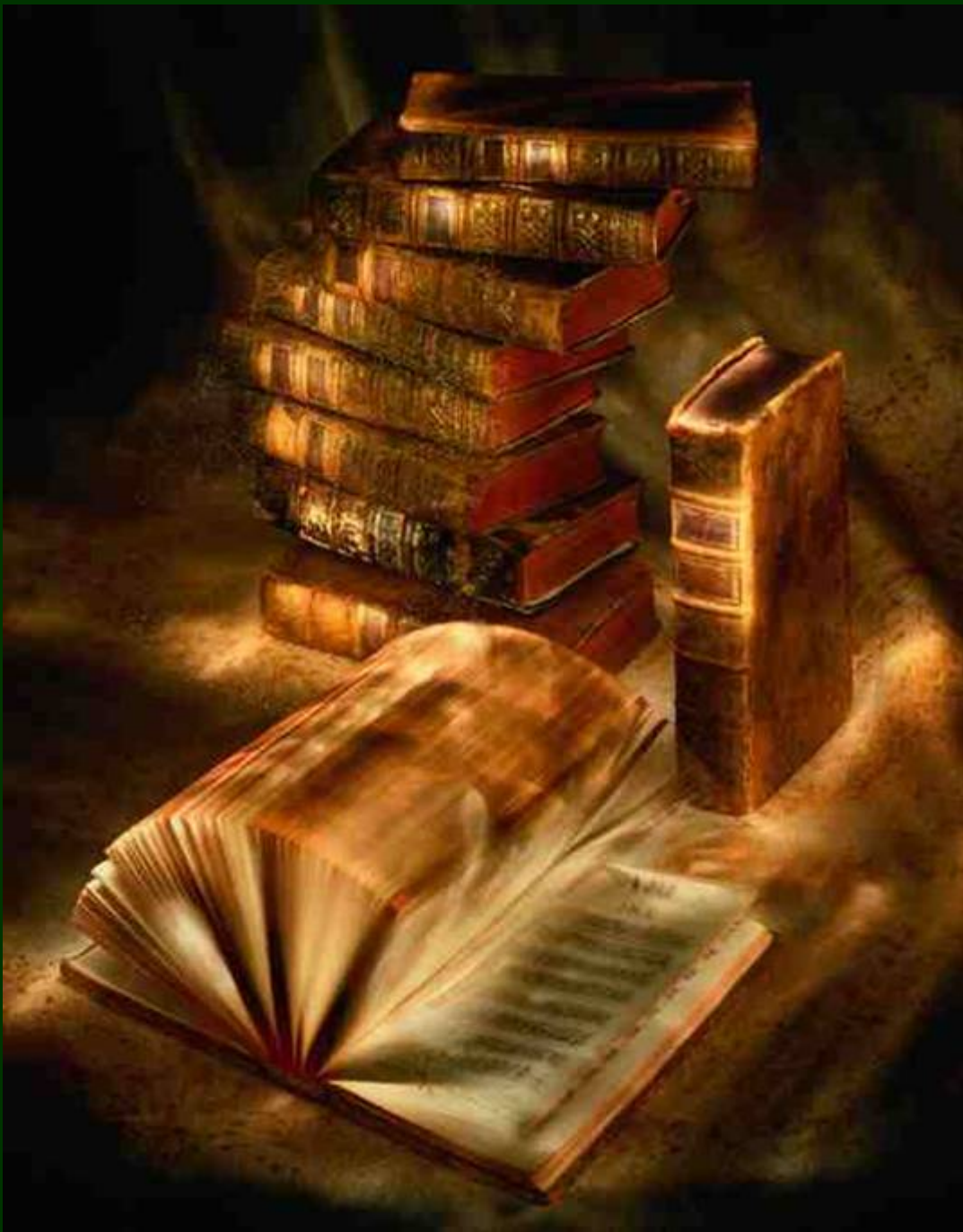
Reassembling Lost Manuscripts

蔡倫造紙：105 AD

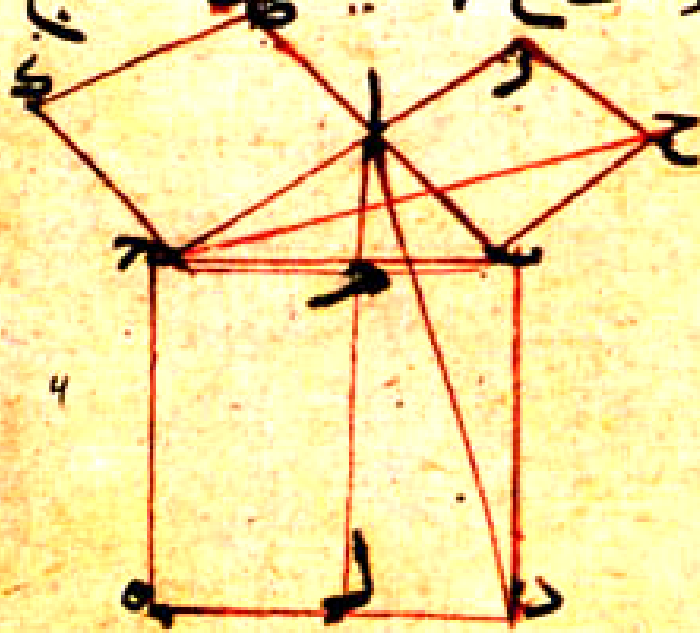
第八世紀傳至歐洲，第九世紀自己製造







زاویه - آ که اقل من زاویه - آ که القائمیه و یقطع لاجاله - آ
 عامر و یقسم به مربع - ه الی سطح - آ که و یصل
 ح - آ فلاز فی مثلثی ح - آ که - آ اضلعی ح - آ
 و زاویه ح - آ مساویه لاضلعی آ - آ که و زاویه آ - آ
 یکون للثلثان متساویین و مثلث ح - آ که یساوی نصف مربع



و - آ لکونها علی قاعده
 ح - آ من متوازی ح - آ
 ر - آ و کذلک مثلث آ - آ
 یساوی نصف سطح - آ
 لکونها علی قاعده - آ
 من متوازی - آ که
 مربع ر - آ یساوی

سطح - آ که لساوی نصفیها و مثلث آ - آ که نیز از مربع ط - آ که یساوی
 سطح آ - آ فلاز مربع - آ که یساوی سطحی آ - آ که و الا بالارزاقه

مس ۴

مس ۵

مس ۶

مداد الريح الخمر الجمر

وما توفيق الاباء الله

وإمعن لطف الله الأولي من كتاب البينوس في المعجونات وهي النبيذ كرفها معجونا

صه بنفسين يحي النوري الاسكندراني علي حـ الجوامع اخرجته لانه استقط ما لا يحتاج اليه من الكتاب وانه

مع النبي يحتاج اليها فصيها اساسا وبنو عليها كتابه ذكر اسمها اطبا الذين القوا الدرياق واحد بعد واحد

وه كل واحد منهم علي صاحبه ممن تقدمه ونقصانه عنه وهم تسعة



انفلاخه



البراقيل



ماريني



بوقا



السنو



بوقا



Dioskorides' medicinal plants

Translated in the 9th Century, recopied many times (this copy is from 11th Century)



Medieval
Libraries
Flourished
中世紀圖書館
興旺
(note stacks of
books in alcoves)



The 9th Century Revival

文化在阿拉伯興旺

- Jabir Ibn Haiyan (Geber) - Chemistry - (Died 803 C.E).
- Ali Ibn Rabban Al-Tabari - Medicine, Mathematics, Calligraphy - (838-870)
- Al-Razi (Rhazes) - Medicine, Ophthalmology, Smallpox , Chemistry, Astronomy - (864-930)
- Al-Farabi (Al Pharabius) - Sociology, Logic, Philosophy, Political Science, Music -(870-950)
- Abu Al-Qasim Al-Zahravi (Albucasis) - Surgery, Medicine - (936-1013)

