The age of ENLIGHTENMENT

Collected and edited by Prof. Zvi Kam,
Weizmann Institute, Israel

Age of Enlightenment, the 18th century

The "scientific revolution" that was centered on physics and astronomy at the 17th century, expands, mainly to Chemistry and Biology. Science research is based on "enlightened" rationalism, not on murky beliefs. Elitist science by clergymen (in Latin) becomes popularized and secularized by National Science Societies with publications and conferences in the country's languages.

Logics in Mathematics is extended to law and religion. Freedom of thought lead to the French Revolution and the American Constitution and augurs Socialism and Capitalism as economical system options. Philosophy and politics intermingles: Bacon, Descartes, Spinoza and Hobbs brought forwards human rights. 17th century presents Montesquieu, Voltaire, Diderot, Rousseau (Romanticism) Emanuel Kant (Skepticism) John Locke and Adam Smith (human rights; women's rights start to be discussed, and free market in economy).

Basic science is employed in technological applications: The steam Engine and trains, a direct extension of thermodynamics. They bread the Industrial Revolution. But also help build better scientific instruments: telescopes, microscopes, barometers, batteries, electrical generators, air pumps and surgical tools.

Technology help science advancement and vice versa

Discovery convoys to explore the world and its life and plants in far lands become national missions (for scientific prestige as well as imperialistic ambitions): from Captain Cook (Australia & Tahiti 1768) till Darwin (Galapagos 1831).

Lorentz explain tides and their relation to resonance. Measurements in space and on earth extend from microns to million of kilometers.

1770-1830 is called "The magic era": scientists and artists collaborated to advance humanity, some through vicious wars: Napoleon 1769-1821 & US independence 1776.

MATHEMATICS

Although the list of enlightenment mathematicians is not inferior to previous century lists, the 18th century did not host creations of new fields (such as calculus and theory of functions at the 17th century), but used the existing mathematics in order to carry deeper studies and understand new tools.

Maybe the most important application of differential equations was to describe the behavior of liquids and characterize the functions solving these equations. The solutions defined conservation laws of energy, momentum and the continuum of material, which were previously defined only for discrete balls. They prepared the mathematical basis for electromagnetic field theory at the 19th century, and the mathematics of quantum mechanics and general relativity at the 20th century. The equations describing electromagnetic fields around moving charges and magnets, as well as the equations describing quantum electron wave functions are tightly supported by the 18th century differential equations developments.

Thomas Bayes 1702-1761
Leonhard Euler 1707-1783
Jean (Johann) le Rond d'Lambert 1717-1783
Joseph Louis Lagrange 1736-1813
Gaspard Monge Comte de Péluse 1746–1818
Pierre-Simon Laplace 1749-1827
Adrien-Marie Legendre 1752-1833
Karl Fridrich Gauss 1777-1855

The 19th century

Bernard Bolzano 1781-1848 … epsilon-delta
Augustin Louis de Cauchy 1789-1857

Leonhard Euler 1707-1783 Switzerland

Calculus, Graph theory, Number theory …
Euler's Polygon law, Euler's formula, Euler's identity, Eulerian path, , Euler's equation
, Euler's criterion, , Euler's line, , Euler's conjecture, , Euler's circles, , Euler's polynomial,
, Euler's function, , Euler's angle, , Euler's reflection formula, , Euler's group,
Goldbach-Euler's theory.

Euler was a Swiss mathematician and physicist, who spent his later years in St. Petersburg and Berlin. Euler was considered the greatest mathematician of all times, and certainly was the most productive. Euler studied with Hans Bernoulli, who promoted his position in Berlin. Euler became blind but his phenomenal memory well compensated for his blindness.

Among his contributions: mathematical analysis, establishing the concept of functions, and used them to convert analytical expressions into differential geometry of curves and surfaces. Euler, with Monge and Gauuss, are the fathers of differential geometry.

1750 Defining a position requires three distances from three orthogonal planes.

Euler's contributions (cont):

* The sign "i" for complex numbers: $e^{i\phi} = \cos\phi + i \sin\phi$

and the amazing **Euler identity**: $e^{i\pi}+1=0$

The equation was written independently also by **de-Moivre**

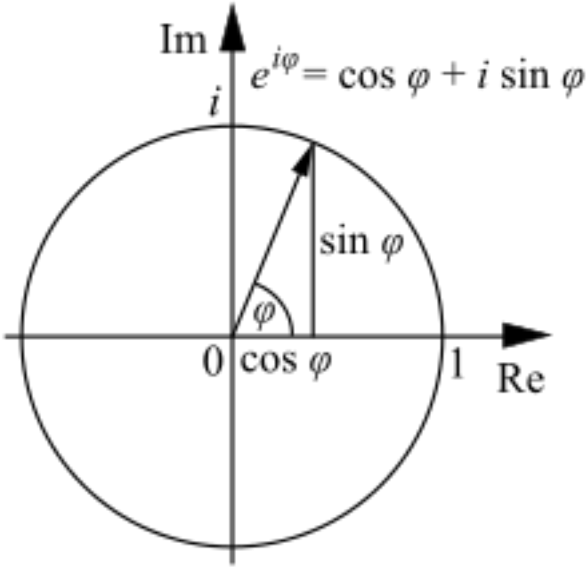
It contains the important mathematical constants: 0,1,i,π,e the last two are irrational, and i is complex, yet all combined yield this simple identity…

* The signs e, π **Σ** (for a sum)

* Taylor series to compute sin, cos, tan, log and other infinite series:

$$e^x = \sum_{n=0}^{\infty} \frac{x^n}{n!} = \lim_{n\to\infty} \left(\frac{1}{0!} + \frac{x}{1!} + \frac{x^2}{2!} + \cdots + \frac{x^n}{n!}\right).$$

$$\sum_{n=1}^{\infty} \frac{1}{n^2} = \lim_{n\to\infty} \left(\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \cdots + \frac{1}{n^2}\right) = \frac{\pi^2}{6}.$$



Euler's contributions (cont):

- Euler-Lagrange equation in calculation of variations of the functional L, yielding a stationary solution in time t.

$$\frac{\partial L}{\partial q_i}(t, \boldsymbol{q}(t), \boldsymbol{q}'(t)) - \frac{\mathrm{d}}{\mathrm{d}t}\frac{\partial L}{\partial \dot{q}_i}(t, \boldsymbol{q}(t), \boldsymbol{q}'(t)) = 0 \quad \text{for } i = 1, \ldots, n.$$

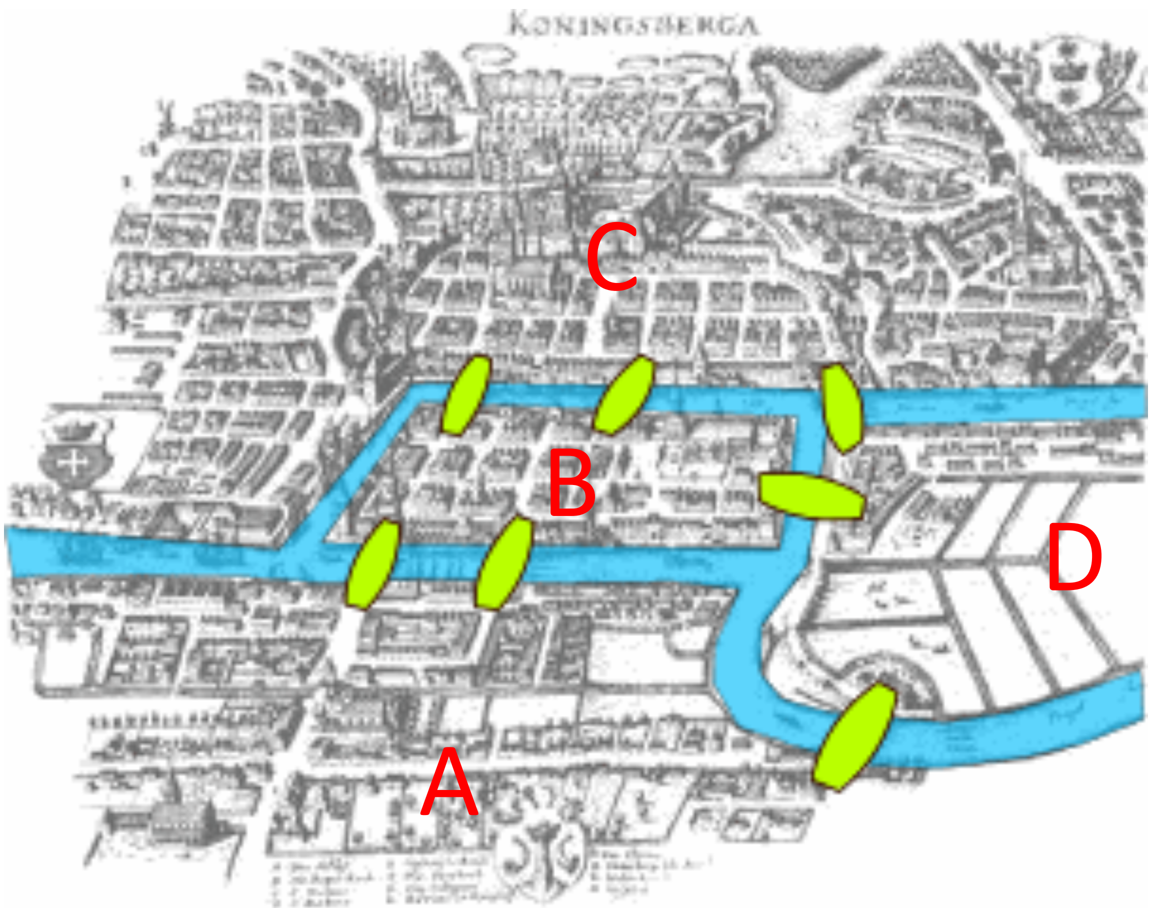
The equation is important for Hamiltonian Mechanics with generalized coordinates.

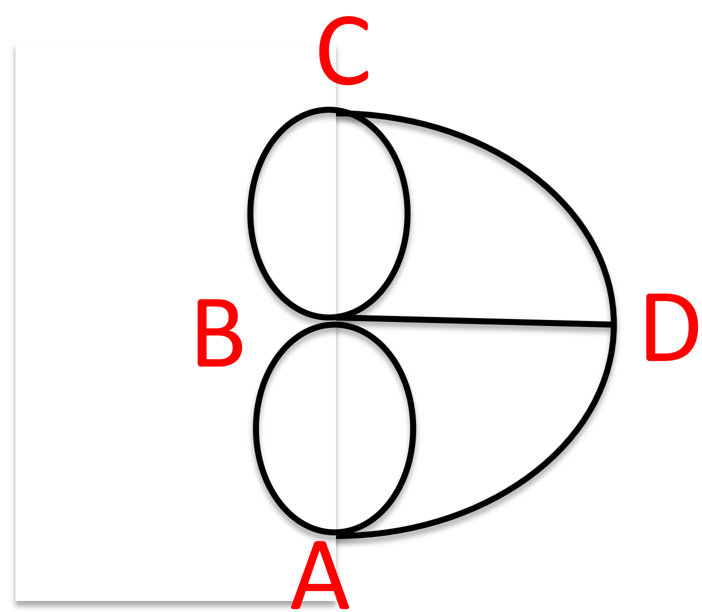
- New functions and properties of old ones: Gamma, Riman's Zeta relation to prime numbers, properties of Bessel function.
- New field of analytical number theory, and properties of primes.
- **1736** Solved the problem of the 7 bridges of Konigsberg, the first law in Graph theory, (see next slide).
- Mathematics of music: formulations are too complex for musicians…
- Contributed to Group theory and Logics.
- Euler equation for liquid dynamics

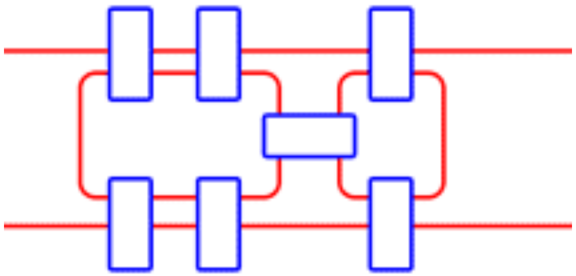
PROPERTIES OF GRAPHS

Present applications: communication networks.

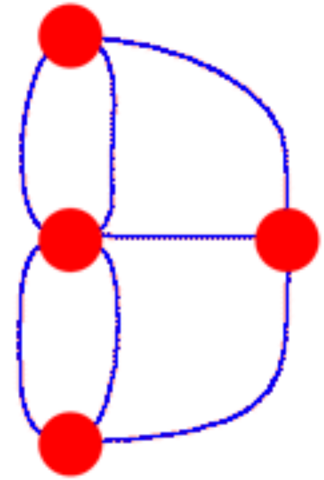
1786 Is it possible to visit all regions of the Konigsbers without crossing any of the bridges twice? Euler transformed the problem into a graph:





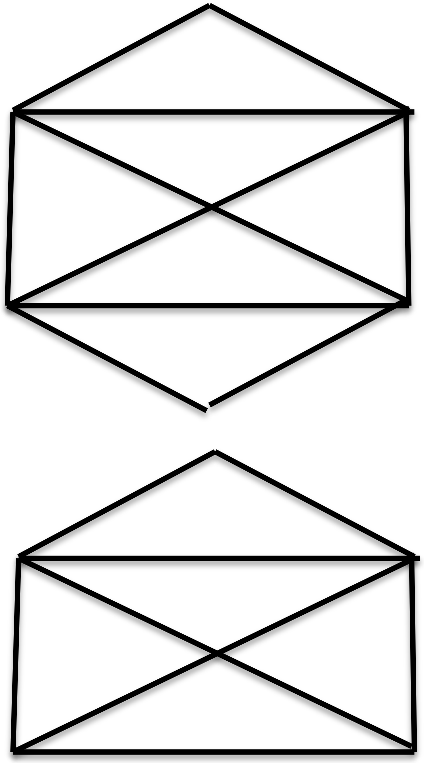


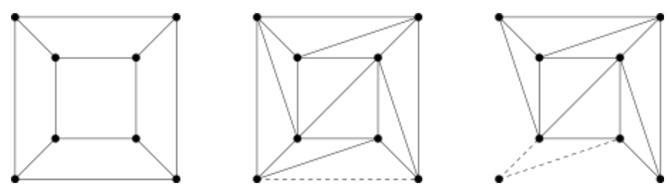
Konigsberg map
with river and bridges

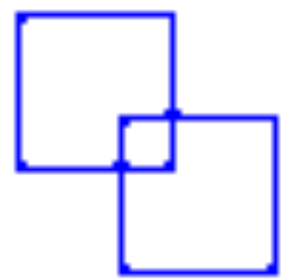


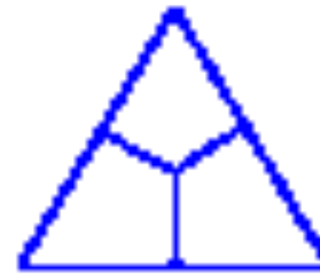
The graph that Euler generated
Red doted vertices: the city regions,
Connecting arcs: The bridges

The solution: One can draw the graph without lifting the pen if zero or two vertices connect to odd number of arcs, and these are the vertices to start and end the drawing.
The proof: From all other vertices with even arcs we can enter and exit (maybe more than once to different arcs). If we start and end at the same vertex all vertices must be even. If we start at one vertex and end at another, they must be the only odd vertices, and all other vertices must be even.









<u>Euler characteristic</u>= # vertices – # arcs (edges) + # faces

<u>For planar connected graph $\chi = 2$</u>: proof by induction, successive deletions:

Delete a triangle with external edge (two vertices left):

edges-1, face-1

$$\chi = V - E + F$$

Delete a triangle with external vertex and its two edges:

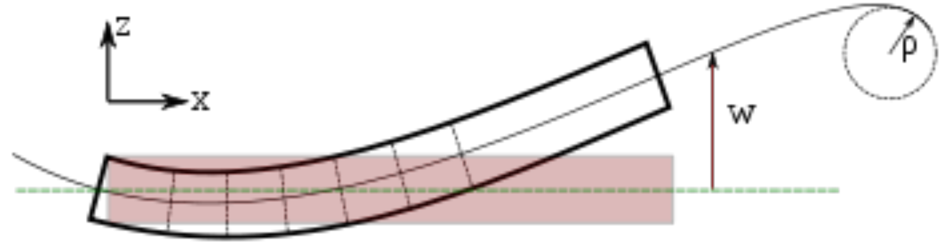
vertex-1 edges-2 faces-1

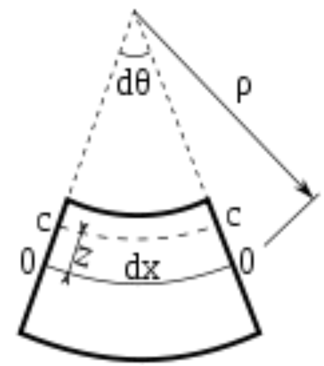
For three-dimensional polyhedron χ <u>depends on topology alone</u>. For convex polyhedrons (as well as for a <u>sphere</u>) $\chi = 2$.

For non-convex polyhedrons it may accept any value. e.g. for a <u>torus</u> $\chi = 0$.

Practical contributions:

Euler-Bernoulli bending beam, a milestone in building engineering:





Tables for longitude positioning for marine navigation.
Precise positioning of comets.

1746 Rejecting Newton's light particles theory, Euler develops the wave theory of light, refraction and color dispersion.
1753 Euler reduces the three-body problem (Sun, Earth & Moon) to a series of elegant equations.
1759 Solves the modes of vibration of a square membrane (drum).
1764 Modes of vibration of circular membrane using Bessel functions.
1761 Euler describes aether with pores filled by magnetic stones, with channels between them establishing magnetic interaction throughout the volume of the magnet.

Abraham de Moivre 1667–1754 French

1718 Father of probability theory. Wrote “The Doctrine of Changes”: Change cannot be predicted, only probabilities can be calculated.

de-Moivre’s equation. Also written by Euler.

$$(\cos x + i \sin x)^n = \cos(nx) + i \sin(nx)$$

Alexandre-Théophile Vandermonde 1735–1796 French

Vandermonde determinant:

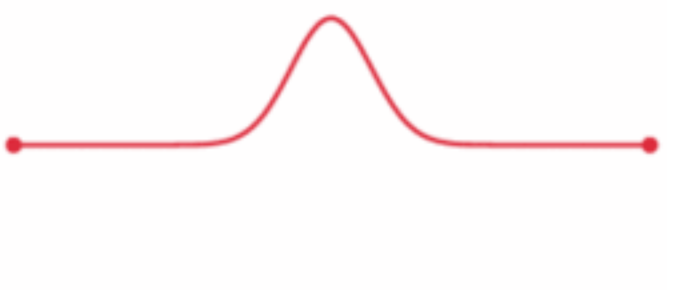
$$V = \begin{bmatrix} 1 & \alpha_1 & \alpha_1^2 & \dots & \alpha_1^{n-1} \\ 1 & \alpha_2 & \alpha_2^2 & \dots & \alpha_2^{n-1} \\ 1 & \alpha_3 & \alpha_3^2 & \dots & \alpha_3^{n-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & \alpha_m & \alpha_m^2 & \dots & \alpha_m^{n-1} \end{bmatrix} \qquad \det(V) = \prod_{1 \le i < j \le n} (\alpha_j - \alpha_i).$$

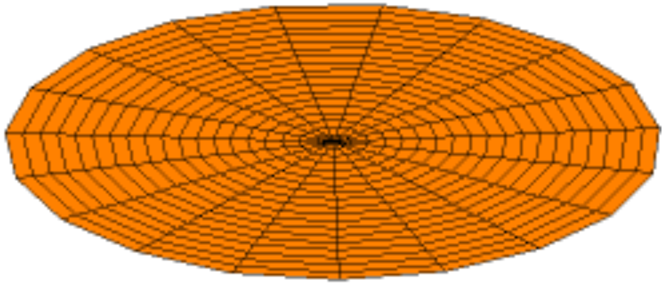
Used for calculating n-th order polynomial coefficients from its n+1 values.

Jean-Baptiste le Rond d'Alembert 1717–1783 French
d'Lambert's paradox,

d'Lambert's equation defines vibrations of strings and 2D membranes.

$$\frac{\partial^2 u}{\partial t^2} = c^2 \nabla^2 u$$





1754 Defines "infinitesimal". Existence criterion for the limit of a series: d'Lambert's ratio

D'Alembert's principle in physics
Extends static equilibrium to dynamic (steady state) equilibrium.
The significance of analytical mechanics is not only the practical method of solving mechanical problems, but the establishing of the mathematical framework for the electromagnetic theory, and later quantum mechanics.

Jean Baptiste Joseph, chevalier Delambre 1749–1822
French

Was appointed by Napoleon as the secretary of the French Academy of Sciences, and was the director of the astronomical observatory in Paris

Johann Heinrich Lambert (1728-1777) Switzerland

Theory of Numbers, Hyperbolic Functions.
Lambert’s W-function: the inverse function of of $f(W) = We^W$
W is a complex variable. This inverse, W-function has many branches.

1770 Lambert proves that p is not a rational number.

Jean-Baptiste Joseph Fourier 1768-1830

Solved engineering problems for Napoleon.
1789 A new proof for Descartes' rule of signs:
the number of positive real zeroes in a polynomial function f(x) is the same or less than by an even numbers as the number of changes in the sign of the coefficients.

1807 Fourier best known development of Fourier expansion for a periodic function, in terms of a series of sine and cosine functions. He defined Amplitude and phase for waves.
1811 solved heat conductance using Fourier series.
1822 added time dependence and boundary conditions to heat conductance equations, and solved partial differential equations..

From estimation of the sun energy radiating on earth, and loss of heat he predicted the greenhouse effect.

Pierre-Simon, marquis de Laplace 1749–1827 French

1806-7 Describes the air-fluid interface in a capillary, forming a meniscus with radius of curvature due to surface tension, the attraction between the liquid molecules perpendicular to the interface. No surface tension tangential to the interface.

Young-Laplace equation:

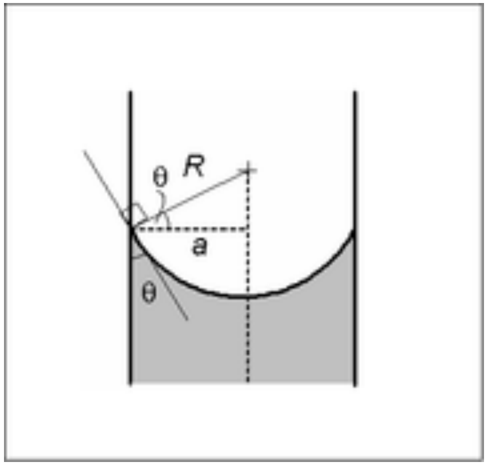
$\Delta p = K + H/2\ (1/R + 1/R')$

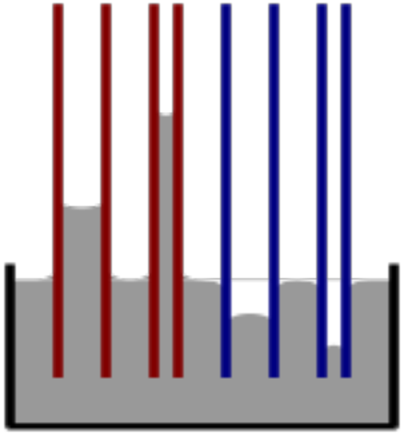
Δp – pressure jump across the meniscus.

K – air pressure

R' & R Radii of curvature of the interface at two orthogonal directions.

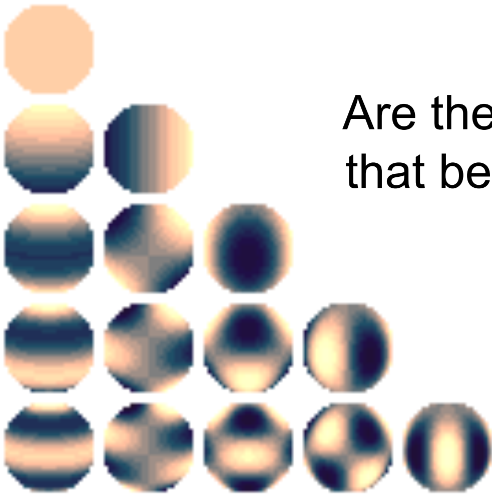
H- Surface tension, a constant for all capillaries.





Laplacian – the most important equation in electrostatic potential theory:

$$\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0.$$



SPHERICAL HARMONICS

Are the solutions of Laplace equation in a sphere,
that became the solution of the quantum electron wave of the atom.

Laplace demon:

If we knew the physical states of all particles in our world, Laplace's demon (which he called "intellect") could calculate the future for any required time.

Laplace transform, Laplacian, Laplace equation, Laplace continuum rule
Laplace random variate, Laplace distribution

1774 Laplace gave a mathematical foundation to probability theory: Statistical prediction, causality, error estimation, degree of certainly estimates, and experimental evidence.

Marc-Antoine Parseval 1755–1836 French mathematician

Parseval's theorem:

The Fourier expansion of a function: $A(x) = \sum_{n=-\infty}^{\infty} a_n e^{inx}$

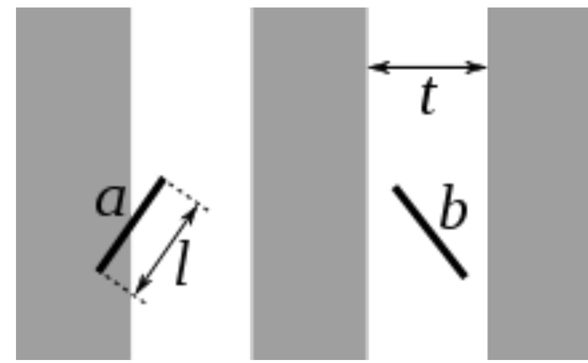
is unique.

