# SCIENCE in al-ANDALUS


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- Introduction and warnings
- Personal interests and links
- Mathematics
- Astronomy
- Physics and Chemistry
- Medicine and life sciences
- Conclusions

**Madrasa de Granada (1349)**

# Introduction and Warnings

When hearing the name “al-Andalus”, most people think about architecture and some of the most visited monuments in the world:

Mezquita/Cordoba

Alhambra/Granada

Giralda/Sevilla

# Introduction and Warnings

Also about art and culture, from decoration to music to gastronomy:

Azulejos/ceramic

Oud/Music/Chant

Cuisine/tapa

But not about scientific work and production of pure knowledge.

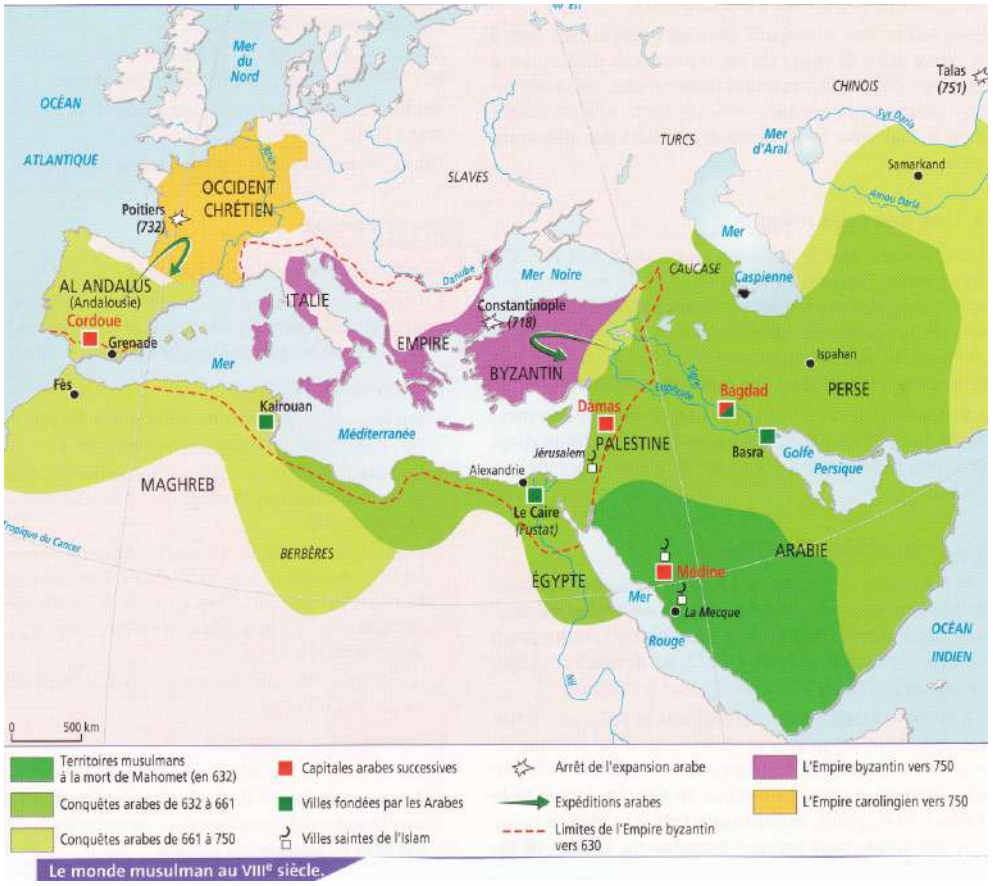
I will show that not only the "Arabs" transmitted the antic heritage of Greece, Persia, Egypt, Mesopotamia, China, ... to the Renaissance, but they also made extremely important new scientific contributions.

First: a few basic/historical facts and important remarks/warnings.

# Introduction and Warnings

Al-Andalus was not isolated: part of an empire or a cultural world; it had roughly three main periods between the years 711 to 1492.

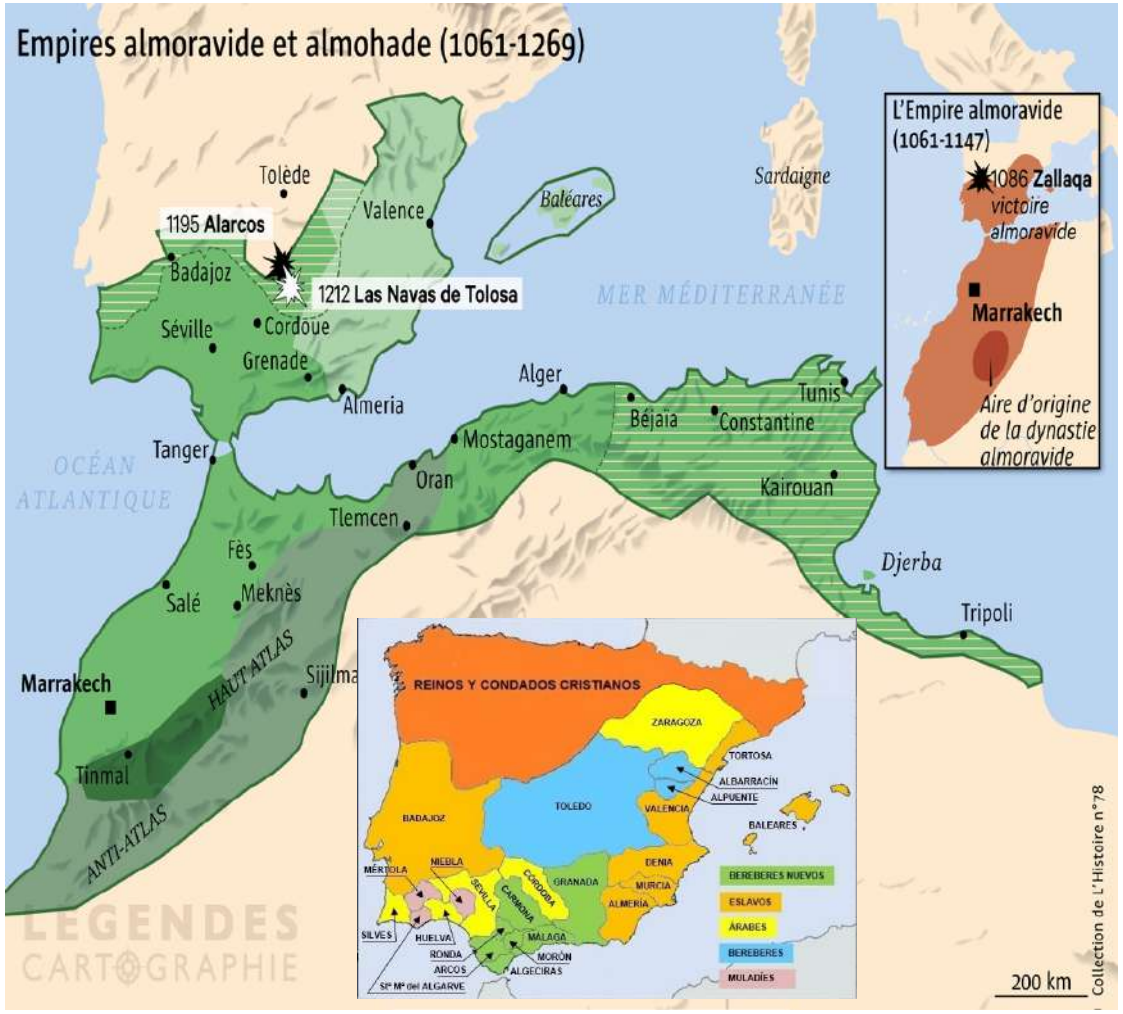
A) Islamic empire to the Caliphate of Cordoba (711-756-929-1031).




