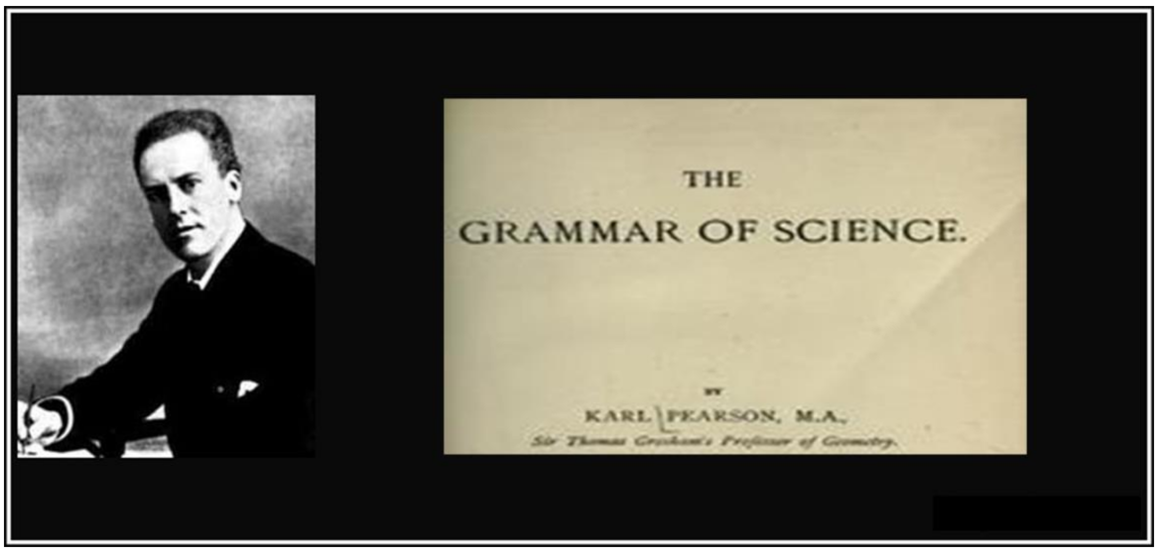
INTRODUCTION TO BIOPHYSICS

Serkan GÜRGÜL, Assist. Prof.

Department of Biophysics, Faculty of Medicine, Gaziantep University

History of Biophysics

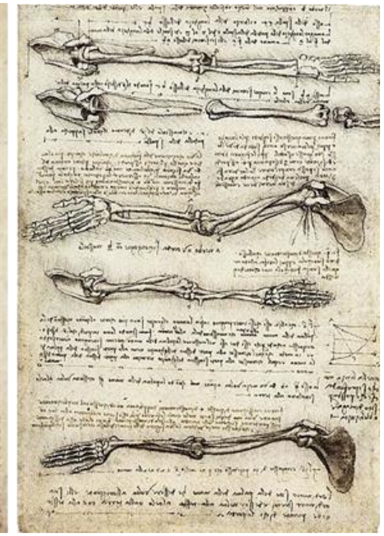
- Is a relatively young branch of science.
- The term “Biophysics” was first used in 1892 by Karl Pearson in his book “The Grammar of Science”.
- Arose as a definite subfield in the early to mid-20th Century.
- But, the foundations for the study of Biophysics were laid down much earlier.



Glaser R., Biophysics, 2012

Leonardo da Vinci (1452–1519)

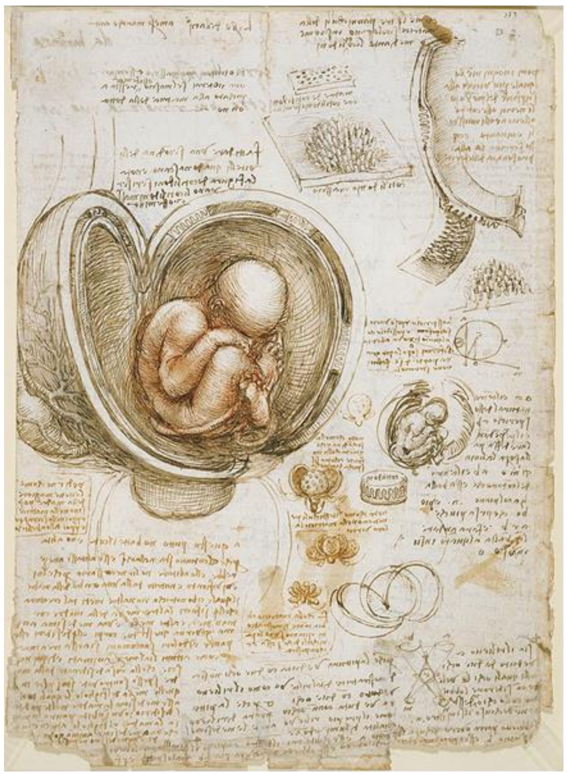


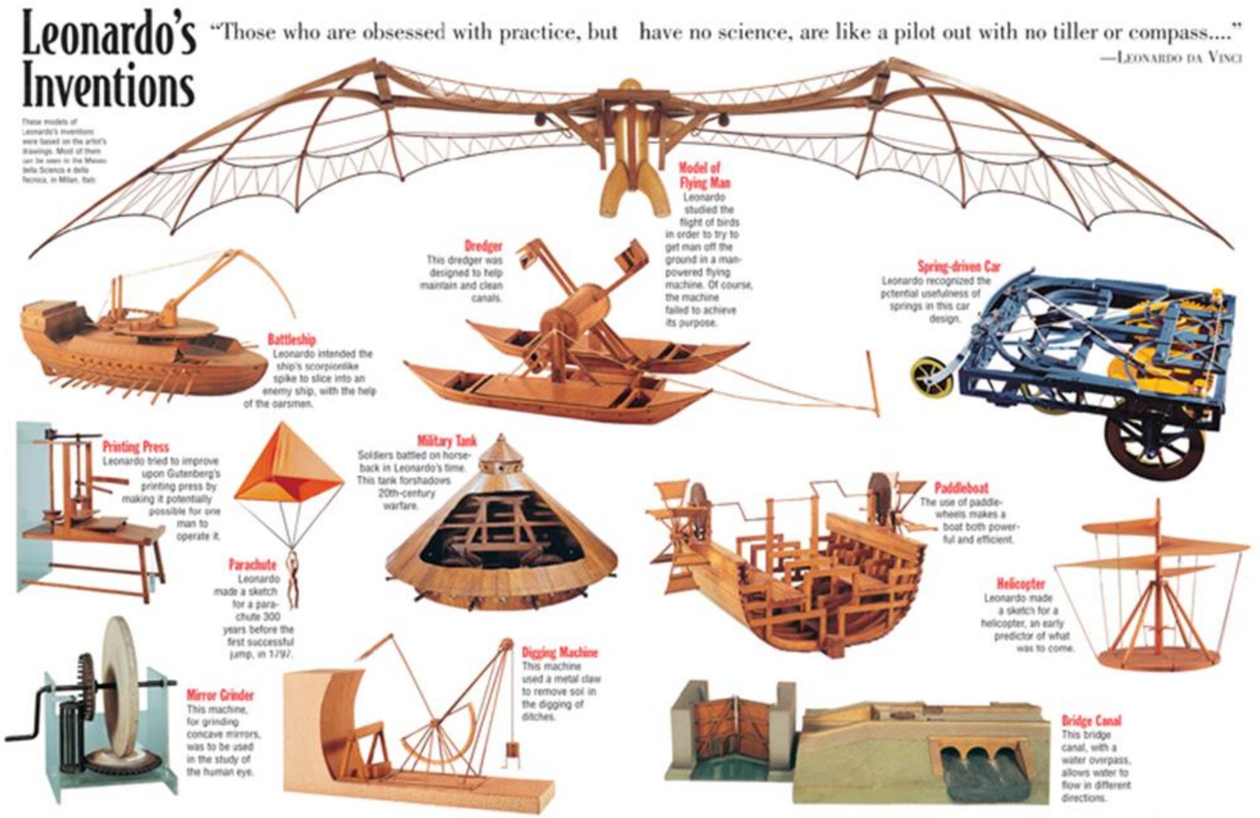



- Was a greatest painter, an engineer and anatomist, a physiologist and palaeontologist (the founding "Father" of Ichnology)
- Studied topographic anatomy, physiology and mechanics of movement, circulation of blood, observed the effects of age, emotion, and rage, etc…

Glaser R., Biophysics, 2012

As an engineer, **Leonardo** conceived ideas vastly ahead of his own time, conceptually inventing…





As an ichnologist, **Leonardo** used trace fossils to complement his hypothesis concerning the relationship of body fossils to the host sediment.

