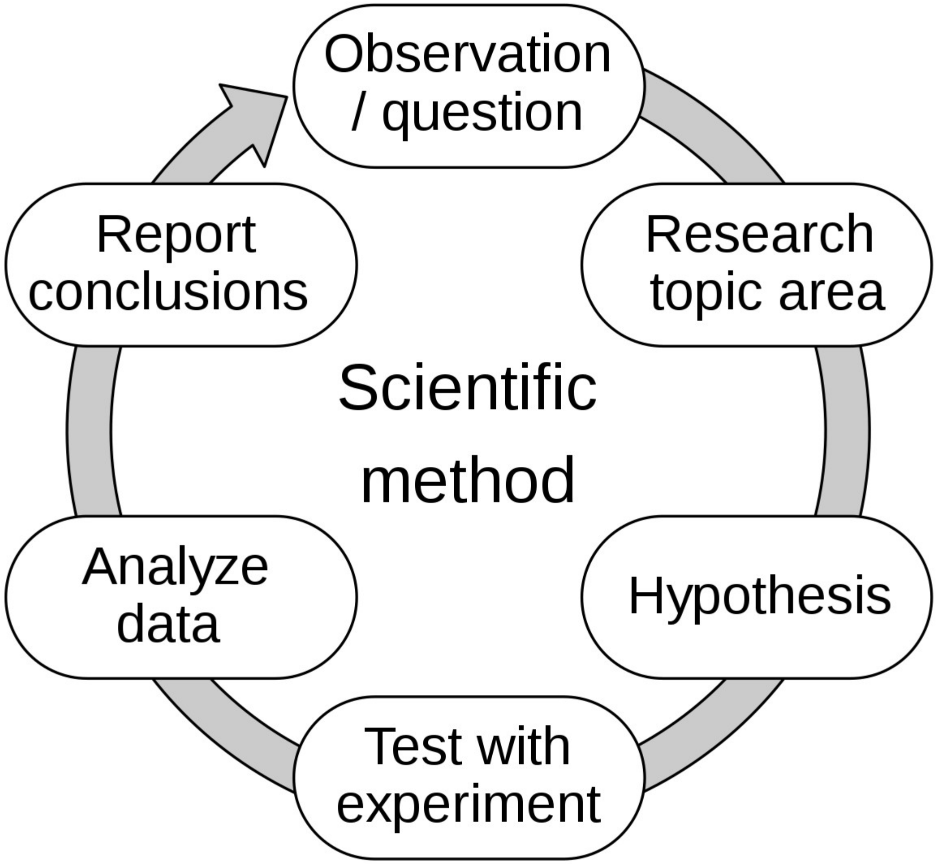
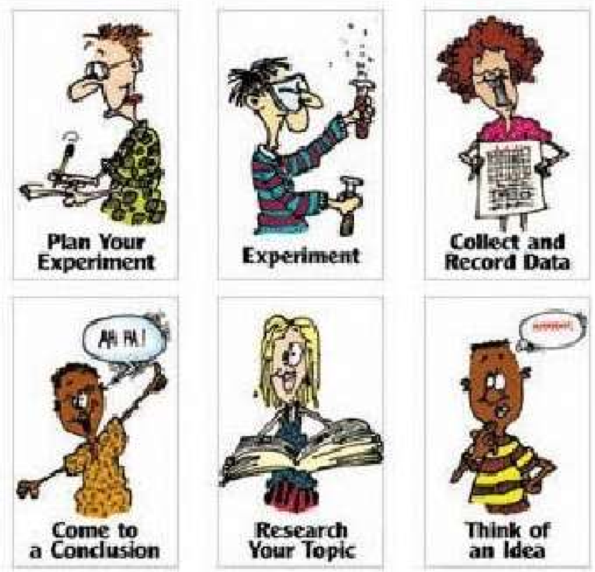
Experimental method


Observation / question
Research topic area
Hypothesis
Test with experiment
Analyze data
Report conclusions
Scientific method


Plan Your Experiment
Experiment
Collect and Record Data
AH HA!
Come to a Conclusion
Research Your Topic
Think of an Idea

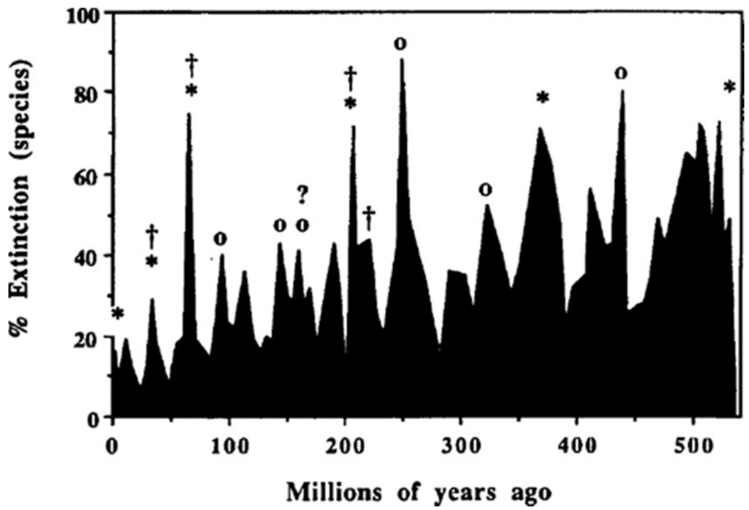
Extinction of species by periodic comet showers

Nature 308 (1984) 715-717

Marc Davis
(UC, Berkeley, Astron. Dept. and UC, Berkeley),

Piet Hut
(Princeton, Inst. Advanced Study),

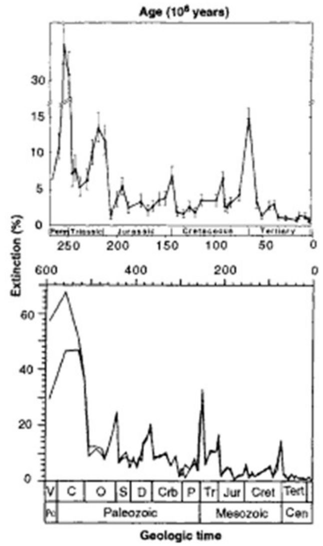
Richard A. Muller
(UC, Berkeley and LBL, Berkeley)



LETTERS

Mass Extinctions and Periodicity

The recent article by Michael J. Benton tracking "Diversification and extinction in the history of life" (7 Apr., p. 52) concludes that periodicity in the mass extinction record is not supported, as echoed in "This Week in *Science*" (p. 9). Benton's article, however, contains no quantitative statistical analyses designed to test the extinction record for periodic components, and may lack the resolution to identify all of the significant species-level extinction events on which such an analysis should be based.