- Vast and multi-faced empire:
  - merged ancient/grand places;
  - it was first unified by religion;
  - and then also* by language.
- An extraordinary period of:
  - (relative) stability and security,
  - diffusion of science/technology*,
  - new libraries/schools/hospitals..
  - religious/administrative needs,
  - courts of emirs* and notables.
- Incredible boost for Science:
  - first translation to Arabic, then,
  - production of new knowledge.

# Introduction and Warnings

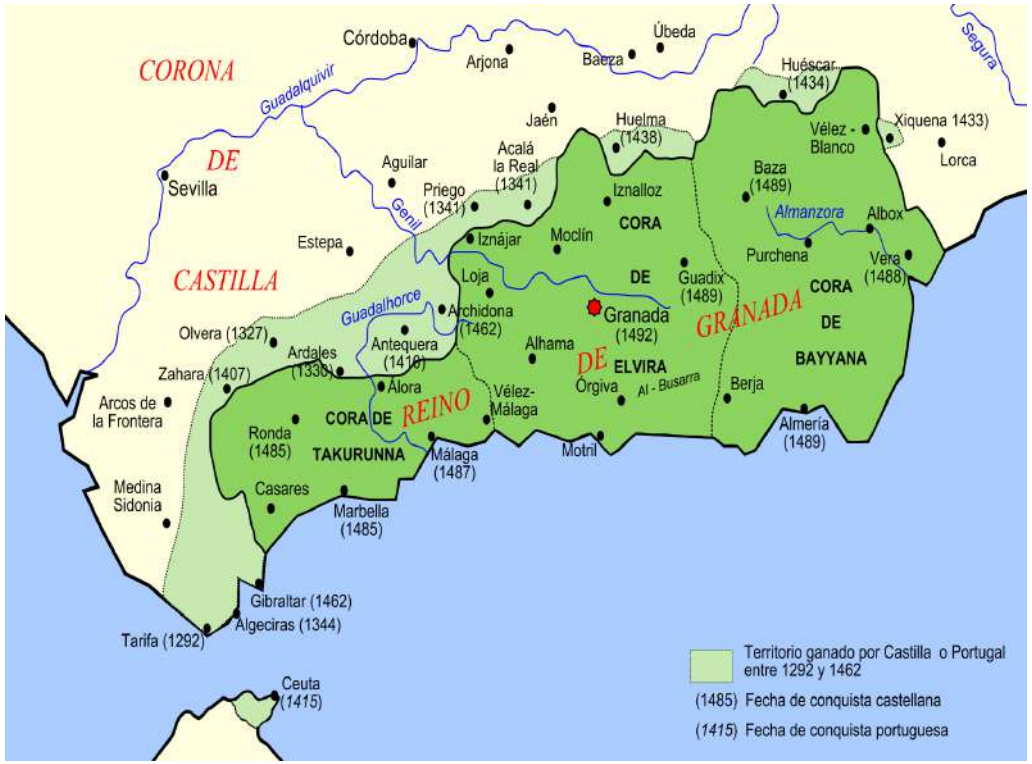
## B) The Maghreban era: Taifas, Almoravids, Almohads (1031-1238).




- First Taifas ($\approx$1031–1085): a century of war and division, but huge circulation of people, $\Rightarrow$ very rich and decisive; ex:
  - Zirids in Granada(+Algiers)*,
  - Zaragoza and al-Mutaman*.
- Almoravids ($\approx$1085–1145), Almohads ($\approx$1147–1238) (and 2d and 3d Taifa periods): less funny (fundamentalism+ pressure from the north); but:
  - strong link with Maghreb,
  - many great characters*,*
  - prodigious times for maths,
  - translation to Latin (Toledo).

# Introduction and Warnings

## C) The Nazari or Granada Emirate/Kingdom (1238–1492).




Politically "stable" but "tricky" :
- much smaller kingdom/emirate,
- still fights with Castilla/Aragon,
- still contacts with → Maghreb,
- plague with bad+good aspects.

Most important achievements mainly in architecture and art, but progress in medicine/math.

But most important aspect is the knowledge transfer to Europe (together with Sicily, north Italy):
- astronomy with Toledo school;
- medicine, e.g. Gui de Chauliac;
- discoveries of the Portuguese?

# Introduction and Warnings

Before entering the subject, a few warnings and some remarks.

- It is often said "Arabic" civilization; not true, esp. during empire.

In al-Andalus, people were mostly Berbers (old and also new ones), "Arabs" (among rulers) "Spanish" (muladis), Saqalibas* (slavics), and from many other origins (in "knowledge", Persians, Egyptians...).

- Not pure Islamic culture neither: also Jews*, Christians*, Asians*, ...

$\Rightarrow$ for the Peninsula, one can speak about the culture of al-Andalus.

- Complicated names: Berber or else $\rightarrow$ Arabic $\rightarrow$ Latin $\rightarrow$ modern.

Ex: ابن رشد is Averroes (Latin), or **ibn Rochd** (FR), Ibn Rushd (EN), Ibn Rušd (SP), Ibne Ruxide (PT), Aven Roshd (IT), Ibn Ruschd (D).

- Very rich and long list of achievements: cannot be too exhaustive,

$\Rightarrow$ I will concentrate on fundamental Sciences with some exceptions.

- I am not an expert in history nor in other sciences than physics (my field is theoretical physics with a focus on Higgs and dark matter)

$\Rightarrow$ what I present is from reading; apologies if inaccurate/incomplete!

# Personal interests and links

Interest in subject boosted when, during covid-confinement, I read:

It becomes clear to anyone who has diagnosed or treated the disease that most of the individuals who have had contact with a victim will die, whereas the man who had no exposure will remain healthy...
The disease can make its first appearance in a house, then spread to other persons-neighbors, relatives, visitors. Many people remained in good health who kept themselves in good isolation from the outside world...
There are many accounts of communities remote from highways and commerce that remained unscathed...

Ibn al-Khatib, 1349, Granada during the Black Death...

**Simon? Pasteur? No!**


Lisan Edine **ibn al-Khatib** (Loja 1313-Fès 1374), a fascinating man:

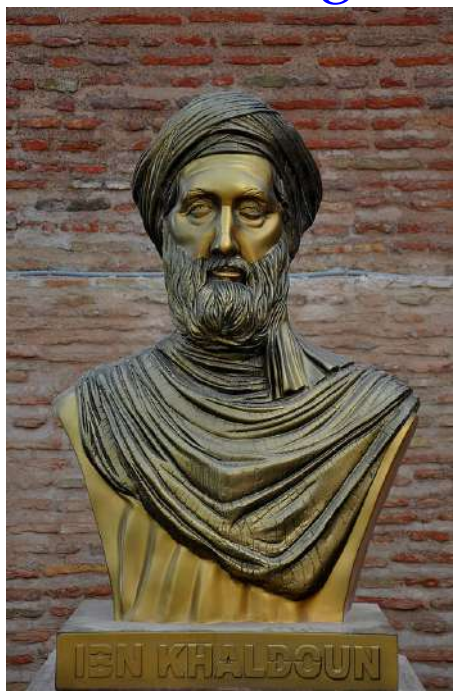

- poet, musician, historian, philosopher;
- twice Vizir of Mohammed V of Granada;
- physician, wrote best treaty on plague;
- seen as father of modern epidemiology;
- acquaintance of another hero, **ibn Khaldoun**.