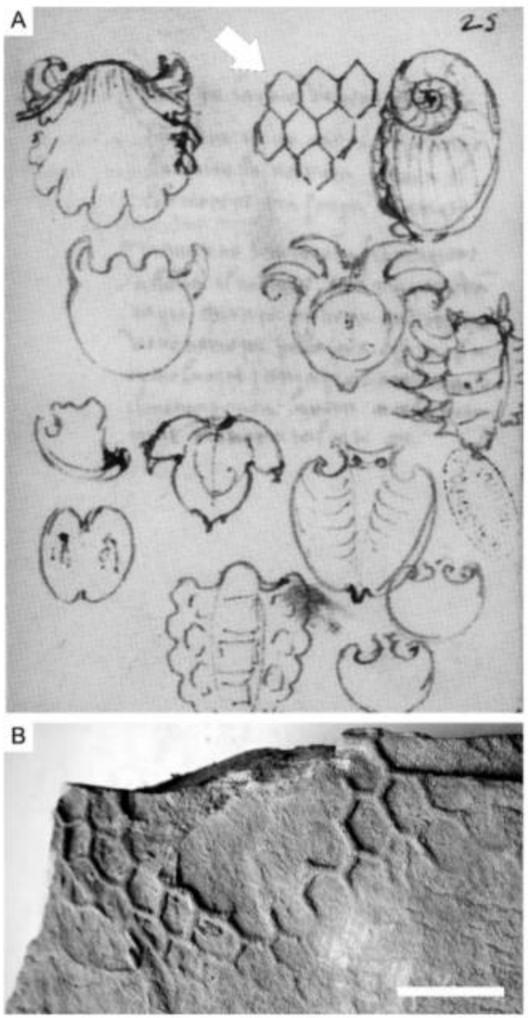


FIGURE 4—Leonardo da Vinci's *Paleodictyon*. A) Reproduction of folio 25r of the Codex I. Leonardo depicted several fossils, among which the trace fossil *Paleodictyon* (arrow). B) Specimen of *Paleodictyon* from an area frequented by Leonardo: Pratomagno (Florence), Apennine foredeep deposits. Note the strong similarity with the drawing by da Vinci in A.

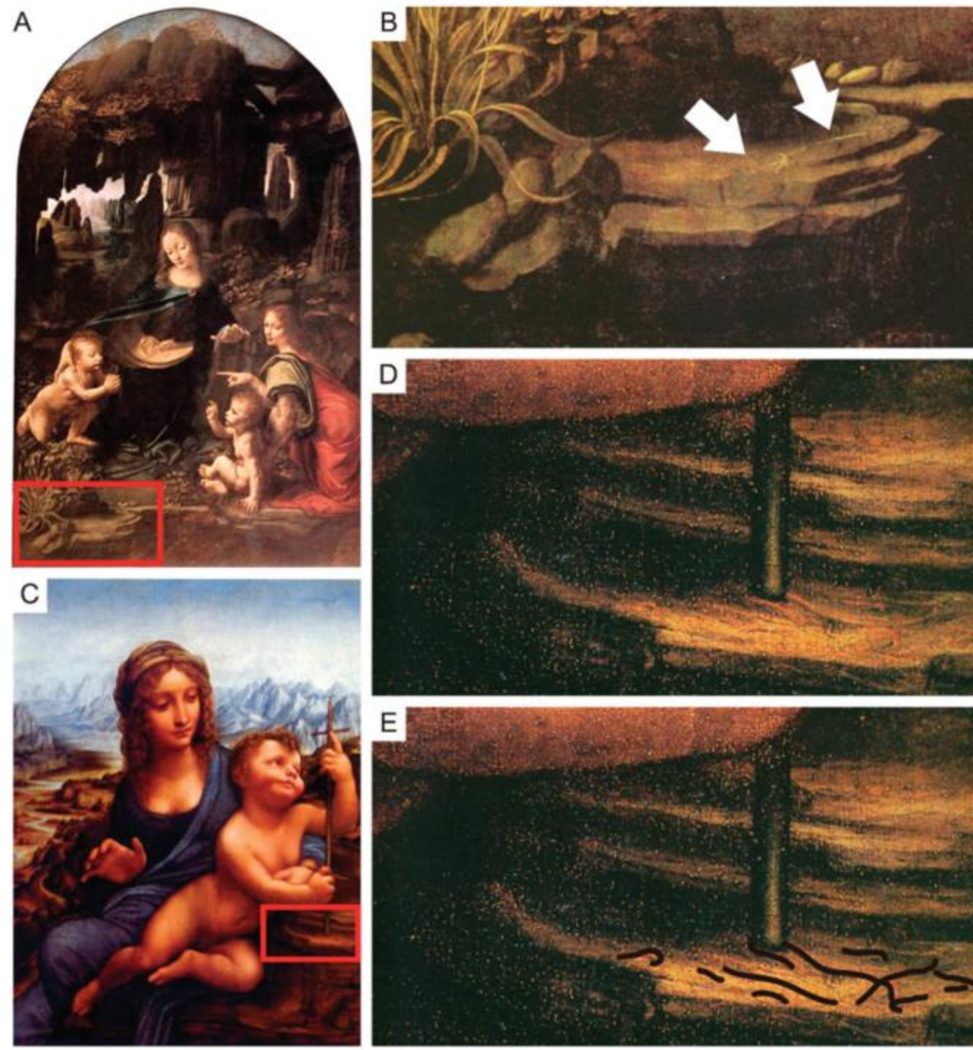
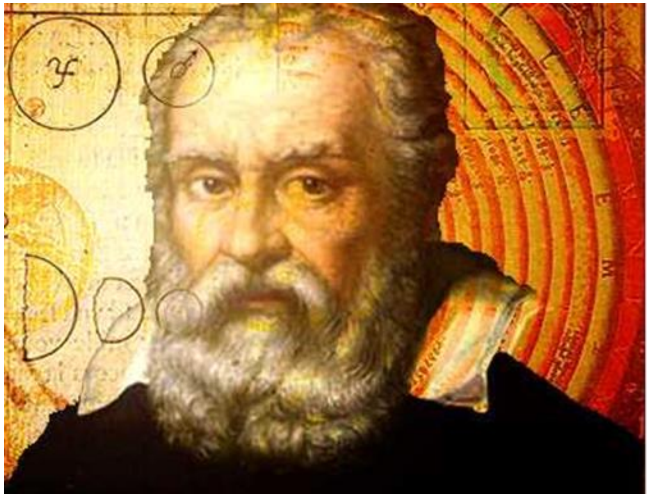


FIGURE 5—Ichnofossil-like structures in da Vinci's paintings. A) Leonardo da Vinci, *Virgin of the Rocks* (Paris, Louvre). The rectangle shows the region corresponding to B. B) Detail of A. Arrows show the trace-like structure. C) Workshop of Leonardo da Vinci, *Madonna of the Yarnwinder* (New York, private collection). The rectangle shows the region corresponding to D–E. D) Trace-like structures of the *Madonna of the Yarnwinder*. E) Interpreted sketch of the ichnofossil-like structures of the *Madonna of the Yarnwinder*.

Galileo Galilei (1564-1642)




- Was an Italian astronomer, physicist, engineer, philosopher and mathematician.
- The “Father of Modern Science”, “Father of Modern Physics”, “Father of Modern Observational Astronomy”
- Studied speed and velocity, gravity and free fall, the principle of relativity, inertia, projectile motion, pendulums and hydrostatic balances.
- Invented thermoscope and compasses; observed the phases of Venus, the four largest satellites of Jupiter, and Saturn's rings.

As an astronomer, **Galileo** contributed to observational astronomy by the telescopic confirmation of the phases of Venus, the observation of the four largest satellites of Jupiter, the observation of Saturn's rings, and the analysis of sunspots.