Jabir Ibn Hayyan



- Jabir Ibn Haiyan (Geber) - Chemistry - (Died 803 C.E).
- Alchemy and Chemistry

Al Razi

- Al-Razi (Rhazes) -
Medicine,
Ophthalmology,
Smallpox ,
Chemistry,
Astronomy - (864-
930)



Farabi

- Al-Farabi (Al Pharabius) -
Sociology, Logic,
Philosophy,
Political Science,
Music -(870-950)



Zahravi (936 – 1013)

- Abu Al-Qasim Al-Zahravi
(Albucasis) -
Surgery, Medicine
- (936-1013)

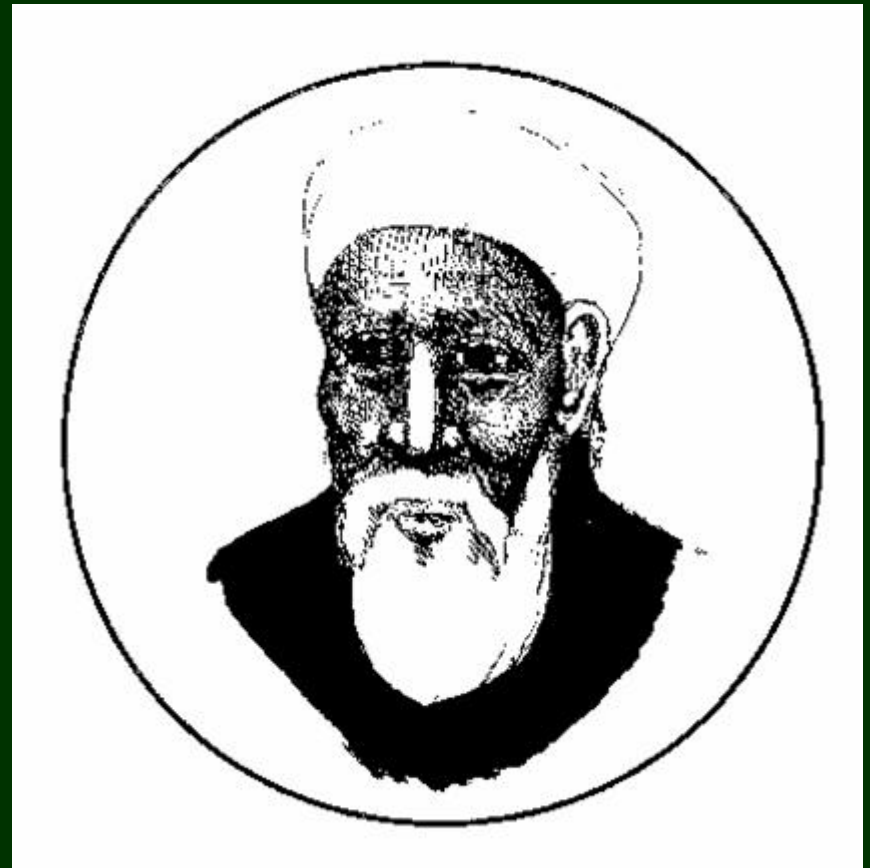


The 10th – 13th Centuries from Persia (Iran) and Iraq

- Muhammad Al-Buzjani - Mathematics, Astronomy - (940-997)
- Abu Raihan Al-Biruni - Astronomy, Mathematics, determined Earth's circumference - (973-1048)
- Ibn Sina (Avicenna) - Medicine, Philosophy, Mathematics, Astronomy - (986-1037)
- Omar Al-Khayyam - Mathematics, Poetry - (1044-1123)
- Nasir Al-Din Al-Tusi - Astronomy, Non-Euclidean Geometry - (1201-1274)

Buzjani

- Muhammad Al-Buzjani -
Mathematics,
Astronomy - (940-
997)



Al Biruni

- Abu Raihan Al-Biruni - Astronomy, Mathematics, determined Earth's circumference - (973-1048)
- Some time after 1017 he went to India and made a comprehensive study of its culture.



Khayyam

- Omar Al-Khayyam
- Mathematics,
Poetry - (1044-
1123)





Rubaiyyat (詩)

Omar Khayyam:

(c. 1050-1122) is better known as poet, but he was brilliant in mathematics and astronomy too!

Al Tusi

- Nasir Al-Din Al-Tusi - Astronomy, Non-Euclidean Geometry - (1201-1274)
- Worked with Hulagu, built the Maragha observatory that became a famous school



Al Tusi's Maragha Observatory (13th C)



Source: *The Oxford Dictionary of Islam*, Edited by John L. Esposito. Oxford University Press, 1999.

Al Khwarizmi and Algebra

代數 780-850 AD?





Al Khwarizmi

- Gave us Algebra and Algorithm
(代數與演算學)
- Distinguished mathematician and astronomer



Ibn Al Haytham (965–c.1040)

- Born in Basra, Iraq, but made his career in Cairo, where he supported himself copying scientific manuscripts. Among his original works, only those on optics, astronomy, and mathematics survive.

卓越的光學、天文和數學家



Ibn Al Haytham

(965–c.1040)

- His Optics, which relied on experiment rather than on past authority, introduced the idea that light rays emanate in straight lines in all directions from every point on a luminous surface. Sight occurs when the ray hits the eye (光學：根據實驗而非古代權威，直線傳播，視覺)



Ibn Al-Haytham's Optics

- Detailed analysis of the eye, coupled with light rays entering the eye gave his optics a very modern twist.