# Personal interests and links

Abderahman **ibn Khaldoun** (Tunis 1332 – Cairo 1406), another fascinating character and a man of great knowledge.

- Considered to be the father of historiography, sociology, economics and demography studies.
  (https://en.wikipedia.org/wiki/Ibn_Khaldun)

Ibn Khaldoun statue/Bugia

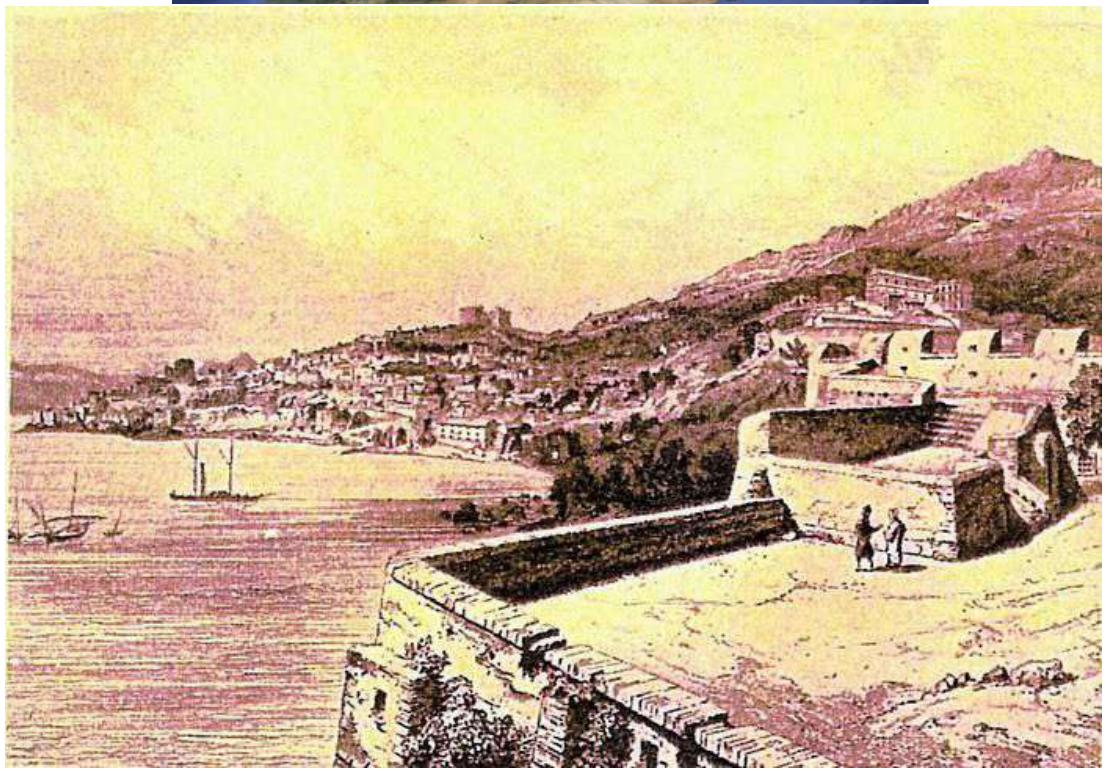



- One of the greatest historians of all times:
  a history of Berbers expanded to universal one;
  an introduction on the empires birth and death.
- Great traveller, ambassador and negotiator:
  - 1400: convinced Tamerlane to spare Damascus;
  - 1362: helps Moh. V and al-Khatib back to power
    (became a Granadino, was offered a village in the Vega);
  - 1365: negotiated peace with Pedro I de Castilla
    (it lasted for a century with minor breaks; thanks to him?)
- Another interesting point is that he lived in Bugia/Algeria...

# Personal interests and links

**Béjaia-Bougie-Bgayeth-Bugia:**


- important Roman city (Saldae);
- once capital of the Vandals;
- capital of the Hamadites
  (ziri dynasty linked to Granada);
- part of the Almohad empire;
- one capital of the Kabyles;
- city of science and culture;
- tight links with al-Andalus
  (from XIc ziri to XVIc expulsion);
- conquered by king Carlos I
  (1510-1555; was mostly destroyed).



Incidentally, it is also my birthplace.

And what is of interest to us:

it hosted a large number of scientists and other scholars; in particular:

# Personal interests and links

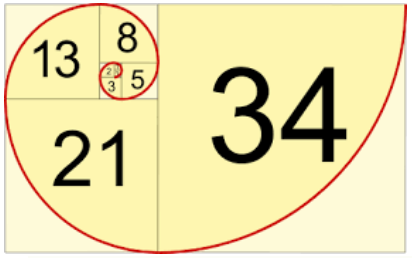
**Leonardo Pisano di Fibonacci**:

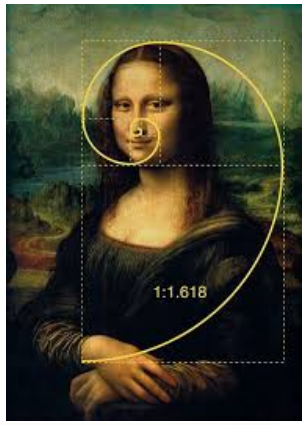
(Pisa 1170 – 1250 approximately).

Italian mathematician, most known for:

Fibonacci series: $\mathbf{U_{n+1} = U_n + U_{n-1}}$,

golden number: $\phi = \lim_{n\to\infty} \frac{U_{n+1}}{U_n} = \frac{1+\sqrt{5}}{2}$.




- youth in Bugia with merchant father;
- learned accounting/mathematics there;
- brought back with him Arabic numbers.

(First attempt made by Pope Sylvester II in Xc;
G. de Cremona translated Khwarizmi in XIIc).

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| ٠ | ١ | ٢ | ٣ | ٤ | ٥ | ٦ | ٧ | ٨ | ٩ |

In 1202, wrote the famous Liber Abaci:
first European mathematical treatise;
it was based on these decimal numbers.

# Personal interests and links

## Abdelhak ibn al-Haim al-Ishbili

(born in Sevilla, lived in Bugia†, XII-XIIIc).
Mathematician, astronomer, jurisconsult?
In 1204, wrote "The Perfect Handbook on Mathematical Astronomy", a treatise with an introduction and seven books; considered exceptionally complete and accurate by astronomers. Selected work:
- spherical trigonometry formulae;
- accurate longitude of the solar apogee;
- moon's longitude+latitude (Ptolemy).

Also† jurist and interpreter of the Quran: a Saint of Bugia with important mosque (at the bottom of a hill/barrio named Abazine !)

(† This is only one (interesting...) possibility; several other alternatives are still debated.)


Mosque Sidi Abdelhak

A question if true :-) did he meet Fibonacci and taught him maths?

# Mathematics

Mathematics important in Islamic world (esp. during empire); e.g.

- arithmetics: change, conversions, salaries and taxes, heritage, ...
- geometry: length/area/volume measure, architecture, decoration,...
- trigonometry: initially for geography, astronomy, astrology...

At first: translated old knowledge into (Aramaic and then) Arabic (House of Wisdom, Baghdad IXc, under al-Mamum+al-Rachid).

- Old Greeks: Euclide, Archimede, Apollonios, Aristotle the master for logic; mostly geometry: polygons, cercles, spheres, conics; but also integer numbers; had a rigorous approach: axioms, postulates, theorems definitions, problems...
- Hindus: had techniques/algorithms to solve basic problems but no "theory"; had decimal/positional system that included "0" (Vc); origin of our numbers;
- Also (mostly oral) contributions from Egypt, China, Persia, Mesopotamia ...