Periodicity or not? Percentages of extinction of families of marine organisms through time as plotted by Raup and Sepkoski (top) in 1988 [adapted from figure 1A of (2)] and by Benton (bottom) in 1995 (adapted from figure 5C). Note that bottom figure extends farther back in geologic time. Abbreviations: (top) Perm, Permian; (bottom) Pc, Precambrian; V, Vendian; C, Cambrian; O, Ordovician; S, Silurian; D, Devonian; Crb, Carboniferous; P, Permian; Tr, Triassic; Jur, Jurassic; Cret, Cretaceous; Tert, Tertiary.

Benton used compilations of unculled family-level data to estimate the magnitude of extinction events, whereas previous analyses (*1*, *2*) have used familial data from Raup and Sepkoski (*3*) culled to enhance the extinction signal by eliminating extant families, those known only from strata with exceptional preservation (Lagerstätten), and families with extinctions not resolved to the geologic stage level. Benton was able to identify the three major events of the last 250 million years (the Late Permian, end-Triassic, and end-Cretaceous events), but only four other less severe events, the end-Jurassic (Tithonian), Aptian, Cenomanian, and Late Eocene (Priabonian) extinctions, in contrast to the earlier studies that had identified a total of from 8 to 12 extinction events in culled, family-level and more detailed genus-level data for the same interval (*1*, *2*).

The apparent lack of resolution in Benton's study is not unexpected, as Sepkoski (*4*) has shown that the use of unculled familial data in extinction analysis is problematic, and has determined that genus-level data are best suited for detecting second-order extinction events. First, as the standard error in any frequency count (n) is approximately $n^{1/2}$, the smaller number of familial extinctions as opposed to those of genera is thus subject to considerable random variation, making detection of signal above noise more difficult (*4*).

Because all species in a family or genus must disappear in order to produce an extinction on those levels, and as species extinctions are independent of family or genus membership, the higher-level data should significantly dampen the severity of species-level extinctions in a manner predictable through rarefaction relationships (*4*). Raup (*5*) has determined that the rarefaction curve for families shows a shallow slope over low levels of species extinction, where even a 50% loss of species results in only a 10% family extinction, whereas a similar loss of species results in a 25% extinction of genera. On the basis of these two factors, one can predict that one's use of family-level data will present difficulty in resolving extinction events involving loss of less than or equal to 40% of species, which is the range of the additional peaks identified in the genus-level data (*4*).

With regard to periodicity, Benton finds that the seven extinction peaks detected in his unculled familial data over the last 250 million years are spaced 20 to 60 million years apart and uses this as evidence against

Fundamental Constants

Constant	Symbol	SI	CGS
Avogadro's constant	N_A, N_O	6.022×10^{23} mol^{-1}	6.022×10^{23} mole^{-1}
Boltzmann's constant	k, $k_B = R/N_A$	1.381×10^{-23} J K^{-1}	1.381×10^{-16} erg/deg
Molar gas constant	$R = N_A k$	8.314 J K^{-1} mol^{-1}	8.314×10^{7} erg/mole-deg
Electronic charge	$-e$	1.602×10^{-19} C	4.803×10^{-10} esu
Faraday constant	$F = N_A e$	9.649×10^{4} C mol^{-1}	9.649×10^{4} C/mole
Planck's constant	h ($\hbar = h/2\pi$)	6.626×10^{-34} J s	6.626×10^{-27} erg sec
Permittivity of free space	ε_o	8.854×10^{-12} C^2 J^{-1} m^{-1}	1
Mass of $\frac{1}{12}$ of ^{12}C atom*	u	1.661×10^{-27} kg	1.661×10^{-24} gm
Mass of hydrogen atom	m_H	1.673×10^{-27} kg	1.673×10^{-24} gm
Mass of electron	m_e	9.109×10^{-31} kg	9.109×10^{-28} gm
Gravitational constant	G	6.674×10^{-11} N m^2 kg^{-2}	6.674×10^{-8} cm^3/gm-sec^2
Standard gravity	g	9.80665 m s^{-2} (N kg^{-1})	980.665 cm/sec^2
Speed of light in vacuum	c	2.998×10^{8} m s^{-1}	2.998×10^{10} cm/sec

*Atomic mass unit (also denoted by a.m.u. and a.u.), which is also the modern unit of molecular weight, the Dalton (Da).