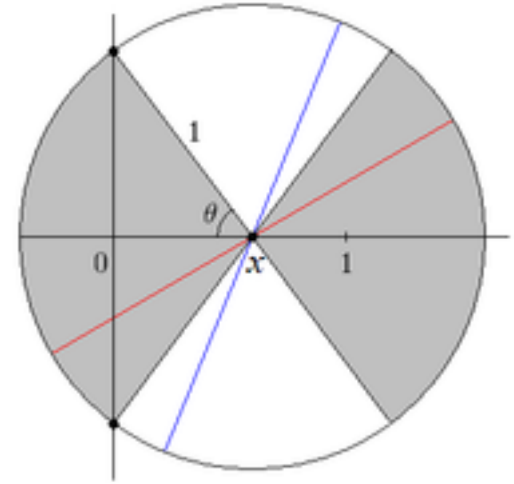
Georges-Louis Leclerc, Comte de Buffon 1707-1788 France

Buffon’s needle: The probability, P that a needle with length=l thrown over strips with width=t will cross the strip borders is (for l<t/2)

$$P=\int_{\theta=0}^{\frac{\pi}{2}}\int_{x=0}^{(l/2)\sin\theta}\frac{4}{t\pi}\,dx\,d\theta=\frac{2l}{t\pi}.$$

This offers an experimental method to find π





Biology:
Leclerc had a strong influence on Lamarc’s theory of evolution .

Thomas Bayes 1702-1761 England

1763 In a paper about probability theory he shows that the probability for an event to happen is independent on previous events.

Bayes equation in probability

$$P(A|B) = \frac{P(B|A)\,P(A)}{P(B)},$$

P(A|B) = The probability for event B given A is right
P(A), P(B) = Independent probabilities for events A and B to happen.

Example I: the probability to get cancer is 0.05=5%
The probability to be a smoker is 0.1=10%
Cancers that are also smoking =0.2=20%=P(smoker | cancer)
P(cancer | smoke)=P(smoker | cancer)*P(cancer))/P(smoker)=(0.20*0.05)/(0.10)=10%
Thus the probability of smokers to get cancer is twice the general population.

Example II: Machines 1,2,3 produce 20,30,50% of the product with 2,3,5% defects.
What is the probability for a defective product to be produced by machine 3:

$P(A_1)=0.2$ $P(A_2)=0.3$ $P(A_3)=0.5$

$P(B \mid A_1)=0.05$ $P(B \mid A_2)=0.03$ $P(B \mid A_3)=0.01$

Total defected products:

$P(B) = \Sigma_i P(B \mid Ai)\, P(A_i) = (0.05)(0.2) + (0.03)(0.3) + (0.01)(0.5) = 0.024$

The probability that it was produced by machine 3

$P(A_3 \mid B) = P(B \mid A_3)\, P(A_3)/P(B) = (0.01)(0.50)/(0.024) = 5/24$

Christian Goldbach 1690-1764 Germany

Numbers theory.

Goldbach conjecture – every number > 2 can be written as a sum of two primes. Was not proved till today.

Goldbach-Euler theorem:

The infinite sum on 1/(p-1) p is an integer power $p=n^m$ omitting 1 and repetitions, converge to 1:

$$\sum_{p}^{\infty} \frac{1}{p-1} = \frac{1}{3} + \frac{1}{7} + \frac{1}{8} + \frac{1}{15} + \frac{1}{24} + \frac{1}{26} + \frac{1}{31} + \cdots = 1.$$

Daniel Bernoulli 1700-1782 Switzerland

Probabilities, Calculus.
Bernoulli's principle: increase in the speed of a fluid cause a decrease in static pressure.
1734 Solution for bending beam anchored at one side.

Jakob Bernoulli 1654-1705 Basel, Switzerland

1713 The simplest case of the law of large numbers:
In repetitious binary experiment (e.g. coin tossing), a large fraction of the success results gather around a small region of the probability of success. Or: mean of a finite number of experiments gets closer to the average for "infinite" number of experiments.

Eduard Waring 1736-1798 England

Waring's prime numbers conjecture: Every odd integer n is a prime or the sum of three primes.

Waring's problem: whether each natural number k has an associated positive integer s such that every natural number is the sum of at most s natural numbers to the power of k. For example, every natural number is the sum of at most 4 squares, 9 cubes, or 19 fourth powers.

John Wilson 1741-1793 England

Wilson's theorem: if p is prime then 1 + (p - 1)! is divisible by p.

Sofi Germain 1776-1831 France

A mathematician who studies problems in number theory and in elasticity.

Brook Taylor 1685-1731 England

Mathematical analysis.
Taylor-MacLaurin expansion of a function by its derivatives:

$$f(a)+\frac{f'(a)}{1!}(x-a)+\frac{f''(a)}{2!}(x-a)^2+\frac{f'''(a)}{3!}(x-a)^3+\cdots,$$

Adrian Murray (-Marie) Legendre (1752-1833) France

Analytical mechanics. Number theory.

Legendre's conjecture: There is a prime number between n^2 and $(n + 1)^2$ for every positive integer n. This was not proved, nor disproved till today.

Legendre's constant, B=1.08366…:

$$\lim_{n\to\infty}\left(\ln(n)-\frac{n}{\pi(n)}\right)=B$$

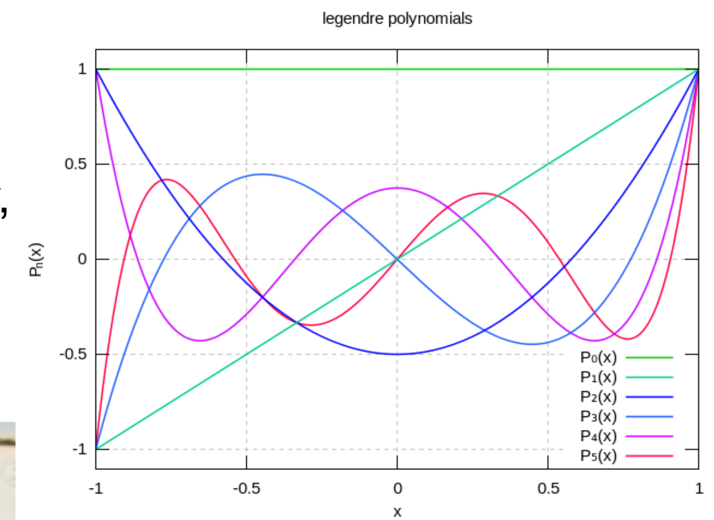
where $\pi(n)$ =number of primes < n.

Legendre's equation,

$$\frac{d}{dx}\left[(1-x^2)\frac{dP_n(x)}{dx}\right]+n(n+1)P_n(x)=0.$$

Solution: Legendre Polynomials defined [-1,1]:

Later applied in quantum mechanics.



Law of quadratic residues: proved by Gauss.

1785 Legendre asks if every arithmetical progression (a, a+d, a+2d …) with a and d having no common factor, contains an infinite number of prime numbers.

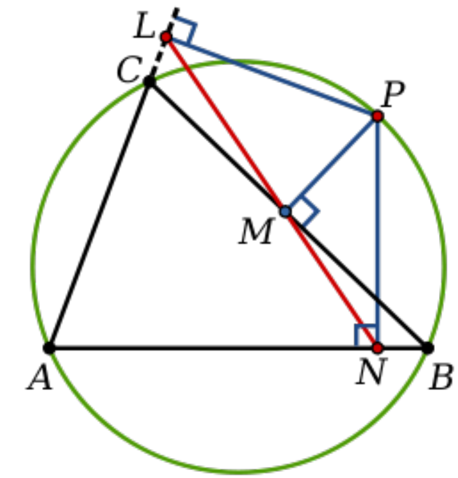
This was proved by **Dirichlet**.

This cartoon was mistakenly assigned to Legendre…

Robert Simson 1687-1768 Scotland

Geometry.

Simpson's line: given a triangle ABC and a point P on its circumcircle, the three closest points to P on lines AB, AC, and BC are on one line: the Simson line



Thomas Simpson 1710-1761 England

Calculus. Simpson's interpolation for integration:

$$\int_a^b f(x)\,dx \approx \frac{\Delta x}{3}\left(f(x_0)+4f(x_1)+2f(x_2)+4f(x_3)+2f(x_4)+\cdots+4f(x_{n-1})+f(x_n)\right)$$

,

where $\Delta x = \dfrac{b-a}{n}$ and $x_i = a + i\Delta x$.

John Landen 1719-1790

1775 'Landen's theorem' – the length of every hyperbolic arc can be approximated by two elliptic arcs. Important for elliptic integrals.

Augustin Louis de Cauchy 1789-1857

See 19th century

Bernard Bolzano 1781-1848

See 19th century

Charles Babbage 1791-1871

Inventor of the mechanical calculating machine.

See 19th century

Gabriel Cramer 1704-1762 Switzerland

Linear Algebra.
Cramer theorem: n-th order curve is uniquely determined by n(n+3)/2 values on it.

1728 Proposed a solution to St. Petersburg Lotto paradox (the solution is similar to Bernoulli’s)
See next slide.

The St. Petersburg Gambling Casino paradox

Stated by **Nicola Bernoulli**, and solved by **Cramer** 1728 and independently by **Daniel Bernoulli** 1738 (who, as mentioned, accepted a position at the Russian Tsar at St. Petersburg): A casino offers a fare game: Two bills are put on the table, by you and by the casino, and a coin is tossed. Each time it falls on "head" you double the number of bills. If the coin falls on "tail" the game is over and you take all the bills on the table. What is a fair sum the casino should ask for a gambler to enter the game?
The chance is ½ to gain 2 bills, 1q4 to gain 4 bills, etc.:

$$E = \frac{1}{2}\cdot 2 + \frac{1}{4}\cdot 4 + \frac{1}{8}\cdot 8 + \frac{1}{16}\cdot 16 + \cdots \quad = 1+1+1+\ldots \quad = \infty .$$

Therefore it is worth paying against the casino with any initial sum they require, since if we continue playing long enough we gain back all the bills we put down on the table. Where is the paradox ? We need to assume our wealth is limited, or at least smaller than the casino's. If the casino asks to put initially on the table a sum c, and our wealth is ω we can define a money usability function E that weights the decline in our remaining wealth so we can continue gambling until we win, only then the change to win is finite. For example, for logarithmic decline:

$$\Delta E(U) = \sum_{k=1}^{\infty} \frac{1}{2^k}\left[\ln(w + 2^k - c) - \ln(w)\right] < \infty .$$

A millionaire can put down 20.88 bills per game to win, and if one has 1000 bills it is worth putting down 10.95 bills. **Kahneman and Tversky** claim that gamblers weight too high the change of improbable events of winning, and the paradox takes over, unless the casino's finite wealth, W enter in.

Cramer (cont.)

Cramer formula: explicit formula to solve n linear equations with n unknowns : $\Sigma_j A_{ij} x_j = b_i$

In matrix notation Ax=b : A: nxn matrix with nonzero determinant.

b: n-vector $b = (b_1, \ldots , b_n)^T$

x: n-vector of unknowns: $x = (x_1, \ldots, x_n)^T$

The solution: $$x_i = \frac{\det(A_i)}{\det(A)} \qquad i = 1, \ldots, n$$

A_i the matrix A with column I replaced by b vector: $b = (b_1, \ldots , b_n)^T$

Example:

$3x_1+5x_2-6x_3=9$

$7x_1-2x_2+4x_3=1$

$8x_1+3x_2-9x_3=5$

$$b=\begin{vmatrix} 9 \\ 1 \\ 5 \end{vmatrix}$$

The solution:

$$A=\begin{vmatrix} 3 & 5 & -6 \\ 7 & -2 & 4 \\ 8 & 3 & -9 \end{vmatrix} \quad A_1=\begin{vmatrix} 9 & 5 & -6 \\ 1 & -2 & 4 \\ 5 & 3 & -9 \end{vmatrix} \quad A_2=\begin{vmatrix} 3 & 9 & -6 \\ 7 & 1 & 4 \\ 8 & 5 & -9 \end{vmatrix} \quad A_3=\begin{vmatrix} 3 & 5 & 9 \\ 7 & -2 & 1 \\ 8 & 3 & 5 \end{vmatrix}$$

Det(A) = 3*(-2)*(-9) + 5*4*8 + 7*3*(-6) – (-6)*(-2)*8 - 5*7*(-9) - 4*3*3 =

= 54+160-126-96+315-36 = 271

x_1=(162-18+100-60-108+45)/271 = 121/271

x_2=(-27-210+288+48-60+567)/271 = 606/271

x_3=(-30+40+189+144-175-9)/271 = 159/271

James Sterling 1692-1770

A Scottish mathematician interested in combinatorics, and known for his approximation to n-factorial:
Newton–Sterling interpolation formula

$$\ln(n!) = n\ln(n) - n + O(\ln(n))$$

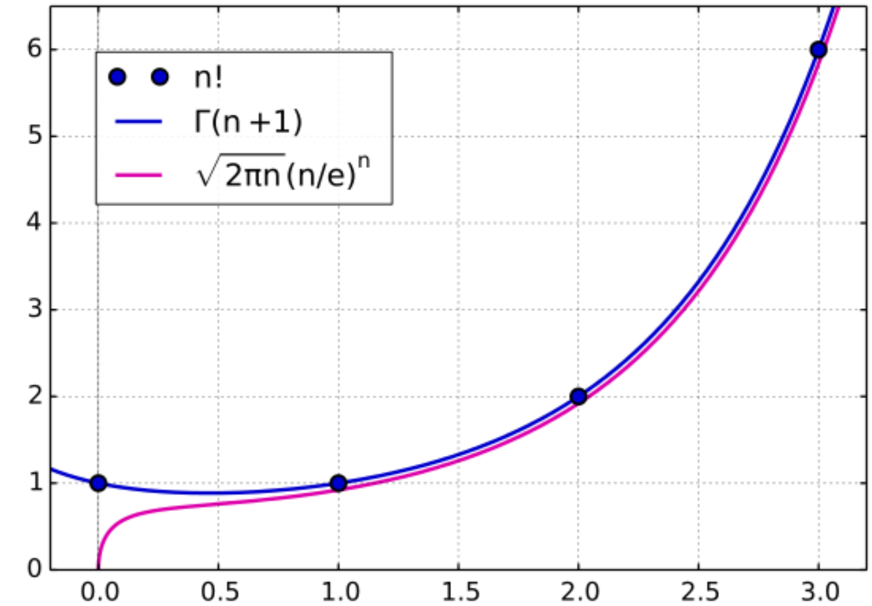
$$n! \sim \sqrt{2\pi n}\left(\frac{n}{e}\right)^n$$

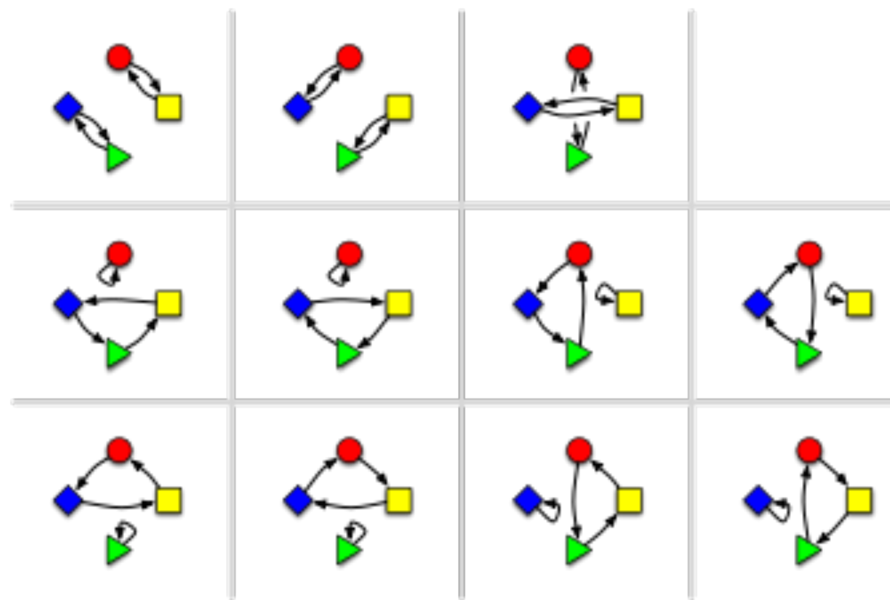
<u>1st order Sterling numbers</u>:
N over k: $({}^{n}{}_{m})$=n!/k!(n-k)!
Is the number of permutations of a group of <u>k elements</u> chosen from n elements.
<u>2nd order Sterling numbers</u>:

$$\left\{ {n \atop k} \right\} = \frac{1}{k!}\sum_{j=0}^{k}(-1)^{k-j}\binom{k}{j}j^n.$$

Is the number of ways to chose <u>ordered k elements</u> from a group of n elements.

Gamma function $\Gamma(z)$ equals n! for integer z





Karl Friedrich Gauss 1777-1855 Germany

A mathematician and physicist, considered the greatest German mathematician.

Gauss-Locas formula, Gauss lemma, Gauss law, Gauss-Jordan matrix inversion, Gaussian, Gauss constant, Gaussian integral, Gauss plan, Gauss integers group

1796 Discovers how to build a heptagon (7-edges) Using only a compass and a ruler. The only Invention in Geometry since Euler.

Gauss also studied non-Euclidian geometry, and defined Gauss curvature (see Geometry)

Gauss did not leave Gottingen, where he studies, taught and worked, other than one travel to Berlin at the Invitation of **Friedrich Wilhelm Heinrich Alexander von Humboldt** who admired Gauss.

Gauss on the Deutsche bill of 10 Marks

.

Gottfried Wilhelm (von) Leibniz 1646-1716 Germany

1714 Mathematics unifies different concepts of the universe.

1715-6 Exchanges letters with **Samuel Clarke** and criticizes the philosophy and theoretical conclusions of **Newton:** Space and time are relative, and have no real existence.

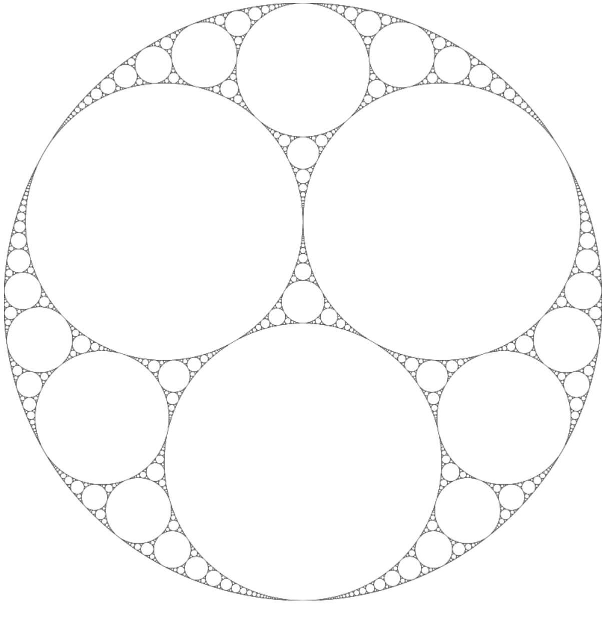
1714 The British parliament establishes an office to decide about methods of localization at sea. Two methods were considered: Tabulate moon coordinates relative to stars, and use of chronometer.

Newton accuses Leibniz of copying calculus from him. It is clear they developed calculus independently, and invented different nomenclatures. Today we use Leibniz' not Newton's.

Leibniz developed mechanical calculators, and binary presentation of numbers.

Leibnitz packing circles diagram: an early example of fractals.

After working at many places, Leibnitz settled in Hannover.



Today we can enjoy the butter biscuits from Hannover that carry Leibniz name…

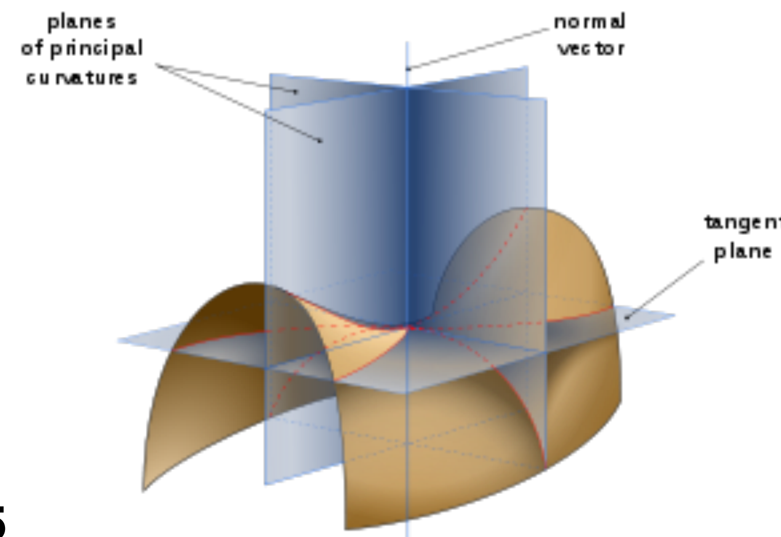
GEOMETRY

Gaspard Monge 1746-1818

Theoretical Geometry, differential Geometry.

Defined curvatures of three-dimensional surfaces.

Monge was the minister of the navy during the French revolution.
He joined Napoleon's delegation to Egypt,
And was buried at the Pantheon.
A square at the 5th quarter in Paris carries his name:
(place Monge, quartier Latin).



Carl Friedrich Gauss 1777-1855

Non-Euclid geometry, developed independently by **Janos Bolyai (1833)** and **Nikolai Lobachevsky (1829),**
defined Gauss curvature: the product of the curvatures of a surface at two perpendicular orientations.

Leonhard Euler 1707-1783 Switzerland

Differential geometry.

PHYSICS

1737 only 50 years after the publication of "Principia" Newton's mechanics become widely accepted. Translation and distribution by **François Marie Arouet de Voltaire** turns it popular in France.

Ernst Mach The world is infinite, and unified by the basic laws of nature. Astronomy and physics are one: same laws for the moon and apples. Harmony, integrity, causality are irrelevant. Order in nature emerges only from physical laws, and disorder from humans greed and pleasure according to **Diderot.**

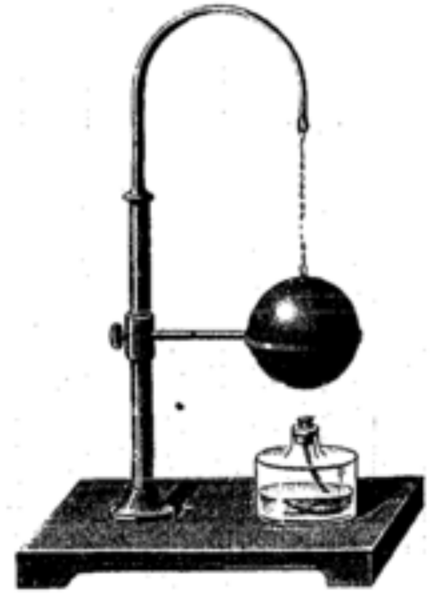
This are the seeds of the urge to "return to nature", the motto of the Romantic Age of the 19th century in arts and sciences.

Wilhelm Jacob 's Gravesande 1688–1742

A professor at Leiden, Holland, who disseminated Newton's mechanic theory. Publishes in Leiden: “Physics elementa mathematica, experimentis confirmata, sive introductio ad philosophiam Newtonianam”, an introduction to Newtonian physics.

Devised a classroom demonstration of thermal expansion: The cold ball freely moves through the ring, but when heated by the alcohol lamp get stuck, and cannot pass through the ring.

1720 the first Physics journal.



GASES

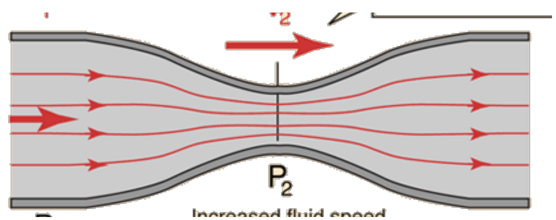
Daniel Bernoulli 1700-1782 (Switzerland)

A manuscript formulating "the kinetic theory of gases" based on a model of billiard balls.

Gas molecules move at speed depending on temperature, so that square of the speed is proportional to the temperature – therefore conservation of energy. The molecules impinging on the gas walls explain pressure proportional to square of speed, and derive Boyle-Marriot law.

The manuscript was forgotten till 1859, when the kinetic theory of gasses was commonly accepted.

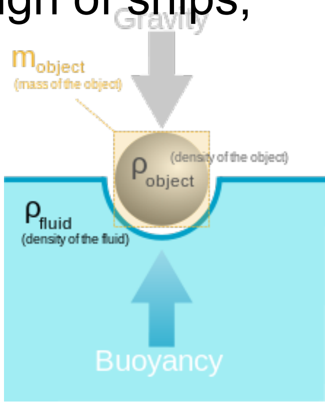
Bernoulli's principle: pressure of flowing gas (or liquid) decreases at faster flow rates. Demonstrated by flow in a narrowing pipe:



LIQUIDS

FLUID MECHANICS - historical landmarks

intuitive understanding of liquid properties is demonstrated by the design of ships, irrigation systems and aqueducts,



287-212 BC Archimedes expresses the laws of floatation. Liquid pressure Is uniformly creating forces at all directions.

Archimedes screw – the first water pump.

120 BC in Ptolemy’s Alexandria: siphons and compression pump with valves developed by **Hero and Ctesibius**. in Egypt water drawing from the Nile was commonly performed by wheels of buckets, and valves Were added to the bucket to facilitate their dipping into the water.

40-103 BC Sextus Julius Frontinus Roman senator, designed the water supply system for the city. Understood that water flow rate depends on pore size as well as the water pressure (or the pore depth below the water level).

973–1048 AC Al-Khazini 1115–1130 Abu Rayhan Biruni

Experimental methods to study liquids. Biruni describes the different densities of salt and sweet water, and of cold and hot water

9th century Banū Mūsā brothers 1206 Al-Jazari

Inventions note books contain designs for hydraulic systems with feedback loops, water pumps with two linked cylinders, one open the other closed.

1452-1519 Leonardo da Vinci describes capillarity effect

1564-1642 Galileo Galilei study fluid dynamics: free fall of metal balls in liquids, siphons, water flow in rivers and in pipes.

17^{th} century (the previous presentation)

1608-1647 Evangelista Torricelli Torricelli's law – pressure in liquid depends only on the height of liquid above.
1648 Raffaello Magiotti confirm this law experimentally.
1629 Benedetto Castelli studies water flow in channels and pipes.

Edme Mariotte 1620-1684

Boyle-Mariotte's law PV=constant at a fixed temperature.
Was the designer of the fountains in Versailles – an impressive Hydrodynamic achievement.
Mariotte also discovered the blind point in eye vision, studies recoil of cannons, water freezing, barometry, light colors, and sound of trumpets.

1623-1662 Blaise Pascal

draws water to a tower from a pipe.
Vacuum exists above the Mercury column in a barometer.