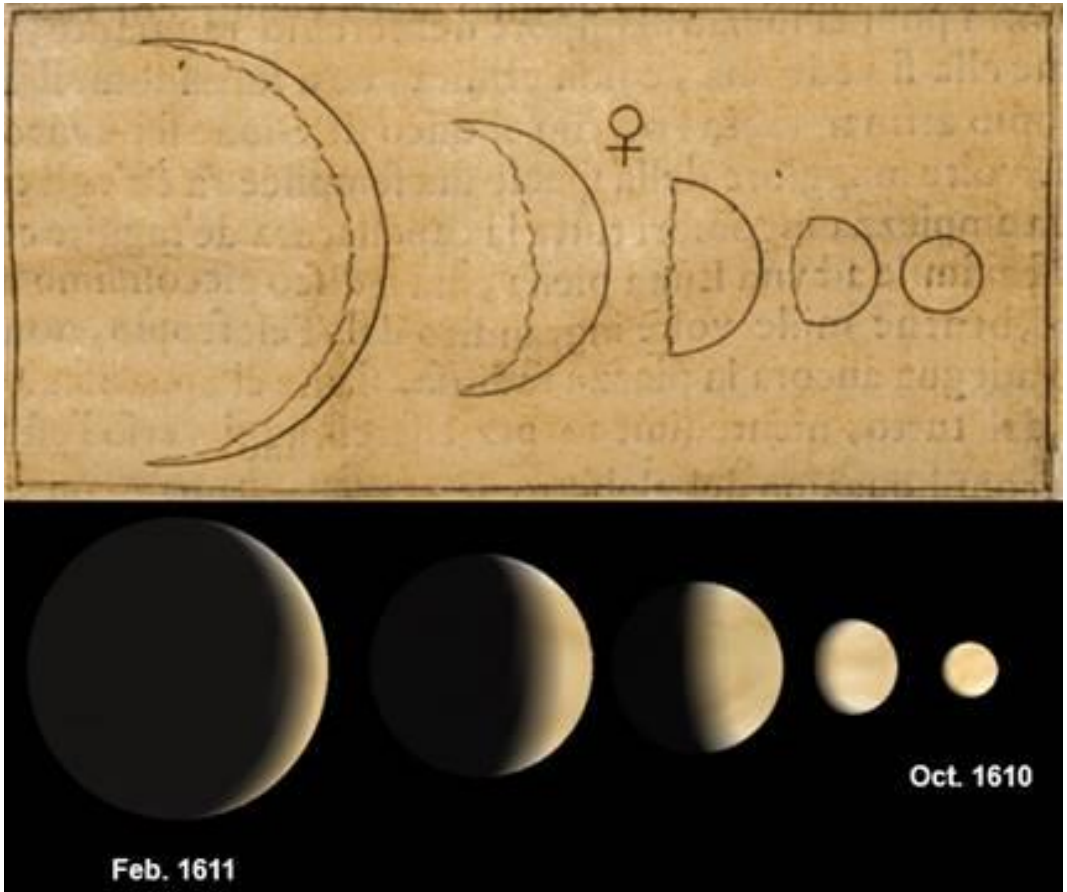
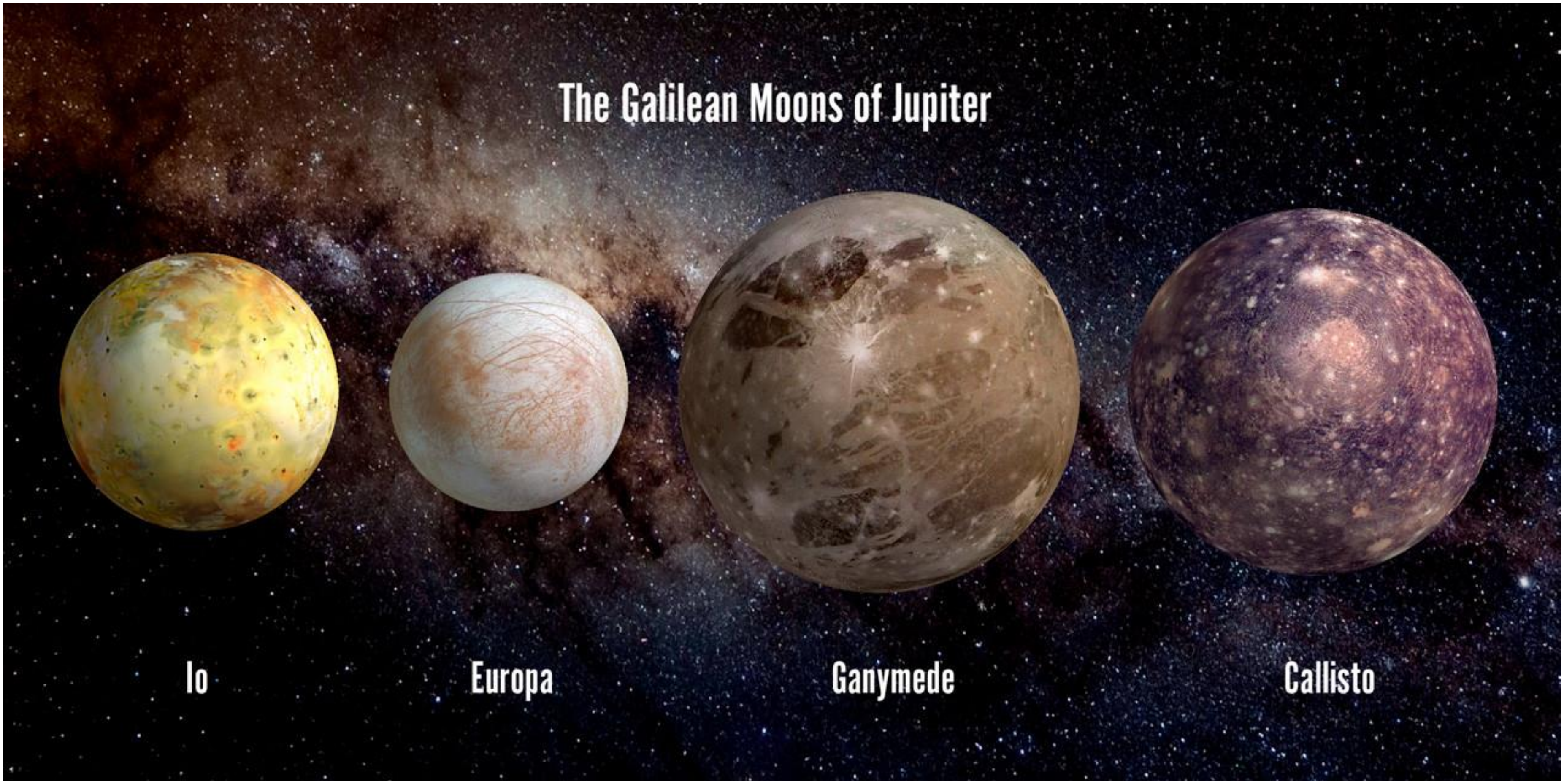
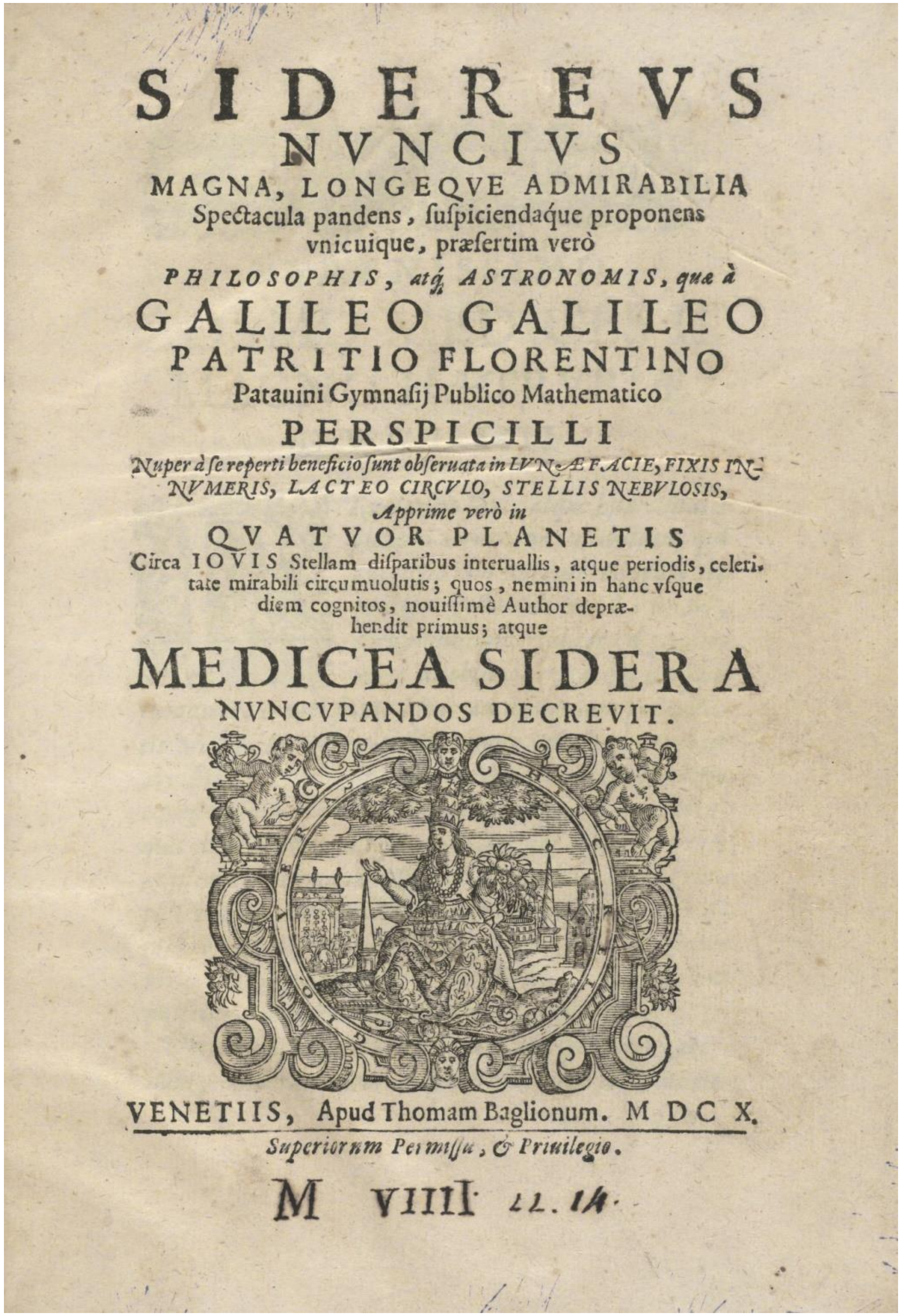
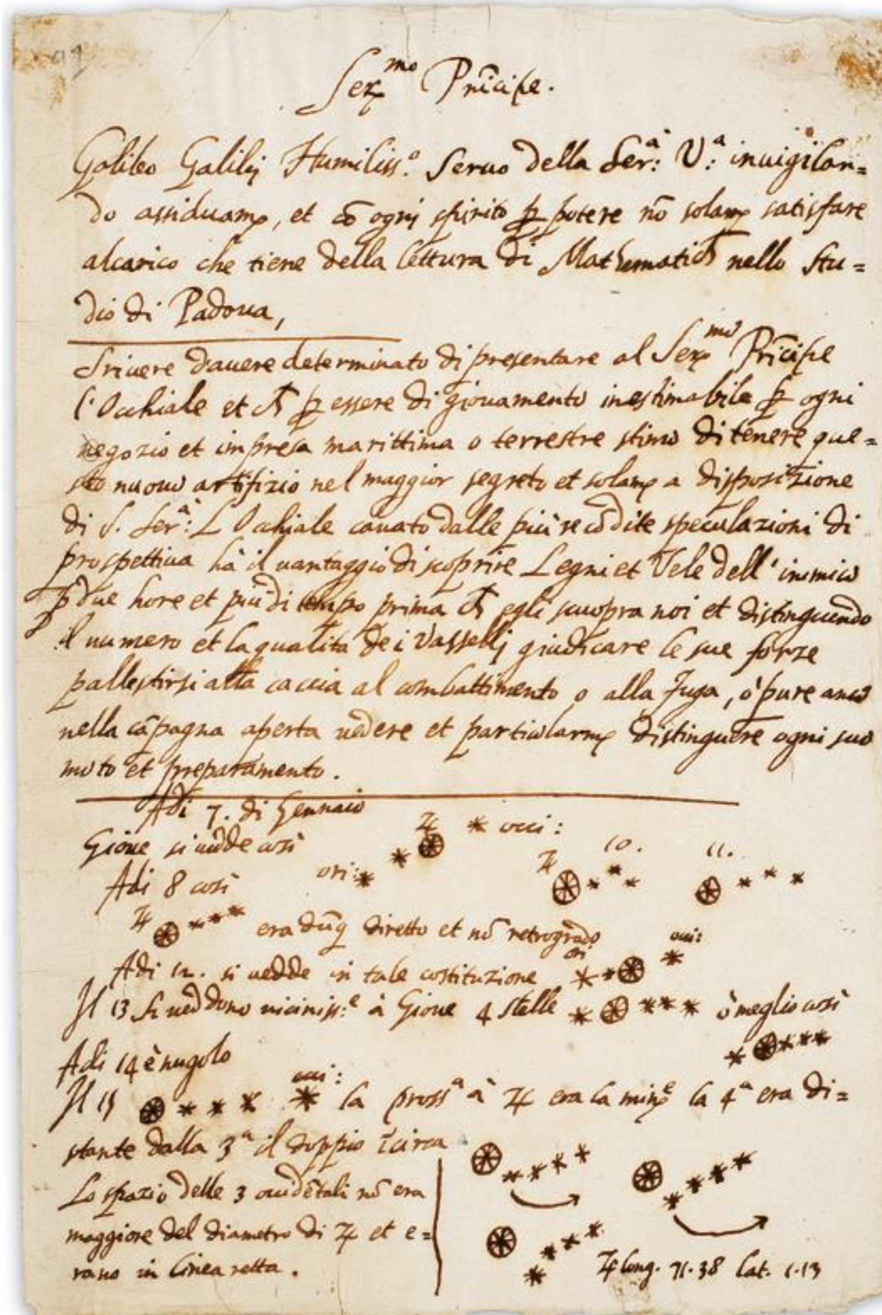