Derived SI units

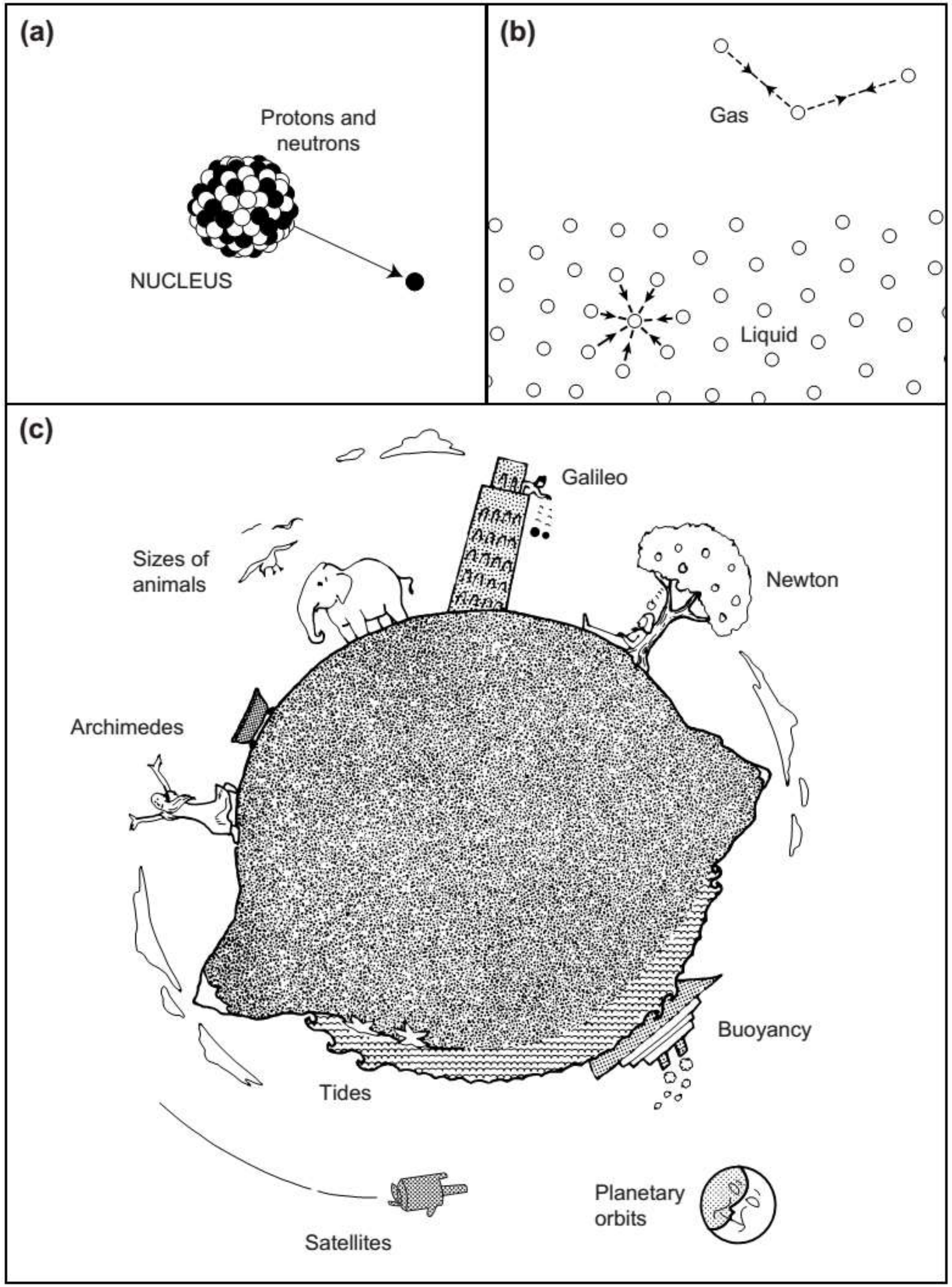
Derived SI Units

Quantity	SI Unit	Symbol	Definition of Unit
Energy	Joule	J	kg m^2 s^{-2} (also Nm and CV)
Force	Newton	N	J m^{-1} = kg m s^{-2}
Power	Watt	W	J s^{-1} = kg m^2 s^{-3}
Pressure	Pascal	Pa	N m^{-2}
Electric charge	Coulomb	C	A s
Electric potential	Volt	V	J A^{-1} s^{-1} = J C^{-1}
Electric field	Volt/meter		V m^{-1}
Frequency	Hertz	Hz	s^{-1}

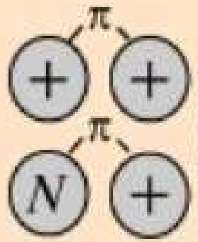
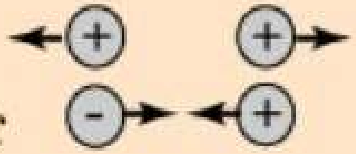
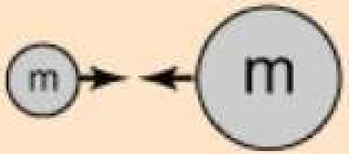
Fraction	10^{12}	10^{9}	10^{6}	10^{3}	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}	10^{-12}	10^{-15}	10^{-21}
Prefix symbol	T	G	M	k	d	c	m	μ	n	p	f	z

The 4 forces of nature

- It is now well- established that there are four distinct forces in nature. Two of these are the strong and weak interactions that act between neutrons, protons, electrons, and other elementary particles. These two forces have a very short range of action, less than 10^{-5} nm, and belong to the domain of nuclear and high-energy physics.
- The other two forces are the electromagnetic and gravitational interactions that act between atoms and molecules (as well as between elementary particles).
- These forces are effective over a much larger range of distances, from subatomic to practically infinite distances, and are consequently the forces that govern the behavior of everyday things.
- Electromagnetic forces—the source of all intermolecular interactions—determine the properties of solids, liquids, and gases, the behavior of particles in solution, chemical reactions, and the organization of biological structures.


(a)
Protons and neutrons
NUCLEUS
(b)
Gas
Liquid
(c)
Galileo
Sizes of animals
Newton
Archimedes
Buoyancy
Tides
Satellites
Planetary orbits

Fundamental Forces

		Strength	Range (m)	Particle
Strong	 Force which holds nucleus togeher	1	10^{-15} (diameter of a medium sized nucleus)	gluons, π(nucleons)
Electro-magnetic		$\frac{1}{137}$	Infinite	photon mass = 0 spin = 1
Weak	 neutrino interaction induces beta decay	10^{-6}	10^{-18} (0.1% of the diameter of a proton)	Intermediate vector bosons W^+, W^-, Z_0, mass > 80 GeV spin =1
Gravity		6×10^{-39}	Infinite	graviton ? mass = 0 spin = 2

mass

- Mass is the quantity of matter in a physical body.
- It is also a measure of the body's inertia, the resistance to acceleration (change of velocity) when a net force is applied.
- An object's mass also determines the strength of its gravitational attraction to other bodies.