1655-1710 Domenico Guglielmini

Viscous friction between the flowing liquid and the walls in a pipe or channel.

1642-1727 Isaac Newton

Defines the shear strain in solids and liquids. Flow from holes. Sound waves in liquids.

18th Century, summary. (see following slides for more details)

1695-1771 Henri de Pitot

Pitot's pipe: creates an under-pressure perpendicular to the liquid flow.

1700-1782 Daniel Bernoulli

Bernoulli's principle: pressure decreases as gas or liquid flow increases

1707-1783 Leonard Euler

Continuity equation in viscous liquids.

1717-1783 Jean de Rond d'Alembert

d'Alembert paradox: zero force on a ball inside liquid with zero viscosity.

Refraction of light in liquids.

1734–1809 Pierre Louis Georges Dubuat

Viscos forces on a falling ball inside liquid are balanced by gravity, therefore the ball reaches a constant velocity. Mathematical solution by **Stokes,** mid 19th century

1718-1798 Antoine de Chézy

Hydrology engineer, expresses the equations for water flow in pipes and channels.

1733-1799 Jean Charles Borda

Naval engineer who improved the performance of water wheels and pumps. Describe flow-lines, and applied for design of boats.

1736-1813 Joseph-Louis Lagrange

Extended hydrostatics to hydrodynamics. Forces that flowing liquid exerts on bodies.

1746-1822 Giovanni Battista Venturi

Venturi's pipe, Venturi's law.

1749-1827 Pierre-Simon Laplace

Laplace' equation: continuity of liquid mass in liquid flow dynamics.

Daniel Bernoulli 1700-1782 Switzerland

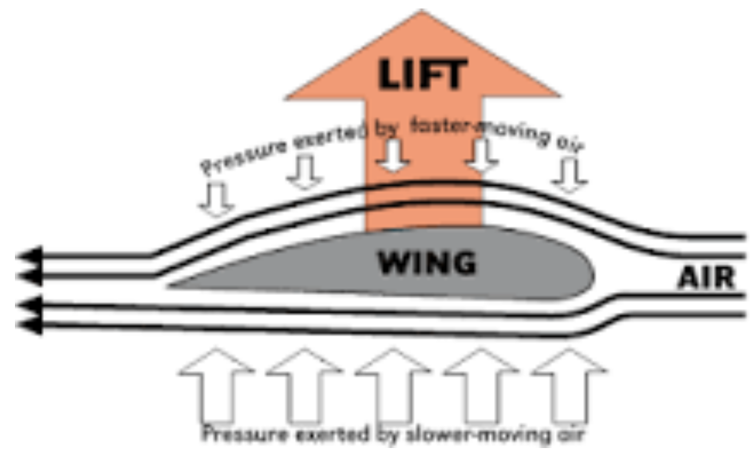
Probabilities. Calculus. See family tree 17th century

1738 Publishes “Hydrodynamics” with <u>Bernoulli’s principle</u>: the relation between increase in flow rate and decrease of pressure. Derived from energy conservation:

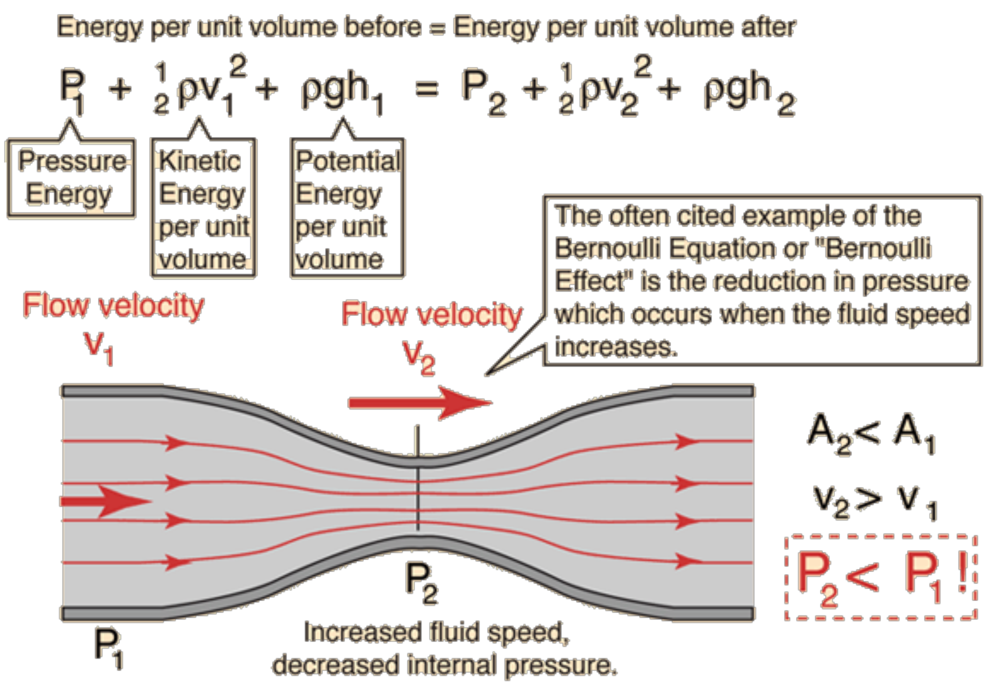
$$\frac{v^2}{2} + gz + \frac{p}{\rho} = \text{constant}$$

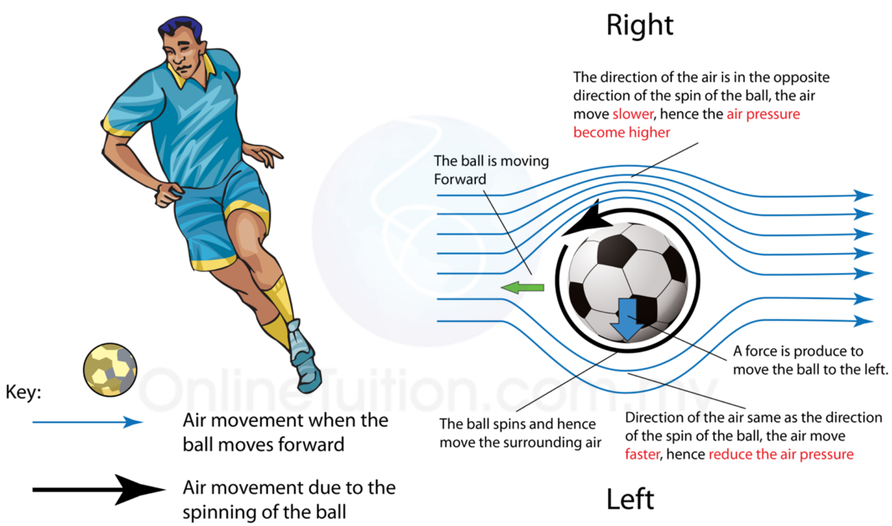
Creates suction in narrow cross section of chimneys.

Relevant for elevation on airplane asymmetric wing, Due to faster flow on the top surface.

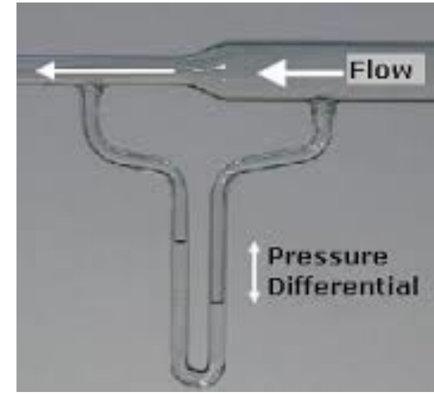


Football twisted kick drifts ball path from a straight line.

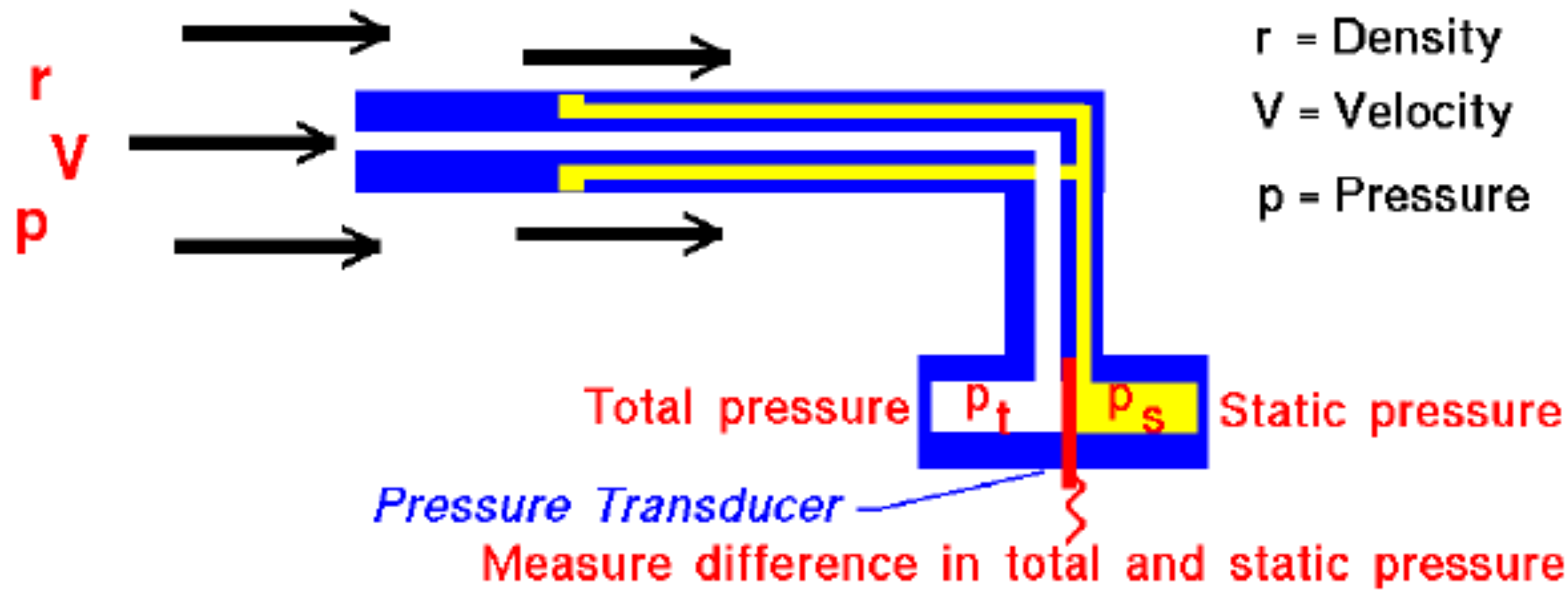




Henri de Pitot 1695-1771 Pitot tube



Pitot Tube



Bernoulli's Equation :

static pressure + dynamic pressure = total pressure

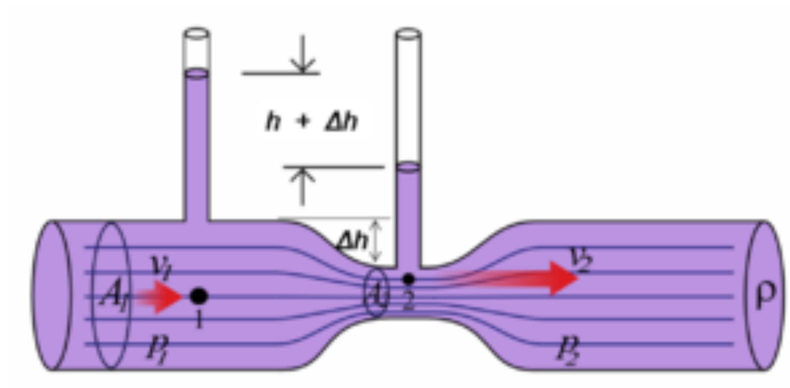
$$\left(p_s + r \times \frac{V^2}{2}\right) = p_t$$

Solve for Velocity :

$$V^2 = \frac{2(p_t - p_s)}{r}$$

Giovanni Battista Venturi 1746–1822 Italian physicist

Venturi pipe: reduced air pressure at increasing flow speed.
The basis for airplane speed measurement, and spray that sucks liquid from a reservoir into a pipe by a fast air flow perpendicular to the pipe orifice.
A new line of “bladeless air fans” (named also “air multipliers”) blow a thin high velocity air stream through a ring, and drags an air flow inside this ring.



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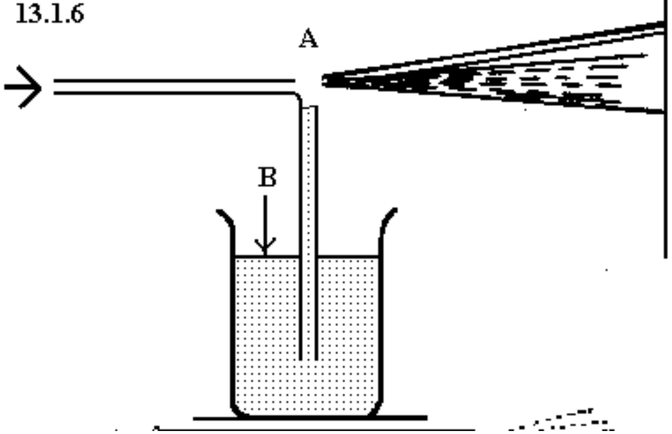


$$p_1 - p_2 = \frac{\rho}{2}\left(v_2^2 - v_1^2\right)$$

Benjamin Robins 1707-1751

1746 A military engineer who invented arm centrifuge to measure drift.

Pierre Louis Maupertius 1698-1759

1747 Applies minimization principle to mechanics. Shows that trajectories of bodies can be derived from minimum action principle.

Leonard Euler 1707-1783

Continuity equation for viscous fluid, with reservation of mass and energy. Euler reached this equation from the mechanical analysis of what enters and leave a small cubicle in the liquid. The basis of **Stokes-Navier equation**.

	THREE-DIMENSIONAL	ONE-DIMENSIONAL
Conservation of mass	$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0$	$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho v)}{\partial x} = 0$
Conservation of momentum	$\frac{\partial \vec{v}}{\partial t} + \vec{v} \cdot \nabla \vec{v} = -\frac{1}{\rho} \nabla P$	$\frac{\partial v}{\partial t} + v \frac{\partial v}{\partial x} = -\frac{1}{\rho} \frac{\partial P}{\partial x}$
Conservation of Energy	$\frac{\partial E}{\partial t} + \nabla \cdot (\vec{v}(E+P)) = 0$	$\frac{\partial E}{\partial t} + \frac{\partial}{\partial x}(v(E+P)) = 0$

Where r is the liquid density
V is the velocity
P is the pressure
E is the energy per unit volume $E = \rho \epsilon + \frac{1}{2} \rho v^2$
e the internal energy

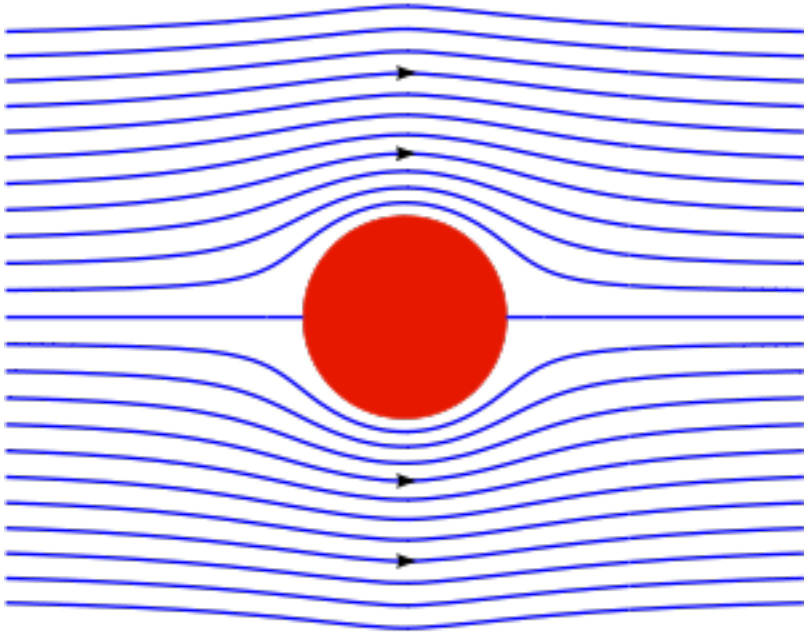
The equation holds for incompressible liquid without viscosity, and for stationary laminar flow.

Jean de Rond d'Alembert 1717-1783

Refraction of light in liquids.

d'Alembert paradox: zero force on a ball inside liquid with zero viscosity.

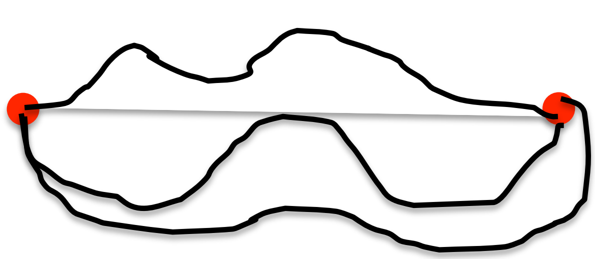
This comes out of Euler's equations.



Pierre Simon Laplace 1749-1827

1782 Shows that Lagrange potential obeys a differential equation
Laplace equation: Continuity equation for liquid dynamic flow.
1785 Gravitational theory based on scalar potential function, therefore additive, unlike the force vectors.
Gravitational force vector $\underline{\mathbf{F}}(\underline{\mathbf{r}})=GmM/r^2$
along the line between the mass and the test mass.
Scalar potential function $V(\underline{r})=GmM/r$
Can be defined for preserving field, meaning the work needed to move a test mass from point 1 to 2 is independent on the path. This is true for Gravitation.

$V(\underline{r_1})$



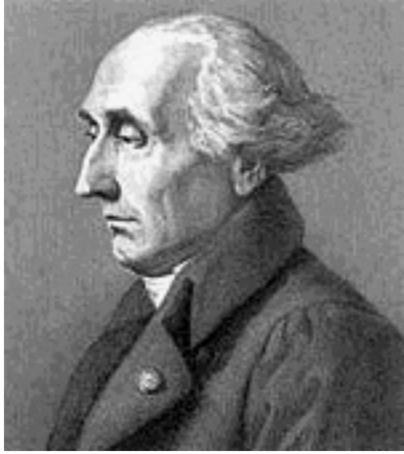
$V(\underline{r_2})=V(\underline{r_1})+W/m$

Laplace proposes to use this potential function also in electricity. Indeed an electric field is preserving too, but magnetic field is not: energy can be obtained by rotating a magnet around itself. The extension to magnetic field require some generalization. See later.

The force can be calculated from the potential at any point in space:

$$\underline{\mathbf{F}}(\underline{\mathbf{r}})=(d/dx,d/dy,d/dz)V(\underline{\mathbf{r}})$$

Joseph Louis Lagrange (1736-1813) Italy



Lagrange contributed in analytical mechanics, variational calculus, group theory (anticipating Galois) number theory,
Lagrange estimated the remains in Taylor expansion series.
1764 Describes the law of the **divergence** later called Gauss law, equating the volume integral of the divergence of a vector field to The surface integral of the vector component perpendicular to the surface.

$$\iiint_V (\nabla \cdot \mathbf{F})\, dV = \oiint_S (\mathbf{F} \cdot \mathbf{n})\, dS.$$

1788 Extends hydrostatics to hydrodynamics. The force exerted by a flowing liquid on a body: **Euler-Lagrange equation**:
Lagrangian, **L(q_i)**, the difference between potential and kinetic energies,
obeys Euler-Lagrange equation.

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right) - \frac{\partial L}{\partial q_i} = 0,$$

$\mathbf{q_i}$ = (x_i, dx_i/dt, t) are generalized coordinates of position, velocity and time.
1796 Lagrange calls dynamics: **4-dimensional geometry** (space+time).

Lagrange notes that **symmetry** in the equations corresponds to **conservation rule** of a dynamic variable. This will be a central issue In the theory of elementary particles and the conservation of their quantum numbers 150 years later (see Emmy Noether, 1915).

<u>Lagrange multipliers</u>:

A method to compute the minimum of a function of n variables, **$f(x_i)$** with m constraints **$g_j(x_i)=0$** through solution of n+m linear equations, the coefficients are the derivatives of f & g:

$$\nabla f + \lambda_1 \nabla g_1 + \lambda_2 \nabla g_2 + \ldots = 0.$$

Jean (Johann) Bernoulli 1667-1748

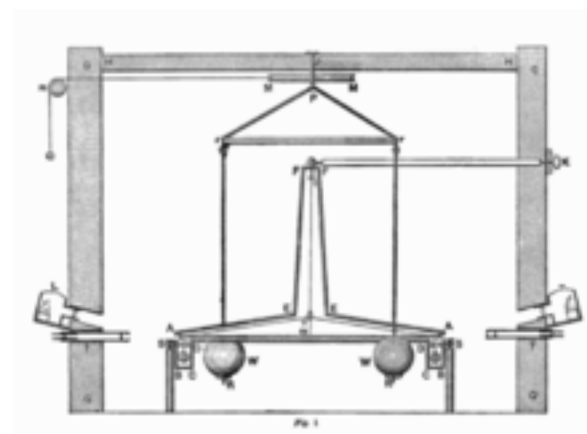
1717 the principle of virtual displacement a generalized Newton's third law, claiming that in equilibrium a body is at a minimum energy against small virtual changes.

Paul-Henri Thiry, Baron d'Holbach 1723-1789

1770 published "The System of Nature" : all is bodies in motion. Atheistic ideas.

John Michell 1724-1793

1775 The periodic nature of earthquakes.
1749 Builds torque balances that were used by Cavendish and Coulomb to measure minute forces.
He found that the two poles of a magnet have equal strengths, and the force to one of the poles is proportional to inverse distance squared,
Michell foresaw black holes.

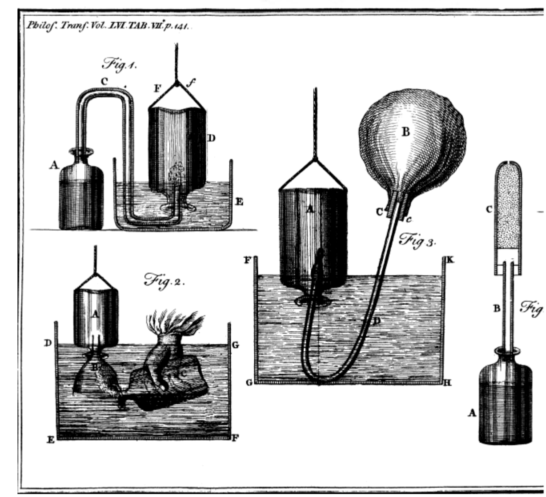


Henry Cavendish 1731-1810

Belong to English nobility. Educated in Cambridge but did not acquire a degree. Was shay and asocial, and his work was published after his death. He left behind a fortune, which funded the Cavendish labs In Cambridge.

Cavendish isolated Hydrogen from metal-acid reaction, and showed that Its burning in air produces water, depletes the Oxygen and leaved the Nitrogen, which he determined as 80% of the atmosphere.

He conducted many experiments in electricity (published By Maxwell). See next chapter.



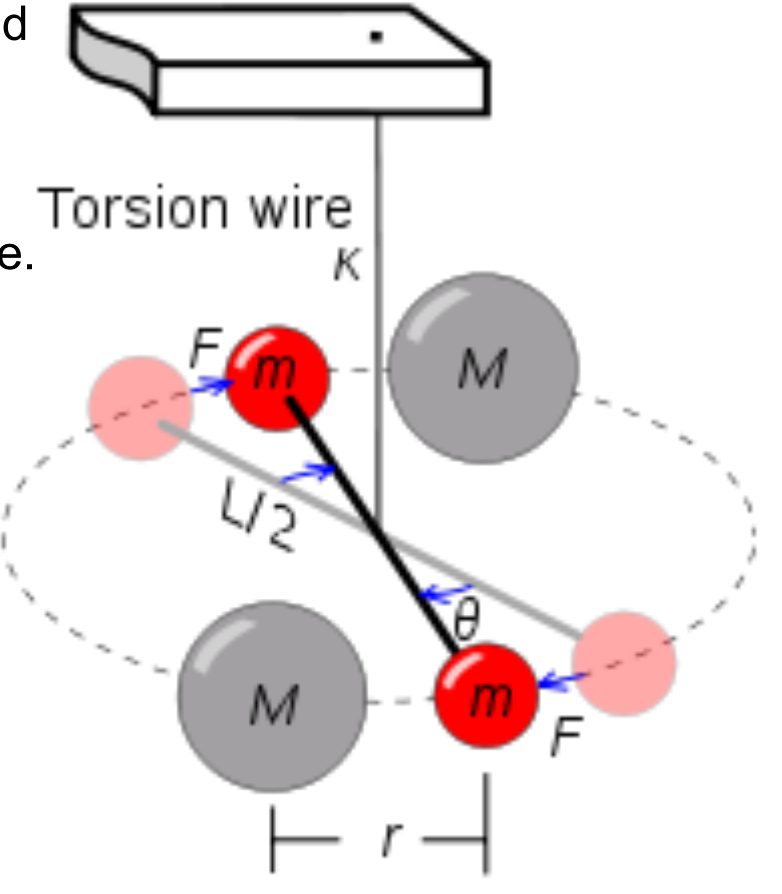
The instruments that Cavendish used to produce and collect Hydrogen

Other contributions: Electric potential, Plate capacitors, Dielectric constant, Ohm’s law, Current splitting in parallel circuits, Coulomb’s law.