Figure 3. Top panel: Galileo's drawings of the phases of Venus from October 1610 (round on the right) through February 1611 (crescent on the left). Bottom panel: Stellarium software image of Venus from the same time frame.


The Galilean Moons of Jupiter
Io
Europa
Ganymede
Callisto

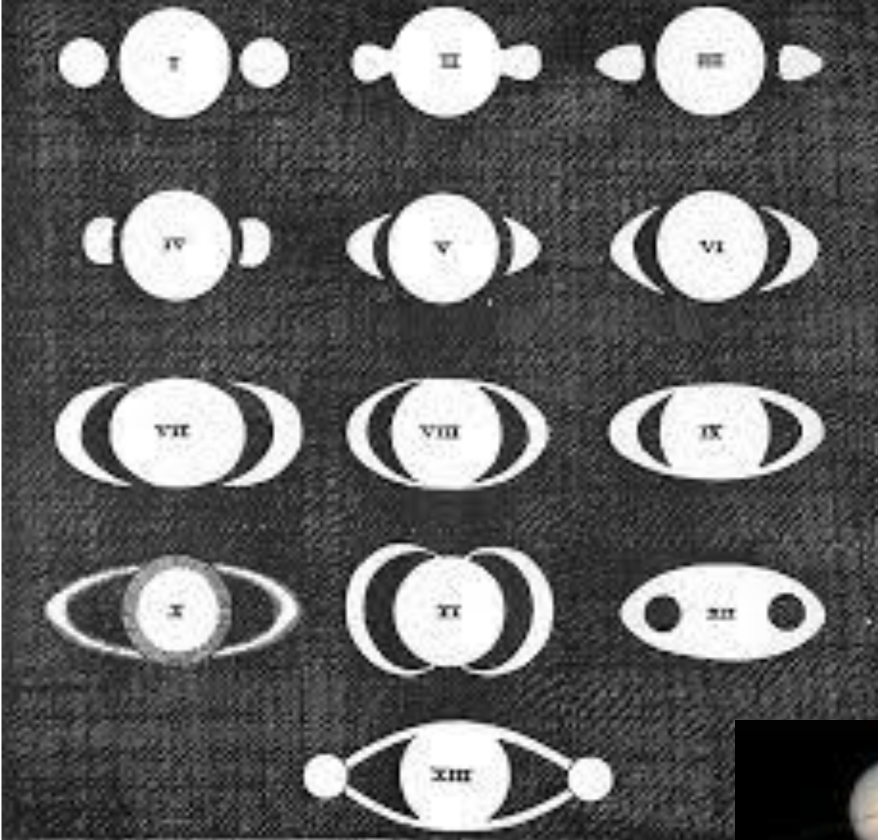

SIDEREVS NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA Spectacula pandens, suspiciendaque proponens vnicuique, præsertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt obseruata in LVNÆ FACIE, FIXIS INNVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS, Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam disparibus interuallis, atque periodis, celeritate mirabili circumuolutis; quos, nemini in hanc vsque diem cognitos, nouissimè Author depræhendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permissu, & Priuilegio.
M VIIII 22. 14.


Ser.mo Principe.

Galileo Galilei Humiliss.o Servo della Ser.tà V.a invigilando assiduam.te, et con ogni spirito per potere non solam.te satisfare al carico che tiene della lettura di Matematiche nello Studio di Padova,

Scrivere d'havere determinato di presentare al Ser.mo Principe l'Occhiale et per essere di giovamento inestimabile per ogni negozio et impresa marittima o terrestre stimo di tenere questo nuovo artifizio nel maggior segreto et solam.te a disposizione di S. Ser.tà. L'Occhiale cavato dalle più recondite speculazioni di prospettiva ha il vantaggio di scoprire Legni et Vele dell'inimico per due hore et più di tempo prima che egli scuopra noi et distinguendo il numero et la qualità dei Vasselli giudicare le sue forze pallestirsi alla caccia al combattimento o alla fuga, o pure anco nella campagna aperta vedere et particolarm.te distinguere ogni suo moto et preparamento.