Later some original contributions/extensions started to appear in
- algebra and calculus: number theory, combinatorics, symbolism, etc.
- all fields related to astronomy: (spherical) geometry/trigonometry,...

# Mathematics

## The first big heroes where in Baghdad's House of Wisdom (HoW).

**Al-Khwarizmi** (Khiva 780-Baghdad 850):
- considered to be the father of algebra;
- first manual of algebra (hissab el *jabr*);
- classification of known *algorithms*;
- description of Hindu numeral system.

$N_T = 3 \cdot 2^n - 1,\ n \in N$
$= 2, 5, 11, 23, 47, 191...$

| 220 | 284 |
|---|---|
| 1, 2, 4, 5, 10, 11, 20, 22, 44, 55, 110 et 220 | 1, 2, 4, 71, 142 et 284 |
| 284 + 220 = 504 | 220 + 284 = 504 |

Thabit **ibn Qura** or Thebit
(Harran 836–Baghdad 901):
- great translator of (lost) Greek work;
- first original research in number theory;
- Thebit numbers and amicable numbers;
- also integral calculus, geometric mean...

**Banou Moussa** 3 brothers (IXc, Persia):
- among earliest to adopt Greek maths;
- wrote 20 books (geometry, devices..);
- original: areas, circfs., conic sections,...
- also calculus of Earth circumference.

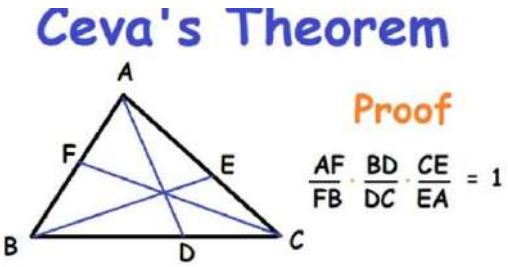
Also **abou Kamil** (IXc-Egypt): first to accept/use irrational numbers.

# Mathematics

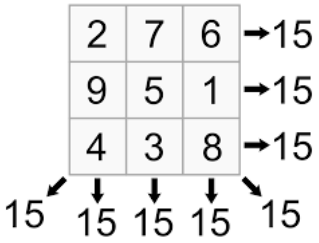
Al-Andalus: very privileged place for maths in XI–XVth centuries; work in various subjects of algebra and (spheric) geometry, like:

- Abu al-Qasim **ibn al-Samh** (979 Cordoba-1035 Granada), **Abulcasim**:
  - pioneer work on algebra, e.g. solutions of quadratic+cubic eqns;
  - also some work on astronomy/geometry (comments on Euclid).
- Yusuf **al-Mutaman** (born ? in Zaragoza, died ? in 1085):
  Emir/King of Zaragoza Taifa (1081-1085); employer of El-Cid.

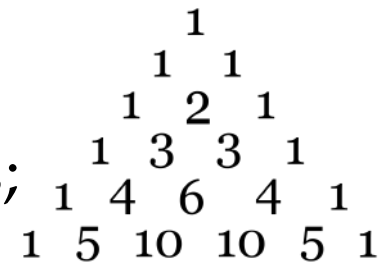
wrote "book of perfection", famous summary of previous work and also original contributions on:
- irrational numbers, conic sections, volumes/areas
- first proof of **Ceva** theorem (GC:1678) in geometry.




- Ahmad **ibn Mun'im** (Denia ?-Marrakesh 1228) in combinatorics:




- major work on magic squares;
- **Pascal** triangle for $(a+b)^n$ coefficients;
- first book with chapter on combinatorics;
- followed by many, especially Maghreb.



# Mathematics

Symbolic notation was another major research field in al-Andalus; a work that did great simplifications to our calculations and life.

- Ahmed **ibn al-Banna** (1256-1321 Marrakesh): **ibn Mun'im** fan:

- dealt with algebra pbs without geometry;
- solved eqns only with remarkable identities;
- solved problems only with combinatorics;
- proposed **Pascal** formulae 3 centuries before.

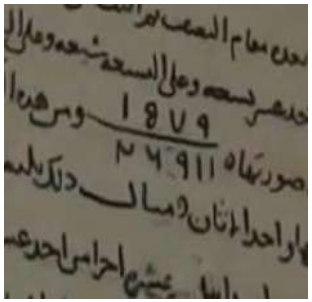
Simple/concise form:

$$p! = 1 \cdot 2 \cdot 3 \cdot (p-1);$$

$$C_n^p = \frac{n!}{p!(n-p)!}$$

- Abu Bakr **al-Hassar** (lived in Sevilla+Morocco; XIIc):

- "complete book on art of numbers" $\ni$ amicable ones;
- "book of demonstration+memorization": first use of **–**
- fraction-symbol adopted in **Fibonacci** Liber abacus.



- Abu al-Hasan **al-Qalasadi** (Baza/Granada 1412-1486 Beja/Tunisia): mathematician, astronomer, jurist, poet, mathematical music;

- و (*wa*) means "and" for addition (+)
- إلا (*illa*) literally, "except"; means "less" fo
- في (*fi*) literally, "in"; means "times" for mu
- على (*ala*) means "over" for division (/)
- ج (*j*) represents *jadah* meaning "root"
- ش (*sh*) represents *shay'* meaning "thing"
- م (*m*) represents *morabba'a* for a square
- ك (*k*) represents *moka'aab* for a cube ($x^3$)
- ل (*l*) represents *ya'adilu* for equality (=)

- wrote "clarification of arithmetic science";
- fundamental work in algebraic symbolism;
- first to use characters for math operations:

**letters for** $+, -, \times, /, \sqrt{\cdot}, {}^2, {}^3$ **and also x !**

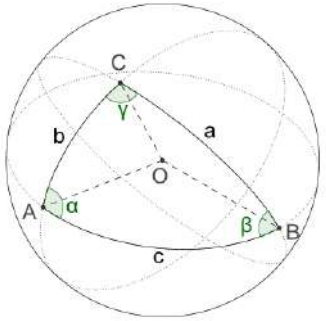
# Mathematics

Another field where Andalusis excelled is spherical trigonometry which is important in astronomy (started/developed also in Persia).

- Ibn Muadh **al-Jayyani** (989 Cordoba-1079 Jaen) pioneered it:

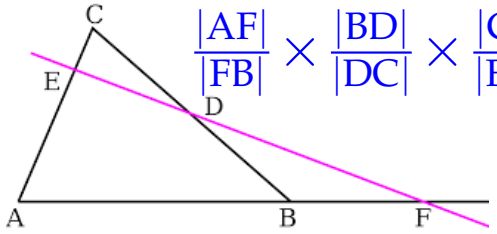
- the "book of unknown arcs of a sphere";
- first complete treatise on the subject;
- has formulae for right-handed triangles, general law of sines; solution of spherical triangle by means of the polar triangle;
- huge influence; work continued by many.

$$\cos c = \cos a \cos b + \sin a \sin b \cos \gamma$$
$$\sin a : \sin b : \sin c = \sin \alpha : \sin \beta : \sin \gamma$$




- Jabir **ibn Aflah** (Sevilla, ≈1100–1150) **Geber** Hispalensis op. c.:

- replaced Menelaus theorem with ones with spherical trigonometry;
- huge astronomy+architecture work




$$\frac{|AF|}{|FB|} \times \frac{|BD|}{|DC|} \times \frac{|CE|}{|EA|} = 1$$

- Additional important work by many Sevillans and others like:

– Abdelhak ibn Haim **al-Ishbili** (Sevilla, fl.c. 1213, Bugia) op. c.