眼睛的構造與光
視覺

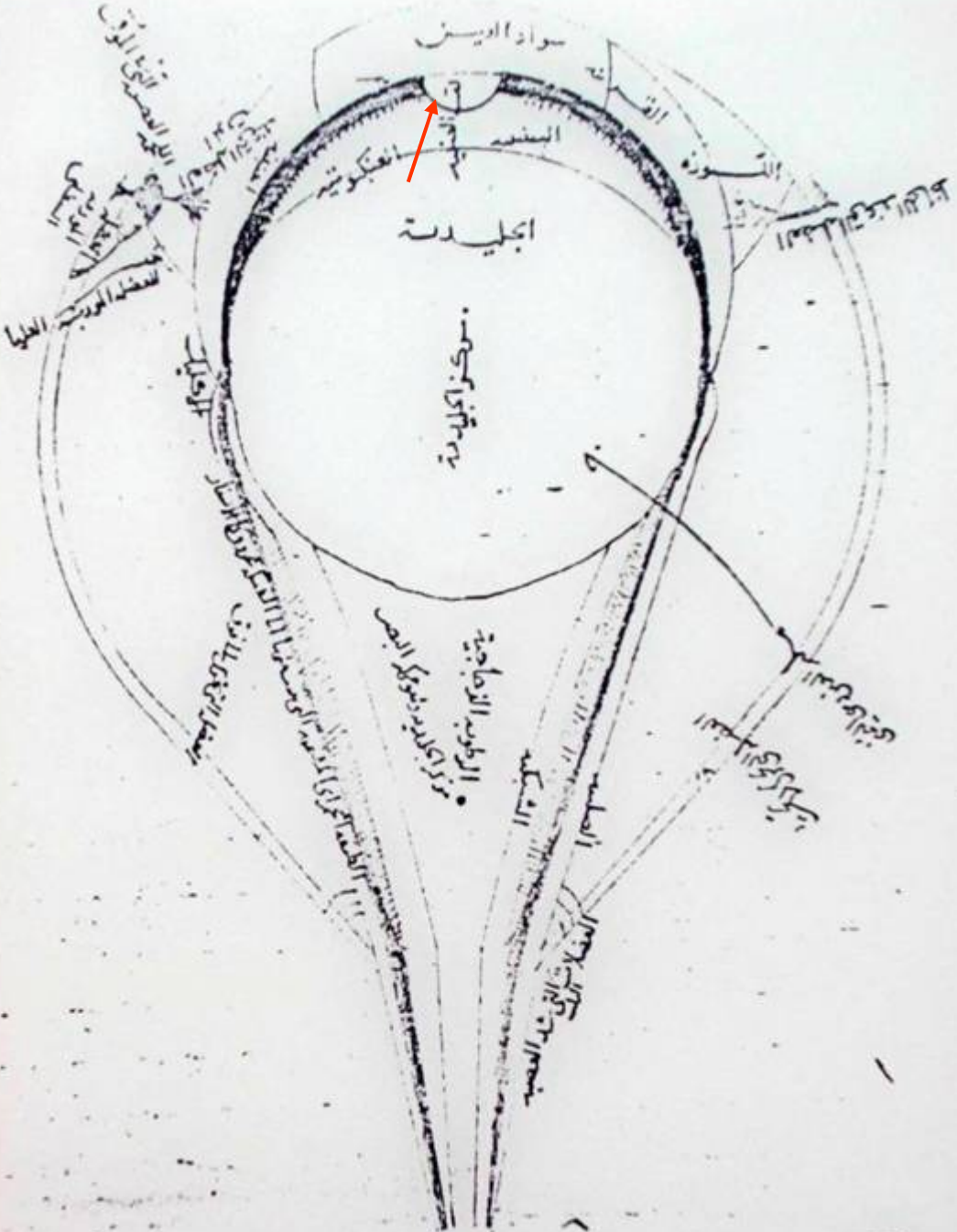


Plate 2 Tunics and Humours of the Eye according to Kamāl al-Dīn. Istanbul, MS

Ibn Al Haytham

- Latin editions of the Optics, available from the 13th century on, influenced Kepler and Descartes.

拉丁版光學一書影響了凱普勒和迪卡兒



ALHAZEN -- 965-1038 A. D. -- STUDIED THE REFRACTION OF LIGHT AND DISPUTED THE ANCIENT THEORY THAT VISUAL RAYS EMANATED FROM THE EYE.

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On Taking Evidence Over Authority

證據勝於權威

“He who searches for truth is not he who reviews the works of the ancients...[it is] he who follows argument and evidence, not the statement by an individual, who is inevitably affected by context and imperfection”.

每個人的說詞會受到個人背景和缺陷所影響，探真者未必要學自古人，而是要根據論辯與事實。

--- Ibn Al Haytham, (965–c.1040)

Al Shukuk Fi Batlaymous

On The Experimental Method

“We start by observing reality ... we try to select solid (unchanging) observations that are not affected by how we perceive (measure) them. We then proceed by increasing our research and measurement, subjecting premises to criticism, and being cautious in drawing conclusions... In all we do, our purpose should be balanced not arbitrary, the search for truth, not support of opinions. ... 「首先觀察事實，選擇不受觀察與量測方法所影響的堅實結果，並接受嚴苛的檢驗，小心下結論... 在真理的追求，我們要客觀，不能隨意或以別人意見當佐證...」

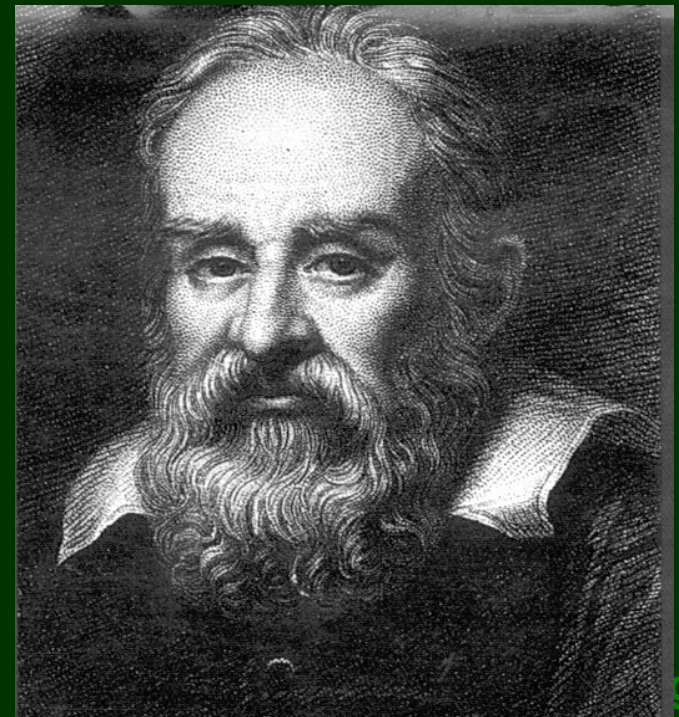
Experimental Method (Cont'd)

... Hopefully, by following this method, this road to the truth that we can be confident in, we shall arrive to our objective, where we feel certain that we have, by criticism and caution, removed discord and suspicion". 「希望以批判和細心，我們達到客觀，不被懷疑或自相矛盾的結果」。

-- Ibn Al-Haytham, (965–c.1040)
Kitab Al-Manadhir.

Way ahead by 600 years!

- Ibn Al-Haytham (965-1040) articulated the experimental method in the 11thC, more than half a millennium ahead of Galileo (1564 – 1642), who suffered for it.



Fear Of Own Biases

擔心自己的偏見

“Yet we are but human, subject to human frailties, against which we must fight with all our human might. God help us in all our endeavors”. 「上蒼幫幫忙，幫助我們這些凡人努力克服自己的弱點與偏見。」

-- Ibn Al-Haytham, (965–c.1040)

Kitab Al-Manadhir.

格物窮理：物理？科學？

周敦西（1017-1073）：太極是天地萬物所以存在之理。

朱熹（1130-1200）：太極只是天地萬物之理。在天地言，則天地有太極；在萬物言，則萬物各有太極。爲有天地之先，畢竟是先有此理。

格物致知、誠意正身、修身齊家、治國平天下。
無極—太極 動—靜 陽—陰

太極：物理定律？智慧設計者？上帝？

Ibn Al Nafis

(1213-1288 A.D)