The most famous Cavendish experiment

1797 Reproduces Michell's torque balance to measure Gravitational forces, and calculates G, the gravitational Constant, and the weight of earth as $6x10^{21}$ tons (the Present value is 5.9725).
He used two metal spheres weighting M=350 pounds, to attract two small balls of weight m at distance r.
He understood that r, although comparable to the dimensions of the two spheres, should be measured From their centers, as symmetry implies that Gravitational force integrate over the ball volume to give a force as if acting at the center on all the Mass. **k** is the torque constant and θ the twist angle.

$$\mathbf{F = k\theta = GmM/r^2}$$

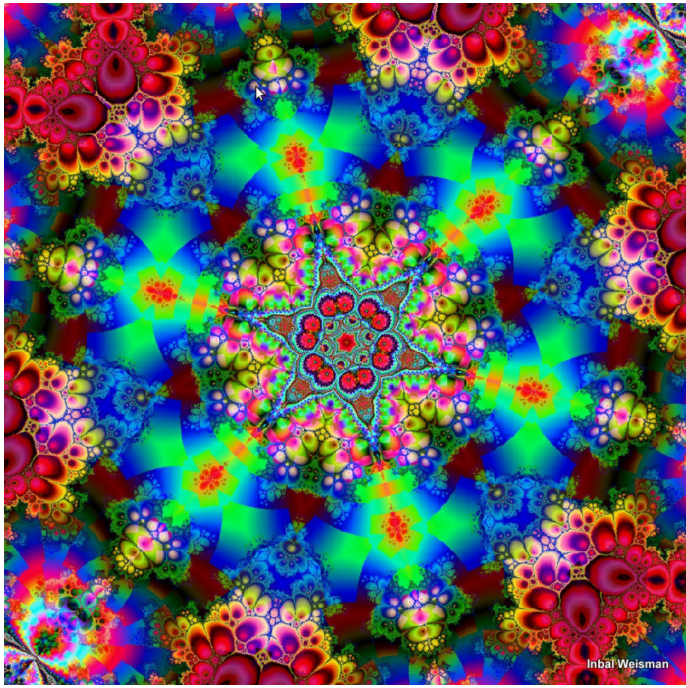


LIGHT

James Bradley 1693-1762

1728 measures the displacement of stars due to earth motion, and concludes that light speed is finite 283,000 km/sec. Improvement of Roemer's measurement.

David Brewster 1781-1868



Studies light polarization from lighthouses.
Invents the Kaleidoscope.
1831 publishes the first biography of Newton.

William Hyde Wollaston 1766-1828

A chemist and metallurgist. Invented Wollaston prism For polarizing light.

Johann Wilhelm Ritter 1776-1810

A physicist, discovered ultraviolet light.

Leonard Euler

1768 Propose that wavelength of light determines the color.

Chester More Hall

1733 Assembled an achromat from two lenses with different refraction indices.

Benjamin Franklin

1784 Invents bifocal eye glasses for reading and far sight.

Thomas Young 1773-1829

Studies medicine, but considered as a scientist who knew all areas.

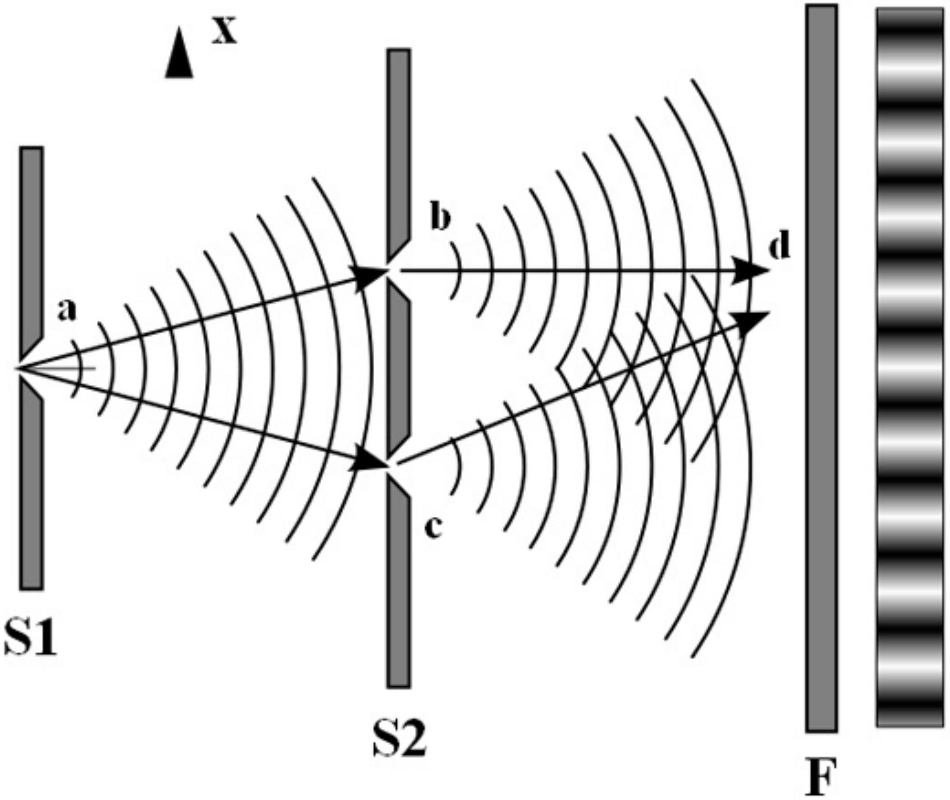
He believed that <u>eye senses colors</u> by different receptors.

Contributed to the deciphering of the <u>Rosetta stone</u>.

1801 Young performs the two-slit interference experiment that confirmed the **<u>wave theory of light</u>** rejecting Newton's light particles model.

Why Young did not illuminate the two Slits directly with a light source, but with light emerging from a third slit?

<u>Hint</u>: light coherence.



ELECTRICITY

And

MAGNETISM

At the 18th century public entertainment included shows of electric and magnetic effects, that attracted large audiences. This demonstrated the wide and popular interest in science that increased since the renaissance and the age of reason (e.g. the telescope competition, and the mechanical demonstrations of Galileo).

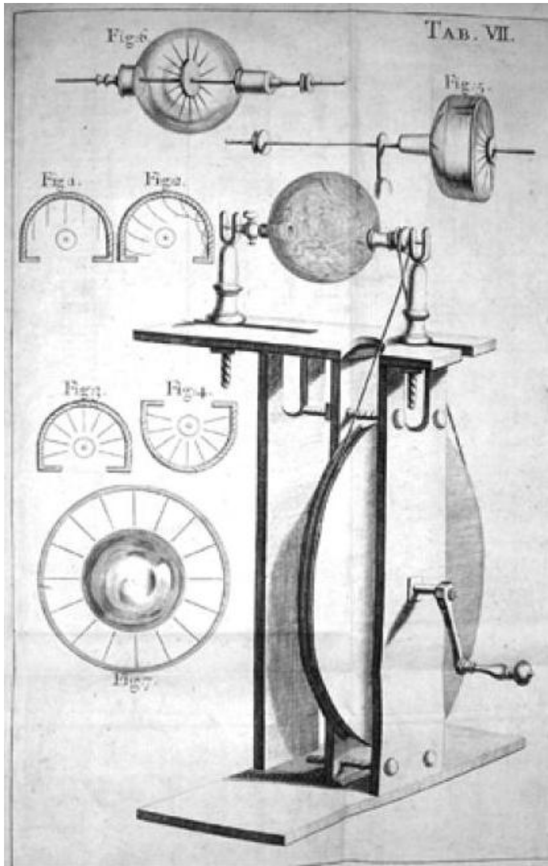
Robert Boyle 1627 –1691 Ireland

Discovers that electric force can be transduce through vacuum, and can be attracting or repelling.

Francis Hauksbee, **1660–1713**

Pumps out air from a glass ball, and found that when the ball is rotated and rubbed with wool cloth light was generated, and It was strong enough to read a book.
The ball attracted light bodies from distance.

The first electric generator by Hauksbee:



Sir William Watson 1715-1787

1748 Used electrostatic charge and vacuum pump to build discharge lamp – the 1st fluorescent lamp.

Stephen Gray 1666 –1736

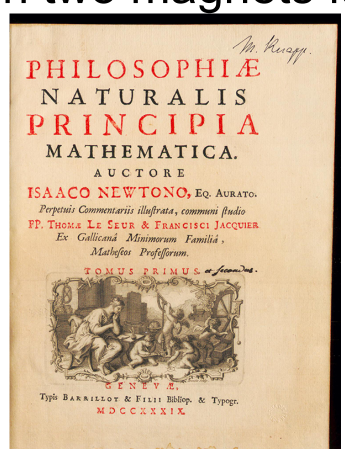
1729 Discovered electric conduction, and shows that electricity can be transferred from one body to another by metallic wires. Demonstrated that electric charge is concentrated on the surface of metallic bodies.
Classified conductors and isolators.

Charles François de Cisternay du Fay, Paris 1698 – 1739

Finds that electricity come in two types: “positive” and “negative” charges.
1733 Summarized the knowledge about electricity: all materials, excluding metals and materials too soft to rub, can be charges and transfer the charge via metals. Bodies with similar charge type repel each other, and with different type attract. He carries many experiments inspired by Gray, and concludes that all materials contain electric charges.

Thomas Le Seur 1703-1770 & Francis Jacquier 1711-1788

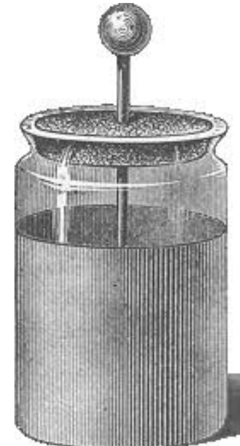
Two French Franciscan monks who worked in Rome at the command of the Pope.
Translated and commented Newton’s work.
1742 Demonstrated that force between two magnets fall as the 3rd power of distance.
Why R^3 when Michell found R^2?
Hint: orientation.



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.
AUCTORE
ISAACO NEWTONO, EQ. AURATO.
Perpetuis Commentariis illustrata, communi studio
PP. THOMÆ LE SEUR & FRANCISCI JACQUIER
Ex Gallicanâ Minimorum Familiâ,
Matheseos Professorum.
TOMUS PRIMUS. et secundus.
GENEVÆ,
Typis BARRILLOT & FILII Bibliop. & Typogr.
MDCCXXXIX.

Jean-Antoine Nollet 1700-1770

1748 Electric theory of two liquids.

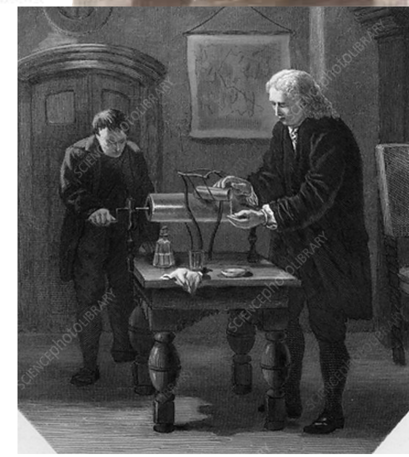


Ewald Jürgen Georg von Kleist 1700-1748 Germany

1745 First electric capacitor. (see next slide)

Pieter van Musschenbroek 1692-1761 &
Andreas Cunaeus 1743-1797 1745

Mathematics school teachers in Leyden, Netherlands. Independently invented the **<u>Leyden Jar</u>**, named after their city. It is a glass jar covered in the inside and outside by two isolated thin metal foils. Connecting the inside by a chain hanged from the bottle opening to a generator charges the jar to a level that almost killed by an electric shock. They demonstrated that the shock can be induced to a chain of hundred hand-holding man.



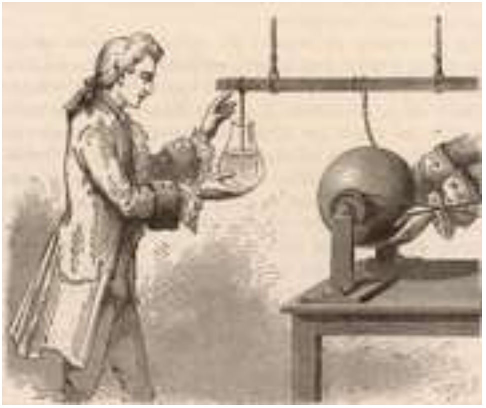
Johan Carl Wilke (Johann Karl Wilcke) 1732-1796

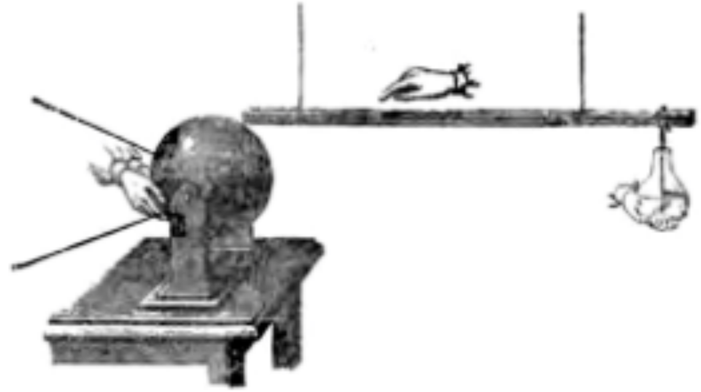
1762 Assembles a capacitor with an early version of electrostatic generator. Explains the charging by transfer of electric material by the atmosphere around the charged body.

John Canton 1718-1772

1762 Reports that a sharp hot pin discharges a body when come close to it without contact.

From **von Kleist** lab book: Charging his capacitor



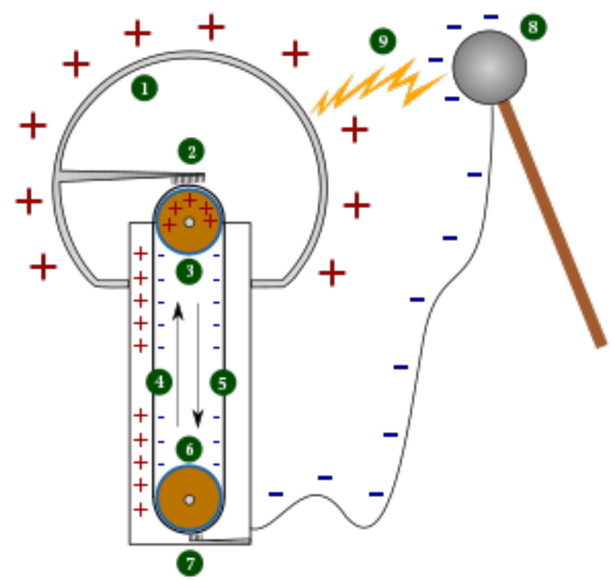


Modern Van de Graaff generator:

The rubber band is rubbed at the bottom, and discharged at its top to the inside of the metal sphere. When isolated from the ground one can touch a body charged by thousands of volts, causing one's hair to stand out.

WHY is the charge accumulated when "inserted" from the inside of a metal body ?

HINT: charges in conductors are repelled from each other towards the farthest position.



1. hollow metal sphere
2. upper electrode
3. upper roller (for example an acrylic glass)
4. side of the belt with positive charges
5. opposite side of belt, with negative charges
6. lower roller (metal)
7. lower electrode (ground)
8. spherical device with negative charges
9. spark produced by the difference of potentials

Joseph Priestly 1733–1804

1766 At Franklin's proposal, he showed that in a charged conductor all the charge is on the surface. Allows to accumulate charges on a sphere from its inside: the principle of the Van de Graaff generator and particle accelerator.
Since also inside a spherical shell gravity is cancelled to zero, Priestly deduced that the electrical forces fall as the inverse distance squared.

Henry Cavendish 1731-1810

Cavendish conducted many experiments in electricity, that were only published after his death by Maxwell, therefore had little effect on his contemporaries.
1771 Explained electricity by elastic fluid that provide positive and negative charges by excess and shortage.
1775 Invented capacitors and resistors, but could not measure electric current. This was published by Lord Calvin 1879.
1776 Attempting to mimic the electric shock from torpedo fish he put capacitors in series and reproduced the shock.
He showed that resistance of pure water is 100 times that of salt solutions.
Cavendish understood the concepts of electric potential, capacity of plate-capacitor, dielectric index, Ohm's law, splitting of electric current in parallel circuits, and Coulomb's law.

Ruggero Giuseppe Boscovich (or Rudjer Boskovic) 1711-1787

1758 Particle is an attracting force at short distances, and repulsive at large distances. The inversion of the forces create chemical compounds..

Francis Ulrich Theodore Aepinus 1724-1802

1756 Proposes that magnetic and electric properties are similar. Capacitor is created by two conducting plates separated by an isolating layer.

1759 Electric effects are due to combination of fluid currents limited to within materials, and forces acting from distance.

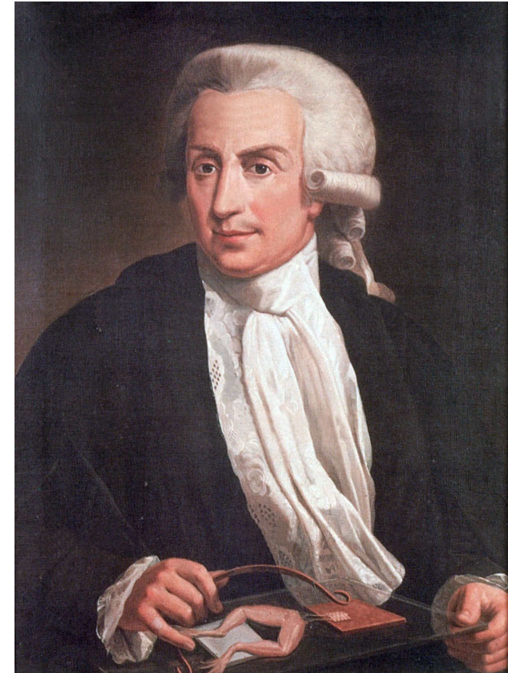
Discovers charging by induction from a distance with no contact.

Electric forces are rejecting and gravitational forces are attracting, both act from distance.

Joseph de Herbert 1863-1923

1778 Electric force is not induced by transfer of fluid from one body to the other, but is acting from a distance.

Luigi Galvani 1737 –1798



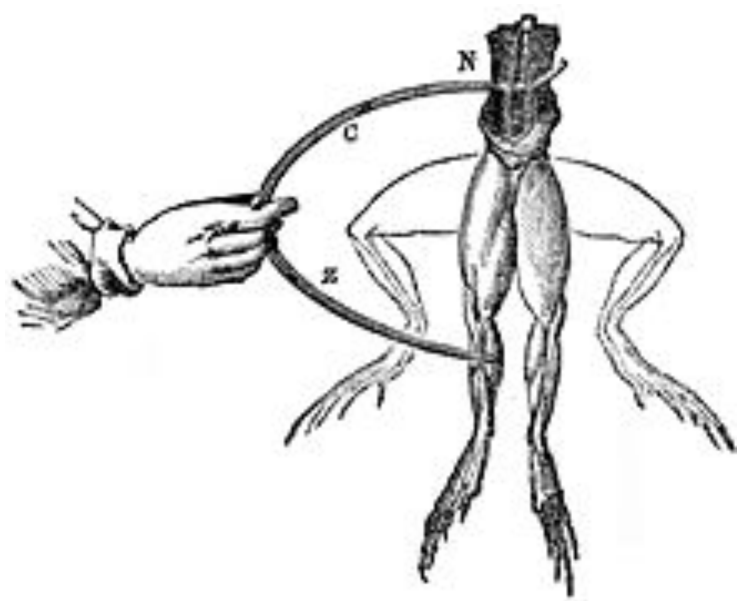
1780 Makes a dead frog's leg jump due to static electricity. Also found that contact between two different metals create leg movements.

His city mates in Bologna called him: "Frogs dancing teacher".

Galvani mistakenly attributed the leg contraction to "animal fluid".

<u>Volta</u> rejected this idea, built "Voltaic battery" and established electric conduction in metal wires and in muscles.

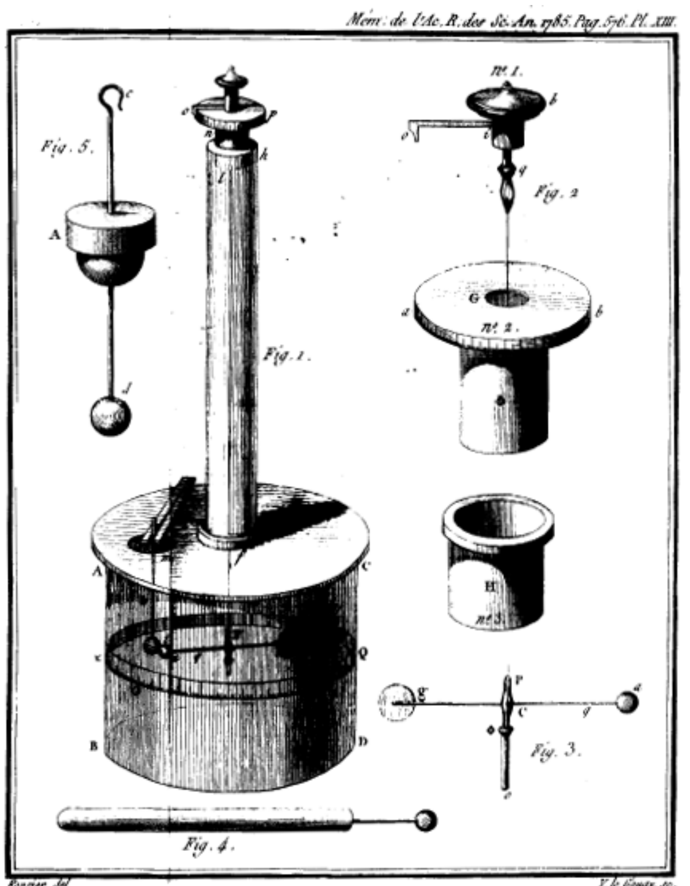
1791 Developed a conductor metal coil with iron core between magnetic poles: The coil is deflected when a current flows in it. He measured the deflection by reflected light beam: a <u>Galvanometer</u>.



Charles Augustin de Coulomb 1736-1806

1785 Used torque balance to prove that electrostatic force has inverse square dependence on distance: Coulomb's law.
Also showed that electric force near planar charged conductor is independent on distance, but proportional to the charge density.
Coulomb proposes TWO kinds of electric fluids, rather than one fluid with excess or shortage making positive and negative charges. He also proposes magnetic liquid. While others were engaged in the generation of electricity, Coulomb was the first to measure electric charges and discovered the magnetism induced in a circuit with electric current.

The unit of electric charge is called after his name.



The torque balance used by Coulomb to measure electric forces as a function of distance.

Benjamin Franklin 1706–1790

A physicist and a politician. Was the American ambassador in Paris during 1776-1785 the years of the American independence war against the British Empire (1775-1783).

Franklin studies electric charges, and proposed in **1747** the electric fluid with excess or shortage makes positive and negative charges, implying conservation of total charge in electric currents in metals. He showed that sharp metal tips conducts better than a spherical tips.

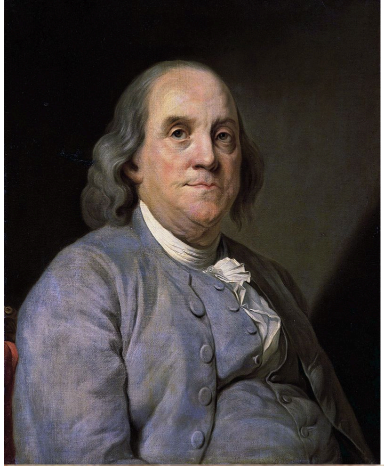
Franklin discovered remote force action on charges by electric current.

He used terminology we use today: Capacitor, Battery etc.

1751 Franklin assumes that lightening is an electric discharges, and tests his hypothesis by “Catching” lightening by a kite which he flew with wet thread connected to a key hanging inside Leyden Jar.

The jar got loaded by electric charge until he could not touch it, and the lightening induced a spark between the key and the jar.

He showed that clouds charges may be positive and negative.



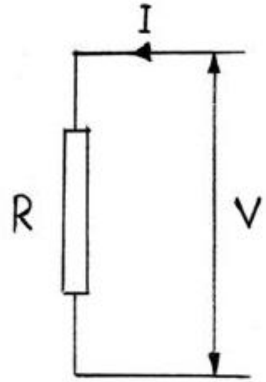
This is Franklin’s most famous experiment, and resulted with an important practical device he sold: “lightening rod”: grounded metal pole rising over houses “catching” lightening, thus preventing them to hit the house and cause burnings.

1784 Franklin also invented bifocal eye glasses for far vision and reading.

Studies in electricity at the beginning of the 19th century

Georg Ohm 1789 –1854 Germany

1827 "Ohm's law" defines resistance as the ratio between the electric potential and the current, as well as the heat energy (power) generated by the resistor.



$$R = \frac{V}{I}$$

WHAT WAS NEEDED TO SHOW THIS RATHER SIMPLE RELATION ?
Hit: The **Battery**. The chemical battery was invented by Volta at 1800. Prior to that, Leyden Jars stored electricity (charged capacitors) and supplied electric potential and current, but the "voltage" and the "current" were not constant but decayed fast, preventing the ability to measure voltage and current for various circuits systematically and study their relations.

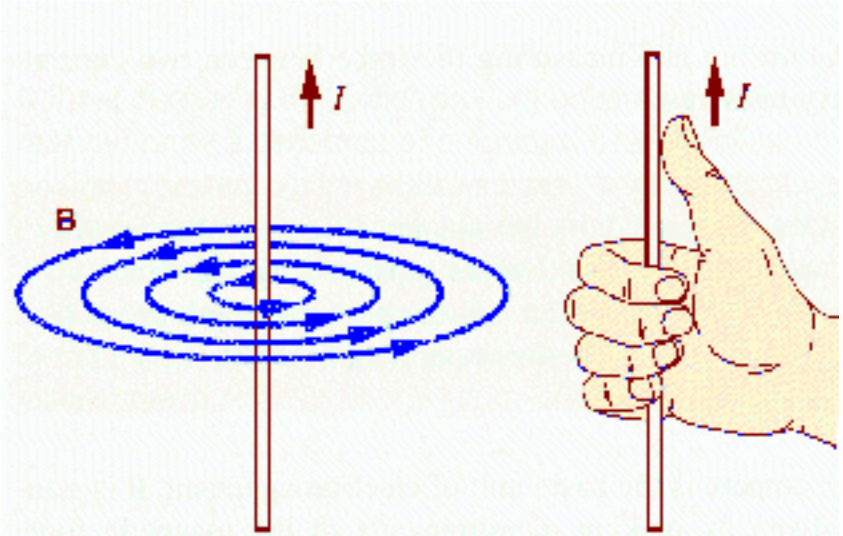
Hans Christian Oersted, Andre-Marie Ampere, Francios Arago

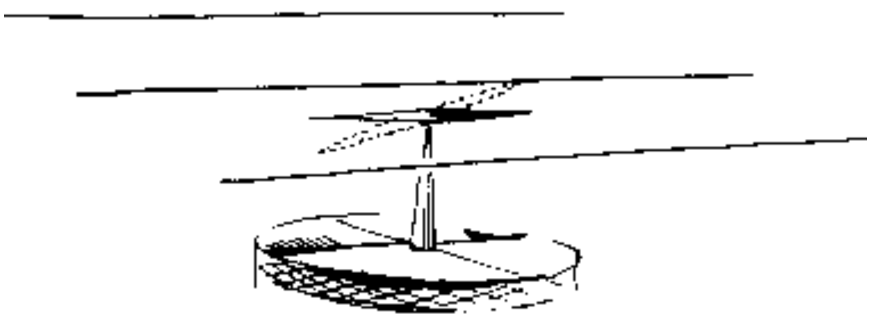
Demonstrate the connection between electricity and magnetism.