Adi 7. di Gennaio Giove si vedeva così
Adi 8 così
era dunq; diretto et non retrogrado
Adi 12. si vedde in tale costituzione
Il 13 si veddono vicinis.e à Giove 4 stelle o meglio così
Adi 14 è nugolo
Il 15 la pross.a à ♃ era la min.e la 4.a era distante dalla 3.a il doppio in circa
Lo spazio delle 3 occidentali non era maggiore del diametro di ♃ et erano in linea retta.
♃ long. 71.38 lat. 1.13


I
II
III
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VII
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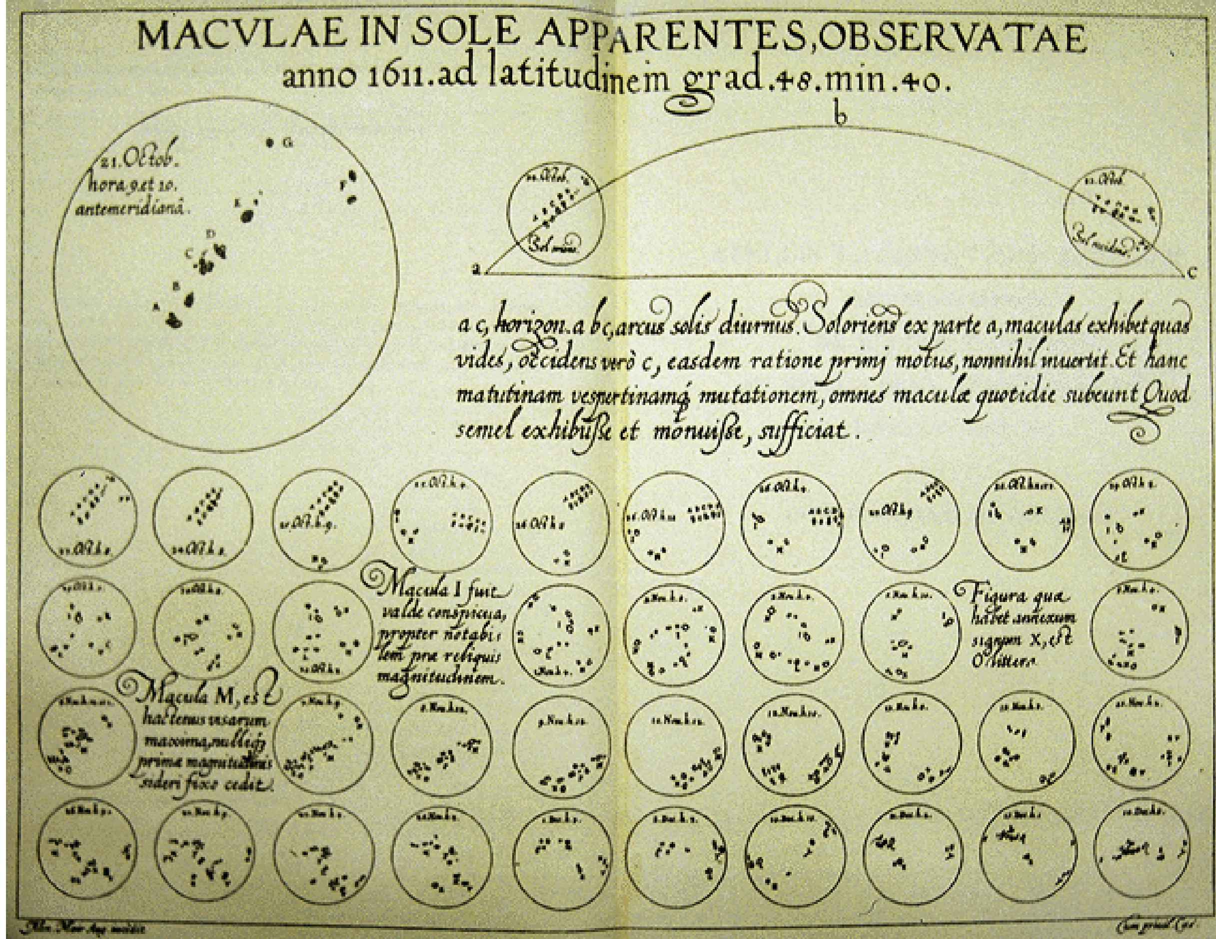
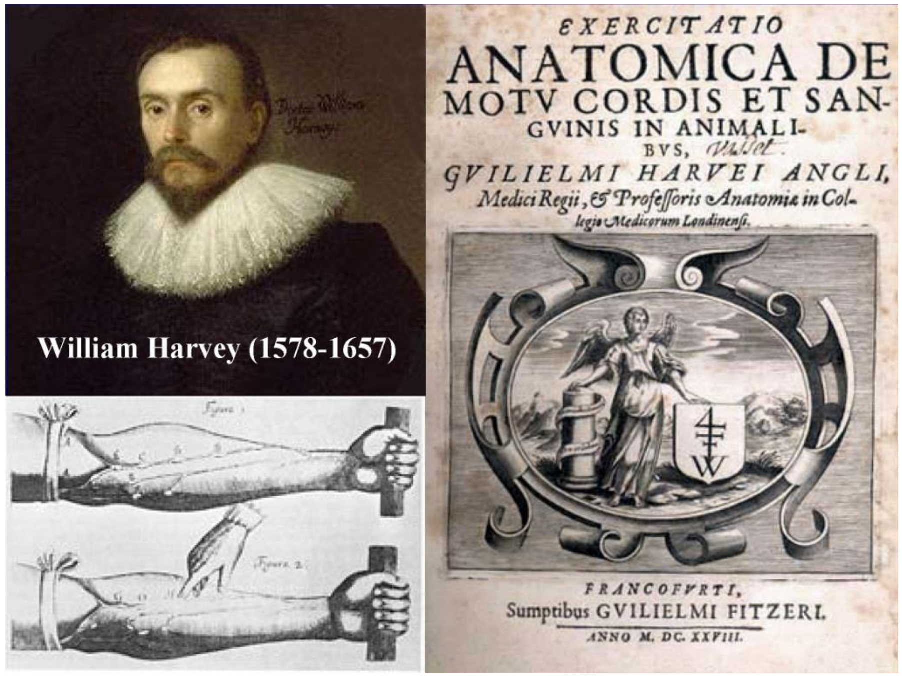
XI
XII
XIII


MACVLAE IN SOLE APPARENTES, OBSERVATAE
anno 1611. ad latitudinem grad. 48. min. 40.
21. Octob. hora 9. et 10. antemeridianâ.
a c, horizon. a b c, arcus solis diurnus. Sol oriens ex parte a, maculas exhibet quas vides, occidens verò c, easdem ratione primi motus, nonnihil invertit. Et hanc matutinam vespertinamq mutationem, omnes maculæ quotidie subeunt Quod semel exhibuisse et monuisse, sufficiat.
Macula I fuit valde conspicua, propter notabilem prae reliquis magnitudinem.
Figura quae habet annexum signum X, est O litterae
Macula M, est hactenus visarum maxima, nulliq; primae magnitudinis sideri fixo cedit.

William Harvey (1578-1657)



- ❑ Was a physician who made influential contributions in anatomy and physiology. “Father of Modern Physiology”
- ❑ Was the first known physician to describe the "Blood Circulation Theory" completely and in detail by using mathematical techniques in biologic research, (the systemic circulation and properties of blood being pumped to the brain and the rest of the body by the heart), Showed existence of valves in veins.
- ❑ "De Motu Cordis (On the Motion of the Heart and Blood)“

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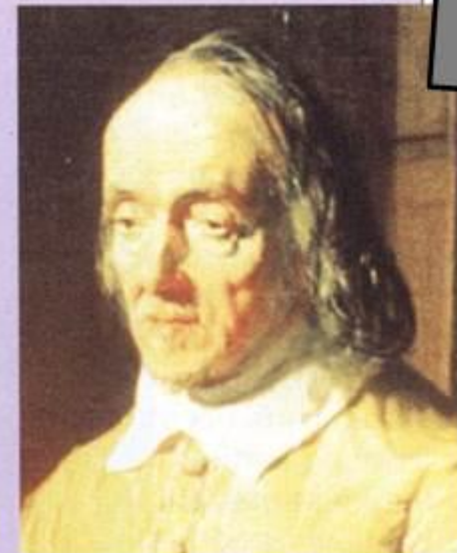
William Harvey

William Harvey



Biography

Born in 1578 in Kent. Studied medicine at Cambridge and Padua. Worked as a doctor in London and then as a lecturer in anatomy. In 1628 he published *An Anatomical Account of the Motion of the Heart and Blood in Animals.* He died in 1657.

Specialism

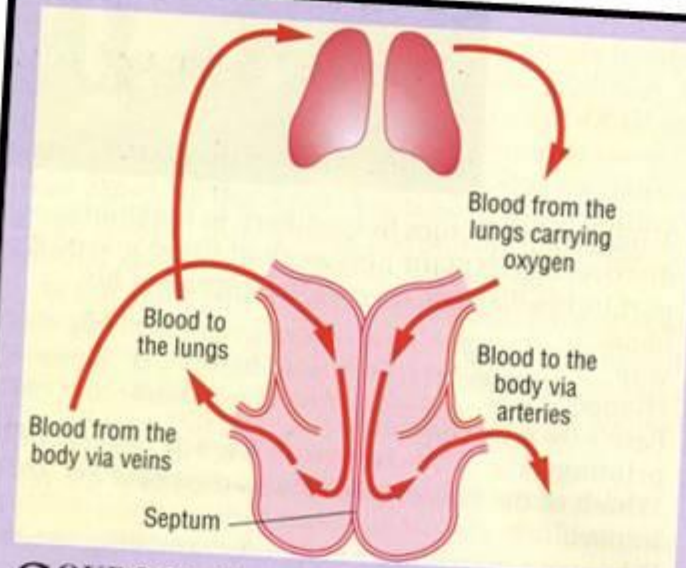
The circulation of the blood

Importance

Before Harvey: many doctors still believed in Galen's idea that new blood was constantly being manufactured in the liver to replace blood that was burnt up in the body in the same way as wood is burnt by fire. This idea had been challenged by a number of doctors but no one had proved exactly how the blood moved around the body.