– Mahieddine **al-Ishbili** (Andalus 1220-1283 Maragha) al-Tusi coll.

# Astronomy

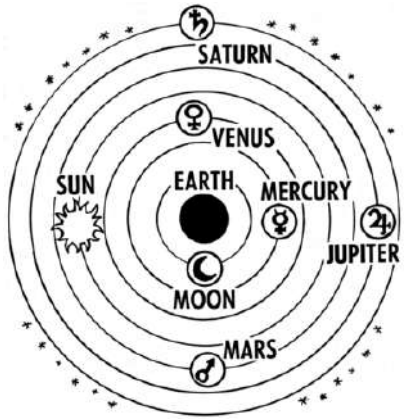
Most important science in Islam: highest status and investment.

First scientific curiosity: oldest and most studied branch of science.

And exact celestial body position/motion at any time important:

- admin: vast empire, useful for position/travel/navigation etc;
- religion: know exact date/time/position of Mecca everywhere;
- astrology: belief in impact of celestial bodies on human life;

Arabs first assimilated Hindi+Farsi knowledge as well as the old Greek ideas from Ptolemy:




- sky: sphere moving around axis passing on its center;
- the earth is spheric and is at the center of the sky;
- heavenly bodies travel in uniform motion along circle;
- only a circle is perfect; no translation movement.
- needs a slightly sophisticated treatment (see later).

They made original contributions mainly in:

- description of stars; realization of sky maps;
- spherical astronomy; astronomy tables (Zijs);
- constitution of (Ptolemaic) planetary models;
- conception/use of astronomical instruments.

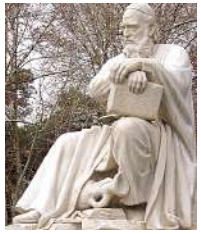
# Astronomy

Most famous astronomers came from Persia (before al-Andalus):
(I skip many important eg **al-Battani**, the Arabic Ptolemy (tan) ...)

- Mohammed **al-Fazari** and Yacoub **ibn Tariq** (VIIIc, Baghdad):

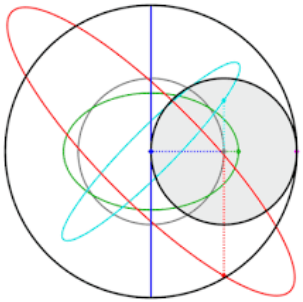
- first astronomers in al-Mamun's House of Wisdom;
- translated Brahmagupta (VIc), Sindhind Zij (VIIIc);
- also introduced Zoroastrian/Persian astronomy;
- al-Farazi built the first astrolab in Islamic world.

- Omar **al-Khayyam** (1048–1133 Nishapur) also maths/philo/poet:



- most known for his Rubayates on life, love and wine...
- but great mathematician too, e.g. solved $ax^3+bx=c$;
- calculated solar year duration with 8 digits accuracy;
- directed Isfahan observatory; made Persian calendar.

- Nasir al-Din **al-Tusi** (1201–1274, Tus): also math/philosophy:



- huge contributions to maths and astronomy;
- constructed/directed Maragha/Iran observatory;
- father of al-Tusi couple (La Hire, 1706) in 1247;

solution for latitudinal motion of inferior planets
(replaces Ptolemy's equant; used by Copernicus).

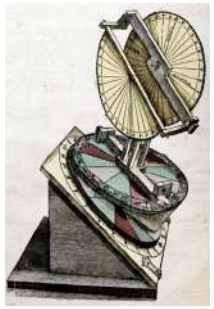
# Astronomy

Al-Andalus was a major place for astronomy in X–XIII centuries.

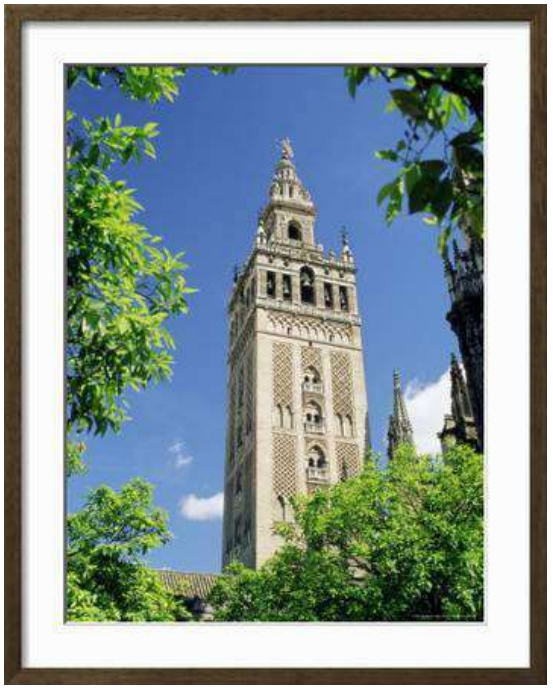
- An observatory on Sevilla's Giralda: second after Baghdad's.
- Toledan Tables: astronomical data to locate Toledo coordinates, which became later the Tablas Alfonsies (Alfonso X, 1252–1272).
- A large number of astronomers with important contributions.

- Jabir **ibn Aflah** (Sevilla ≈ 1100-1150) known as **Geber** Hispalensis op. c. in maths:
  - translated by M. ibn Tibbon and G. Cremona;
  - built Giralda minaret and astro. observatory;
  - corrected Ptolemy's (with **Betruji**) and gave the "correct" Mercury and Venus position;
  - inventor of the torquetum device:

takes and converts measurements in three different coordinate sets: the horizontal, equatorial, ecliptic (a kind of analog computer..).



**Giralda/Sevilla**



# Astronomy

- Ibrahim **al-Zarqali** or **Azarquiel** (1027 Toledo–1087 Cordoba):

- corrected **Ptolemy** and **Khwarizmi** data on precise width of the Mediteranian sea;
- modeled sun motion; used by **Copernicus**;
- measured the solar apogee motion/stars;
- launched the work on the **Toledan Tables**;
- conceived and built many instruments like water clock, equatorium, universal astrolab.


Had a huge influence and many followers esp. in al-Andalus:

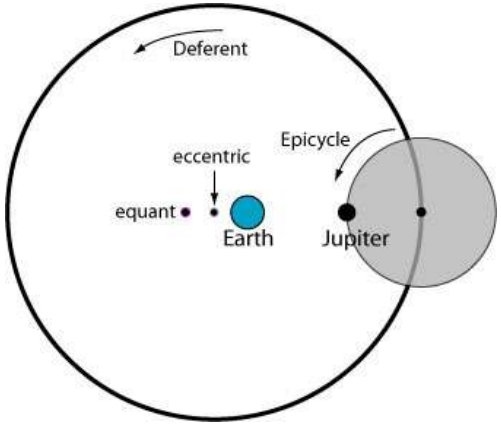
- Said **al-Andalusi** (Almeria 1029-Toledo 1070) also math+history: compiled a biographic scientific encyclopedia; dir. Toledan tables.
- Ahmed **ibn al-Kammad** (born-Sevilla, died-1095?) also astrologer.
- Abdelhak **al-Ishbili** (Sevilla-Bugia) op.c. criticized work of above.
- Ibn Khalaf **al-Muradi** (Toledo?) universal astrolab (Azafea) with **Z**.
- Ibn **al-Raqqam** (1250 Murcia-1315 Granada) lived in Bugia-Tunis:

- cheikh in many fields: maths, astronomy, medicine, jurisprudence;
- astronomical tables suitable for the coordinates of 3 cities (GBT);
- famous/most complete treatise in al-Andalus on sundials/gnomon.