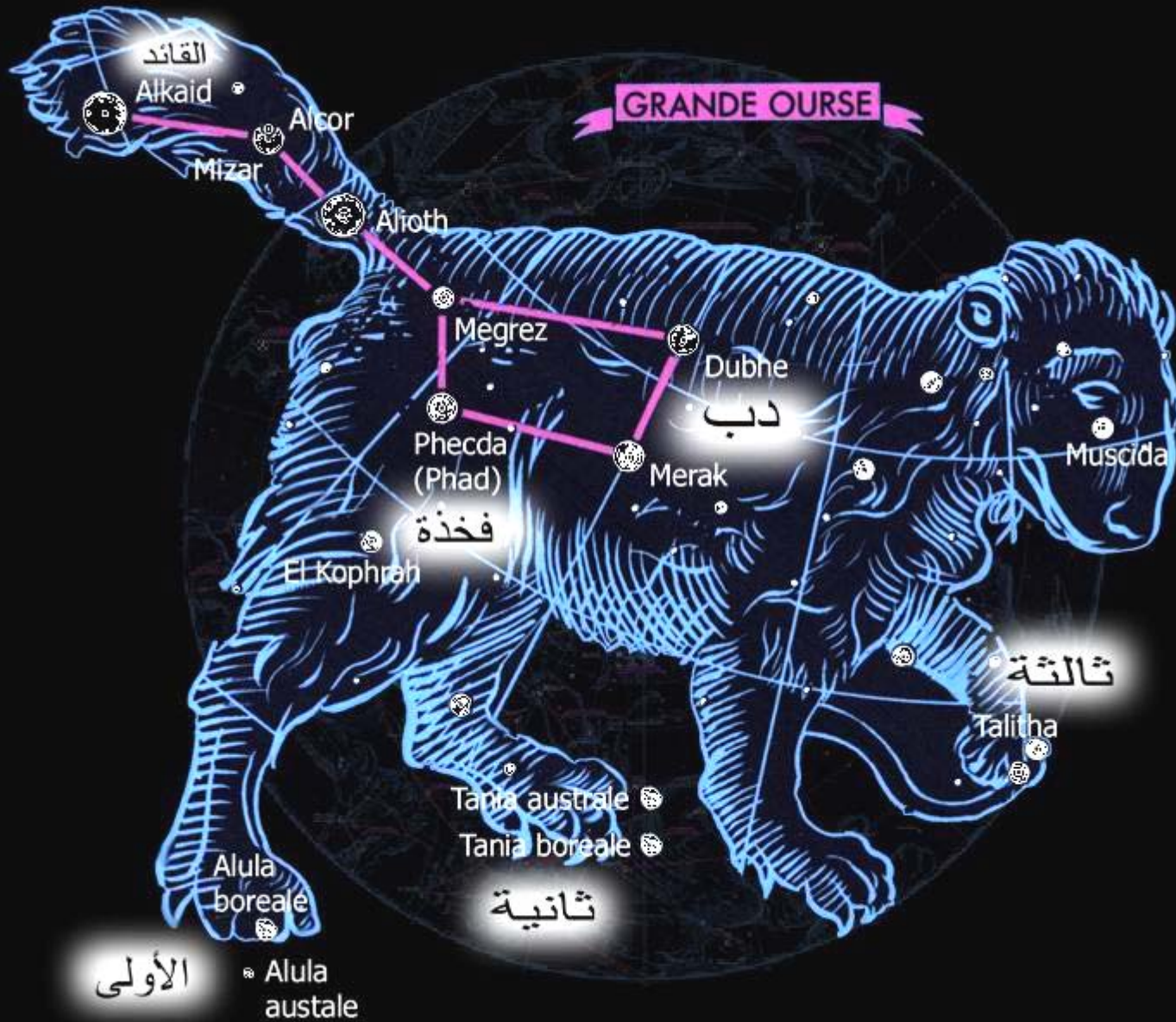
- Discoverer of the circulation of the blood – 400 years before Harvey.
- Author of the magisterial *Al-Shamil* in Medicine



On Accepting The Contrarian View: 如何對待不同觀點

“When hearing something unusual, do not preemptively reject it, for that would be folly. Indeed, horrible things may be true, and familiar and praised things may prove to be lies. Truth is truth unto itself, not because [many] people say it is.” 「只有傻瓜才會一聽到奇怪的想法就馬上唾棄它。荒唐事可能是真的，習以為常或被人稱讚的反而可能是錯的。真就是真，不是因為很多人說是真才是真。」

--- Ibn Al-Nafis, (1213-1288 A.D.) *Sharh' Ma'na Al Qanun.*



Elegant astrolabes (星盤) made for the Safavid rulers of Iran



Made for Abbas II in 1647-48.



Made by Abu al-Aimma in 1712-13.

Source: *The Oxford Dictionary of Islam*, Edited by John L. Esposito. Oxford University Press, 1999.

Madian Al-Qawsouni (d. 1634 AD) discussing simultaneity

同時性與觀察者關係的討論

- The earth is spherical, and from there flows a problem. If three people stand together and one goes east, the other west, while the third would remain where he is. (三人之中一人往東，一人往西，一人不動)
- The two travelers would return to him, the one going east returning from the west, and vice versa. (兩旅行者環繞地球一圈後回到原點)
- But the number of days spent by the travelers would be increased by one day for the one traveling east and decreased by a day for the one traveling west. (往東者增一天，往西者少一天)

Madian Al-Qawsouni (d. 1634 AD) (cont'd)

- This leads to the question: is it possible that one day is Friday for one person and Thursday for another and Saturday for still another? (會不會一個人說那天是星期五，另一說是星期四，又另一人說是星期六?)
- We think yes. (沒錯)

Madian Al-Qawsouni

-- *Sharh li Qasidat Ibn Sina*



Astronomy

- Although the Arabs and Muslims made major discoveries and contributions, they did not provide an alternative model to the Ptolemaic (related to AD 2 scientists) one, as did Copernicus

阿拉伯學者未能提出地球中心之外的宇宙模型

Copernicus (1473 -1543)

Passing The Torch: Europe Ascendant

十五六世紀火炬傳遞給歐洲

Nicolaus Copernicus

(1473-1543) Polish Astronomer

波蘭天文學家

Heliocentric Theory
vs. Ptolemaic
Theory

Ming Dynasty







1633 -- Galileo Recants

宗教迫害受審，撤銷原來主張

天體運行定律



**Tycho Brahe
(1546-1601)**

Data from
observations



**Johanes
Kepler
(1571-1630)**

Sorted out three laws of
planetary motion from
the data

Derived these laws
from law of universal
gravitation

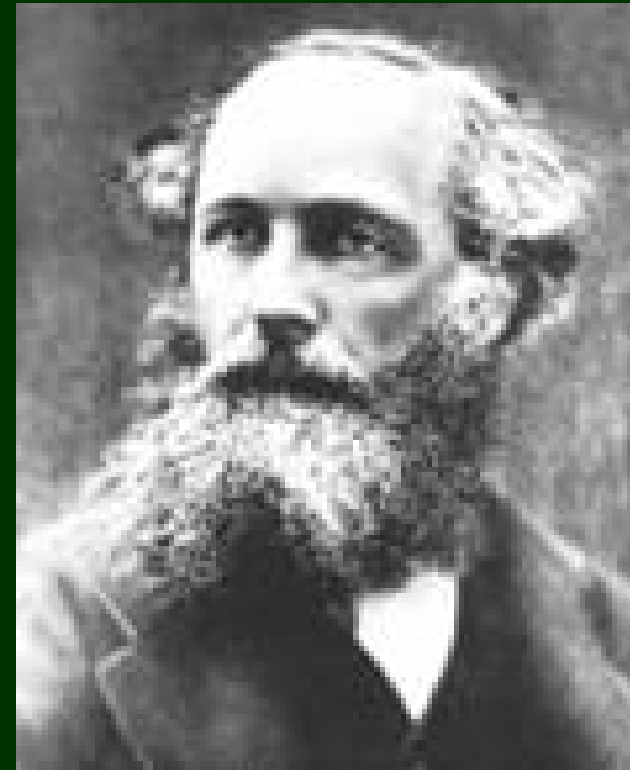


**Newton
(1642-1727)**

電磁波



Michael
Faraday
1791-1867

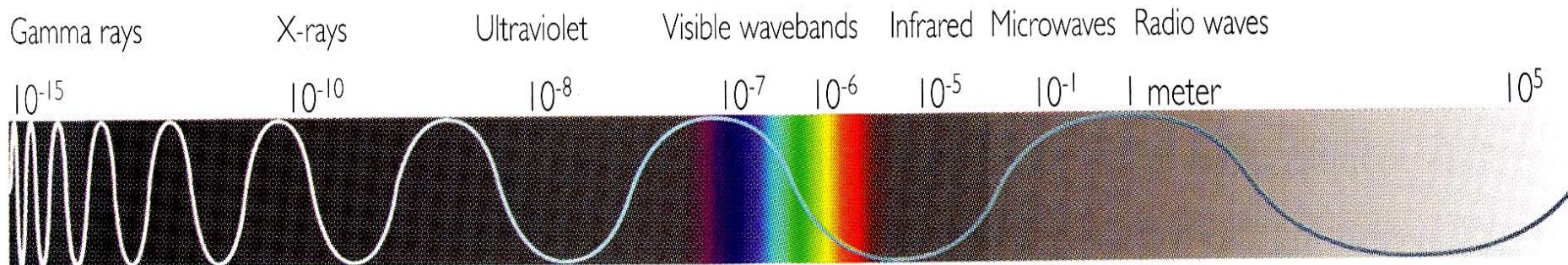


James Clerk
Maxwell (1831-
1879)

According to Maxwell, **God** say:

$$\begin{aligned}\nabla \cdot \mathbf{E} &= \frac{\rho_t}{\epsilon_0}, \\ \nabla \cdot \mathbf{B} &= 0, \\ \nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} &= 0, \\ \nabla \times \mathbf{B} - \frac{1}{c^2} \frac{\partial \mathbf{E}}{\partial t} &= \mu_0 \mathbf{J}_m;\end{aligned}$$

and there is **light**!