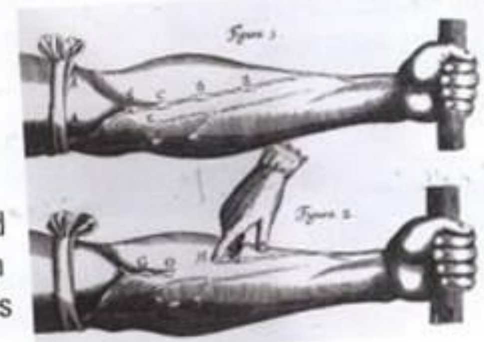
After Harvey: Harvey showed that blood flows around the body, is carried away from the heart by the arteries and returns to the heart in veins.

He proved that the heart acts as a pump, recirculating the blood and that blood does not burn up so no other organ is needed to manufacture new blood.

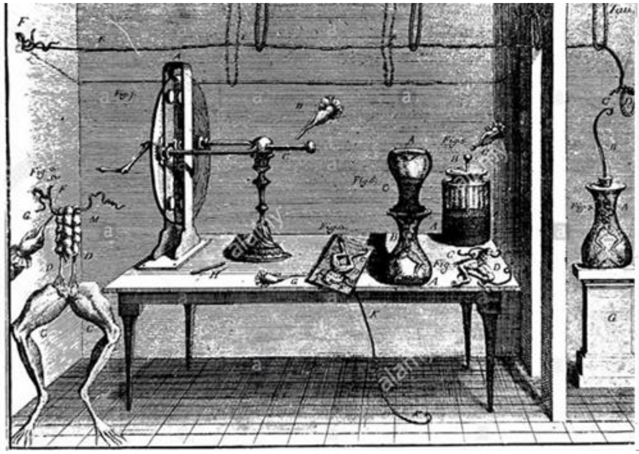


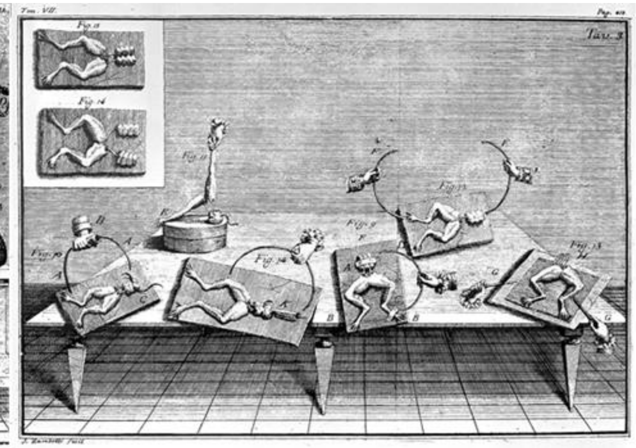
SOURCE 1 Diagram showing the circulation of the blood

Source B: An illustration from Harvey's book, showing an experiment that proved blood flowed only in one direction in the veins, towards the heart.



Luigi Galvani (1737-1798)





Alessandro Volta
(1745-1827)

- Was a physician, surgeon, anatomist, physicist, biologist, and philosopher.
- Observed contractions in the muscles of dead frogs' legs when struck by an electrical spark, which was in contact with two different metals, and revealed the presence of bioelectrical events. (called it animal electricity)
- This was one of the first forays into the study of bioelectricity, a field that studies the electrical patterns and signals from tissues such as the nerves and muscles.
- “Father of Bioelectricity”, "Forefather of Bioelectric Magnetics"

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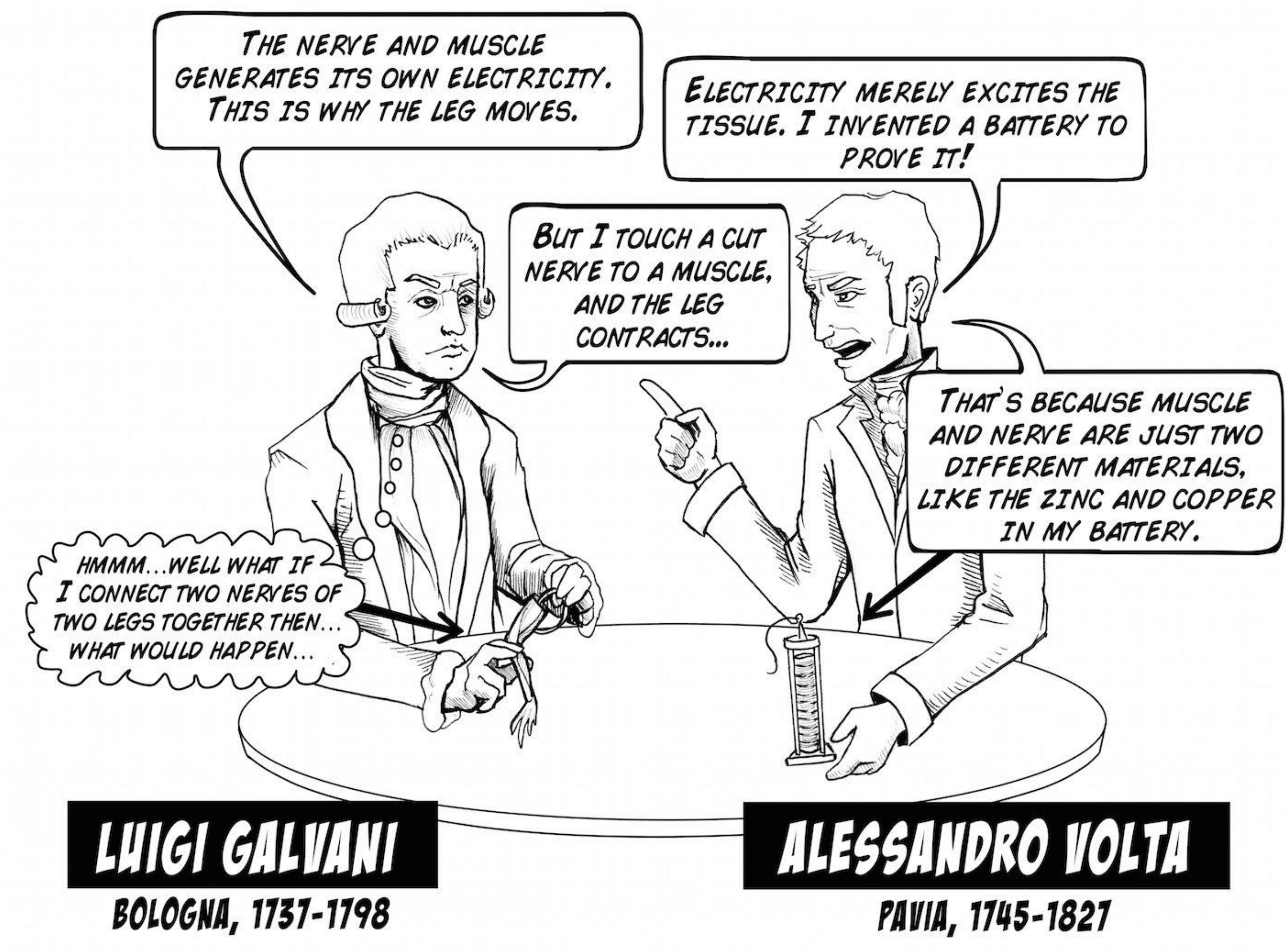
Luigi Galvani vs. Alessandro Volta

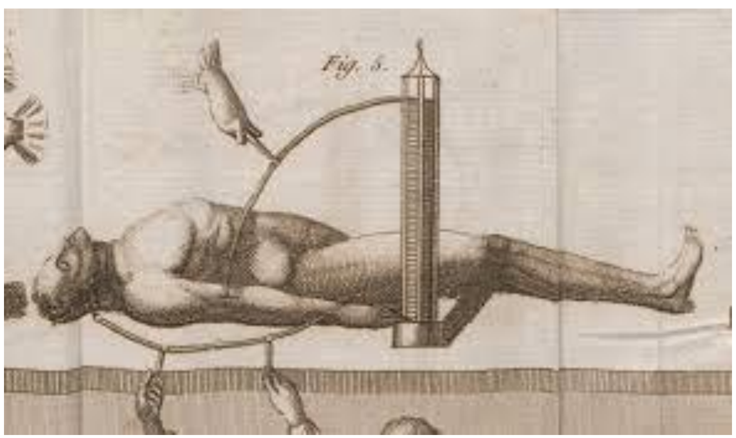


An Intresting Note !!!!