# Astronomy

## Important Andalusi work: motion of celestial body/gravity:

Ptolemy modification for the apparent motion of planets:
it is based on an equant and two different mobile circles:
a big "eccentric/deferent" circle and a small "epicycle"
(replaced and improved later by **al-Tusi** with its couple.)
Model too theoretical and it fails to explain many facts.
The first doubts on it started with **ibn al Haytham** work.
Also questioned by great Andalusi philosophers like
**ibn Tufayl** (Guadix), **ibn al-Arabi** (Murcia), **ibn Rochd** (Cordoba).




- Abu Bakr **ibn Bajja** (1085 Zaragoza-1139 Fès) alias **Avempace**:
  - also in philosophy, medicine, physics, botany, poetry, music;
  - acc. **Maimonides**: solved pb with position of Mercury and Venus;
  - a non-Ptolemaic model based on eccentric without epicycle.
- Nourredine **al-Betruji** (born-Pedroche, died-1204, lived-Sevilla):
  - first to present an alternative non-Ptolemaic astronomical system;
  - possibility of a physical cause to celestial motions (impetus ...);
  - established spiral motion of planets (the man who shook heaven!);
  - theoretical astronomy book translated to Hebrew by ibn Tibbon.

# Astronomy and impact on Geography

Astronomy work significantly impacted Geography. Twos aspects:

- Descriptive geography of countries and populations (way of life, economy, beliefs) and travel books. There were great Andalusis:

- Ahmed **al-Razi** (Cordoba Xc): history+geography of al-Andalus.
- Abdallah **al-Bakri** (Huelva XIc): geography of the known world
- Mohamed **ibn Batuta** (Maghreb, XIVc): the Berber Marco Polo..
- Hassan **al-Wazzan** (Granada 1494-??) Leo Africanus; Leo X's son.

Also books by **ibn Said** (Alacala la Real) and **Al Zuhri** (Granada).

- Cartography: more technical and needs some astronomical tools.

Here also Andalusis had a significant impact, most famous being:

Cherif **al-Idrissi** (Ceuta 1100 – 1166? Sicily) studied in Cordoba:

- traveled in Peninsula, Maghreb and Europe;
- recorded knowledge of merchants/explorers;
- served in the court of king Roger II at Palermo;
- directed the work for the Tabula Rogeriana: the most advanced medieval world maps.

Knowledge as source of Portuguese discovery age (V. de Gama)?

# Physics and Chemistry

Following ancient Greeks, Arabs focused in 2 branches of Physics:

- A first field is optics and besides its military (incendiary devices..) and playful (light shows) sides, the emphasis was on two points:
  - physiological/medical aspects of vision (eye function and diseases);
  - classical optic problems: reflection/refraction/eclipse/rainbow, etc...

  First translated Greek (Euclide/Ptolemy) and Alexandran (Theon...) knowledge (light propagation, mirror properties, binocular vision,..).
- A second field is mechanics with two aspects: statics and dynamics. Again after translating the Greek work (Aristotle/Euclide/Archimede, Heron of Alexandria) they made contributions in two directions:
  - statics: lever (constrc.), balance (trade), center of gravity (navigat.);
  - dynamics: did some theoretical work on gravity and on forces.
- A last field: technical/applied mechanics, aka science of ingenious processes/devices, where al-Andalus had significant contributions: devices for water+agriculture, instruments, clocks and automates.

# Physics and Chemistry

In optics, a revolution was initiated in XIc by Arab scholars:

• Al-Hasan **ibn al-Haytham** (Basra 965-1040 Cairo), alias **Alhazen**:

- pioneer scientific method: physics=math+experiment;
- astronomer/math: gravity,number theory,geometry,...;
- founder of optics: reflection/refraction, 600years ahead;
- theory of vision, role of brain, camera obscura, etc ...;
- UNESCO: 2016 "international Light Year" on his honor.

But work on sunset/sunrise as result of sun passage at 19° under horizon (which fixes the terrestrial atmosphere) was in fact due to:

• Ibn Muadh **al-Jayyani** (989 Cordoba-1079 Jaen) op. c. in maths.

In al-Andalus, little work in theoretical optics (but see later). But:

• Ali **ibn Hazm** (Cordoba 994–1064 Huelva), example of muladi:

- mostly on comparative religion; as a poet, precursor of courtly love;
- rediscovered some of **al-Haytham** work in optics (independently?);
- calculated the speed of sound by echoes in Cordoba Mezquita;
- proposed that thunder was due to the production of lightning (?).

# Physics and Chemistry

Work on mechanics extended Greek knowledge in several ways:

In statics: major work (60 books) on forces acting on levers, various kinds of balances, centers of gravity of e.g. 3 dimensional objects,...
A pioneer (translation + first work) was Thabit **ibn Qura** in HoW;
also work by **al-Haytham**, **al-Razi**, **al-Khayyam** and some Persians:

- Abu Sahl **al-Quhi** (Xc): perfect (with a variable leg) compass,
- Mansur **al-Khazini** (XIc): mass scales and hydrostatic balances,
- Abu Hatim **al-Isfazari** (XI+XIIc): balances with unequal arms.

**al-Haytham**, **al-Quhi** and **al-Khazini** worked on gravity and e.g.:
- idea that gravity of bodies depend on distance from earth center;
-unified the two notions of force, gravity and force related to levers.

Al-Andalus: not much work on statics (lost?) but some on dynamics.
Ex: continuation on idea of the impetus by Jean Philipon (VIc) by **al-Betruji** (op.c.) to give a physical cause to celestial body motion.

Possible impact and help on Galileo for his XVIc breakthrough?

# Physics and Chemistry

Technical/applied mechanics, aka science of ingenious processes $\in$ :
- all automatons for distraction: devices, animals, humanoids,...
- utility mechanics: clocks, irrigation devices, mills, hoists, lamps,...
-military technology: handguns, projectile launchers, siege engines...

Important in Arabic world since **Banou Moussa**, **ibn Hayyan** and :

• **al-Jazari** (XIIc in Anatolia): many inventions+important treatise; described as the "father of robotics" and modern day engineering.

In al-Andalus, important were the devices for water and agriculture (low rainfall, tricky topography, baths, big fields/cities/factories, etc): impressive works for baths, paper+floor mills, irrigation, cisterns,...





Baths/Jaen paper-mill-Xativa Noria-Cordoba qanat-Alpujarra Aljibe-Granada

Some of it, like mills (XIc), entered medieval Europe via the Pyrenees.

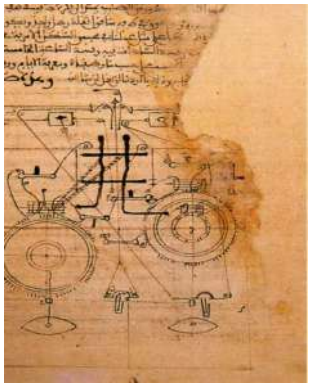
# Physics and Chemistry

About instruments and automates, important Andalusi work.

- Ibrahim **al-Zarqali** (1027 Toledo – 1087 Cordoba) op. c. :

in 1080, he built in Toledo two giant hydraulic clocks on Tajo river.