$$\boldsymbol{F} = m\,\boldsymbol{a} \quad [N]$$

$$F = G\,\frac{m_1 m_2}{r^2}$$

On the Earth's surface

$$G = 6.67 \times 10^{-11}\ N\,m^2 kg^{-2}$$

$$m_1 = 5.97 \times 10^{24}\ kg$$

$$r = 6371 \times 10^3\ m$$

$$F = m_2\, g$$

$$g \sim 9.86\ (m/s)/s$$

mass

$F = m_2\, a$ This is the inertial mass

$F = m_2\, g$ This is the gravitational mass

$$a \equiv g \quad sse \quad m_2 = m_2$$

This is not **non-sense**

We are saying that the gravitational accelaration equals the acceleration of a body on the Earth's surface, if the gravitational and inertial mass of the body, coincide

$$a = 1\, g$$

$$a = \frac{dv}{dt} = 9.81\ (m/s)/s$$

$$\frac{dv}{dt} = \frac{d^2 s}{dt^2} = 9.81\ (m/s)/s$$

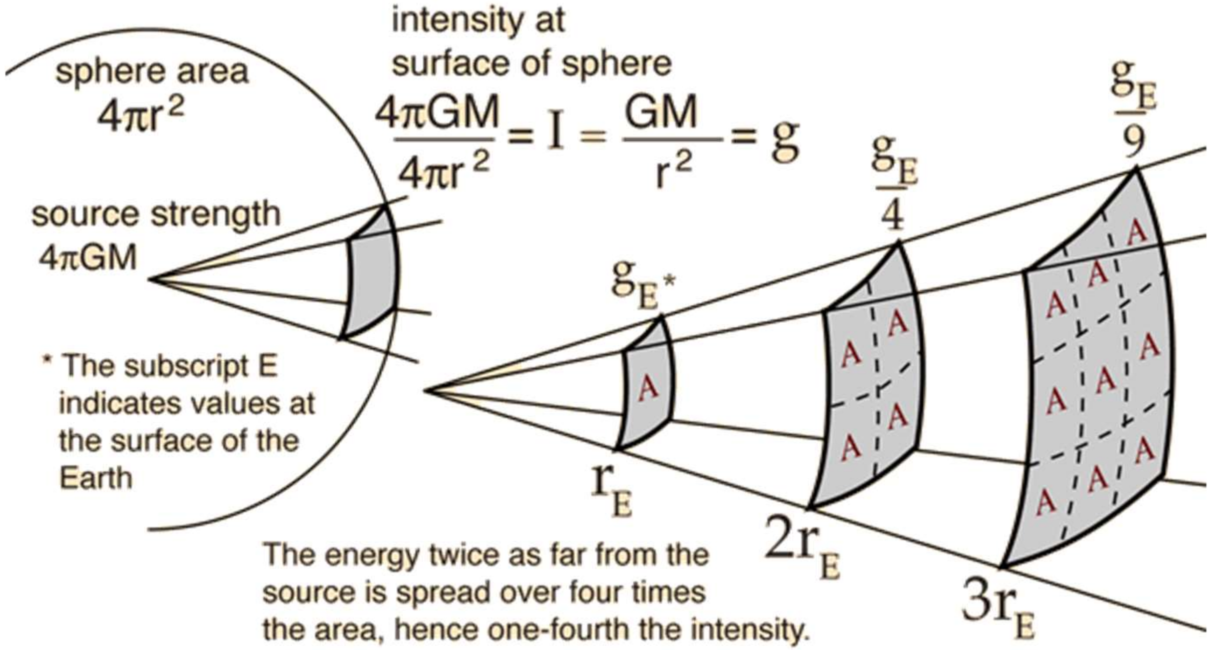
$$\frac{ds}{dt} = \int_0^t g\, dt = g\, t$$

$$s = \int_0^t ds = \int_0^t g\, t\, dt = \frac{g\, t^{\,2}}{2}$$

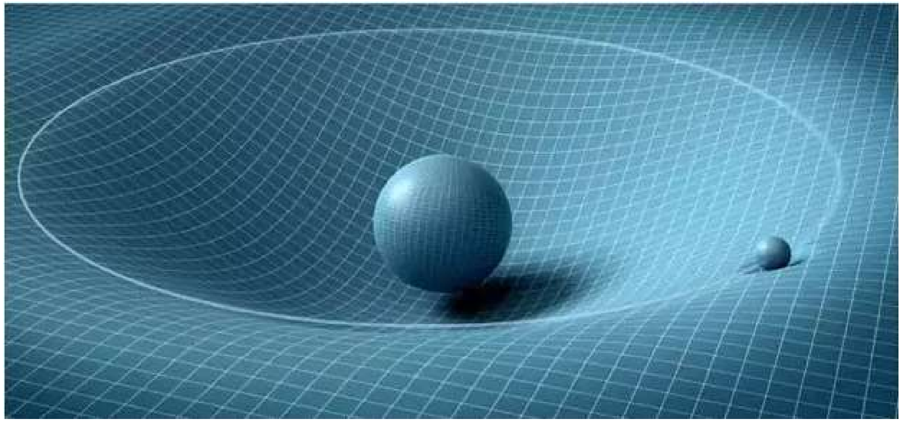
$$s = C_0 + C_1 t + \frac{g\, t^{\,2}}{2}$$

Newton's law of universal gravitation

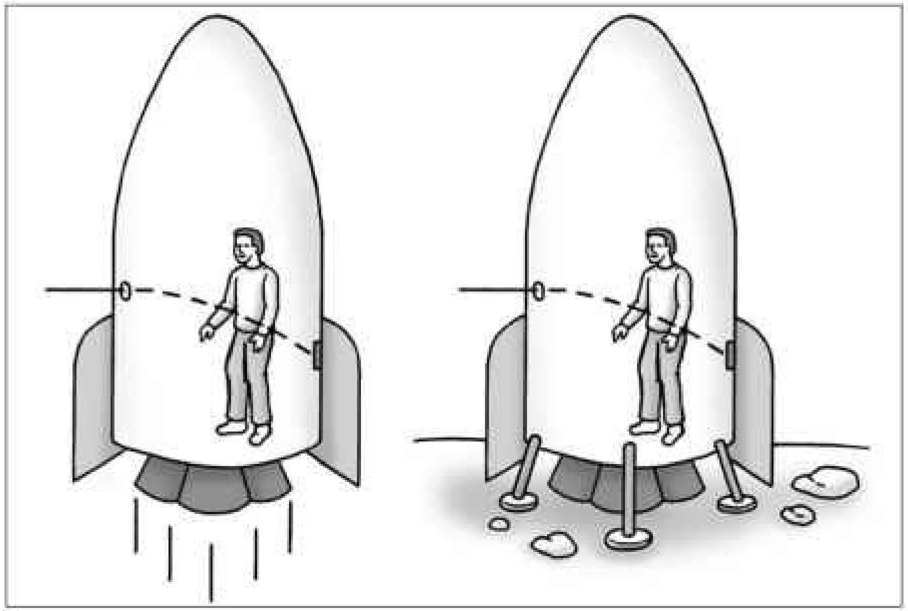
$$F = G\,\frac{m_1 m_2}{r^2}$$



General theory of relativity



Gravity isn't a force, it's the curvature of space-time caused by the presence of mass-energy