Did you know the Real Doctor behind "Doctor Frankenstein"?

Giovanni Aldini (1762 – 1834)
Galvani's Nephew
Physician, Physicist

Mary Shelley (1797 – 1851)
Novelist



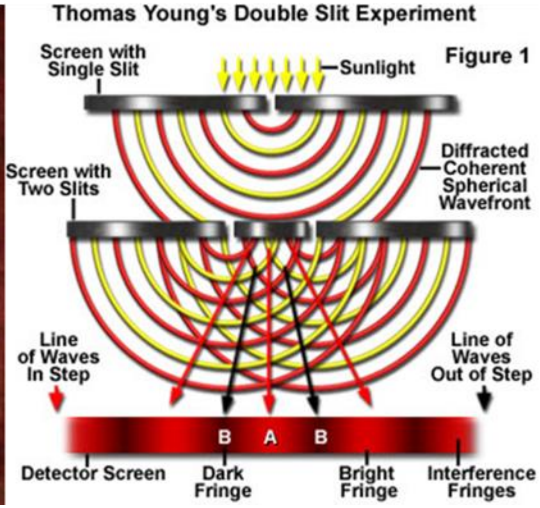
Aldini's public demonstration of the electro-stimulation technique of deceased limbs was performed on the executed criminal George Forster (or Foster) at Newgate in London in 1803.

Inspired !!!

Frankenstein (1831)

He’s Alive! – Frankenstein (1931)

Thomas Young (1773-1829)



Rosetta Stone

- "The Last Man Who Knew Everything"
- Was a physician, physicist, physiologist, Egyptologist.
- Made notable contributions to the fields of vision, light, solid mechanics, energy, medicine, physiology, language, musical harmony, and egyptology.
- Discovered wave theory of light, Young's modulus (Biomechanics), lens accommodation, astigmatism, color vision (three different nerve theory), surface tension (capillary phenomena), hemodynamics (vascular wall tension).

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Jean Leonard Marie Poiseuille (1797-1869)

$$\Delta P = \frac{8\mu L Q}{\pi r^4}$$

- Was a physicist, physiologist, and mathematician.
- Made notable contributions to hemodynamics.
- Discovered the relationship between blood flow, pressure and resistance in capillaries and veins (Laminar flow and Hagen-Poiseuille equation).

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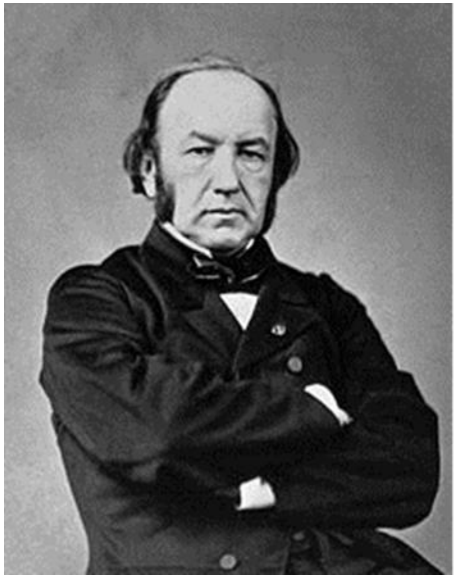
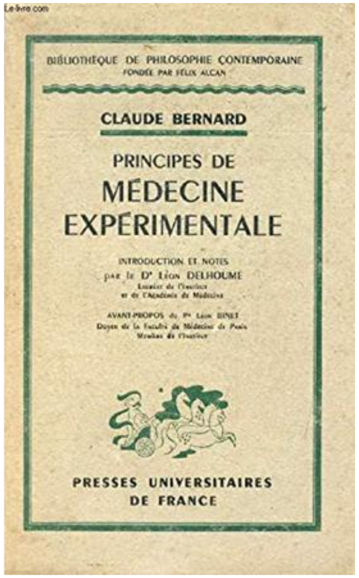
Claude Bernard (1813-1878)





- Was a physiologist. "The Father of Modern Physiology"
- Unlike most of his contemporaries, he insisted that all living creatures were bound by the same laws as inanimate matter.
- Made remarkable contributions to experimental medicine (Principes de Médecine Expérimentale).
- Discovered pancreatic functions, glycolytic functions in the liver (throws light on the causation of diabetes mellitus) and vasomotor system (vasodilator-vasoconstrictor nerves)

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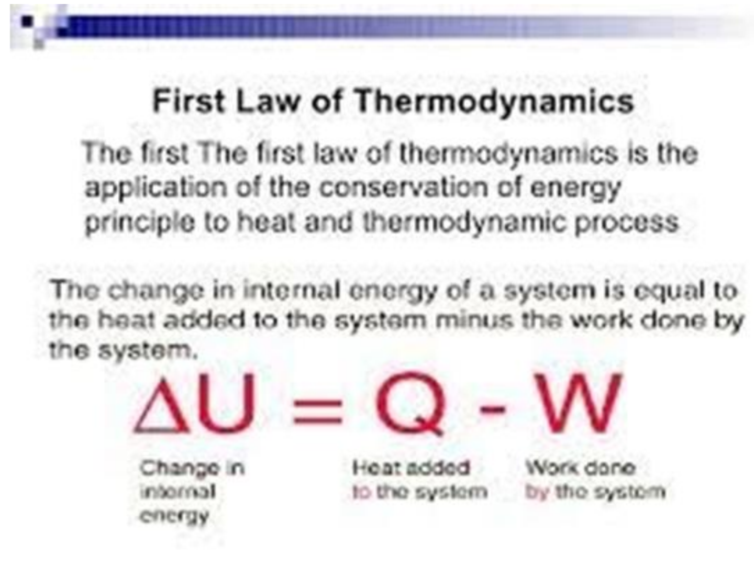
Julius Robert von Mayer (1814-1878)



- ❑ Was a physician, chemist and physicist and one of the founders of thermodynamics.
- ❑ Best known for enunciating one of the original statements of the "**conservation of energy**" or what is now known as one of the first versions of the first law of thermodynamics, namely that "energy can be neither created nor destroyed".

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Hermann L. F. von Helmholtz (1821-1894)

- Was a physicist and physician.
- Is known for his mathematics of the eye, theories of vision, ideas on the visual perception of space, color vision research, and on the sensation of tone, perception of sound, and empiricism in the physiology of perception; theories on the conservation of energy, work in electrodynamics, chemical thermodynamics, and on a mechanical foundation of thermodynamics.
- Discovered ophthalmoscope and Helmholtz resonator, measured the nerve conduction speed for the first time.

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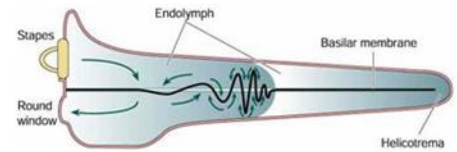
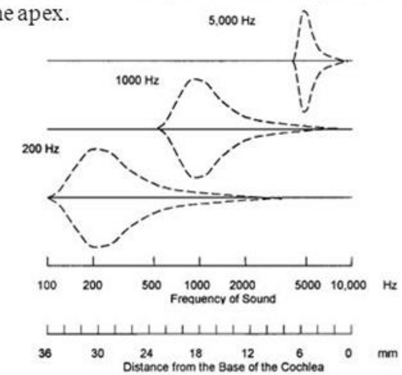
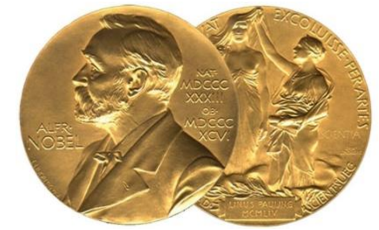
Georg von Békésy (1899-1972)



The sound pressure applied to the oval window is transmitted as a travelling wave along the basila membrane. The peak diplacements for high frequencies are toward the base, and for low frequencies are toward the apex.



Envelopes induced by sound at 3 different frequencies



- Was a Nobel Prize awarded-biophysicist (1961 in Physiology or Medicine).
- Is known for his research on the function of the cochlea in the mammalian hearing organ.
- Observed that the basilar membrane moves like a surface wave (Békésy's Travelling Wave Theory; Békésy waves) when stimulated by sound.