Hans Christian Oersted 1777-1851 Denmark

1820 Discovered that electric current displaces compass magnetized needle, and showed that electric current creates a magnetic field.

Electric current (brown) and the magnetic field it induces (blue). The orientation of the magnetic filed lines is determined by the



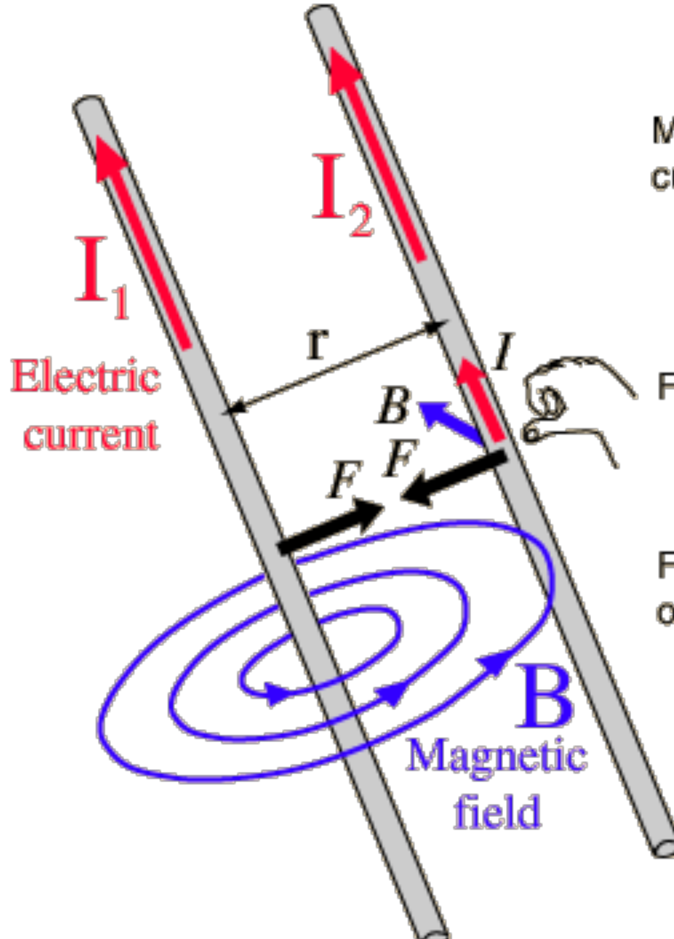


Andre Ampere 1775—1836 France

1820 Ampere shows that two electric wires carrying electric currents are attracting or repelling each other if the currents Are parallel or antiparallel correspondingly. He determined that The force is inversely proportional to the distance between the wires. He measured the strength of electric currents by the turning Degree of compass needle.

Ampere measured the heating of the wires by the current, and showed it was proportional to the square of the current.

The unit of electric current is named after him.



Magnetic field at wire 2 from current in wire 1:

$$B = \frac{\mu_0 I_1}{2\pi r}$$

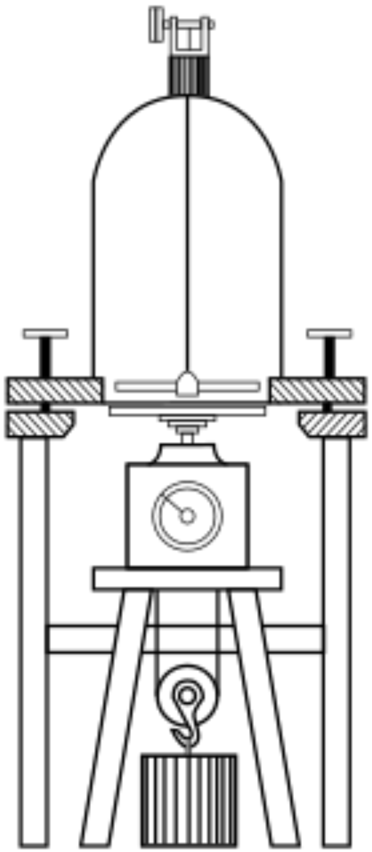
Force on a length ΔL of wire 2:

$$F = I_2 \Delta L B$$

Force per unit length in terms of the currents:

$$\frac{F}{\Delta L} = \frac{\mu_0 I_1 I_2}{2\pi r}$$

Francios Arago 1786—1853   French



1824 The interactions between a magnetized needle and a metal disk: A magnetic needle is freely suspended on a string, above a non-magnetic metal disc. If the disk is stationary, the needle aligns itself to north. If the disc is rotated, the needle rotates in the same direction as the disc. The effect decreases with distance between the needle and the disk. And vice verse: if the needle is rotated, the disk rotates in the same direction as the needle.

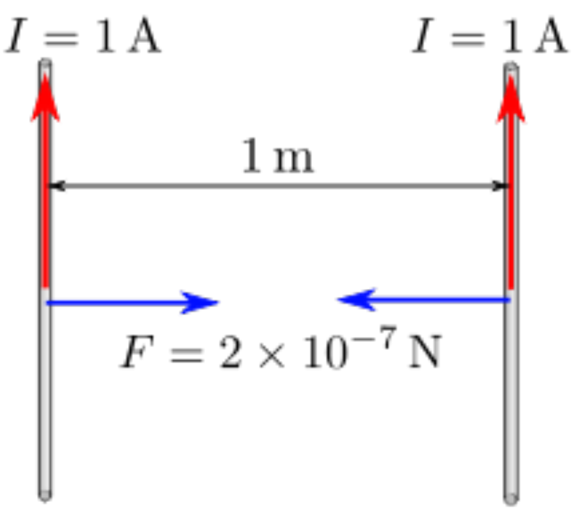
We know today that relative motion of conductors and magnets induce eddy currents in the conductor, which produce a force or torque that opposes or resists relative motion, or tries to "couple" the objects. This drag-like force is used in eddy current braking and magnetic damping.

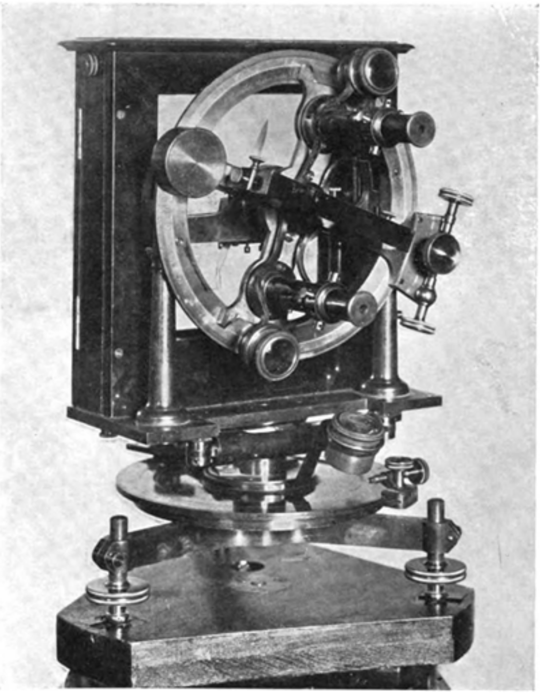
Karl Gauss 1777 –1855

1830 Builds a magnometer, to measure the strength of magnetic fields. Defines the unit of magnetic flux (magnetic induction) that carries his name:

1 Gauss = the magnetic flux created by 1 Ampere electric current in a wire at 1 meter distance

Gauss magnometer was built from a bar magnet suspended horizontally from a gold fiber. The bar oscillated with frequency depending if the bar was demagnetized or magnetized and positioned in different magnetic fields.





SOUND and MUSIC

Johann Sebastian Bach 1685-1750

1704 Bach started to compose music based on Pythagorean-Platonic ratios between sound frequencies and their harmonics. At the same year **Newton** added “indigo” to the spectral colors of light “violet,blue,green,yellow,orange,red” to make 7 colors as the 7 notes of sound in the Pythagoras scale.

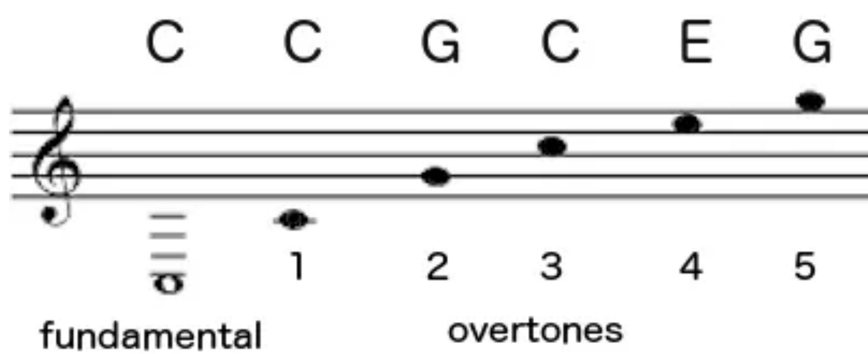
However, the evolution of the Harpsichord (plucking the strings) towards the Piano Forte (hammers tapping the strings) introduced strong overtones (mainly x3 and x5 of the basic frequency) that created unpleasant harmonies for chords (set of pitches played simultaneously) based on equal ratios of (equally tempered) frequencies in an octave (x2 in frequency divided into 5 intervals and two half intervals with frequency ratios of $2^{-1/6}$=1.122462 for full and 1.05946= $2^{-1/12}$ for half intervals)

“The Well Tempered Clavier” was Bach’s composition of preludes and fugues to demonstrate harmonic balance in all 24 Major and Minor scales:

C → C♯ → D → E♭ → E → F → F♯ → G → G♯ → A → B♭ → B

The harmonies: A,C,E. (triad chord)

C-C (twice the frequency) -G (fifth away from C)- C (four times)- E (third away from C)



EXERCISE: using least square fit, find the best frequencies in A major scale that minimize beating frequencies in harmonies due to third and fifth overtones.

C D E F G A B C

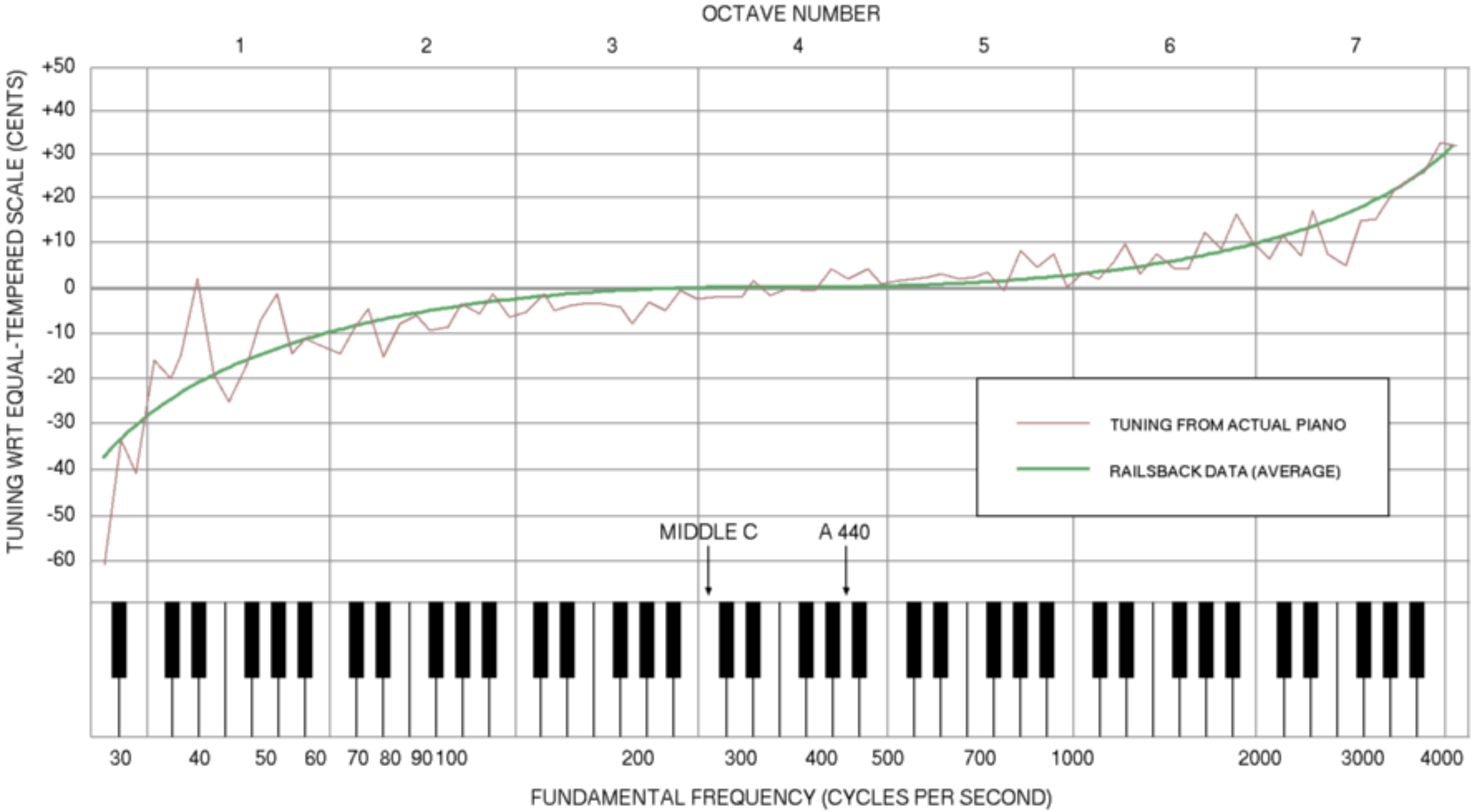
Equal temperament beatings (all figures in Hz)

261.626	277.183	293.665	311.127	329.628	349.228	369.994	391.995	415.305	440.000	466.164	493.883	523.251
0.00000			14.1185	20.7648	1.18243		1.77165	16.4810	23.7444			C
		13.3261	19.5994	1.11607		1.67221	15.5560	22.4117			B	
	12.5781	18.4993	1.05343		1.57836	14.6829	21.1538			A♯		
11.8722	17.4610	.994304		1.48977	13.8588	19.9665			A			
16.4810	.938498		1.40616	13.0810	18.8459			G♯				
.885824		1.32724	12.3468	17.7882			G				Fundamental	
	1.25274	11.6539	16.7898			F♯					Octave	
1.18243	10.9998	15.8475			F						Major sixth	
10.3824	14.9580			E							Minor sixth	
14.1185			D♯								Perfect fifth	
		D									Perfect fourth	
	C♯										Major third	
C											Minor third	

The pitch of beatings

Interval	Approximate frequency ratio	Beating above the lower pitch	Tempering
Octave	2:1	Octave	Exact
Major sixth	5:3	Two octaves and major third	Wide
Minor sixth	8:5	Three octaves	Narrow
Perfect fifth	3:2	Octave and fifth	Slightly narrow
Perfect fourth	4:3	Two octaves	Slightly wide
Major third	5:4	Two octaves and major third	Wide
Minor third	6:5	Two octaves and fifth	Narrow
Unison	1:1	Unison	Exact

Twelfth 3:1



Railsback curve showing the difference between 2^{-12} constant ratio (equally tempered) and well tempered tuning. Higher notes are tuned higher, lower notes tuned lower, so that the 3rd and 5th overtones will beat minimally in harmonies.

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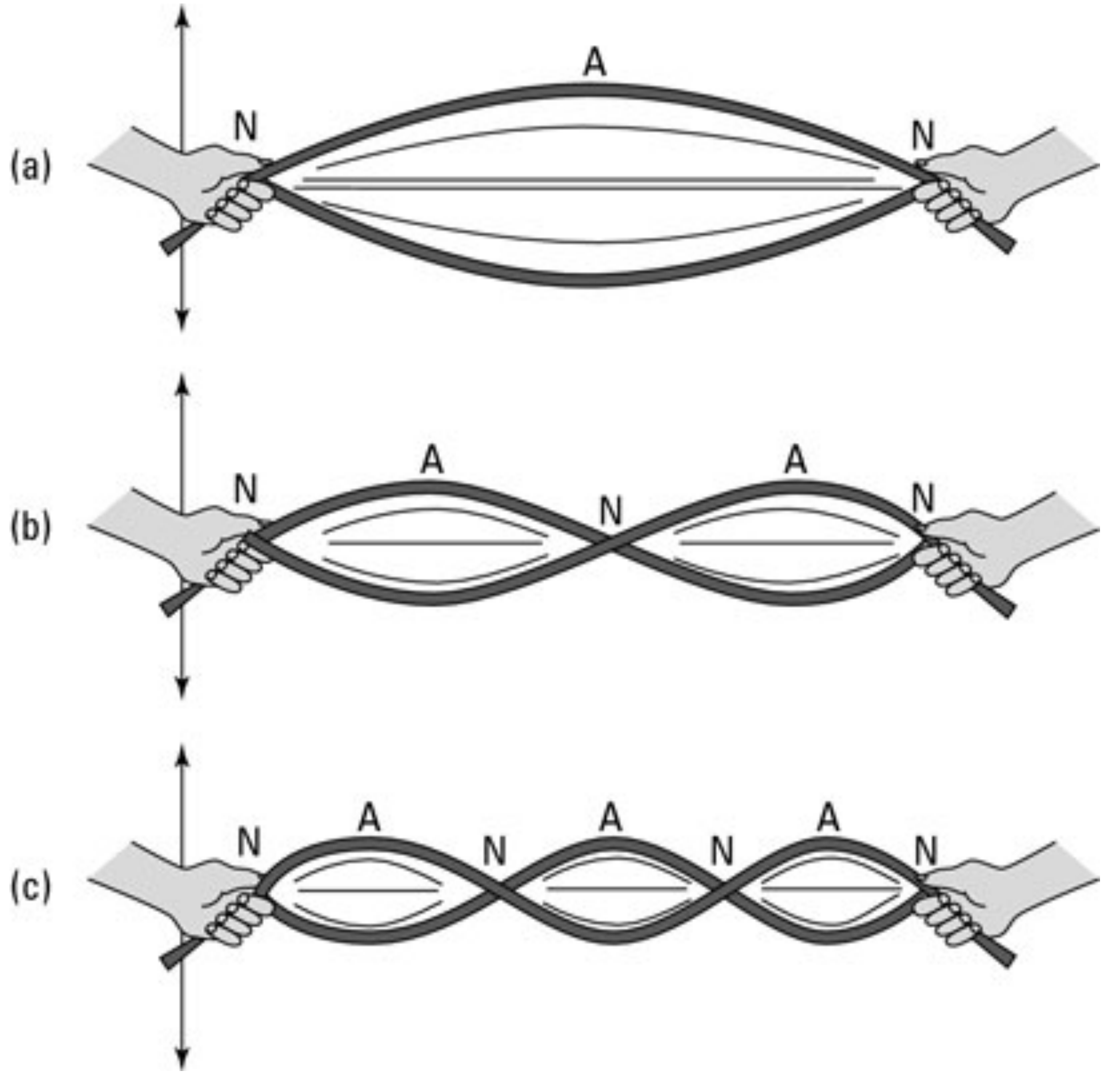


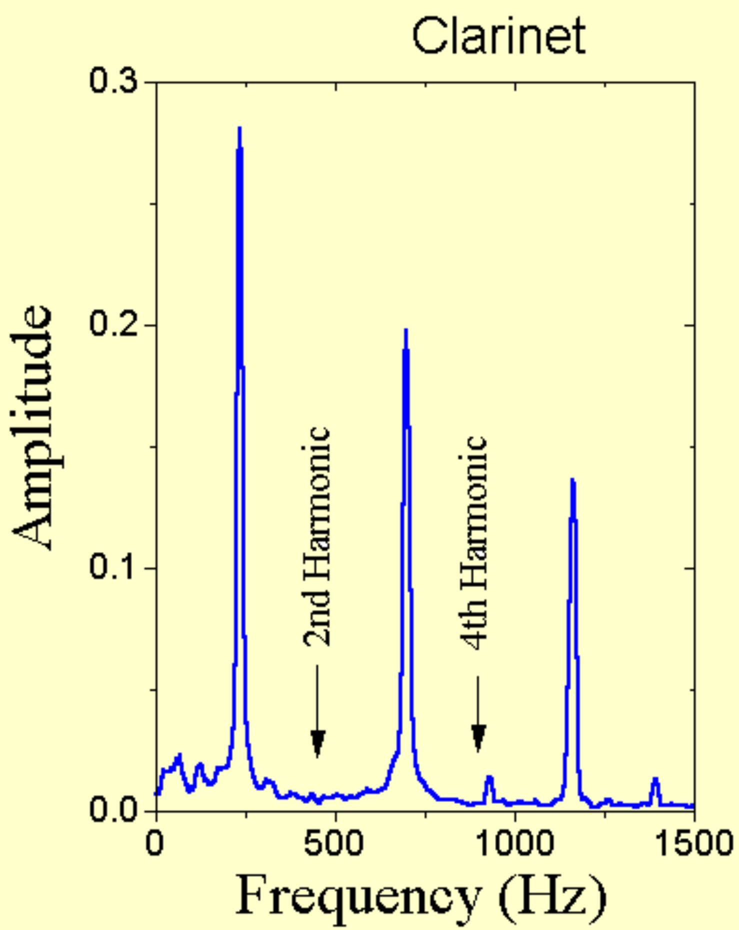
fundamental

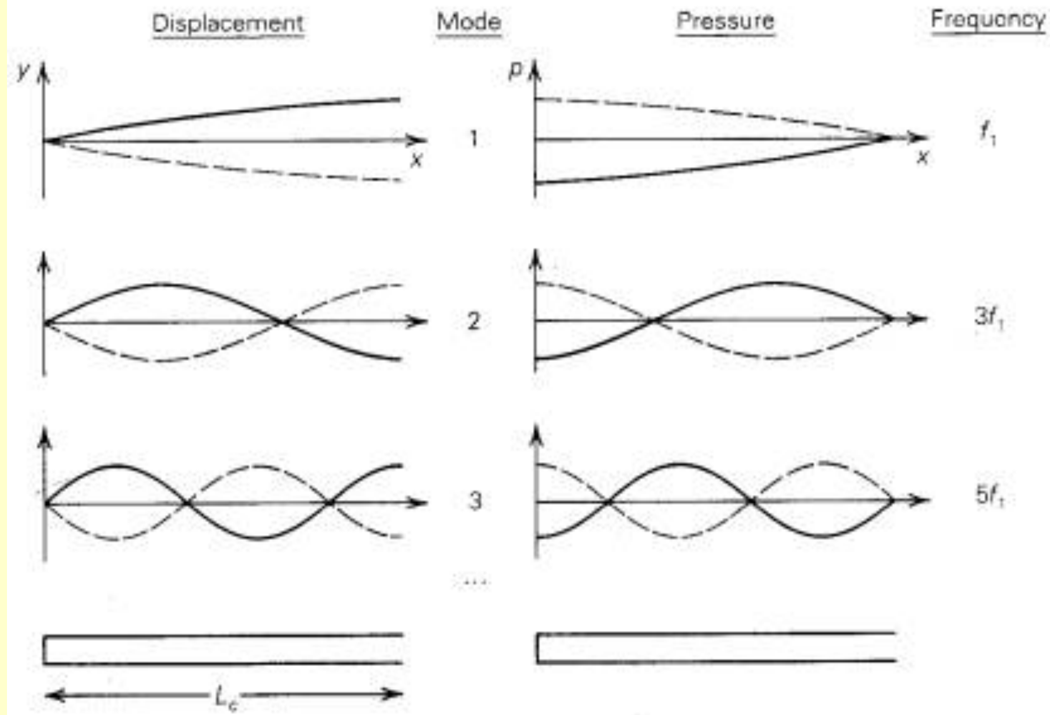
First overtone
(double frequency)

Second overtone
(triple frequency)

String vibrations when its two ends are fixed

EXERCISE: what are the overtones in a wind instrument with one end open





Air vibrations in a clarinet, with one end open – only odd overtones

Francis Hauksbee

1705 Demonstrated that sound waves need air to propagate, and do not propagate in vacuum.

Brook Taylor

1714 Develops from a differential equation the dependence of string vibrations on tension, length and mass.

John Shore

1711 invented tuning fork.