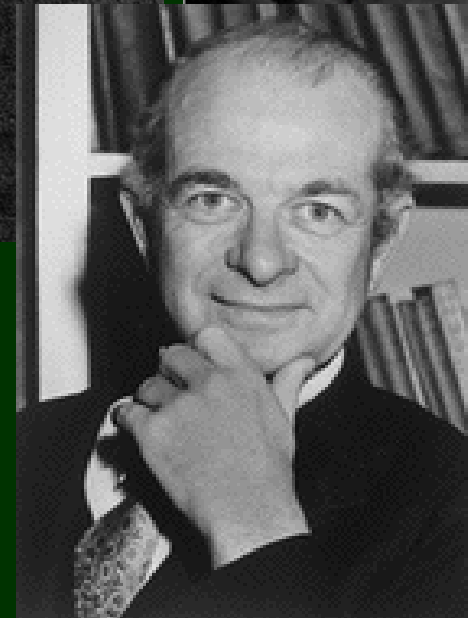
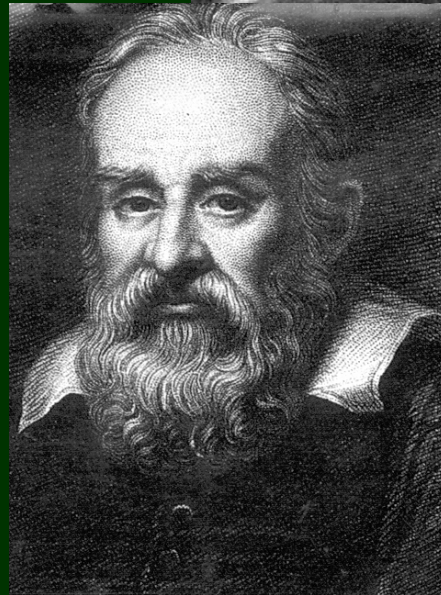
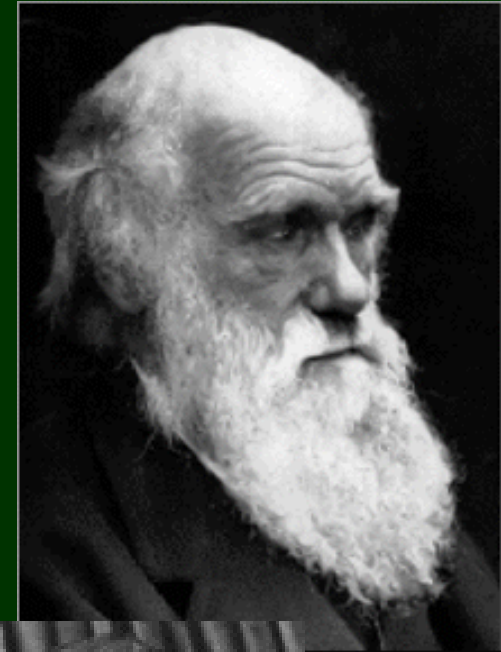
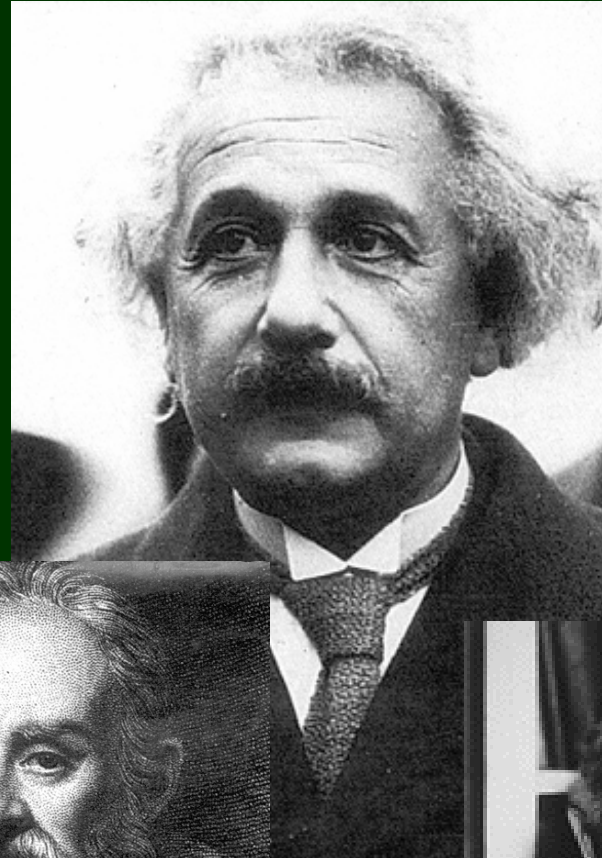


The Four Greatest Theories Of Physics

- **Newton's Principia** 原理
establishes inverse square act-at-a-distance force of gravitation
- **Maxwell's Electromagnetic Waves** 電磁波
unifies electricity & magnetism, Faraday's concept of field, electromagnetic waves, light
- **Einstein's Relativity** 相對論
space & time, mass & energy, gravitation & acceleration
- **Quantum Mechanics: Planck, Einstein, Bohr, de Broglie, Heisenberg, Schroedinger, Born, Dirac ..** 量子力學
matter wave, probabilistic, uncertainty principle

... and the quest continues...

Some Great Scientists of the Past



Science Is Driven by Curiosity
About the Natural World
科學的追求來自對自然的好奇

WHAT IF?

WHAT IF?



WHAT IF?

??

Science

“Knowledge of Natural Rules & Order”

Experiment

Observe, discover, study and understand natural phenomena

Theory (Analytical & Numerical)

Understand, formulate natural phenomena and predict not-yet-observed phenomena

Human Knowledge

Methodology

Logics & Mathematics

Natural Sciences

Physics
Chemistry
Biology
Astronomy
Geology
Etc.

Human & Social Sciences

Sociology
Economics
Political Sci.
History
Psychology
Etc.

objective

subjective

Humanity

Philosophy
Aesthetics
Ethics
Religion
Etc.

Applied to Life

Technology
Architecture
Physiology & Medicine
Law
Education
Art, Music & Entertainment
Etc.

Natural Sciences

(traditional definitions)

- **Physical Sciences:** Physics, Chemistry
- **Life Sciences:** Biology (zoology, botany)
or molecular biology, genetics
- **Earth Sciences:** Geology, Astronomy,
Meteorology

The Nature of Scientific Knowledge 科學知識的性質

- Approximate (概略)
- Empirical (實證)
- Reproducible (可重複)

- And so much more...

The Scientific Method

The Method of Science

Experimental Observation 實驗觀察



Hypothesis & Theory 假說與理論



Theoretical Prediction 理論預測



Experimental Confirmation 實驗驗證

The Method of Science

OBSERVATION: Sense specific physical realities or events.



HYPOTHESIS: Create a statement about the general nature of the phenomenon observed.



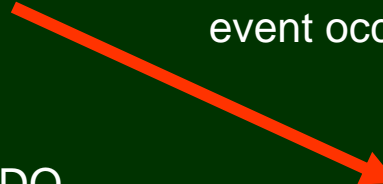
PREDICTION: Forecast a future occurrence consistent with the hypotheses.



EXPERIMENT: Carry out a test to see if predicted event occurs.