- Ibn Khalaf **al-Muradi** (Cordoba 989–1079?) "Leonardo islamico":
  - wrote the "book of secrets in results of ideas" (with many devices-31- and news mechanisms);
  - devised a mercury clock: clepsydra with gazelles;
  - clock with 3 persons giving hours with lamps;
  - also devised war machine to demolish fortresses;
  - permanent exposition of work in Doha museum.



- Abbas **ibn Firnas** (Ronda 810–887 Cordoba) another "Leonardo":

  - planetarium with mobile planets/stars/clouds;
  - manufactured colorless glass (reading lenses!);
  - designed a water clock and a metronome;
  - most famous for making first attempts to fly;
  - has a bridge in Cordoba named after him.

# Physics and Chemistry

Chemistry is from kemia (tapa) in Arabic and is more art than science.

It was a very important field in Islam and it had two main aspects:

- science: the analysis of composition of different forms of matter, fabrication of new products by transforming/combining old ones;
- alchemy: metal transmutation to gold and elixir of life to cure ill.

Heritage: Greece (Democrite), Babylon (Hermes), Egypt (Cleopatra!)

Interest in metallurgy, minerals, organic, glass, body products, oil,...

Old tradition; among leading/pioneering figures in Arabic world:

Jabir **ibn Hayyan** (Tous/Iran 721–815 Koufa/Irak):

- father of Arabic chemistry; wrote about 100 treatises;
- discovery of many acids and invention of instruments;
- classified existing elements and guessed nuclear fission?

Abu Bakr **al-Razi** (864–925 Ray/Iran):

- also physician and (anti-religion) philosopher;
- leading contrib. in inorganic/organic chemistry;
- isolated e.g. sulfuric acid and ethyl alcohol.

# Physics and Chemistry

In al-Andalus, at the industrial level, chemistry was intensively used:

- products for: hygiene/beauty/medicine (soap, make-up, perfume), ink, ceramic/textile/glass, precious stones, alcoholic drinks,...)
- military: incendiary devices, explosives, canon/gun powder

(powder first use in Europe was in Sevilla siege–1247; but then it was forgotten!)

Not much in theoretical part (work lost?) with two big exceptions:

Maslama **al-Majriti** (950 Madrid–1007 Cordoba): another polymath:

- astronomer: introduced/improved tables; surveying/triangulation;
- organized Andalusi scientific research via taxation of economy;
- in chemistry: among first to use and experiment Mercury oxide;
- credited to be first to note the principle of conservation of mass;

– had a daughter, Fàtima **de Madrid**, mathematician/astronomer!?

Abu Al-Qasim **al-Zahrawi** (940–1013 Cordoba), alias **Abulcasis**:

- also a physician, considered among fathers of modern surgery;
- pharmacist: pioneer med. preparation by sublimation/distillation;
- invented antecedents of present-day lipsticks and solid deodorants;
- hydraulic (rose water) and alcoholic (aqua vitae, khol) distillation.

# Medecine and life sciences

Medecine was present in early Islam; Mohamed had own physician;
- traditional medicine: herborists, barbers, midwives; basic hygiene;
- learned one: Aramean (Damascus), Persian (Baghdad) communities;
- translated books: India (Sushruta) and Persia (Gundishapur school).
- Also important translated heritage from Greeks:
  Hippocrates (IV BC), Dioscorides (Ic) and Galen (IIc)
  with their important humoral theory for diseases
  (adopted by the Arabs and which lasted until XIXc).

blood
phlegm
yellow bile
black bile


An Arabic medicine has then emerged with big figures/achievements.

- We know **al-Razi** (IXc Iran) who promoted experimental medicine (diagnosis+therapy), initiated hospital organization and Md. training.
But this knowledge culminated with the work of another Persian.

- **Ibn Sina** (980–1037 Iran) alias **Avicenna**:
- described as the father of early modern medicine;
- "Book of healing"+"Canon": medical encyclopedias;
- symptom description of known diseases (psychiatry);
- proposed a therapy/drug to many of these diseases;
- most of all, promoted dietetics and body/air hygiene.

# Medecine and life sciences

Great contributions in al-Andalus; some polymaths also physicians.

- Abu Al-Qasim **al-Zahrawi** (940–1013 Cordoba), alias **Abulcasis**:

- considered among fathers of modern surgery;
- devised surgical instruments still used now for cesarian, cataract; catgut use for stitches;
- identified heredity of haemophilia, root cause of paralysis; described abdominal pregnancy;
- gave importance to doctor-patient relation.

- Abu Marwan **ibn Zohr** (1094–1162 Sevilla) alias **Avenzoar**:

- known for his emphasis on more rational/empiric basis of medicine;
- performed experimental tracheotomy on a goat (first animal testing);
- description of various cancers and other lesions and inflammations.

- **Ibn Rochd** (Cordoba 1126–1198 Marrakesh) or **Averroes**:

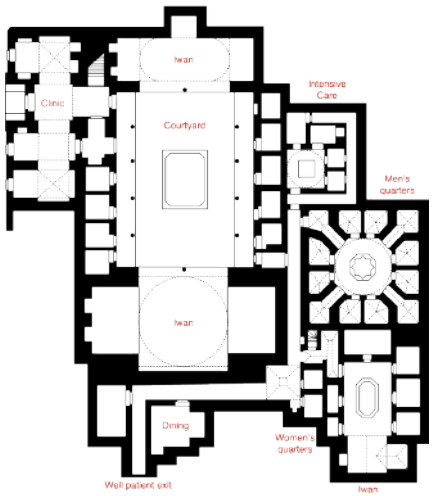
- worked on medicine philosophy; promoted anatomy (no dissection);
- role of artery obstruction in stroke and retina of eye in sensing light;
- first to understand rage and describe signs/symptoms of Parkinson.

**Ibn al-Khatib** (Granada) and **ibn Khatima** (Almeria) in 1348-1349: described plague, guessed contagious infection, started epidemiology.

# Medecine and life sciences

## Important aspect was healthcare and public hospital construction.

The first was leprosarium in Damascus early VIIIc.
First general hospital: Baghdad in 805 (al-Rachid):
- later ran by **al-Razi** and had 25 appointed doctors (surgery, optics, bone-setting, obstetric, psychiatry);
- had free pharmacy, library; used as medical school;
- was public and for the poor; focused on hygiene (had space, light, fresh air, running water, music..)
- many big hospitals in Baghdad and major cities.




## Many important public and general hospitals also in al-Andalus.

- In Xth century, Cordoba alone had 50 hospitals (with some exclusively for wounded/military), involving original work (surgery by **Abulcasis**).
In Granada, important was Albaicin's **Maristan** founded by Mohammed V and **al-Khatib** (1365): general hospital with focus on mental diseases.
It was the first hospital/asylum in Europe.
Was restored recently and became a museum.

# Medecine and life sciences

Important/complementary aspect of medicine is pharmacopoeia.
Starting from Galen+Dioscorides books on plants, Arab physicians, pharmacists, chemists, botanists like op.c. Jabir **ibn Hayyan** (VIIc) enriched pharmacopoeia and included minerals+artificial products.
In al-Andalus, there were a few influential scholars in this field.

- Suleiman **ibn Juljul** (944–994 Cordoba), also a physician:

- wrote various treatises and letters concerning pharmacology;
- added 62 drugs to Greeks (mostly vegetal and coming from India).

- Ali **ibn al-Wafid** (1008-1074 Toledo) vizir of King al-Mamun:

- the book "simple medicines" contains 520 $\neq$ kinds of medicines;
- also a therapy manual and a book on botany and agriculture.