Principle of equivalence

$$F = G\,\frac{m_1 m_2}{r^2}$$

space-time curvature ∝ mass-energy stress

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

curvature

stress-energy tensor

Linear momentum

$$q = m\,v$$

$$\frac{dq}{dt} = m\frac{dv}{dt} + v\frac{dm}{dt}$$

$$F = \frac{dq}{dt} \quad \longleftarrow$$

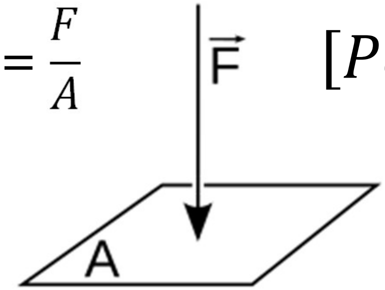
$$Fdt = dq$$

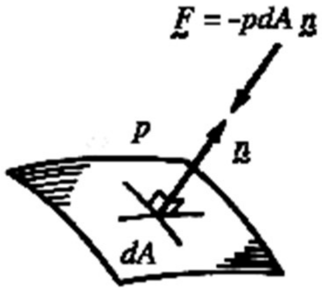
$$\int_1^2 Fdt = \int_1^2 dq$$

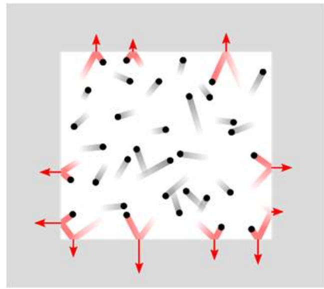
$$F\,\Delta t = q_2 - q_1$$

Pressure

$$p = \frac{F}{A} \qquad [Pa]$$



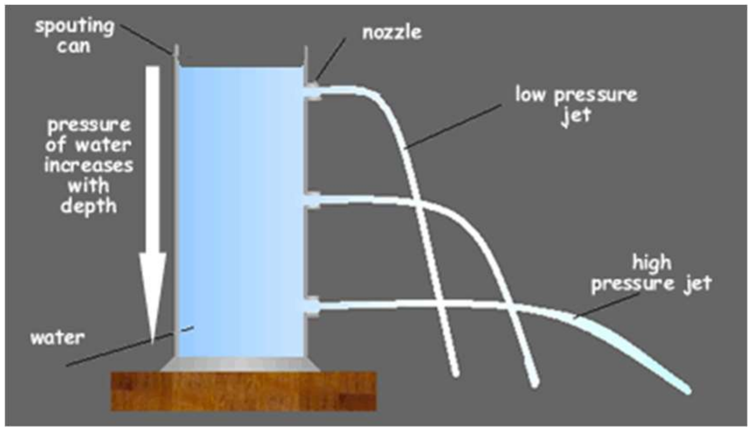




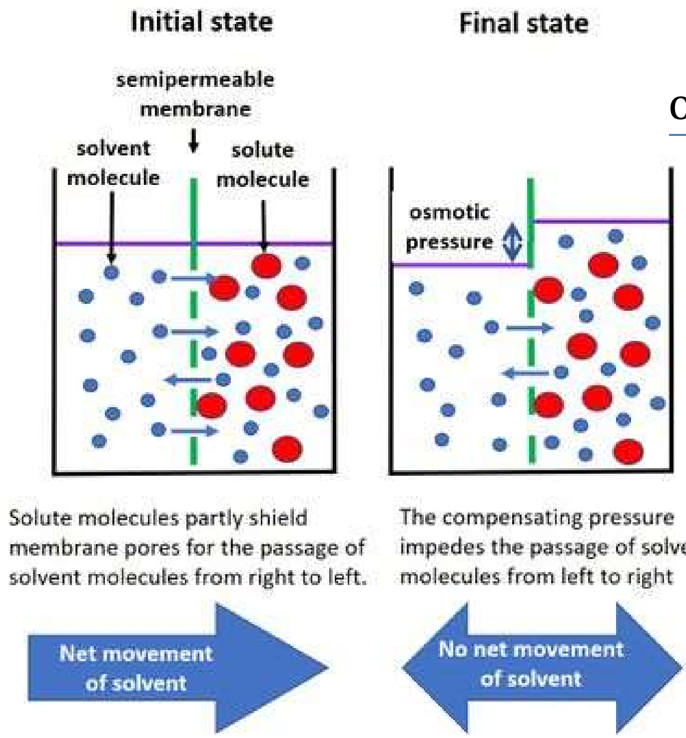
$$p\,V = n\,R\,T$$

Ideal gases

Hydrostatic pressure



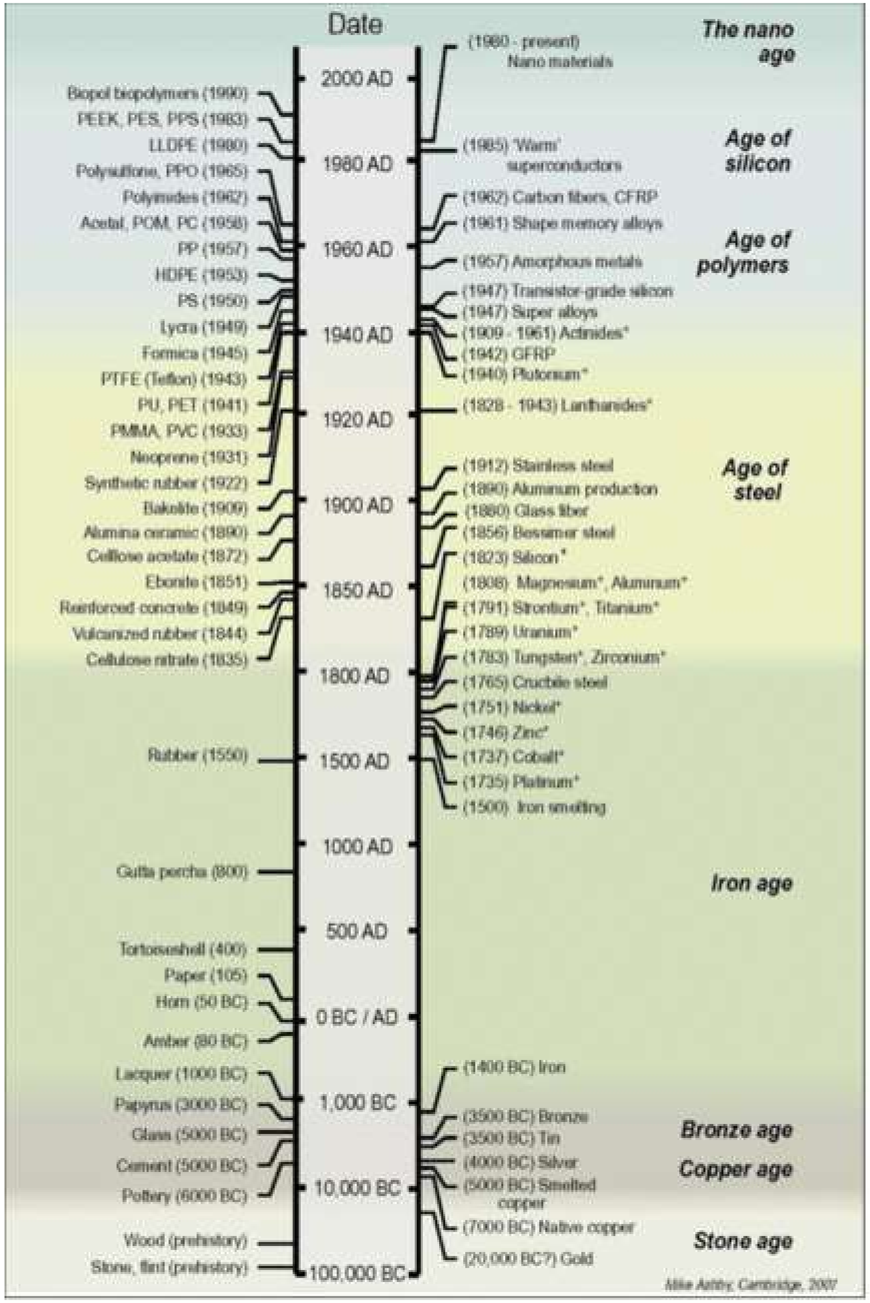
osmosis

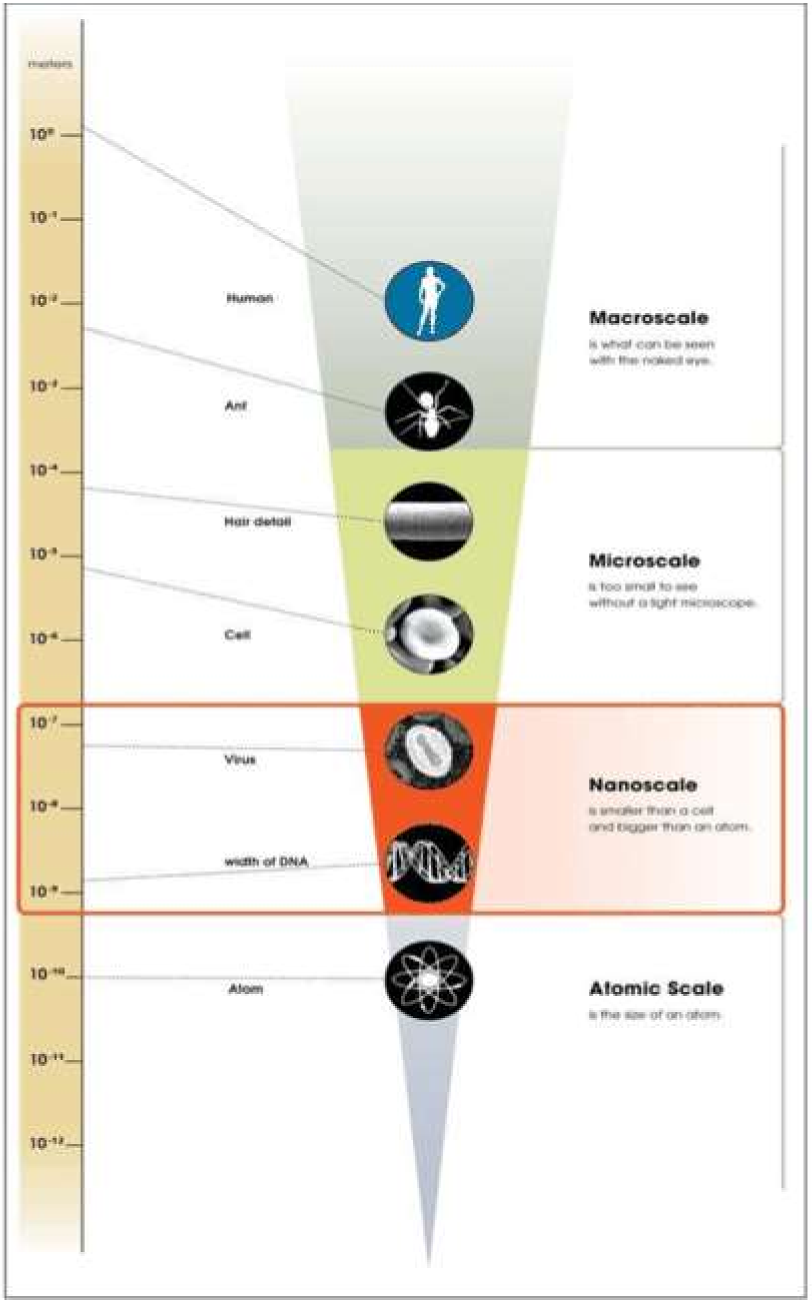


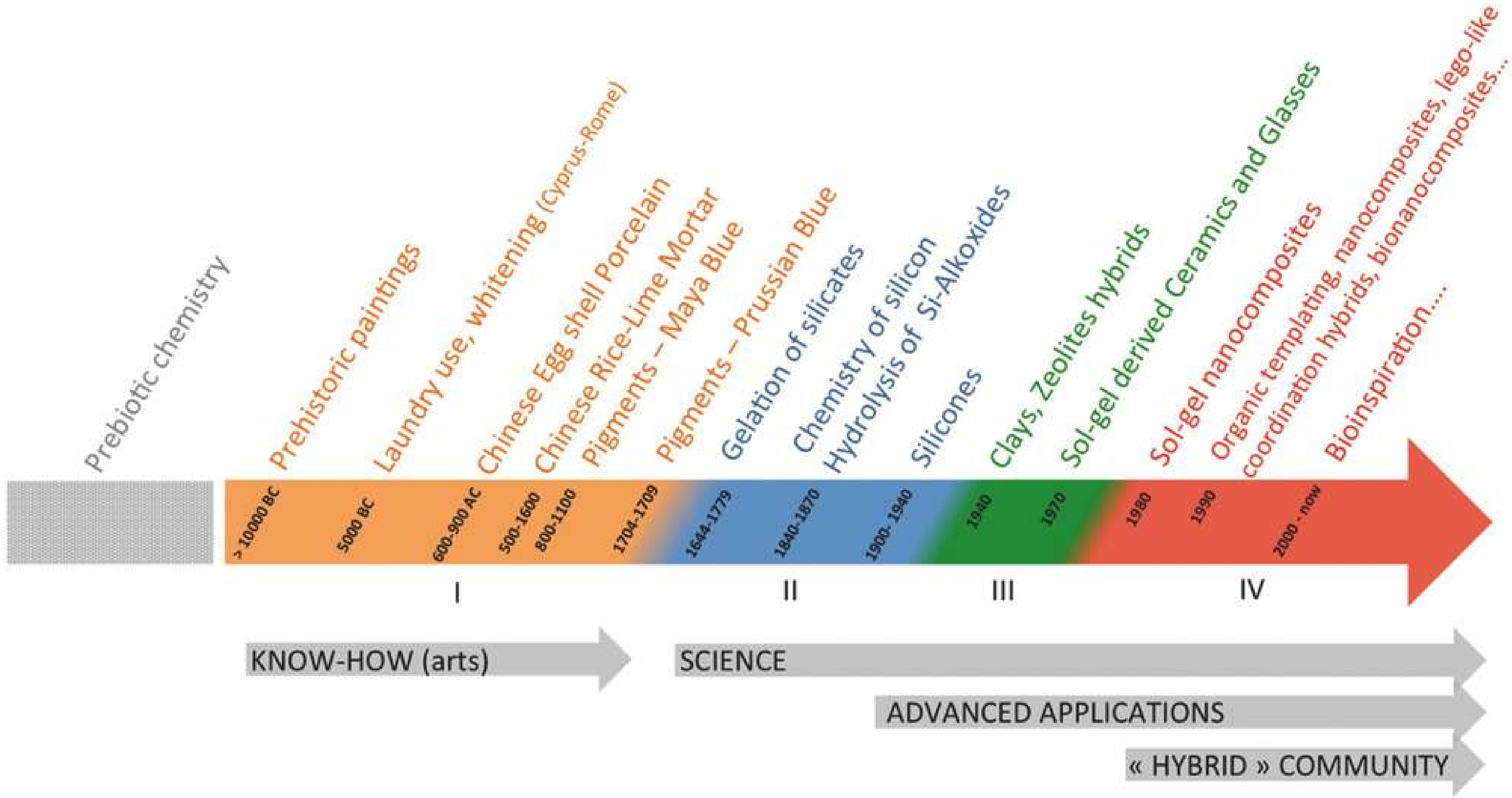
work

- $w = F\ s \qquad J$
- $w = \int_1^2 F\ ds$
- $w = \Delta E$ work-energy theorem
- $\Delta E = \Delta K + \Delta U$
- $\Delta E = \Delta K + \Delta U$