If results **DO** match prediction, hypothesis is supported.



If results **DO NOT** match prediction



RECYCLE



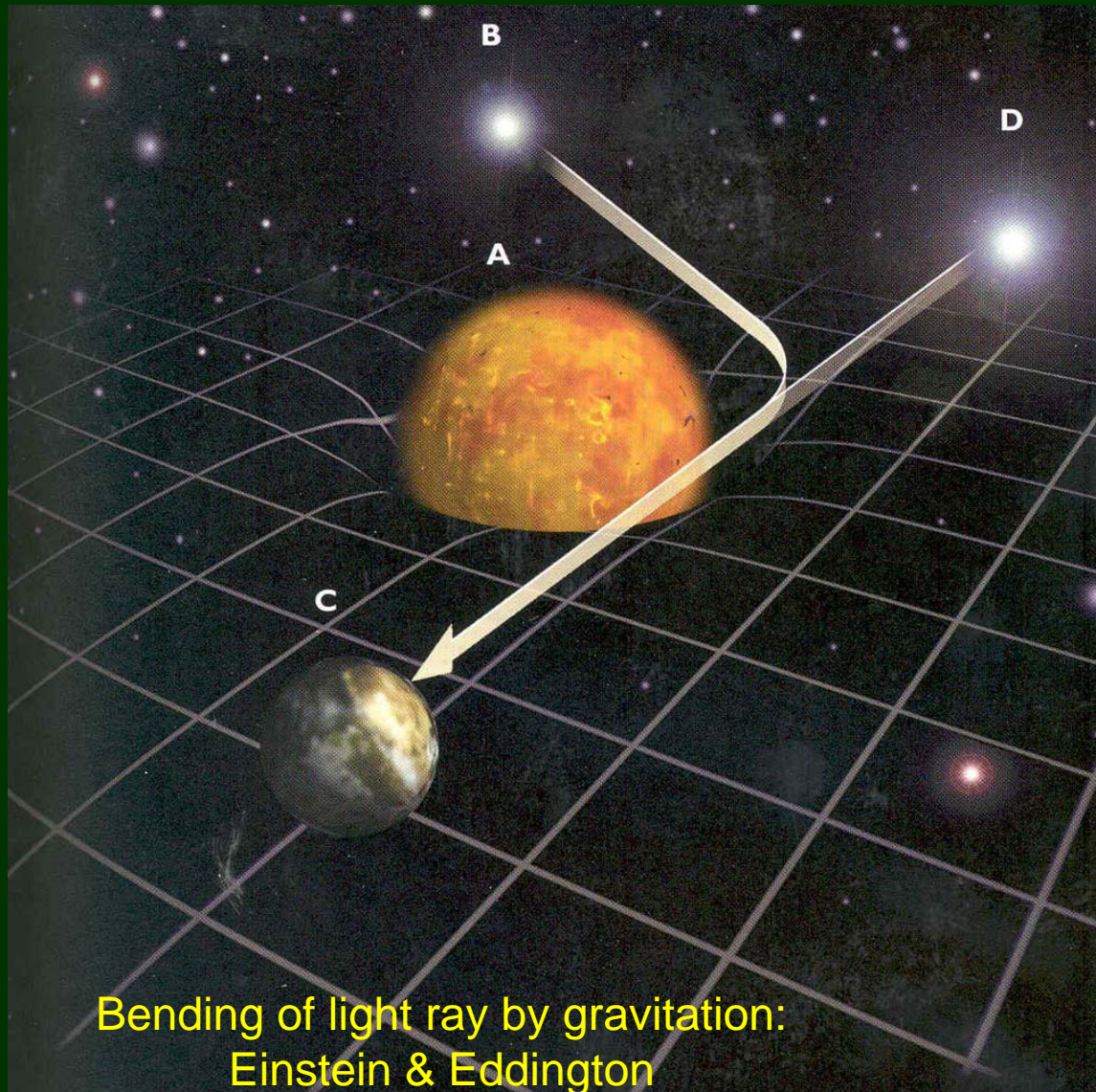
REVISED HYPOTHESIS



PREDICTION



EXPERIMENT



Bending of light ray by gravitation:
Einstein & Eddington

No amount of experimentation can ever prove me right; A single experiment can prove me wrong. 「不論多少實驗都無法證明我的理論，但是只要一個實驗就可能推翻它。」

Albert Einstein

Fact

- An observation that has been repeatedly confirmed, and is accepted for all practical purposes to be “true”.
- 一個經重複觀察驗證的事實，實際上便可稱之為「真」。

Truth

- Truth in science is never final, and what is accepted as fact today may be modified or even discarded tomorrow.
- 科學的真不是終極，今天的真，也許明天會被修正，或甚至於被推翻而丟棄。

Hypothesis 假說

- A tentative statement about the natural world leading to deductions that can be tested 暫時解釋，從演繹結果來驗證
- Hypotheses can be verified or rejected by tests 假說可由測試證實或丟棄
- Hypotheses can be used to build more complex inferences and explanations 根據假說建立更複雜的解釋與推論

Model

- A Hypothesis can also be a Model, which is also a tentative statement about the natural world leading to deductions that can be tested 假說也可以是一個模式，一個暫時可由推論的正確與否來檢驗的說詞

Law

- A descriptive generalization about how some aspect of the natural world behaves under stated circumstances
- 定律乃普遍化敘述自然世界裡在某一情況下發生的某些事的運行法則

Theory

- Well-substantiated explanation of some aspect of the natural world that can incorporate a large body of scientific facts, laws, logical inferences and tested hypotheses. 由很多經過相當程度驗證的假說與定律組成的某些自然現象的解釋
- Evolution is one of the strongest and most useful scientific theories today. Evolution vs. Intelligent Designs (believe that cannot be tested).
- 進化論（可驗證） vs. 智慧設計（信仰）
Charles Darwin (1809-1882): 物競天擇 (1838-1859) On the Origin of Species（物種原始）

Step by Step Proof: Darwin's Theory of Evolution

...t-great-great cousin!"
 ...nates scientists about
 ...it fits so neatly into
 ...ng chapters in the his-
 ...atures that swam
 ...e rise to things
 ...crept on
 ...pears
 ...in