- Diya al-din **ibn al-Baytar** (Malaga 1097-1162 Damascus):

- "compendium on simple medicaments and foods" encyclopedia;
- lists 1400 plants, foods, drugs and their use ($\frac{1}{3}$ unknown to Greeks).

- And finally, again **ibn Zohr** (1094–1162 Sevilla) alias **Avenzoar**:

- "the book of foods" manual with classification of foods/regimen;
- different dishes and foods based on taste, usefulness, digestibility;
- a guidelines for healthy life: one of the first treatises on dietetic.

# Medecine and life sciences

Another important field related to medicine is botany/plant science. After digesting Greeks (Theophrastus), Asians, new work appeared in Xc Irak by **ibn Hayyan, al-Dinawari, ibn Wahshiyya** on botany. Andalusis very active in botany/agriculture; some selected work:

- **Ibn al-Wafid** (XIc-Toledo) op.c., also physician and pharmacist:
  - wrote spread "compendium of agriculture", botanical dictionary;
  - made famous al-Mamun botanic garden in Toledo: among earliest in Europe (with exotic plants and in which he made experiments).
- **Ibn Bassal** Tulaytuli (XIc-Toledo-Sevilla) his student/successor:
  - influential books on agronomy and plants and on fertility of soils;
  - Sultan's botanical garden in Sevilla; introduced cotton in Europe;
  - dixit a Sevillan "**anonymous botanist**" was "the eminent master".
- Moh. **al-Tighnari** al-Gharnati (active in 1075-1118 in Granada):
  - agronomist, botanist, poet, physicist and traveller (e.g. ziri Bugia);
  - "Book of the garden glory and recreation of the minds" in 12 vols.
- **Ibn al-Awwam** al-Ishbili (XIIc-Sevilla) quoted by **ibn Khaldoun**:
  - renowned "book of agriculture", first translated to a EU language;
  - cultivated wine, wild olive, saffron.. and described drip irrigation.

# Medecine and life sciences

Closing panorama with important/related topic: traditional cuisine.
Illustrates/summarizes refinement/splendor of al-Andalus culture.

- Pioneered by **Ziryab** (Mosul 789-857 Cordoba) who came from Baghdad court and introduced:
  - oud/lute and zagal/Flamenco early e-A music;
  - court judge of elegance in fashion/cosmetics;
  - chess game and use of crystal glass in Europe;
  - eastern cuisine with new fruits/vegetables;
  - ordered 3-course meals served on plates...

Continued for centuries with enrichment from Asia+Maghreb; until:

- Ibn Razin **al-Tuyibi** (Murcia 1227-1293?) lived in Bugia and Tunes:
  - "Best of delectable foods and dishes from Andalus and Maghreb";
  - many recipes with various Muslim/Christian/Jewish influences.
- An **anonymous Andalusi** author of XIIIc wrote the very famous
  - "book of cooking in Maghreb and Andalus in the era of Almohads";
  - $\approx$ 1000 recipes for meet, fish, vegetables, rice, pasta, sweets, drinks...

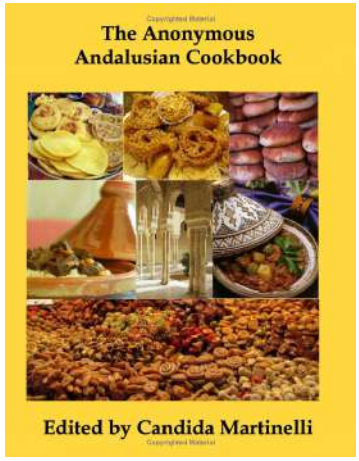
This art entered the rest of Europe and became part of our daily life.

# Medecine and life sciences

## So, let us end the discussion with a recipe of a "dish for kings/vizirs":

**Andalusi Tharid**

**From the XIIIc**




Take fat beef from the chest, hip, shoulder blade, waist, neck, belly and from the fatty sites, cut it up and put it in a big pot with salt, onion, pepper, ginger, coriander seed, cumin and a quantity of oil, cook it over a moderate fire until it is ready; take the meat out of the pot and leave it to one side. Then do the same with a fat sheep, chicken and young pigeons and turtledoves. Take the broths of these specified meats and put them together in a clean pot, after removing the bones and add to it what is needed of strong vinegar, saffron, pepper and of spices and prunes infused with vinegar; cook until it is done and moisten with it a Tharid crumbled from white bread crumbs and leavened se Molina well kneaded and baked and put its meat on top. Arrange the beef in a circle on the dish, the lamb near it, the chickens on top and at the lowest the pigeons and turtledoves. Spot on top of it some fried birds, meatballs and sausages, the ah rash, egg yolks, olives and chopped almonds; sprinkle it with ground pepper and cinnamon; cover with a flat bread and serve it. A dish for kings and vizirs.

# Medecine and life sciences

The meal is to be served with a "bottle" of good Andalusi red wine.
Al-Andalus kept its wine industry during the entire Islamic period;
from **al-Awwam** (Sevilla) and **al-Tighnari** (Granada) agronomists:

- there were about 20 terroirs which produced wine;
- some gave their name to a cépage like the ones from Jaén, Marbella, Almuñecar, Jete, campiã de Cordoba;
- there are at least five grands crus that were known: the Sevilla, Granada, Lorca, Minorca and Malaga ones;
- these wines range from red-brown to golden yellow (while white wines were apparently not known).

It is attested that drinking alcohol was pretty common in al-Andalus in almost all social classes, in particular the elite, at home (including women) but also publicly. So,

one may dream of a **Tharid plate** with friends with a **glass** of **Almuñecar wine**, in the **patio** of an **Albaicin Carmen** facing **the Alhambra**, while listening to an **al-Khatib musical poem**, played on a **oud**, and pondering on the latest **Abdelhak al-Ishbili** work on **spherical trigo**.

# Conclusions

Al-Andalus lived a Golden Age for almost eight centuries.

When part of the Arabic empire and alone after its collapse, it:

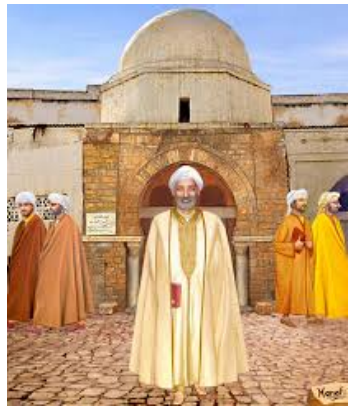
- collected/translated/preserved important knowledge of Antiquity;
- made huge advance in Science and opened many new directions,
- enabled that many of these novelties enter the rest of Europe.

But like many of preceding civilizations, it declined and disappeared, ending with the fall of Granada and expulsion of Jews and Muslims.

Why is this decline? Partition? Reconquista/crusades/invasions? (which led to loss of monopoly on international trade in east/west?) Or rigidity of religion (no dissection, no new technology at end...)?

Or the reason is simply the one **ibn Khaldoun** was advocating in his "Prolegomena" (XIVc) about the birth and the decline of Empires ?

"The goal of civilization is culture and luxury. Once this goal is achieved, civilization spoils and declines, following the example of living beings."



# Conclusions

Fortunately, we are still left with some splendor of this golden age:

We were also left with the rich and diverse intellectual knowledge, technical realizations and ingenious inventions that managed to get to medieval Europe via the Pyrenees or the Mediterranean sea, and ultimately contributed to its Renaissance and scientific revolution.

So, long lived and will live al-Andalus !