- $K = \frac{1}{2} m v^2 \qquad U = \frac{1}{2} k\ x^2$

  $U = mgh$
- $P = \frac{dw}{dt} \quad J/s \quad W$


Date
The nano age
Age of silicon
Age of polymers
Age of steel
Iron age
Bronze age
Copper age
Stone age
2000 AD
1980 AD
1960 AD
1940 AD
1920 AD
1900 AD
1850 AD
1800 AD
1500 AD
1000 AD
500 AD
0 BC / AD
1,000 BC
10,000 BC
100,000 BC
Biopol biopolymers (1990)
PEEK, PES, PPS (1983)
LLDPE (1980)
Polysulfone, PPO (1965)
Polyimides (1962)
Acetal, POM, PC (1958)
PP (1957)
HDPE (1953)
PS (1950)
Lycra (1949)
Formica (1945)
PTFE (Teflon) (1943)
PU, PET (1941)
PMMA, PVC (1933)
Neoprene (1931)
Synthetic rubber (1922)
Bakelite (1909)
Alumina ceramic (1890)
Celllose acetate (1872)
Ebonite (1851)
Reinforced concrete (1849)
Vulcanized rubber (1844)
Cellulose nitrate (1835)
Rubber (1550)
Gutta percha (800)
Tortoiseshell (400)
Paper (105)
Horn (50 BC)
Amber (80 BC)
Lacquer (1000 BC)
Papyrus (3000 BC)
Glass (5000 BC)
Cement (5000 BC)
Pottery (6000 BC)
Wood (prehistory)
Stone, flint (prehistory)
(1980 - present) Nano materials