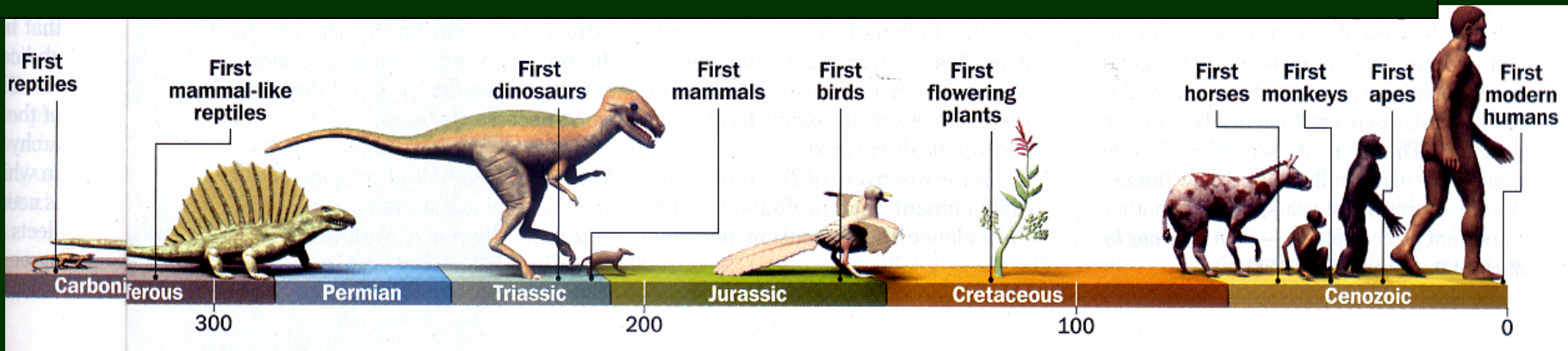
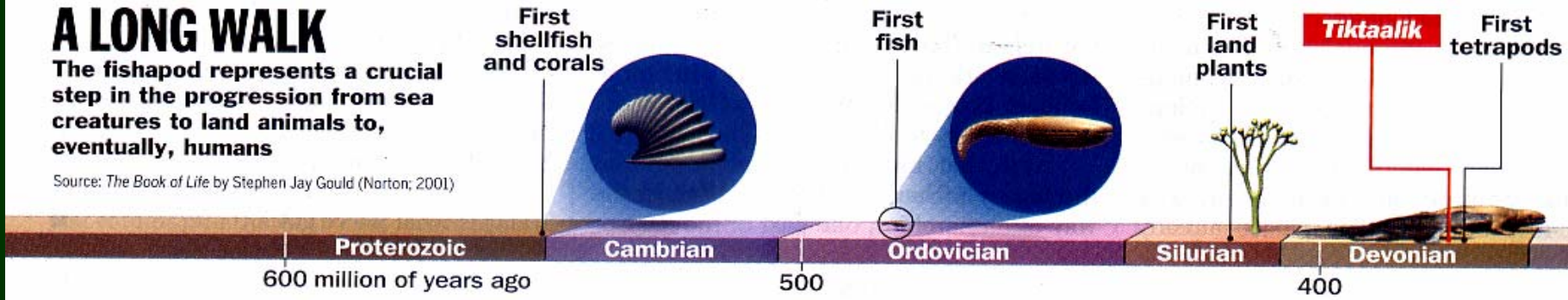
in Green-



A LONG WALK

The fishapod represents a crucial step in the progression from sea creatures to land animals to, eventually, humans

Source: *The Book of Life* by Stephen Jay Gould (Norton, 2001)



Coherent Domains of Knowledge

- Overall Paradigm 範疇
- Central concepts 主要概念
- Developments within the domain 在某一範圍內發展
- Interlocking 交織
- Mutually supportive or inconsistencies 相互同意或互相矛盾
- Not necessarily 100% interlinked (e.g. Quantum and General Relativity) 不必完全交織

Ultimately, in Science, the final authority is not a person, but a reasoning process

科學定論來自推理，非來自權威

The Values Of Science

科學的價值觀

Values of Science

- **Truth** 真
- **Honor** 誠（榮譽，不作假，不抄襲）
- **Creativity and imagination** 創意與想像力

Values of Science

- Truth 真
- Honor 誠 (榮譽)
- Creativity and imagination 創意與想像力
- Constructive subversiveness 疑
- Tolerance of engagement 忍
- Arbitration of disputes 公平

Truth vs. Consensus Science vs.
Consensus Politics

Science is about originality,
creativity and excellence
regardless of age, race, religion,
language, sex, or national origin...

科學只有創新、創造力和卓越，與
科學家的年齡、種族、信仰、語言
文化、性別或國籍無關...

The values of science are
forged by student practice and
teacher example

科學由學生的參與而造就
老師是先行者

The Role of Youth

年輕人的角色

歷史上重要科學貢獻來自年輕人



Sir Isaac Newton (1642-1727)

Newton

By age 30 Newton had:

- Revolutionized optics and the nature of light 對光學有革命性的貢獻
- Thought out gravitation 萬有引力
- Invented the calculus 發明微積分
- Full professor at Cambridge 劍大教授
- Elected Fellow at the Royal Society 皇家學院院士

1905

Einstein's miraculous year

- Molecular Dimensions 分子的尺寸
- Brownian Motion 布朗運動
- Photoelectric Effect 光電子理論
- Special Theory Of Relativity 狹義相對論
- $E = mc^2$

Only 26 years old!



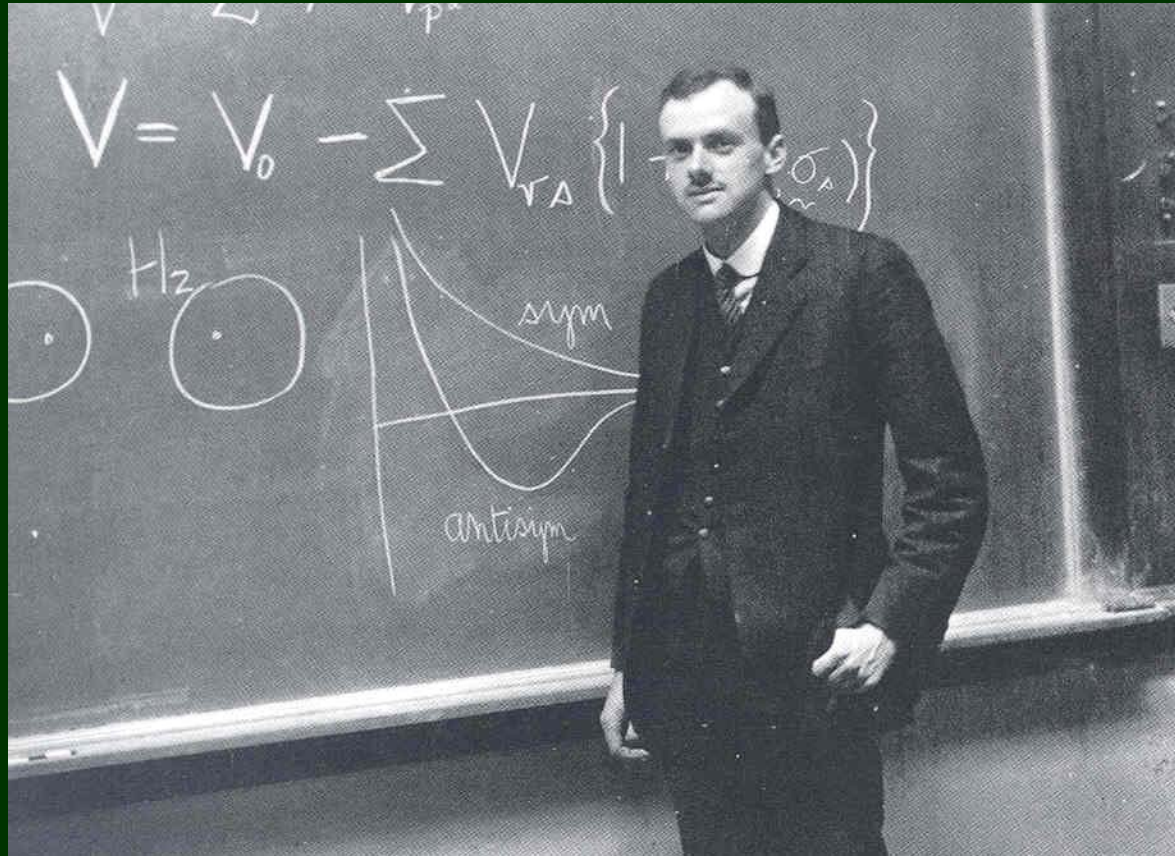
1879-1955

Werner Heisenberg (1901 – 1976)

- Created the first version of quantum mechanics at **age 24** (1925) 創造量子力學
- Formulated the “Uncertainty Principle” at **age 26** (1927) 提出測不準原理



Paul Dirac (1902-1984)