Daniel Bernoulli

1733 Develops from a differential equation the fundamental and overtone vibration frequencies of a hanging chain

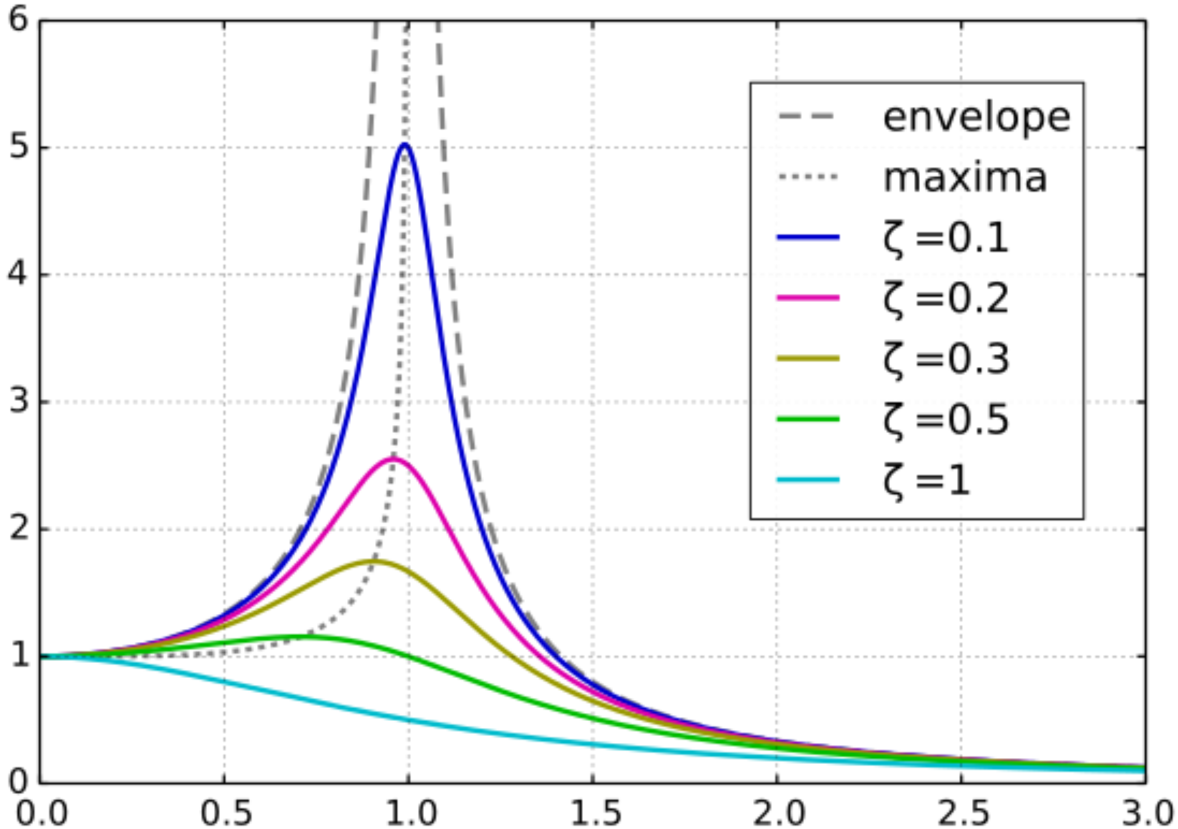
Leonhard Euler

1739 Solves forced vibration of harmonic oscillator and the effect of resonance:

Resonance $A(w)=A_0/(w^2-w_0^2)$

with friction $A(w)=A_0/(w^2+d-w_0^2)$

EXERCISE: Try to vibrate a pole anchored at the ground, tuning to a resonance.



CHEMISTRY

FROM ALCHEMISTRY TO CHEMISTRY

Chemistry turned to be a science starting at the second half of the 18th century due to Lavoisier's work. He was recognized as the one who finally buried Aristo's 4-sources (elements) and Paracelsus' three principles. According to Lavoisier, the number of elements will be determined from experiments and chemical analysis of materials, and he found at least 33 elementary materials in nature.

Although chemistry uses the nomenclature of alchemistry, it is not its extension. It extended its research from medicine, pharmacology, mineralogy, and the technologies of iron locksmiths, glass blowers, construction people, painters and sculptors. All those joined to the development of chemistry based on the understanding of nature through mathematical laws and experimental work.

Peter Leopold's chemistry cabinet (1747-1792)

During his rule as the Grand Duke of Tuscany 1760-1792 he devotedly advanced science with great passion and personal interest in inventions, especially in chemistry. He collected preparations and experiments in a cabinet that when opened was a fully equipped laboratory with drawers full of bottles storing chemicals, reaction chambers, heating lamps and candles, and air blowers. The cabinet became a trade-mark for pharmacists in the coming centuries.

The interest in chemistry emerged from the practical applications as well as the spirit of the enlightenment era to gain basic knowledge.

Following the discovery of the Americas a flow of new plants supplied source to extract new medical drugs by Renaissance people such as Paracelsus. This trend continued by **Nicolas Lémery** in France and others. But only during the 18th century this became a central theme in medicine and chemistry mainly by **Antoine Baumé** who developed reproducible preparation methods for the drugs and conducted experiments with lab animals – experimental pharmacology.

Antoine-Laurent Lavoisier 1743-1794

Lavoisier was born to a rich Parisian family. In college he absorbed the spirit of the French enlightenment era. He got his degree in law, and continued to study sciences. He was specially keen on chemistry, the area of his first publication in 1764.

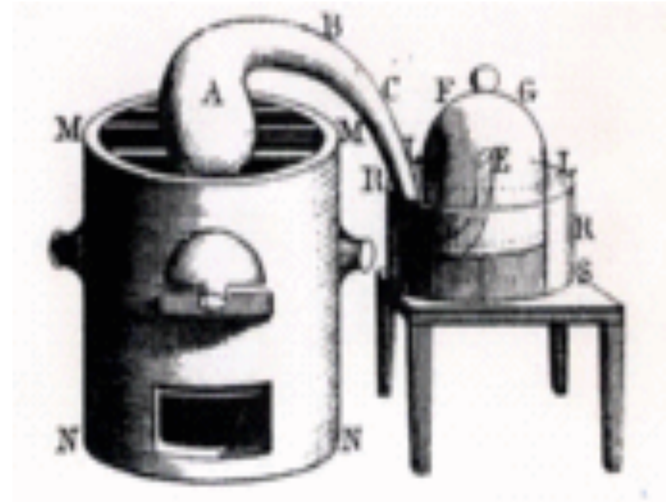
1767 Lavoisier makes a geological survey in Alsace-Lorain, and was elected to the French academy at the age of 25, after publishing about street lamps, and acknowledging his previous work. He continued his geological mapping of France, and at the age of 26 he was appointed tax collector in an agricultural association and initiated changes to help the farmers. During this time he also participated in the implementation of the metric system.

1771 He married Mary-Ann, 13 years old, who became his scientific partner. She translated publications from English on Phlogiston, and Joseph Priestley's work, including drawing of the instruments he built for his research. Mary-Ann hosted many receptions were scientists discussed issues, mainly in chemistry, and edited Lavoisier's memoirs.

Lavoisier's statue at Hotel de Ville in Paris

1774 Oxygen was discovered by **Priestley** (maybe “stolen” by Lavoisier), killing the Phlogiston theory. Lavoisier understood the “fixed air”, carbon dioxide, is a chemical material created by combination of oxygen and carbon from burnt vegetables.

The drawing shows the experimental system built by Lavoisier to study the Phlogiston theory of heat.



Jean-Paul Marat

1780 The theory of burning, adopted by Lavoisier.

1780 Lavoisier’s research with **Pierre-Simon Laplace** explained burning as combination with Oxygen, and defying the theory that Phlogiston is released.
Lavoisier deduced from his experiments that burning is reaction with “Oxygen”, (the name is “maker of acids”, since he assumed all acids contain Oxygen).
1789 He showed that glucose turns into ethanol and carbon dioxide during fermentation. Lavoisier proposed that metabolism and fermentation get Oxygen from from decomposition of water.

He showed that rust formation involves Oxygen, as well as breathing of plants and animals, and showed that oxygenation of materials increases their weight.
1789 Lavoisier defined “Law of Conservation of Mass” deduced from increasing weight of rusted iron. Maybe the starting point of modern chemistry

They assumed that heat is a kind of material, “Caloric” that is added upon burning.

Caloric Heat Theory (~1780's to ~1860's)

Lavoisier’s with **Pierre-Simon Laplace** conducted first revolutionary chemical physics experiments when they measured the heat generated by burning carbon in a calorimeter. They also measured the heat generated by breathing of a guinea pig, and concluded that food metabolism is a slow burning using oxygen from breathing air. They measured the heat in a container of ice in 0^0C and weighted the water melted, after calibrating that 80 kilocalories melted 1kg of ice. The “law of Energy Conservation” is a natural conclusion of this study.

They defined “specific heat”, the heat required to raise the temperature of a material in 1^oC.

Lavoisier called the “burning air” that Cavendish discovered “Hydrogen”–water producer, since upon burning it combines with oxygen and produces droplets that Priestley showed were water. He found that air consists of Nitrogen and Oxygen, thus rejecting Aristo’s model of air and water as two of the four elements.

Lavoisier commonly used others results without crediting, but he was capable of interpreting the experiments and draw conclusions that surpassed those of the original publications of his competitors. He was the first quantitative chemist, carefully weighted all the materials before and after each reaction, and was first to understand that even though materials changed forms and shapes, the total mass of all reacting components was preserved.

Mikhail Lomonosov 1711-1765

1748 Also described mass conservation law, as well as others:

Joseph Black , 1728-1799, Henry Cavendish, 1731-1810 & Jean Rey , 1583-1645

Nevertheless, Lavoisier's formulation of the law from 1989 was the acknowledged landmark, since it was backed up by careful weighting of the incoming and resulting components of the chemical reactions he studied. Lavoisier was also the first to define **histochemistry** –predefined quantitative combination of chemical components reacting in a chemical reaction.

1787 Claude-Louis Berthollet, **Antoine Fourcroy, Guyton de Morveau** with Lavoisier Established terminology for chemicals that facilitated communication in publications, and is in use today, such as sulfuric acid, sulfur salts, and sulfur oxides, sulfates and sulfides.

1789 Lavoisier's book about chemistry, translated to English by Robert Ker, is considered the first modern chemistry text, including unification of new chemical theories (mass conservation, stoichiometry), and rejection of wrong classical models. He defines chemical element, and composition of chemical compounds by reactions between the elements and other compounds. The list of elements he recognizes are: Oxygen, Hydrogen, Nitrogen, Phosphorus, Mercury, Zinc and Sulfur. But he included in this list also light and heat (Caloric)…

He was first to observe "radicals" as repeated unit in chemical reactions. When he discovered that diamond is carbon crystal, he was first to recognize "Allotropy".

Although Lavoisier's chemistry was not easily accepted by his contemporaries, it was supported very firmly on experimental facts and on a sharp intellectual theoretical argumentation that convinced next generations.

1770 Lavoisier's experiments to ignite materials by focusing sunlight.

Lavoisier stood for foreign scientists (e.g. Lagrange) who were deprived of rights and property. As one of 28 tax collectors he was accused of treason, and probably an old dispute with young **Jean-Paul Marat,** where he displayed Marat's invention as ridiculous, set his destiny to the guillotine when Marat became a leader in the revolution under the Robespierre rule of terror. He was prosecuted at 1794 when he was 50. Attempts to ease the verdict was answered by the judge: "the revolution is in no need of scientists or chemists". After he was beheaded Lagrange said: "it took a moment to cut his head, but France will need a century to grow another head like his".
A year later, the state inverted the sentence and returned all property to his wife.
A statue of Lavoisier used bronze melted from the head of the French academy. The statue was melted during WWII, but in Hotel de Ville and in the Napoleon section in the Louvre, Paris, his statues are still displayed.

At previous times people said that chemistry is for business men, while physics and geology is for gentlemen. Indeed rich business men acquired "chemical cabinets" for entertaining themselves and display magical shows to their guests.
Lavoisier was the one who turned chemistry into science, and was therefore named "the father of modern chemistry"

Sir Benjamin Thompson, **Count Rumford 1753-1814**

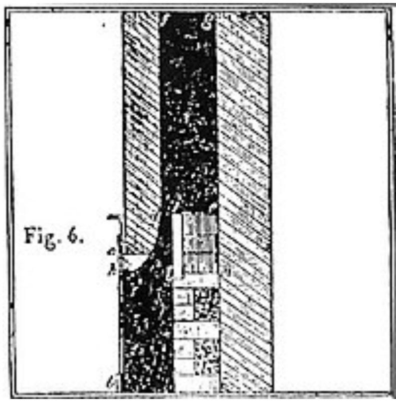
1753 Thompson, an American physicist who served the British during the independence war, returned to England as a talented administrator, and designed ships. He married Mary-Ann, Lavoisier's widow, hired in Munich and at 1790 received the title of honor **Count von Rumford** from the holey Roman Empire. His work in explosives brought him to thermodynamics: specific heat, heat loss isolation by furs, due to the prevention of air circulation (had theological explanation to the creation of fur for animals…), heat conduction and convection in liquids, earth flow and ocean streams. He understood that air and water have poor heat conductance, and can be isolators if their circulation is inhibited. He discussed heat flow in earth crust.

Thompson believed in heat and cold radiations.

He observed that the drilling of cannon bores creates heat, and concluded that heat is motion : preliminary understanding of energy preservation laws.

Thompson invented coffee percolator, Rumford Fireplace named after him, with narrow slit expanding to the chimney to effectively exhaust smoke but minimize heated air loss.

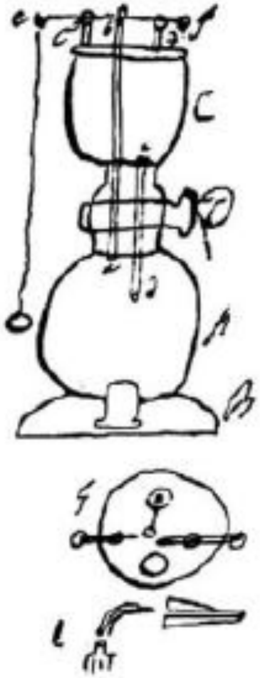
1799 Thompson and **Sir Joseph Banks** established the British Royal Academy.



A section through Rumford Fireplace

Sir Joseph Banks 1743-1820

The first president of the British Royal Society. This establishment had great impact on scientific publications, fund raising for scientific delegations, and meetings of scientists.



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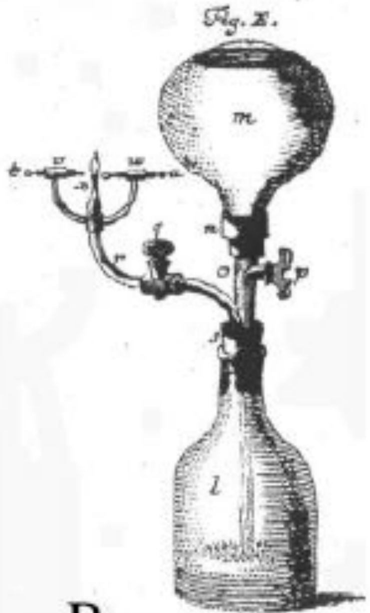

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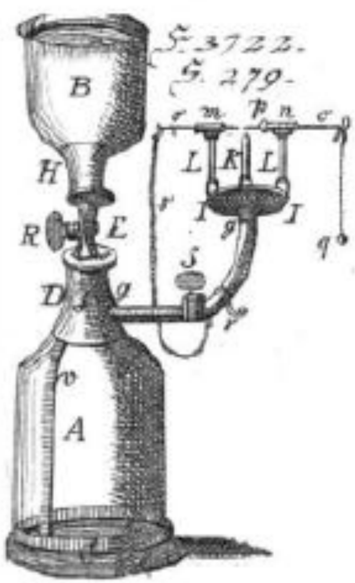
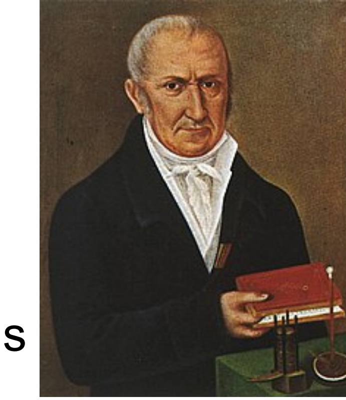


C

D

Alessandro Volta 1745-1827



1776 Volta collects gas bubbles from the marshes around Lago-Maggiore, north of Italy, and calls it “inflated marshes gas”, Methane. He showed that like Hydrogen, the gas can be ignited by electric spark. He wanted to develop gas spark igniter. Since the methane gas container needed to be big, he used Hydrogen with two glass containers, top filled with water, that when a valve between the containers opened, water pushed the Hydrogen out to the pipe and ignited by sparks from a Leyden Jar.

The idea was also developed by other instrumentalists, where Hydrogen was created from Zinc in contact with acid. The lamp became a display item in the wealthy people’s saloons. The invention of matches made this show device redundant…

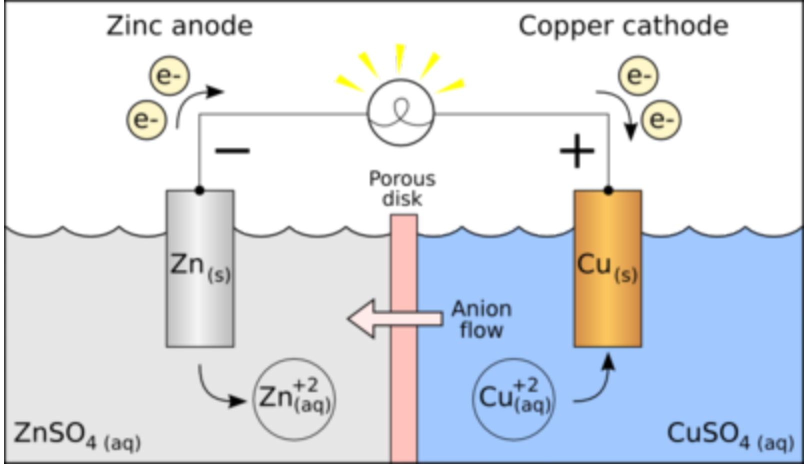
Volta

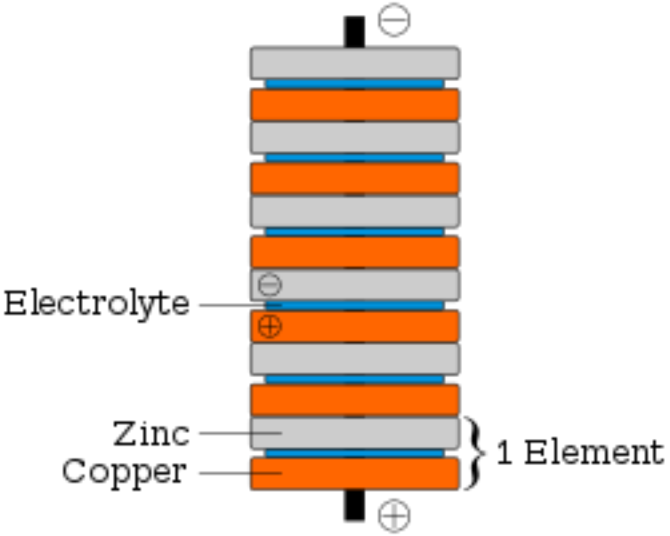
1775 Invented the Voltaic electric cell. The principle of operation was explained theoretically by **Wilcke**.

Volta did not accept the theory of special animal electricity of **Galvani**, and maintains it is the same electricity in frog muscles, Leyden Jar and his electric cell.

1792-3 Volta develops the Voltaic pile, the first chemical battery: two different metal disks, Silver and Zinc, hold paper towel or cardboard sucked with salt solution, stacked in a pile and immersed in an electrolyte. This pile produced higher voltage than the Voltaic cell.

Volta understand how to close an electric circuit.





Johann Sulzer

1752 Touched lead and silver with his tong and feels the electric current they generated: "tong test" to a new or dead battery.

Joseph Black 1728-1799

1750 Described latent heat (e.g. melting of ice at 0^{o}C)
1754 Heated $CaCO_3$ and got CO_2 + CaO_3, and when cooled return to $CaCO_3$. He calls CO_2 "trapped gas" since it can be trapped in solids.
1757 Discriminated between temperature and heat. Explains phase transitions Solid-liquid-gas.
1761 Reports that ice melts without changing its temperature.

Henry Cavendish 1731-1810

Conservation of Energy.
1797 Isolated Hydrogen, and showed that its burning (actually explosion) with Oxygen makes water.

Joseph Priestley 1733–1804

1781 Make water from burning Hydrogen and Oxygen.

Pilatre de Rozier

Explodes Hydrogen.

Joseph Gay-Lussac 1778-1850

Analytical Chemist who studies expansion of gases by heat, Boron and Iodine.
Launched to a height of 7 km in hot balloon.

Thomas Wedgwood 1771-1805

A chemist who first used silver salts to produce photographic plates.

Karl Wilhelm Scheele – Sweden

1750 Produces phosphorus for matches.
Isolated Chloride (as bleaching solution), Manganese Fluoride, Barium, Molybdenum, Tungsten (Wolfram), and Nitrogen.
1772-4 Isolated Oxygen from Silver Carbonate – "fire air" but published the results only after the publication by **Priestley**. Showed that air contain Nitrogen. Isolated Glycerin and various acids (Tartaric, Lactic, Uric, Prussian, Citric, Tannic, Malic and Gallic).
1777 Specified heat loss by radiation, convection and conduction.
Died when tested Hydrocyanic acid.

Henry Cavendish 1731-1810

1766 Isolated "burning air" called Hydrogen by Lavoisier, and separated it from Carbon dioxide. Measured its specific weight.

Joseph Priestley 1733–1804

1774 Recognized as the discoverer of "phlogiston-depleted air" called Oxygen by Lavoisier. He also discovered Sulfur dioxide and Ammonia

Humphry Davy

1800 Recognized as the discoverer of Chlorine.
He was a chemistry professor, who isolated elements by <u>electrolysis</u> – Potassium, Sodium, Magnesium, Calcium, Strontium, and Aluminum.
1829 Davy died from NO intoxication.

Jeremias Richter

1791Established <u>Stoichiochemistry</u> – the principle of constant chemical reactions.

Jeremias Benjamin Richter

1792 Published measurements on "equivalent weight" – how much acid is needed to neutralize a base.

Guillaume François Rouelle

1744 Acid with another materials make salts.

George Brandt

1730 Discovered Cobalt

Charles François de Cisternay Dufay

1730 Claims that every material, other than metals and hard precious stones, can show phosphorescence.

Thomas Melvill

1752 Finds that when metal salts are placed in a flame, the emitted spectra is metal specific.

Noble gases

(later edited by **James Clerk Maxwell**)

Jacob Berzelius 1779-1848

A Swedish chemist, pioneered electrochemistry.

1828 First table of the weights of 28 atoms. Annotated elements by the first letter of the name.

Axel Fredric Cronstedt

1751 Discovered Nickel.

Joseph Louis Proust

1799 The law of constant ratios of elements in their reactions, concluded from binding of Copper Carbon and Oxygen to Copper Carbonate in different reactions.

Eli Whitney

1794 Register a patent for producing Gin from cotton.

Peter Jacob Hjelm

1782 Discovery of Molybdenum

SUMMARY: Within half a century, a large number of elements were isolated and identified. This is facilitated by the availability of batteries as stable electric sources for electrolysis of solutions, increasing range of acids and bases, and controlled heating of compounds in defined gas atmosphere to activate chemical reactions.

GASES
and
THEMODYNAMICS

Daniel Gabriel Fahrenheit 1686–1736

1709 Builds an alcohol thermometer. 5 years later he built Mercury thermometer.

Anders Celsius 1701–1744

1742 Defined the Celsius temperature scale: 0: Ice melts 100: water boils.

Georg Ernst Stahl 1659-1734

1723 Supported vitalism, popularized Phlogiston theory and **Johann Becher**'s ideas. Aggregates of wrong theories…

Hermann Boerhaave 1668-1738

1724 Proposed that heat is a kind of liquid.

Johann Juncker 1679-1759

1730 Writes a book that systematically extends the Phlogiston theory

George Martine 1702-1741

1939Notes that the volume of bodies is not proportional to the heat it contains.

Mikhail Vasilievich Lomonossov 1711-1765

1744 Publishes a paper about the reason for heat and cold: heat is a kind of motion.

1748 Formulated the laws of energy and mass conservations.

William Cullen's 1710-1790

1756Described cooling when vapor condenses to a liquid. Latent heat in phase transitions.

Daniel Rutherford (Black's student) 1749-1819

1772 Describes Nitrogen – “Air residue” or “Air without Phlogiston.

Johan Carl Wilcke 1732-1796

1772 Measured latent heat of ice melting.

1781 Specific heat

John Smeaton 1724-1792

1776 A paper about experiments related to power output, work energy, momentum, and kinetic energy: confirmed conservation of energy.

Jacques-Alexandre Charles 1746-1843

1787 Proposes “Charles’ law” that complements Boyle’s law: the proportionality of volume and temperature. He found that different gases expansion with temperature changes are equal.

1802 Charles’ law published by **Gay Lussac**, and derived the existence of absolute zero.

Pierre Prévost 1751-1839

1791 Cold is lack of heat. All bodies emit radiation. No emission only at equilibrium with environment temperature.

Thomas Wedgwood 1771-1805

1792 Was a photographer. Noted that different metals become red upon heating to the same temperature.

Richard Kirwan 1733-1812

1791 Past supporter of Phlogiston theory admits it should be aborted facing experimental evidence.

Count Rumford (Benjamin Thompson) 1753-1814

1798 Measured heat produced by drilling cannon bores – heat is created from kinetic energy – work generated by friction. Proposed to reject the caloric theory since heating does not add to body's weight.

Humphrey Davy 1778-1829

1799 Rubbing ice demonstrates transformation of work to heat: A body can generate unlimited amount of heat, conflicting Lavoisier's caloric theory. Concludes that heat is motion, as Newton claimed.

Guillaume Amontons 1663-1705

1702 Suggests the idea of absolute zero from the gas laws: pressure is proportional to temperature, and it must be positive, there is a lower limit to temperature.

John Dalton 1766-1844

A chemist and meteorologist.

1803 Elementary atoms are characterized by weight –

<u>The atomic theory</u>

All materials are made of atoms. Atoms cannot be created or destroyed. All atoms of the same element are equal, and Different elements consist of different atoms.

During chemical reactions atoms rearrange, and compounds are created from association of the atoms they consist of.

1808 A table of 20 elements

Expansion coefficient of gases.

Measured air pressure as a function of heights of mountains in Scotland.

Dalton law of partial pressures $p=S\ p_i$

STEAM ENGINES

Thomas Newcomen 1664-1729

1712 Newcomen builds a steam engine with pistons

James Watt 1736-1819

A Scottish engineer who built with **Matthew Boulton** the first steam engine.
1765 Watt's steam engine is 6 times more efficient than Newcomen's.
Built with **Humphry Davy** gas-breathing device.
1769 Registered a patent on the steam engine with a separate condenser and air pump to supply steam to the piston. He included security control- if the engine runs too fast, there is an automatic reduced energy supply. Named "horse power" to the unit for work per time.
1782 The first steam engine is built

One should note that generation of motion by steam power was in use in the ancient world. E.g. Nero Caesar used this technology to activate temples gates.

Lazare Nicolas Marguerite Carnot 1753 –1823

1783Defined optimal abstract conditions to the action of real engines. Engine is a mediator between two reservoirs that are not directly operating on each other.
1784See 19th century

Claude de Jouffroy 1751-1832

1776 Steam boat

BIOLOGY

and

MEDICINE

Maria Sibylla Merian 1647-1717

~1680 Life cycle for plants and insects

Hermann Boerhaave 1668-1738

1708 Recommended Hippocrates‘ instructions for bedside behavior. Applied autopsies to uncover link between symptoms and injuries. Copley medal1739.