(1985) 'Warm' superconductors
(1962) Carbon fibers, CFRP
(1961) Shape memory alloys
(1957) Amorphous metals
(1947) Transistor-grade silicon
(1947) Super alloys
(1909 - 1961) Actinides*
(1942) GFRP
(1940) Plutonium*
(1828 - 1943) Lanthanides*
(1912) Stainless steel
(1890) Aluminum production
(1880) Glass fiber
(1856) Bessemer steel
(1823) Silicon*
(1808) Magnesium*, Aluminum*
(1791) Strontium*, Titanium*
(1789) Uranium*
(1783) Tungsten*, Zirconium*
(1765) Crucible steel
(1751) Nickel*
(1746) Zinc*
(1737) Cobalt*
(1735) Platinum*
(1500) Iron smelting
(1400 BC) Iron
(3500 BC) Bronze
(3500 BC) Tin
(4000 BC) Silver
(5000 BC) Smelted copper
(7000 BC) Native copper
(20,000 BC?) Gold
Mike Ashby, Cambridge, 2007


meters
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
Human
Ant
Hair detail
Cell
Virus
width of DNA
Atom
Macroscale
is what can be seen with the naked eye.
Microscale
is too small to see without a light microscope.
Nanoscale
is smaller than a cell and bigger than an atom.
Atomic Scale
is the size of an atom.