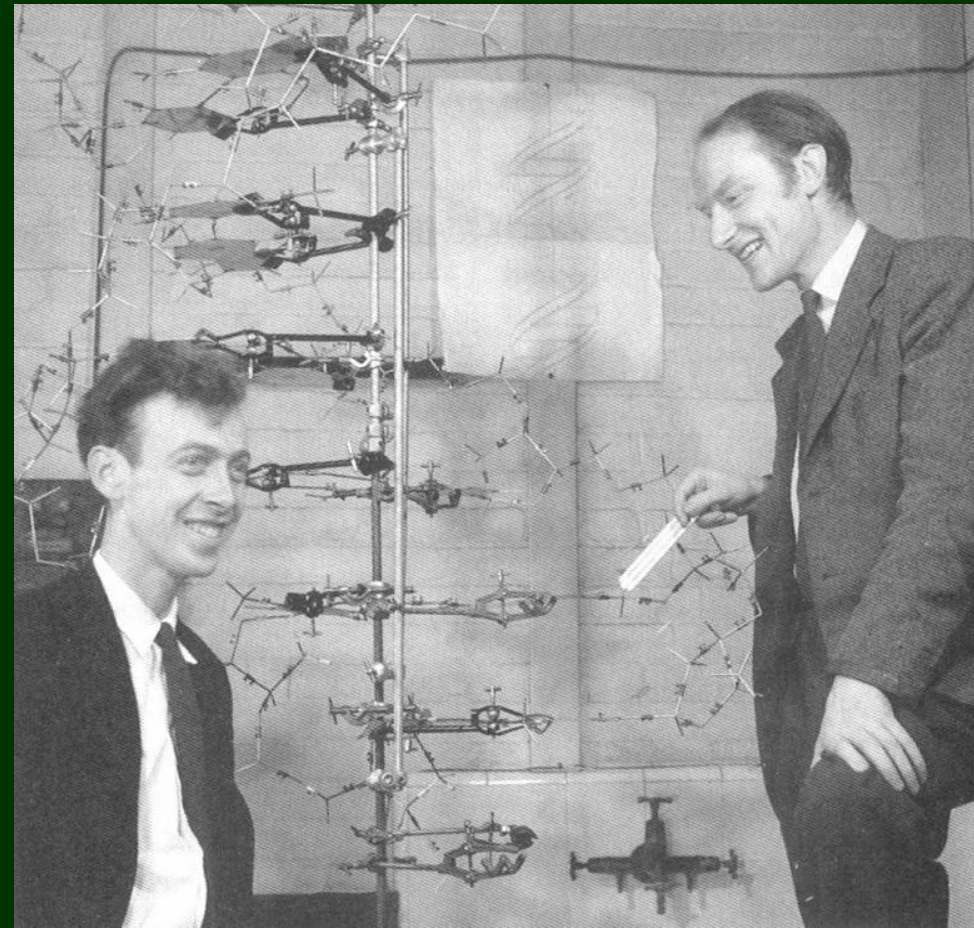


Dirac – The brilliance of youth

- At **age 24**, in 1926, while still a graduate student, he made his first major contribution to physics by devising a form of quantum mechanics. 提出量子力學的新表達方式
- At **age 26**, in 1928 he formulated the full quantum treatment (relativistic QM) of the electron and predicted anti-matter -- Positron found four years later. 相對論量子力學，預測反物質，反電子在四年後被發現
- At **age 31** shared Nobel prize with Schrödinger in 1933 三十一歲獲得諾貝爾獎

Double Helix: The Tinker Toy Model of DNA

- James Watson was **25** at the time of the discovery of the structure of DNA in 1953
- Tinker Toy Model
DNA 結構模型



Older People: Don't be Discouraged

- Einstein: General Relativity: age 37
- C. N. Yang: age 32-35
- Erwin Schrödinger: Wave equ. : age 39
- John Bardeen: BCS Theory: age 49

Theorists: Imagination, creativity, bold...

Experimentalists: ... + experience + cautious in interpretation, age plays less important role

E. W, Müller, Atom-Probe FIM at age 56

Whereas Science is Experimental

The Ultimate Glory Goes to Theorists

They Formulate the Laws & Theories of Nature

科學終極榮耀屬於理論學家，且長壽

Experimentalists Discover Natural

Phenomena and Help Sorting Out the Order of These Phenomena

Experimentalists Benefit Society More Directly by Developing Technologies

實驗科學家透過科技發展，直接造福人類

Physics to Science & Technology

Technology & Engineering:

Apply scientific
knowledge to benefit
mankind



Big Bang

Formation of Universe

Solar System

$\sim 13 \times 10^9$ yr

5×10^9 yr

Australopithccus Afarensis

Homo Erectus

Homo Sapiens

Human Evolution

Ape

Java Man

Peiking Man

$\sim 4 \times 10^6$ yr

$\sim 1.9 \times 10^6$ yr

$\sim 2 \times 10^5$ yr

Human Civilization starts

Human Civilization

Agriculture

Agriculture Society
Handicraft Economy

Industrial Revolution

$\sim 13,000$ yr

~ 6000 yr

300 yr

0

✓ Handicraft Economy: Based on experiences, human & animal power, small to midsize scale, little science.

✓ Industrial Revolution: Started 1760-1840, based on experiences & simple science. Materials: iron & steel. Motive power: engine, electricity. System: factories. Transportation: automobile, train & ship. Knowledge: A little physics & chemistry. Industry stimulated progress in science.

Physics & Science & Technology Time-Line Spectrum

1604: Galileo, Science is based on experimental facts!

1609, 1618: Brache, Kepler laws of planet mo.

1687: Newton, Principia

1690: Huygens, optics
1704: Newton, Optics

1770: Black, calorimetry

1600

1700
1698 1712

1769
Automobile
Cugnot

1800
Iron
industry

幾千年的醞釀，終於
開花結果，剛開始不
久，現在不能鬆懈。

Steam engine
Savery, Newcomen

Industrial Revolution
(1760 – 1840)

**1873: Maxwell
em-wave**

1900-1926 QM:
Planck,
Einstein, Bohr,

**1957, DNA: Watson & Crick
Molecular Biology**

1905:
Einstein, th.
relativity

Heisenberg,
Schroedinger

1948: transistor. 1950:
laser. 1980: STM

1824: Carnot cycle
1831: Faraday,
field & em induction

1849: Kelvin temp.
1850: Clausius laws
of thermodynamics
1875: Gibbs

**Nuclear, Atom & mole.
H.E. & Solid state phys.**

**Surf. Sci., Materials Sci.
Cosmology, Nano Sci.**

1800

Steel indu.

1900

1936: EM,
1951: FIM
1981: STM

2000

1803: Train (Trevithick)
1803-1807: Steam boat
(Symington, Fulton)

1875-1876: Bell
Telegraph
telephone

1901-1907: Wireless
comm. Edison,
Marconi
Fleming, Forest
1903: Airplane, Wright
brother, etc.

1957: Sputnik, 1960: laser,
1969: moon landing, 1947-
now, solid state electronics &
computer & information tech.

**1900-1950: modern industry
1950-now: high tech. industry**

Modern Physics & Science & Technology

1) Electromagnetic Waves

1831: Faraday, Induction & Field

1873: Maxwell, EM waves

2) Relativity, Einstein

1905: Special Th. Space & Time,
Mass & Energy

1915: General Th. Acceler. & Gravity

3) Quantum Mechanics

1900: Planck, Energy Quantization

1905: Einstein, Photon

1913: Bohr, H-Model, Appl. of QM

1924: de Broglie, Matter Wave

1925: Heisenberg, Quantum Mech.

1926: Schroedinger, S-Equation

4) Particle & Fields

Atom & Molec. Phys.: Laser,
Optical Trap, BE-Condens.

Condensed Matt. Phys.:

Solid state electronics,

Computer, Informat. tech.

Chemistry: Chem. bond, Chem.

Indus. Pharmaceutical Ind.

Biology: Double helix,

Molecular bio., Genetic eng.

Medical science

Surface Sci. : Thin films,

Electronic materials, Catalysis

Materials Sci.: Interdisciplinary

Astrophysics & Space Sci. & Tech.

Nanoscience: Interdisciplinary

科學迅速進步只有幾百年歷史，可說剛剛開始，所以

年輕人，加油！

年重人，加倍努力！

謝謝聆聽