Stephen Hales 1677-1761

1727 Investigates water rise in plants based on physical laws – Plant physiology

1733 Was the first to measure blood pressure as a diagnostic tool

Thomas Fairchild 1667-1729

1715 A gardener who collaborated with Linnaeus. Studied sex in plants. Created the first artificial hybrid mule.

Louis Joblot 1645-1743

1718 Proves that microorganisms in rich medium come from the air, confirming Leuwenhoek’s conclusion denying spontaneous creation of life.

Mary Wortley Montagu 1689-1762

1718 As the wife of the British ambassador to Turkey she studied Turkish habits, especially of women, and discovered their smallpox (variola) inoculation (variolation) to children. The procedure introduced small amount of material from a sick person to a scratch in the skin, to activate his immune system against the variola, and caused mild form of the disease. She inoculated her children. Upon returning to England she promoted this procedure against the 1721 burst of the smallpox epidemics. To prove efficiency 7 death sentenced prisoners volunteered to be inoculated, and all survived infection and set free, yet the procedure was not accepted as safe. When later **Edward Jenner**, developed the much safer technique of vaccination using cowpox instead of smallpox it became an established procedure. The world effort to diminish smallpox inoculated people at the last pocket of the epidemics in Bangladesh in the 70th.

Pierre Fauchard 1678-1761

1728 A physician and a surgeon promoting methods for mouth and teeth care, and the name "dentist"

David Hume 1711-1776

1734 A Scottish philosopher who proposed that the brain accumulated memories and the relations between them.

Pierre Louis Maupertius 1698-1759

1745 Proposed the idea of comparing siblings from common parents, and believed that body organs are collected in the sex lymph from parents organs. Hereditary characteristics result from change of body fluids or the environment. Although wrong, this was the beginning of genetic principles in proliferation.
1755 Many new combinations of species in nature are destroyed, and only few that adapt to the environment survive.

Georges-Louis Leclerc Comte_de_Buffon 1707–1788

A naturalist and geologist, whose work influenced Lamarck and Cuvier development of ideas about common origin of life species. He was a mathematician (probabilities) and a cosmologist. He directed the king's gardens in Paris, now the museum and gardens "Jardin des Plantes". He believed in catastrophism as a geological theory of evolution of earth: the flood, volcanoes, and glaciers shape the land as we see today.
1755 Proposed that species are affected by the environment, and the changes are preserved by heredity. His 44 volumes encyclopedia "The History of Nature" began publishing at **1749** and was thoroughly studied by Darwin.

Jean-Baptiste Lamarck 1744-1829

Believed in gradual evolution of life forms. See 19^{th} century.

Mark Catesby 1683-1749

During a travel to south America he painted animals and plants in their natural habitat.

Xavier Bichat 1771-1802

Was a physician in “Hótel Dieu” hospital in Paris (next to the Notre Dame). Studied histology of tissues.

Johann Friedrich Blumenbach 1752-1840

Studied anatomy in Göttingen. Started anthropology - sorting of races by their skull structure. His skull collection was called “Dr.B’s Golgotha”.

Fanny Burney, Madame D’arblay 1752-1840

A Feminist and writer. Promoted Caroline Herschel’s membership in the Royal Academy after she discovered comets.

1811 After she was diagnosed for breast cancer she went through mastectomy without anesthesia, survived the surgery and wrote about her experience.

Charles Bonnet 1720-1793

1745 Demonstrated recovery of amputated limbs in warms.

1746 Discovered that Aphids are parthenogenic – reproduce without fertilization.

Étienne Bonnot de Condillac 1714-1780

1746 All knowledge is acquired by senses. There are no ideas generated “internally”.

Julien Offray de la Mettrie 1709-1751

1747 Thoughts are property of organized material. Man is a machine.

Bernard Siegfried Albinus 1697-1770 & Jan Wandelaar 1690-1759

1747 A physician and an artist who worked together drawing human skeletons and muscles.

René Antoine Ferchault de Réaumur 1683-1757

1752 Showed that gastric juices digest meat.

James Lind 1716-1794

1752 In a controlled experiment demonstrated the value of fresh fruits to sailors nutrition, to prevent scurvy in long trips.

Caspar Friedrich Wolff 1733-1794

1759 Studied chick embryonic development, and described ordered generation of limbs: various limbs are generated from the same tissues.

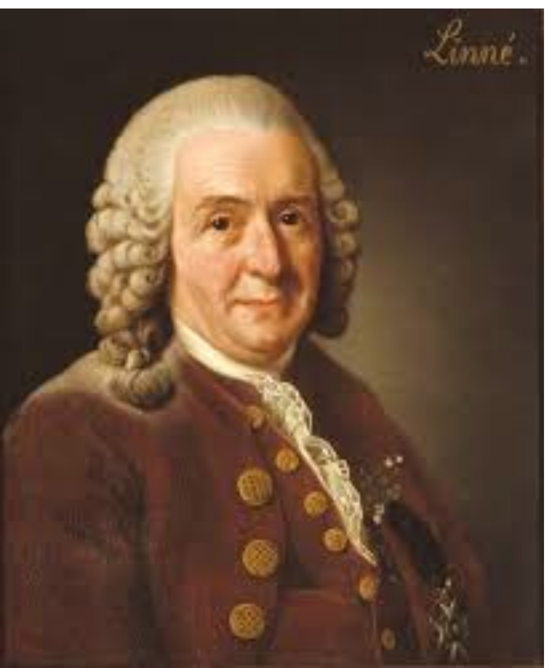
1767 New tissues do not develop in the chick embryo from already existing tissues.

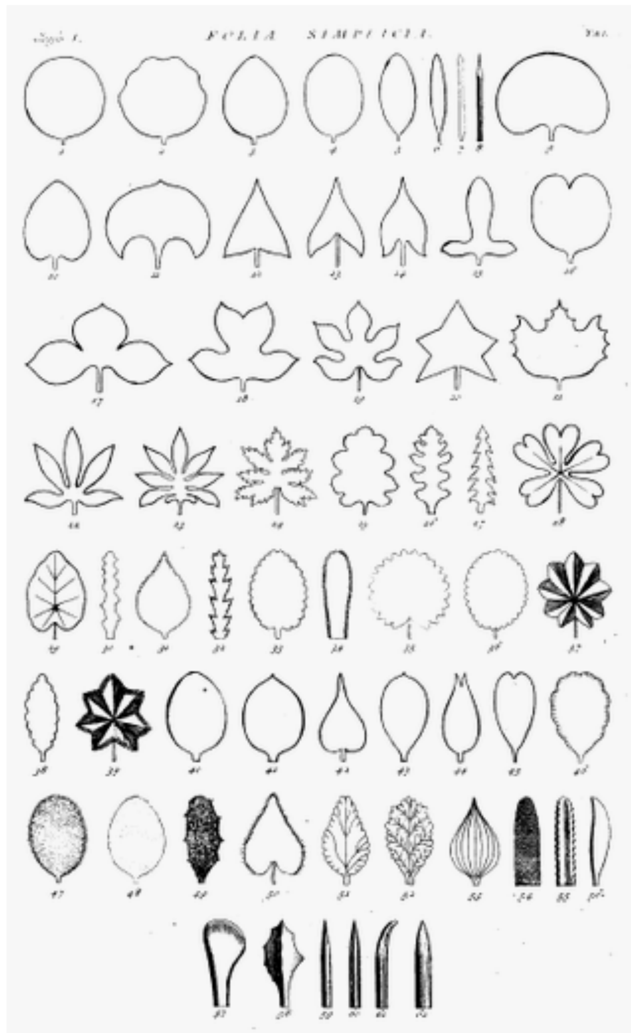
Carl Linné – Carl Linnaeus 1707-1778

Swedish botanist, who established the binomial taxonomy system for sorting animals and mainly plants.

1753 published a book with plants classification according to shape and properties.

Had seminal influence on English plant researchers in the coming centuries.





Bernhard Siegfried Albinus 1697-1770 & Jan de Wandelaar 1690-1759

1753 Studied bone anatomy and published drawings.

Giovanni Battista Morgagni 1682-1771

1761 A book recommending to know internal organs to understand diseases.

Joseph Gottlieb Kölreuter 1733-1806

1766 Published 136 experiments of controlled hybridization and concludes that heredity is quantitative.

Marcus Antonius Plenciz 1705-1786

1762 Living agents cause infectious diseases: Germ theory.

Joseph Priestley 1733–1804

1771 Plants create a gas that animals and fire consume: Oxygen

Otto Frederik Müller 1730-1784

1773 Recognized two bacterial species: Bacillus and Spirolum.

Lazzaro Spallanzani 1729-1799

1768 Confirmed Joblot's findings that microorganisms cannot be generated spontaneously: Heated rich medium to kill all existing organisms, then cooled in sealed bottle. Concluded they are dispersed in the air.
Nevertheless, the belief in spontaneous generation survived till **Pasteur**, 1862.
The criticism on his experiment was that heat destroyed "vital power" needed for spontaneous generation.
1765 Showed that mammal fertilization require contact between the sperm and the ovum. Demonstrated artificial insemination of frogs and dogs.
Showed recovery of Salamander amputated limbs.
Navigated bats at total darkness with sound waves.
1783 Digestion is not just a mechanical crashing of the food, but a chemical processing by stomach juices.
1799 Died from prostate cancer, in Pavia. His prostate was taken out during autopsy, and is on display in formalin jar till today.

Denis Diderot 1713-1784

1769 Studied animals fertilization, mutations, eugenetics (controlled proliferation in order to obtain better species).
Studied the body mechanical systems and the nervous system.

Johann Friedrich Blumenbach 1752-1840

1775 initiator of physical anthropology

Jan Ingelhousz

1779 Show that plants assimilate CO_2 and need light to emit Oxygen.

William Withering

1785First report on treating ascites (liquid accumulation in the body) by digitalis (from foxglove plants)

1788, Jean Senebier

1788Demonstrated that photosynthesis need sunlight, not heat.

James Burnett Monboddo

1773-6 Three publications about the source and evolution of language. Calls to teach Ourang-Outangs to speak.

Franz Anton Mesmer

1774 Initiated experiments in hypnosis: “animal magnetism”, which he considered a liquid. Demonstrated success in treatment of psychosomatic diseases. Some of his methods were taken from exorcists (bad spirits expelling).

Johann Wolfgang von Goethe 1749-1832

Yes, the author of “Faust” and “Werther” and the poet was also a Scientist, and had strong influence on impressionist painters.

1790 Searches for the primary plant. Name the term “morphology“

1791 Published a book in optics, with (wrong) theory of light colors. Rejected Newton’s reductionism, and support personalization.

Franz Joseph Gall 1758-1828

1791 Described the nervous system as a series of ganglions that relate to each other.

Erasmus Darwin, (Charles' grandfather) **1731-1802**

1794 Proposed that hot-blooded animals have common origin, and pass on their properties by heredity. Struggle between males improves the specie.

Antoine Laurent de Jussieu 1748-1836

1789 Importance of organisms inside arrangement.

Emmanuel Kant 1724-1804

1781 Brain purpose is to generate sensible data based on intuition. Philosophy moves from existence characteristics to information.

1786Theory of uniformity and exchangeability of forces.

1790Analogies in animal shapes must originate from common source.

Percivall Pott 1714-1788

A surgeon. Father of orthopedics. Indicates that cancer is caused by carcinogens.

Luigi Galvani   1737-1798

1791A physician. Showed that electric shock makes a dead frog leg jerk. Deduces that nerves conduct electricity.

Edward Jenner 1749-1823

1796 A villege doctor, who invented the smallpox vaccine by placing cowpox on a skin scratch. His study was initiated by rumors that milk girls are not infected by smallpox, and that people that were once sick never get the disease again. Inoculation was known at the end of the 18th century in Turkey, by touching skin scratches with mild forms of smallpox, inducing a mild form of the disease that prevented infection later. But the import this method to England by 1721 by the wife of the English ambassador to Turkey **Mary Wortley Montagu** was not accepted.

Jenner wrote papers about bird migration and cuckoo singing.

Baron Georges Cuvier 1769-1832

A zoologist and comparative anatomist. Wrote 22 volumes about fishes.

1796 Establishes extinction of species in nature. See 19th century.

Frederick Wilhelm Joseph von Schelling 1775-1854

1797 The difference between physical and mental forces is only in their intensity. Nature binds to brain, and knowledge merges into the brain material.

Thomas Robert Malthus 1766-1834

1798 Population growth is exponential, but production of resources grows arithmetically.

ASTRONOMY
and
EARTH SCIENCES

Edmond Halley 1656-1742

1705 In a conference claimed that the comet seen at 1682 is the same comet seen earlier at 1531 and 1607, and it will appear again in 1758.
1718 Stars changed their positions since Ptolemy reported them in the “Almagest”.

Jean (Johann) Bernoulli 1667-1748

1710 Noted that Newton did not prove Kepler’s law for ellipses, but the inverse. Therefore he developed the “necessary and sufficient” proof using differential and integral calculus.
1742 Proved that orbits of bodies attracted by forces following inverse square distance dependence are cone sections.

George Berkeley 1685-1753

1710 Challenged Newton’s “absolute space”: physical properties are perceived relative to the observer.

John Flamsteed 1646-1719

1725 Published a 3000 stars “Catalogus Britanicus“

George Graham 1674-1751 & Anders Celcius 1701-1744

1727 Both independently reported that sun eruptions cause magnetic storms.

John Harrison 1693-1776

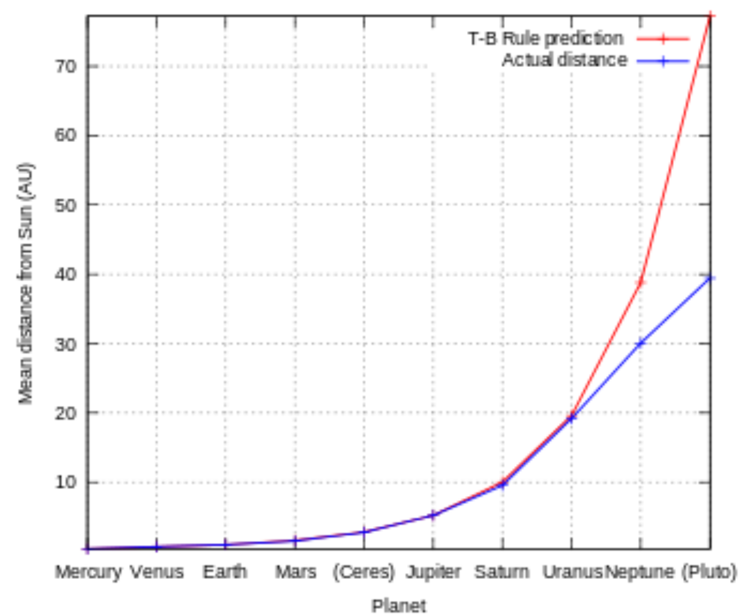
1736 Built and tested the first marine chronometer to determine latitude. This was an important contribution for the institutionalization of transatlantic marine lines that supplied raw materials, an enabling component of the industrial revolution.
1757 Perfected his chronometer with bimetal couple that compensated pendulum moment change with temperature, and with ball bearing frictionless axels.

Pierre Louis Moreau de Maupertius 1698-1759

1742 Nebula look like empty ellipses.

Johann Daniel Titius 1729-1796

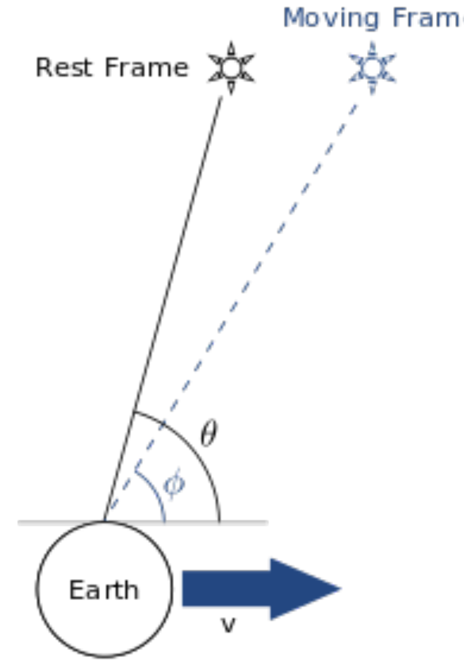
1766 Proposed the law of planets orbit distance from the sun:
The major axis, a, a planets is twice that of its closer one,
or explicitly: $a=2^n x3+4$ $n=-\infty,0,1,2,\ldots$



Johann Elert Bode 1747-1826

Published **Titius-Bode law**
The diversion from the law for the far planets made scientist understand this is an accidental fit and has no underlying astronomical significance…

James Bradley 1693-1762



1728 Discovered the nutation of earth rotational axis
1748 Explains the drift by the moon attraction.
Bradley also discovered aberration of light due to earth motion in speed v, causing a star to shift its apparent position towards the motion.

$\text{Tan}(\theta) = u_y/(u_x+v) = \sin(\theta)/[\, v/c + \cos(\theta)\,]$
For $\theta=90^o$ the angular aberration is: $\text{Tan}(\theta-\phi)=v/c$
and since $v/c<<1$: $\theta-\phi=v/c$

Thomas Wright 1711-1786

1750 Describes the milky way as a disk where all stars move at one plane and in the same rotational direction (as the planets around the sun). Nebulas are small clusters of stars, <u>some may be out of the milky way.</u>

Nicolas Louis de Lacaille 1713-1762

1754 Returned from 4 years of telescope scanning of stars at the cape of good hope, and added 2000 new stars seen from the southern hemisphere to the star catalogue.

Immanuel Kant 1724-1804

1755 Chaos converts into form at sites where attraction between particles is strong, forming stars. He believed that all stars eventually get populated…

Johann Tobias Mayer 1723-1762

1755 Composed tables for moon positions at 12 hours intervals for navigation purpose.

Mikhail Vasilevich Lomonsov 1711-1765

1759 Earth today is a result of slow erosion and rising of earth crust layers

1761 Discovered Venus atmosphere.

Alexis Claude Clairaut 1713-1765

1758 Haley‘s comet orbit motion is due to unknown forces

1759 Haley‘s comet returns – confirm Newton‘s mechanics and gravitation.

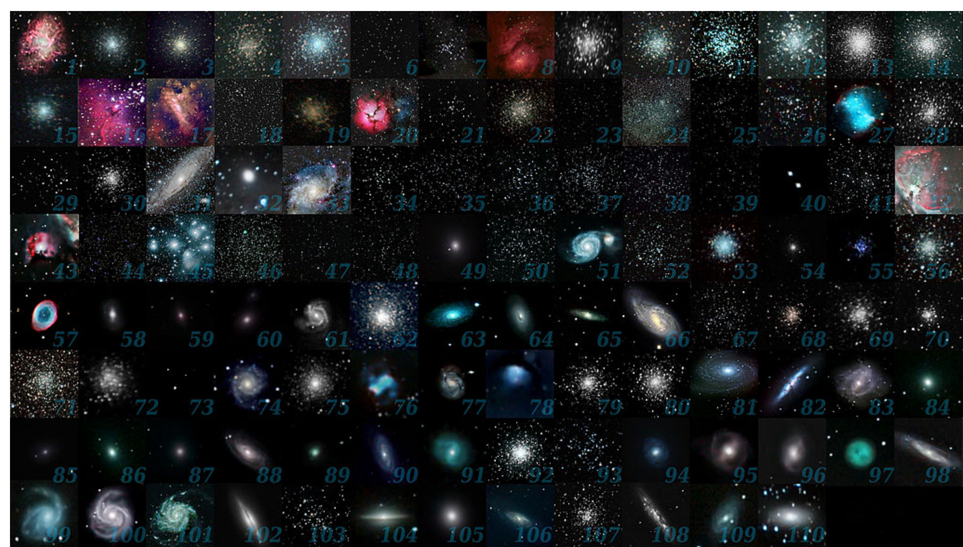
Johann Heinrich Lambert 1728-1777, Thomas Wright 1711-1786 & Immanuel Kant 1724-1804

1761 Independently conclude that the universe is organized in galaxy, as is the milky way.

Charles Messier 1730-1817

1771 Published a catalogue of heavenly objects defined today as galaxies, star clusters and nebulae.

In the montage: All Messier objects assembled by an amateur.



Frederick William Herschel 1738-1822

Built the best telescopes of his time.

1781 Discovered Uranus and measured his orbit: the first planet unknown at the ancient world. Uranus was seen before at different places and marked as different stars. He first thought it is a comet, but **Anders Johann Lexell** concluded it is a planet since the orbit radius matched **Bode's law.**

This law predicted a planet in a "missing" radius of a planet between Mars and Jupiter. 1801 **Giuseppe Piazzi** discovered small "Ceres" that fits this radius. **Heinrich Olbers** discovered soon later "Pallas" in the same orbit, then "Juno" and "Vesta" which made **Herschel** distinct them from other planets and term them "Asteroids".

1787 Discovered two largest moons of Uranus, and two years later two additional moons of Saturn Mimes & Enceladus. Previously, 1655 Huygens discovered Titan and 1671-1684 Cassini discovered Tethys, Dione, Rhea and Lapetus (called by him the "Sidera Lodoicea"). These findings of moons rotating about other moons fed into the possible universe models.

John Goodricke 1764-1786

1784 Identified the first variable star: Delta Cephei,

John Michell 1724-1793

1783 Noted that star of sufficiently large mass creates such intense gravitational field that prevents light emitted from it to escape: "black hole".

Designed the torsion balance used by Cavendish to measure the gravitational constant and the weight of earth.

SUMMARY: MODELS OF THE SKY IN HISTORY

The Solar System

Antiquity: Stars are fixed in the sky dome, the sun, moon, and 5 planets have their own domes, rotating around earth: geocentric model.
Copernicus: Heliocentric model.
Galileo: discovered planets of Jupiter – supporting earth as a planet.
Telescope Astronomers: discover more planets, and their moons.
The Asteroid belt: a new feature of objects circling around the sun. By 1857 a flood of new asteroids.
Small diversions in Uranus orbit lead to discover Neptune: 1864 recognize 12 planets, 1930 diversions in Neptune's orbit lead to discover Pluto.

The Universe

The milky way: a dense region of the sky
Supernova explosions in the sky: the "sky dome" is not static.
With better telescopes: some "stars" resolve elliptic shapes at different angles: galaxies.
With better triangulation and parallax: galaxies are out of the milky way.

Pierre-Simon Laplace 1749-1827

1796 Kant-Laplace theory : the sun was created from turbulent of gas clouds attracted to the center of gravity. More distant masses balanced by centripetal forces condensed into rotating planets.

1799 Laplace started publications of 6 volumes about the planets, their moons, and ocean tides.

Sir George Howard Darwin 1845-1912

The son of Charles Darwin.

1884 The frictional effect on tides, and on slow down of earth rotation. Monumental analysis based on **Laplace** and **Lord Kelvin** method.

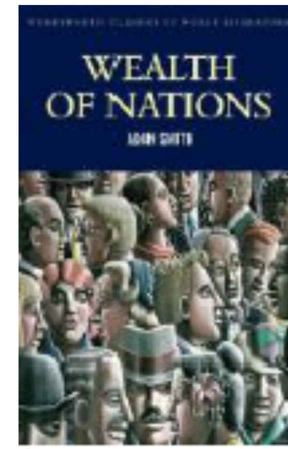
<u>GEOGRAPHY – the area of discoveries</u>

John Hadley & **Thomas Godfrey**

1731 Independently built in England and in Philadelphia the Sextant, to measure precisely angles between two objects. Rotatable mirrors and half reflecting prisms make them overlap through the observer's telescope, who can read the angle between them on the sextant scale.

PHILOSOPHY and SOCIAL POLITICS

Immanuel Kant 1724-1804 Separation of religion from science and reason.
David Hume 1711-1776 Naturalism and Skeptics.
Adam Smith, 1723-1790 Political economy. Considered the father of capitalism: the wealth of a nation is in the production capacity, that will be enhanced by the free market.

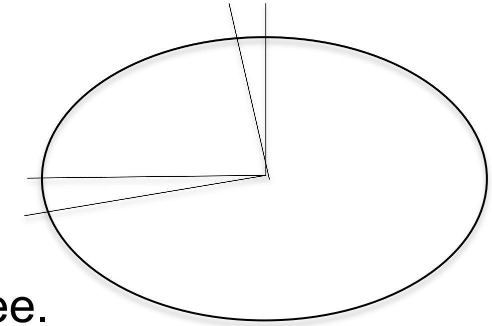


Adam Smith's book "Wealth of Nations"
is still a best seller 250 years after its first publication.
Today, many economists claim that the modern free market
is far from implementation of the original concept,
due to overwhelming economical power of large companies.

Voltaire (François-Marie Arouet) 1694-1778 Enlightenment era philosopher.
1718 protector of civil rights, freedom of speech and freedom of religion.
Jeremy Bentham 1748-1832 English social and economic philosopher. Seeded welfare economics. "the greatest happiness of the greatest number is the foundation of morals and legislation". **1789** Reorganize semantics: contextual definition of words.

1787 Philosophers publish together a manifest about women's rights
1787 – The American constitution signed
1789 – The French revolution started

TERRESTRIAL
And
ASTRONOMICAL
MEASUREMENTS



1735 Delegations to Peru and Scandinavia by the French Royal Academy in order to measure earth perimeter and decide if a longitudinal degree is longer at the poles – confirming that earth is an oblate ellipsoid. The mission: measure star viewing angle at the moment Venus passes the sun from two places on earth at known separation distance, then calculate the length of 1 degree.
Charles Marie de La Condamine, a mathematician and soldier, and **Pierre Bouguer,** a hydrologist were sent to the Peruvian Andes on the equator. They also tried to measure the inclination of a builders plummet by mountain gravitational attraction.
1761 Nevil Maskelyne the watch builder concludes that the measurements failed. With **Joan Harrison** they tried to calculate earth weight from the inclination of a builders plummet by mountain gravitational attraction.
1769 Halley calculated that the next Venus passage over the sun will make it possible to calculate the distance to the sun. Delegations to several places on earth guaranteed that at least two delegations will not be interrupted by clouds: **Maskelyne** (St. Helena) **Guillaume le Gentil** (India) **Jean Chappe** (Siberia) and **Manson & Jeremiah Dixon (**were sent to Sumatra but due to storms reached only the cape of good hope).
Captain **James Cook** (Australia) measured the Venus passage and claims Australia to the British crown.
1769 Manson & Dixon conduct measurement of the length of longitude 1 degree. Due to their expertise, they were called to mark the border line between **William Penn & Lord Baltimore** colonies in America, Pennsylvania and Maryland. This “Manson Dixon” line became the separation line at the civil war between the states holding slaves in the south and the slave-free states at the north.