Prebiotic chemistry
Prehistoric paintings
Laundry use, whitening (Cyprus-Rome)
Chinese Egg shell Porcelain
Chinese Rice-Lime Mortar
Pigments – Maya Blue
Pigments – Prussian Blue
Gelation of silicates
Chemistry of silicon
Hydrolysis of Si-Alkoxides
Silicones
Clays, Zeolites hybrids
Sol-gel derived Ceramics and Glasses
Sol-gel nanocomposites
Organic templating, nanocomposites, lego-like
coordination hybrids, bionanocomposites…
Bioinspiration….
> 10000 BC
5000 BC
600-900 AC
500-1600
800-1100
1704-1709
1644-1779
1840-1870
1900- 1940
1940
1970
1980
1990
2000 - now
I
II
III
IV
KNOW-HOW (arts)
SCIENCE
ADVANCED APPLICATIONS
« HYBRID » COMMUNITY

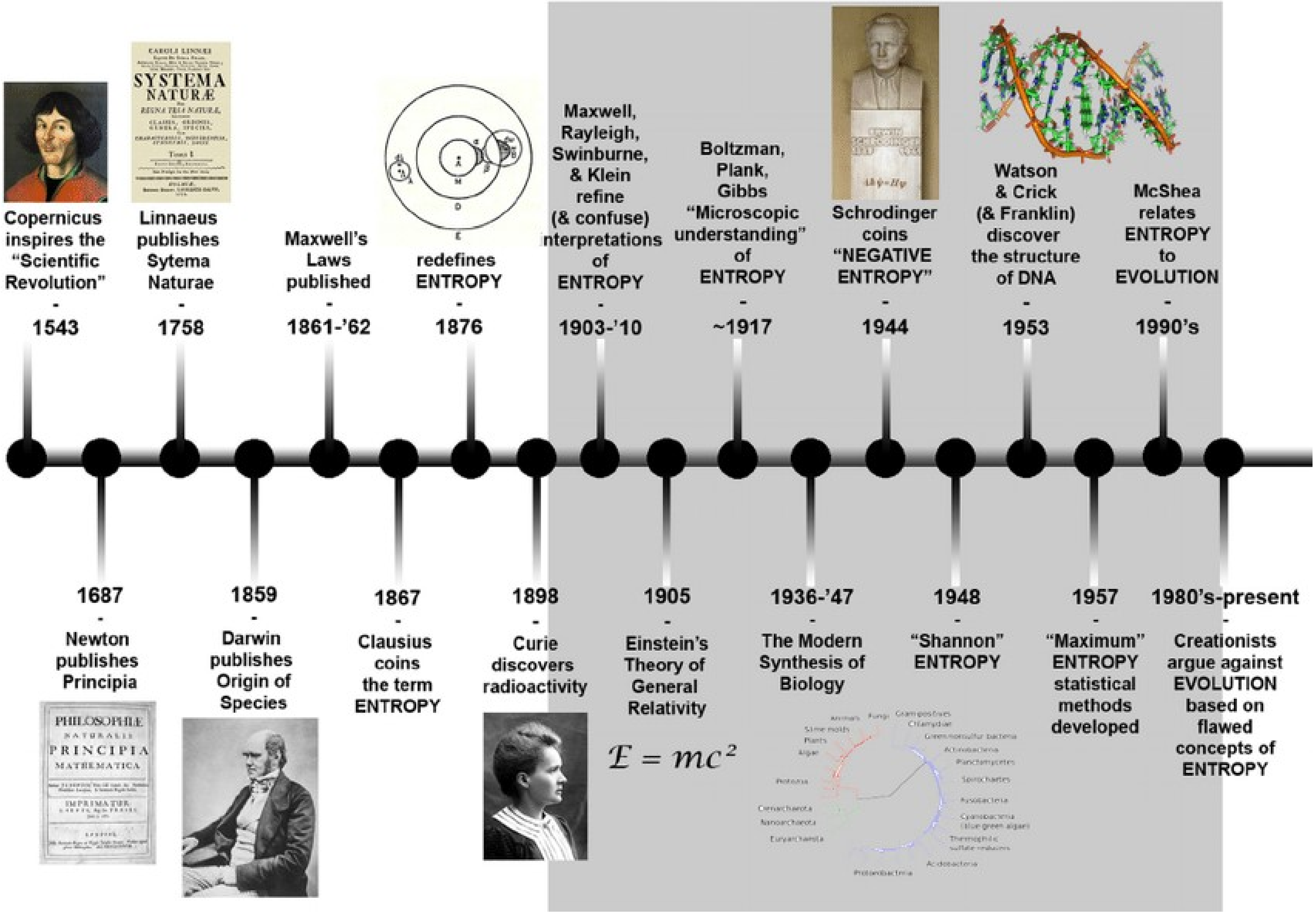

Copernicus inspires the "Scientific Revolution" - 1543
1687 - Newton publishes Principia
PHILOSOPHIÆ NATURALIS PRINCIPIA MATHEMATICA
Linnaeus publishes Sytema Naturae - 1758
SYSTEMA NATURÆ
1859 - Darwin publishes Origin of Species
Maxwell's Laws published - 1861-'62
1867 - Clausius coins the term ENTROPY
redefines ENTROPY - 1876
1898 - Curie discovers radioactivity
Maxwell, Rayleigh, Swinburne, & Klein refine (& confuse) interpretations of ENTROPY - 1903-'10
1905 - Einstein's Theory of General Relativity
E = mc²
Boltzman, Plank, Gibbs "Microscopic understanding" of ENTROPY - ~1917
1936-'47 - The Modern Synthesis of Biology
Schrodinger coins "NEGATIVE ENTROPY" - 1944
1948 - "Shannon" ENTROPY
Watson & Crick (& Franklin) discover the structure of DNA - 1953
1957 - "Maximum" ENTROPY statistical methods developed
McShea relates ENTROPY to EVOLUTION - 1990's
1980's-present - Creationists argue against EVOLUTION based on flawed concepts of ENTROPY

Table 1.1 Scientists Who Made Major Contributions to Our Understanding of Intermolecular Forces (including some whose contribution was indirect)