What is the significance in the length of 1 latitude degree at the equator ?

1. Scientists national pride (French academy vs. British Royal society).
2. A standing issue since Newton and Cassini claimed earth is a prolate ellipsoid.
3. Practical consequences affecting theories of creation of the earth.
4. Rotating earth rigidity and density in gravitation should account for shape.

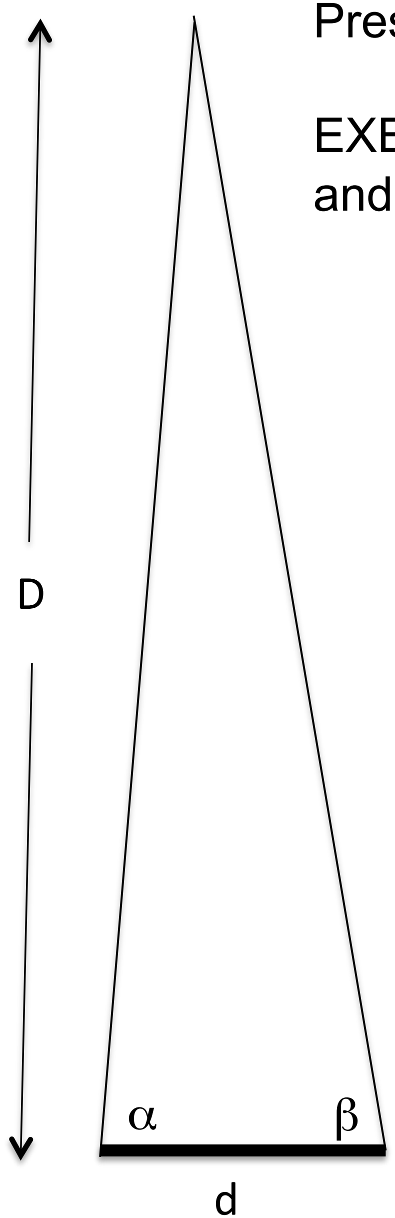
1774 Maskelyne & Charles Hutton the mathematician locate mount Schiehallion , a symmetric mountain over Loch Tay in Scotland to measure the inclination of a builders plummet by mountain gravitational attraction, where its mass could be evaluated from its shape. They invented <u>equi-altitude contour maps</u>. Assumed density of 2.5 gr/cm and calculated earth mass $5x10^{15}$ tons and from it the masses of the moon and the sun. REMINDER: Newton's gravitational laws eliminate planets mass from the equations of their orbital motion. We can measure g, the gravitational acceleration. $g=Gm_E/r$ thus we need to know earth mass and radius to eliminate G, the universal gravitation constant.

Joseph (Jérôme Lefrançois de) Lalande 1732-1807

1770 Calculated the distance to the sun as 150 million km.

Present value: 149,597,870,691 km

EXERCISE: find the error in D in terms of the errors in d,a,b and substitute realistic values.



Nevil Maskelyne 1761-1811

1766 Proposed longitude determination by moon locus, which he tabulated till his death.

Francis Beaufort 1774-1857

A sailor and explorer of sees and oceans (hydrographer).
Invented winds scale 1-12.

Jean-Pierre Balanchard 1753-1809

Crossed the Lamanche tunnel in a hot balloon. Founded a balloon flying school, Vauxhall, London.

Louis-Antoine de Bougainville 1729-1811

A Marine officer who landed in Tahiti a year before captain **James Cook**.

Mungo Park 1771-1806

Explorer of central Africa (Congo).

Erasmus Darwin 1731-1802

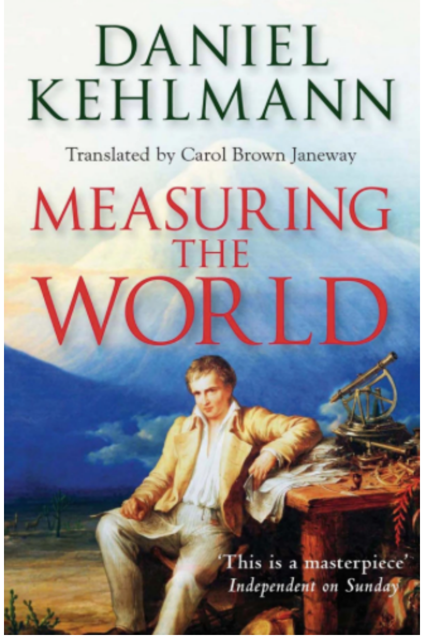
A physician and polymath who wrote “scientific poetry”.

Luke Howard 1772-1864

Investigated weather phenomena, and classified cloud forms and types.

Alexander von Humboldt 1769-1859

Came from a wealthy industrialist family. Botanist, zoologist, climate inspector, cosmologist and world traveller. Was a typical romantic-age scientist. Strived to measure the height of the highest mountain and climb on it, collected seeds and plants, “stole” skulls from Native American tribes for his collection.
His brother founded the Humboldt university in Berlin.



A fascinating book about Humboldt and Gauss,
two scientists of opposite characters,
both aspired to advance science by measurements,
one never left home, the other traveled unexplored worlds.

James Hutton 1726-1797

A physician and a geologist. Inspected rock layers and their erosion and sedimentation by rivers, to reject catastrophism and support the uniform principle (the changes that occurred to shape earth crust as seen today are due to long times geological processes we can see and study today). He prepared the ground to **Lyell** (deep time), **Herschel** (deep space) and **Darwin** (evolution).

He was considered the "father of modern geology".

1795 Supports the extreme old age of geological forms: the first extensive composition discussing earth geology. Hutton succeeded in lab experiments to simulate rock layer formation on the earth crust according to a proposal by **James Hall.**

Georges Louis Leclerc de Buffon 1707-1788

1744 Publicized that earth is 75,000 years old.

TECHNOLOGY

Cotton Mills

John Kay 1704-1779

1733 Patented the “flying shuttle“ in a weaving machine, to fast weave in the welf thread into the warp threads.
This technology allowed for automatic machine looms starting the industrial revolution.

1764, James Hargreaves

1764 Invented the “spinning jenny”, 8 spools spinning wheel that was improved later for the mechanized cloth industry.

FLIGHT
and
PARACHUTING

Atmospheric research was advanced by experiments on high mountains. Yet, flying was human's mind aspiration since antiquity (e.g. Icarus & Daedalus, Aladdin and the flying carpet). The 18th century enthusiastically experienced the development of flying balloons, specially in Paris, although they did not reach the heights of the Alps…
Attempts to fly progressed cautiously, first unmanned, then land-tied balloons, and with more confidence gained bold balloonists had accidents. First air was warmed on ground and the balloon released to tens of meters height. Later, Hydrogen-filled balloons reached thousands of meters, but readily exploded.
As commonly happened in history, balloons found their military uses (Napoleon)

Father Bartolomeu de Gusmão

1709 Builds a hot air balloon, which he demonstrated to John V king of Portugal.

Joseph Michel and Jacques Étienne Montgolfier (brothers)

1783 June 5, Launched unmanned balloon. Floating balloons are named Montgolfier.

Professor Jacques Alexandre César Charles and the brothers Roberts

1783 August 27, Unmanned Hydrogen balloon flown from Paris to 25 km distance. Frightened farmers destroyed it when it landed.

Montgolfier Brothers

1783 September 19, A show to king Louis XVI: launch a ship, a duck and a chick in a balloon to 500 meter height, and bring down alive.

October 15, Jean-François Pilâtre de Rozier 1754-1785 and Marquis d'Arlandes

1783 October 15, Launch together in a hot air tied balloon to 26 meters. First men to fly.

de Rozier and d'Arlandes

1783 November 21, First to fly for 25 minutes in untied balloon.

Charles and his assistant Robert

1783 December 1, First to fly Hydrogen-filled balloon. In 2nd flight reach 2,700 meters and come back 43 km from start position.

The balloon has a valve to release gas for descending, and a net engulfing the carry basket and the balloon.

Vincent Lunardi

1784 September 15, The Tuscan Italian who floated in England.

James Sadler 1753-1828

1784 October 4, The first English to build Hydrogen balloon and fly it.

Pilâtre de Rozier and Pierre Jules Romain

1785 June 15, The first flight accident during attempt to cross the Lamanche.

Jean-Pierre Blanchard and the American meteorologist John Jeffries

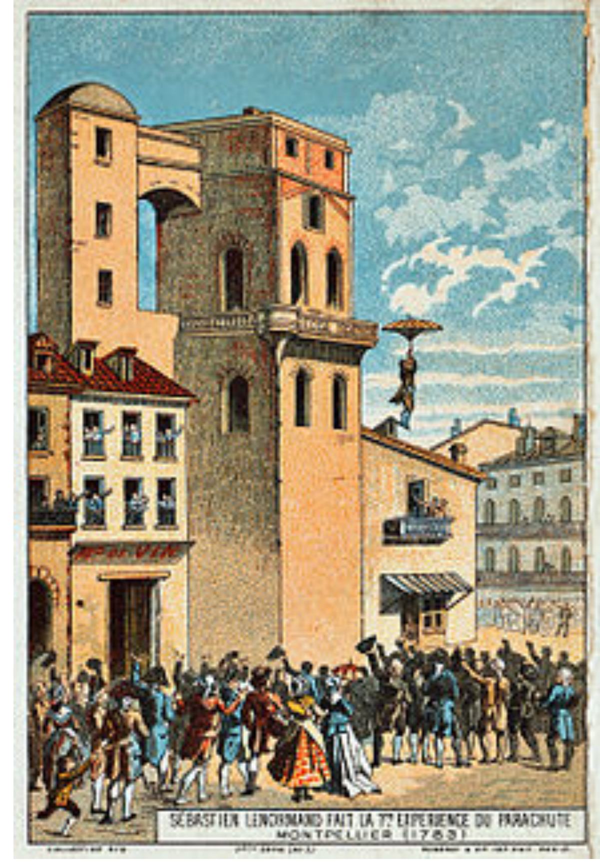
1785 July 1, Cross in a balloon the Lamanche from Dover castle To Guînes.

Richard Crosbie

Several failures trying to cross the Irish see in Hydrogen balloons

Claude Berthollet 1748-1822

A chemist and Lavoisier's colleague. The commander of Napoleon's flying balloon brigade, the first air force unit, founded 1794.



PARACHUTES

Sebastian Lenormand 1757-1837

1783 Jumped several times from the Montpelier observatory tower.

Dominikus Dufort

1777 A prisoner in St. Lewis, who jumped from a high Building with a parachute and won money.

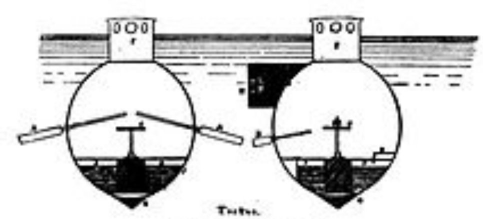
Jean Pierre Blanchard

1783 A parachuter

SUBMARINES

David Bushnell

1773 Designed and built the first submarine, “turtle” with manual Paddle propeller. Was employed (unsuccessfully) to attach explosives to British ships during the American independence war,



Turtle.

BUSHNELL'S SUBMARINE

A A. Oars. B. Rudder. C. Seat. D. Immersion tank. E. Pipe. F. Conning tower. G. Safety weight. H. Torpedo.

HISTORY OF AVIATION – Otto Lilienthal museum, Anklam, Germany

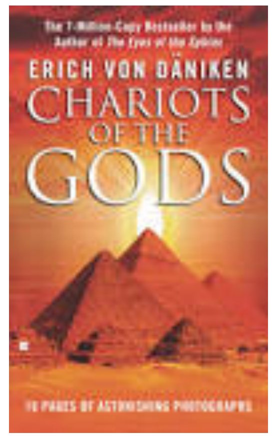
2300 BC King Etana rides an eagle over the ruins of Ninve

7500 BC The story about Icarus and Daedalus

400 BC Pigeon of the Greek mathematician Archytas of Tarant, (probably a kite)

220 BC Chinese use kites in land surveys to determine distances.

200 BC A story tells Alexander the great reach the end of the world riding a Griffin (A Lion with wings and eagle's head).



2nd - 5th centuries Nazca lines, drawn with stones on the Peruvian desert mesa: huge patterns of "Geogliphs", maybe sites of kite or gliders flying. Ignited the speculative "Chariots of the Gods" book of Erich von Däniken.

10th century The Pacific cultures use gliders-kites in religious ceremonies, and for military uses.

1247 Mongols use lighted kites in the battle of Liegntiz

1282 Marco Polo described manned kites/gliders.

1316-1390 Bishop Albert from Saxony proposed to float in air like ships float in water by Archimedes law.

During Medieval times flying capability was associated with saints and witches…

1486-1513 Theoretical and experimental research by **Leonardo da Vinci** on birds flight, air streaming and floatation. Drawings of a parachute, Helicopter & Ornitopter (flap wings).

1496 The Italian mathematician **Giambattista Danti** glides from a tower.

1500 Hieronymus Bosch painted "air ship" flying over a burning city (see painting in "Renaissance" presentation).

1558 Giambattista della Porta published guide and theoretical explanations for kite building.

1644 Evangelista Toricelli explains atmospheric air pressure, and creates vacuum.

1654 Otto von Guericke mayor of Magdeburg weighted air and demonstrated the force of vacuum holding two hemispheres against 16 horses: "Magdeburger Halbkugeln".

1670 The Jesuit **Francesco Lana de Terzi** described air ship carried by vacuumed balloons.

1678 The French locksmith **Besnier** fly in wing machine.

1680 Alphonso Borelli figured out that wing flapping with human muscles would not be able to lift a man.
1687 Newton, in the second edition of "Principia", derived the drift force by viscous liquid.
17th century – Kites become popular.
1709 Montgolfière fly men in balloons. **Lourenco de Gusmao** in Lisbon attempted to float.
1716 Emanuel Swedenborg in Sweden use kites and bird wings in a flight project.
1738 Daniel Bernoulli express energy conservation and connection to velocity and pressure in gases and liquids (Bernoulli's law).
1746 English military engineer **Benjamin Robins** built a device to measure drift.
1766 Cavendish determined the specific weight of Hydrogen.
1772 Abbé Desforges failed to fly in a basket and feather wings.
1777 Dominikus Dufort jumps with a parachute from a high building in St. Lewis
1781 Tiberiua Cavallo, an Italian scientist, living in England, fly soap bubbles filled with Oxygen.
1783 Sebastian Lenormand parachuted from the observatory tower in Montpelier.
Montgolfier brothers fly hot air balloons.
Prof. Charles and the Robert brothers fly Hydrogen balloon over Paris.
A few months later they float over Vivarais to 2.7 km height.
In Versailles animals are flown in hot Montgolfier tied to the ground.
Pilatre de Rozier and **Marquis d'Arlande** made the first untied balloon flight.
1784 Untied balloon rise to 4 km height.

1784 Jean Baptiste Meusnier initiate an air ship project with elongated balloon and man operated propeller.
1784 Robert and Colin Hullin used elongated balloon with oars to fly 186 km from Jardin des Thuileries, Paris.
1785 Jean-Pierre Blanchard and John Jeffries cross the Lamanche in hot air balloon, after Pilâtre de Rozier and Piére Romain attempt to cross the tunnel ended in a crash.
1793 Blanchard made the first balloon flight in America from Philadelphia to New Jersey, carrying a "Air Mail" letter… President Washington follows the operation.
1793 Military use of a balloon in a siege on Meintz.
1794 Air ship battalion in Napoleon's army.
1797 André-Jaques Garnerin parachuted from a balloon: "Official French aeronaot"
1799 Sir George Cayley draws a glider with steering wheel and lift wing.
1800 **Francisco Goya** painted men with bird wings driven by the arms.

APPENDIX:

Copley Medal of the British Royal Academy 18-th century

Copley medal is given by the Royal Academy of Sciences in London, in all fields of science, and is the oldest prize in the sciences. It was established by a donation of 100 sterling pounds by Sir Godfrey Copley to support experimental work. Additional contribution of 1666 sterling pounds was donated by his son in 1971. The interest funds today a silver medal and 5000 sterling pounds.
52 of the Copley medal laureates also received Nobel prize.
Only one woman received the price at 1976: Dorothy Hodgkin.

1731 **Stephen Gra**y "For his new Electrical Experiments: – as an encouragement to him for the readiness he has always shown in obliging the Society with his discoveries and improvements in this part of Natural Knowledge"

1732 **Stephen Gray** "For the Experiments he made for the year 1732"

1734 **John Theophilus Desaguliers** "In consideration of his several Experiments performed before the Society"

1736 **John Theophilus Desaguliers** "For his experiments made during the year"

1737 **John Belchier** "For his Experiment to show the property of a Diet of Madder Root in dyeing the Bones of living animals of a red color"

1738 **James Valoue** "For his invention of an Engine for driving the Piles to make a Foundation for the Bridge to be erected at Westminster, the Model whereof had been shown to the Society"

1739 **Stephen Hales** "For his Experiments towards the Discovery of Medicines for dissolving the Stone; and Preservatives for keeping Meat in long voyages at Sea"

1740 **Alexander Stuart** "For his Lectures on Muscular Motion. As a further addition for his services to the Society in the care and pains he has taken therein"

1741 **John Theophilus Desaguliers** "For his Experiments towards the discovery of the properties of Electricity. As an addition to his allowance (as Curator) for the present year."

1742 **Christopher Middleton** "For the communication of his Observations in the attempt of discovering a North-West passage to the East Indies through Hudson Bay"

1743 **Abraham Trembley** "For his Experiments on the Polypus" —

1744Henry Baker "For his curious Experiments relating to the Crystallization or Configuration of the minute particles of Saline Bodies dissolved in a menstruum"

1745 **William Watson** "On account of the surprising discoveries in the phenomena of Electricity, exhibited in his late Experiments"

1746 **Benjamin Robins** "On account of his curious Experiments for showing the resistance of the Air, and his rules for establishing his doctrine thereon for the motion of Projectiles"

1747 **Gowin Knight** "On account of several very curious Experiments exhibited by him, both with Natural and Artificial Magnets"

1748 **James Bradley** "On account of his very curious and wonderful discoveries in the apparent motion of the Fixed Stars, and the causes of such apparent motion"

1749 **John Harrison** "On account of those very curious Instruments, invented and made by him, for the exact mensuration of Time"

1750 **George Edwards** "On account of a very curious Book lately published by him, and intiyled, A Natural History of Birds, &c. – containing the Figures elegantly drawn, and illuminated in their proper colours, of 209 different Birds, and about 20 very rare Quadrupeds, Serpents, Fishes, and Insects."

1751 **John Canton** "On account of his communicating to the Society, and exhibiting before them, his curious method of making Artificial Magnets without the use of Natural ones"

1752 **John Pringle** "On account of his very curious and useful Experiments and Observations on Septic and Anti-septic Substances, communicated to the Society"
1753 **Benjamin Franklin** "On account of his curious Experiments and Observations on Electricity"
1754 **William Lewis** "For the many Experiments made by him on Platina, which tend to the discovery of the sophistication of gold: – which he would have entirely completed, but was obliged to put a stop to his further enquiries for want of materials"
1755 **John Huxham** "For his many useful Experiments on Antimony, of which an account had been read to the Society" [22]
1757 **Lord Charles Cavendish** "On account of his very curious and useful invention of making Thermometers, showing respectively the greatest degrees of heat and cold which have happened at any time during the absence of the observer" [14]
1758 **John Dollond** "On account of his curious Experiments and Discoveries concerning the different refrangibility of the Rays of Light, communicated to the Society"
1759 **John Smeaton** "On account of his curious Experiments concerning Water-wheels and Wind-mill Sails, communicated to the Society. For his experimental enquiry concerning the powers of water and wind in the moving of Mills" [24]
1760 **Benjamin Wilson** "For his many curious Experiments in Electricity, communicated to the Society within the year"

1764 **John Canton** "For his very ingenious and elegant Experiments in the Air Pump and Condensing Engine, to prove the Compressibility of Water, and some other Fluids"

1766 **William Brownrigg** "For an experimental enquiry into the Mineral Elastic Spirit, or Air, contained in Spa-Water; as well as into the Mephitic qualities of this Spirit."

Edward Delaval "For his Experiments and Observations on the agreement between the specific gravities of the several Metals, and their colours when united to glass, as well as those of their other preparations."

Henry Cavendish "For his Paper communicated this present year, containing his Experiments relating to Fixed Air."

1767 **John Ellis** "For his Papers of the year 1767, On the animal nature of the Genus of Zoophytes called Corallina, and the Actinia Sociata, or Clustered Animal Flower, lately found on the sea coasts of the new-ceded Islands"

1768 **Peter Woulfe** "For his Experiments on the Distillation of Acids, Volatile Alkalies, and other substances"

1769 **William Hewson** "For his Two Papers, entitled, An Account of the Lymphatic System in Amphibious Animals, – and An Account of the Lymphatic System in Fish"

1770 **William Hamilton** "For his Paper, entitled, An Account of a Journey to Mount Etna"

1771 **Matthew Raper** "For his paper entitled, An Enquiry into the value of ancient Greek and Roman Money"—

1772 Joseph Priestley "On account of the many curious and useful Experiments contained in his observations"

1773 **John Walsh** "For his Paper on the Torpedo"

1775 **Nevil Maskelyne** "In consideration of his curious and laborious Observations on the Attraction of Mountains, made in Scotland, – on Schehallien"

1776 **James Cook** "For his Paper, giving an account of the method he had taken to preserve the health of the crew of H.M. Ship the Resolution, during her late voyage round the world. Whose communication to the Society was of such importance to the public"

1777 **John Mudge** "On account of his valuable Paper containing directions for making the best Composition for the metals of Reflecting Telescopes; together with a description of the process for grinding, polishing, and giving the best speculum the true parabolic form"

1778 **Charles Hutton** "For his paper, entitled, The force of Fired Gunpowder, and the initial velocity of Cannon Balls, determined by Experiments"

1780 **Samuel Vince** "For his paper, entitled, An investigation of the Principles of Progressive and Rotatory Motion, printed in the Philosophical Transactions"

1781 **William Herschel** "For the Communication of his Discovery of a new and singular Star; a discovery which does him particular honour, as, in all probability, this star has been for many years, perhaps ages, within the bounds of astronomic vision, and yet till now, eluded the most diligent researches of other observers"

1782 **Richard Kirwan** "As a reward for the merit of his labours in the science of Chemistry. For his chemical analyses of Salts"

1783 **John Goodricke and Thomas Hutchins** "For his discovery of the Period of the Variation of Light in the Star Algol. (Goodricke)"

"For his Experiments to ascertain the point of Mercurial Congelation. (Hutchins)"

1784 **Edward Waring** "For his Mathematical Communications to the Society. For his Paper On the Summation of Series, whose general term is a determinate function of z the distance from the first term of the series"

1785 **William Roy** "For his Measurement of a Base on Hounslow Heath"

1787 **John Hunter** "For his three Papers, – On the Ovaria, On the identity of the dog, wolf, and jackall species, and On the anatomy of Whales, printed in the Philosophical Transactions for 1787"

1788 **Charles Blagden** "For his two Papers on Congelation, printed in the last (78th) volume of the Philosophical transactions"

1789 **William Morgan** "For his two Papers on the values of Reversions and Survivorships, printed in the two last volumes of the Philosophical Transactions"

1791 **James Rennell** "For his Paper on the Rate of Travelling as performed by Camels, printed in the last (81st) volume of the Philosophical Transactions."

Jean-André Deluc "For his Improvements in Hygrometry."

1792 **Benjamin Thompson** "For his various Papers on the Properties and Communication of Heat"

1794 **Alessandro Volta** "For his several Communications explanatory of certain Experiments published by Professor Galvani"

1795 **Jesse Ramsden** "For his various inventions and improvements in the construction of the Instruments for the Trigonometrical measurements carried on by the late Major General Roy, and by Lieut. Col. Williams and his associates"

1796 **George Atwood** "For his Paper on the construction and analysis of geometrical propositions determining the positions assumed by homogeneal bodies which float freely, and at rest; and also determining the Stability of Ships and other floating bodies"

1798 **George Shuckburgh-Evelyn** "For his various Communications printed in the Philosophical Transactions."

Charles Hatchett "For his Chemical Communications printed in the Philosophical Transactions."

1799 **John Hellins** "For his improved Solution of a problem in Physical Astronomy, &c. printed in the Philosophical Transactions for the year 1798; and his other Mathematical Papers"

APPENDIX:

LIST OF SCIENTISTS
THE AGE OF ENLIGHTENMENT

Bolzano Bernard 1781 –1848 math, astronomer, optics
Daniel Bernoulli
Bralkenridge
La Condamine
Bayes
Deparcieux
Castillon
Cramer
Fontaine des Bertins
Senger
Chôtelet
Vincenzo Riccati
Euler
Buffon
Robins
Johann (II) Bernoulli
Simpson
Boscvich
Samuel König
Clairaut
Alexander Wilson
Giovanni Fagano

Stewart
d‘Alembert
Angesi
Landen
Kaestner
Tobias Mayer
Aepinus
Montucla
Frisi
Lambert
Bourgaiville
Bézout
Bossut
Maseres
Malfatti
Ajima
Maskelyne
Borda
Dionis
Waring
Vandermonde

Ramsden
Lagrange
Coulomb
Bring
Tetens
Hutton
Klügel
Lexell
Hindenburg
John Wilson
Condorcet
Johann (II) Bernulli
Cunha
Wessel
Atwood
Monge
Trail
Aida
Playfair
Tinseau

Laplace
Delambre
Caroline Herschel
Lhuilier
Marcheroni
Glenie
Legendre
Carnot
Troughton
Vega
Fuss
Parseval
de Prony
West
Arbogast
Bernullli-Jacob(II)
Kramp
Budan de Boislaurent
Ivory
Lacroix
Ruffini

Pierre Girard
Pfaff
Osipovsky
Leslie
Fourier
Francais Francais
Argand
Servois
Wallace
Hachette
Puissant
Gergonne
Reynaud
Bowditch
Woodhouse
Francoeur
Biot
Ampére
Frakas Bolyai
Jacques Francais
Malus

c