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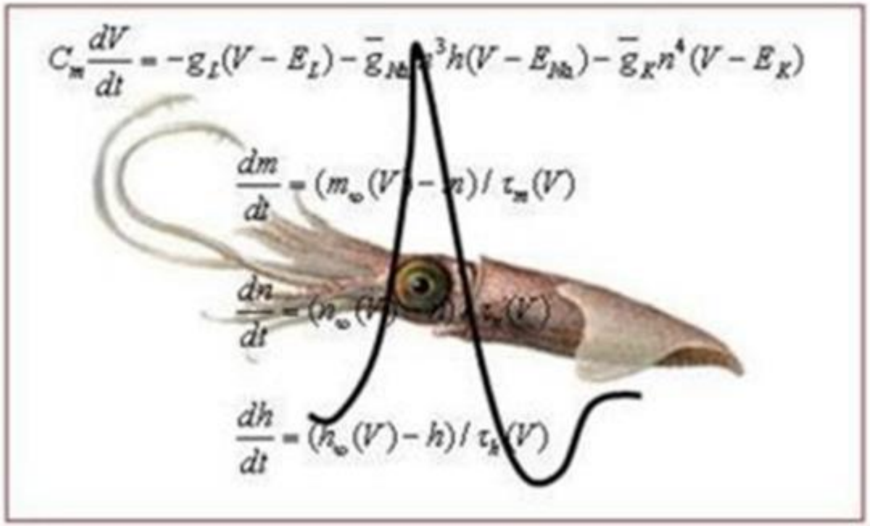
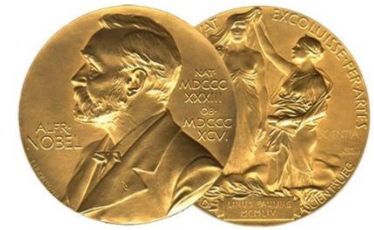
Alan Hodgkin & Andrew Huxley

Alan L. Hodgkin



Andrew F. Huxley



- Were Nobel Prize awarded-biophysicists and -physiologists. (1963)
- Are known for their discoveries concerning the ionic mechanisms involved in excitation and inhibition in the peripheral and central portions of the nerve cell membrane (known as the Hodgkin–Huxley model of the action potential).
- Andrew Huxley, together with Rolf Niedergerke, discovered the mechanism of muscle contraction, popularly called the "sliding filament theory", which is the foundation of our modern understanding of muscle mechanics.

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Allan M. Cormack & Godfrey N. Hounsfield

Photo from the Nobel Foundation archive.
Allan M. Cormack

Photo from the Nobel Foundation archive.
Godfrey N. Hounsfield

- Were Nobel Prize awarded-biophysicists. (1979)
- Are known for the development of computer assisted tomography (CT; CAT; CAT scan).

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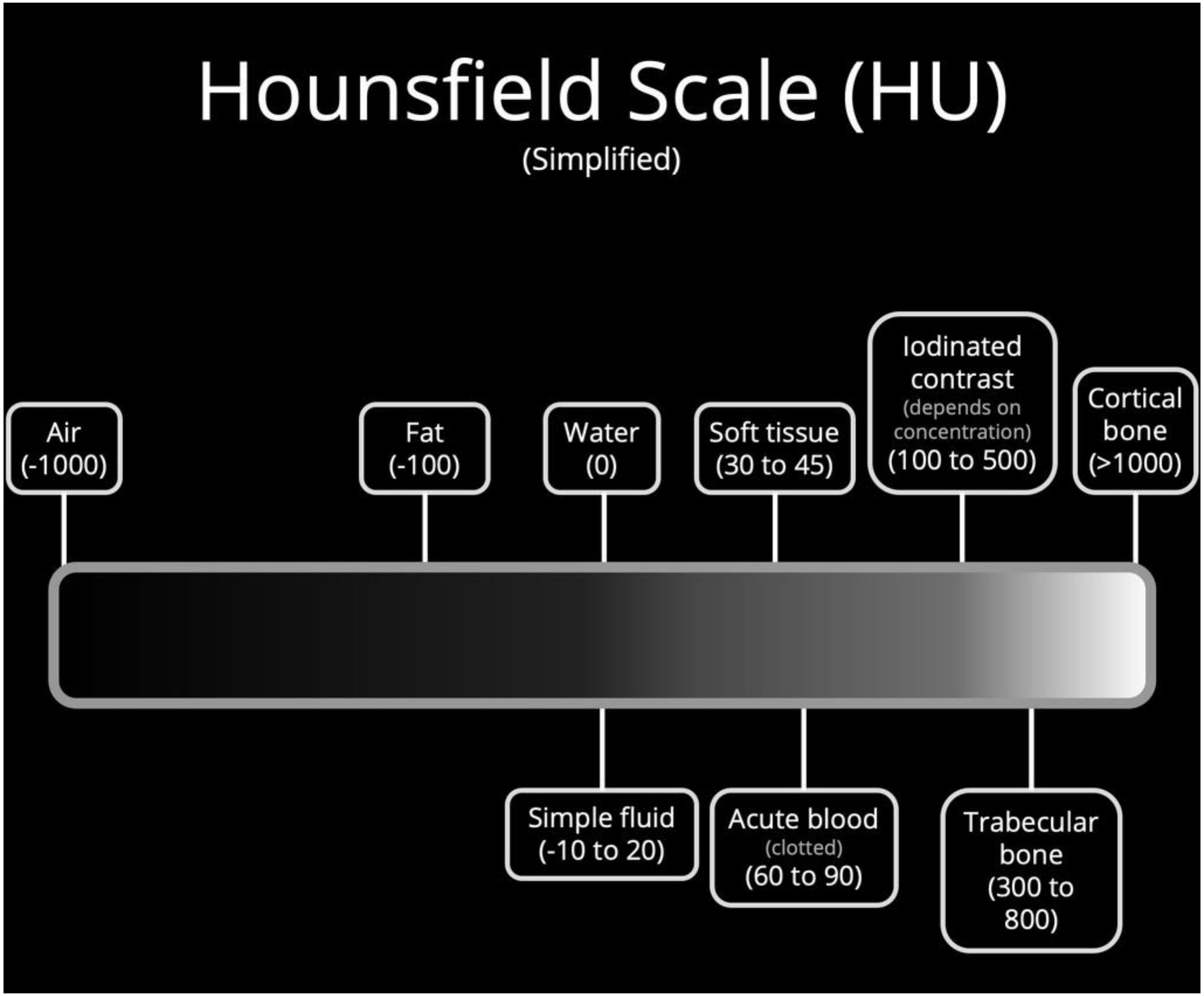
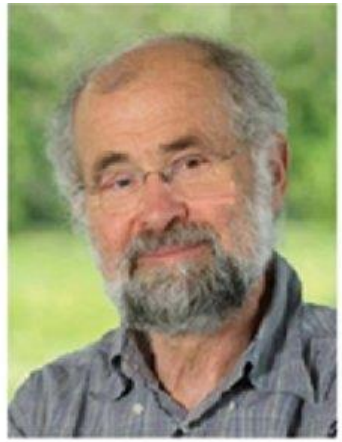
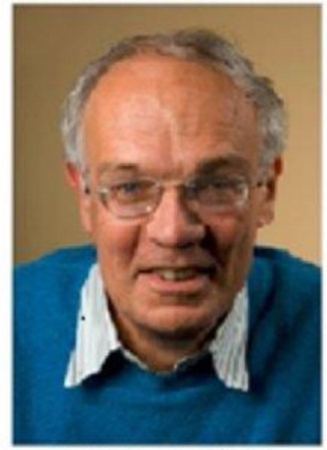


His name is immortalised in the Hounsfield scale, a quantitative measure of radiodensity used in evaluating CT scans.

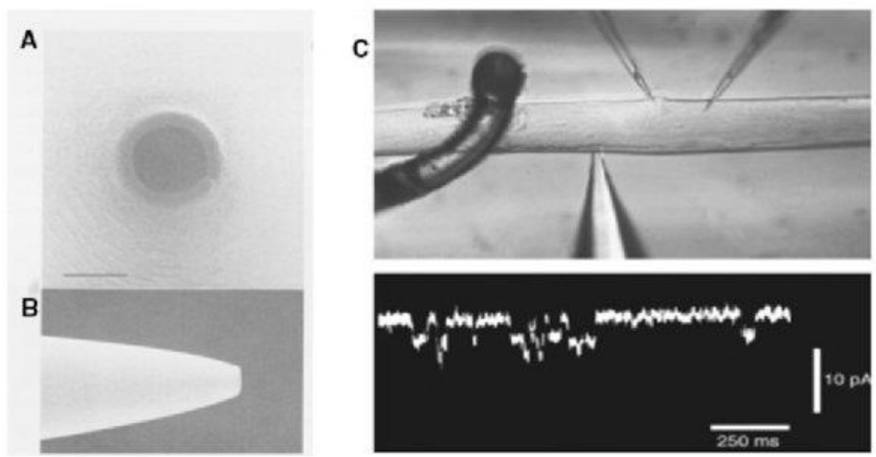
Erwin Neher & Bert Sakman



Erwin Neher (1944)



Bert Sakmann (1942)



- ❑ Were Nobel Prize awarded-scientists (1991).
- ❑ Are known for their discoveries concerning the function of single ion channels in cells (known as gate currents) and the invention of the patch clamp technique.

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Paul Lauterbur & Peter Mansfield

Paul Lauterbur, professor of chemistry, biophysics, and computational biology at the University of Illinois

Peter Mansfield, emeritus professor of physics, at the University of Nottingham

Raymond Vahan Damadian

- ❑ Were Nobel Prize awarded-scientists (2003).
- ❑ Are known for their discoveries concerning magnetic resonance imaging.

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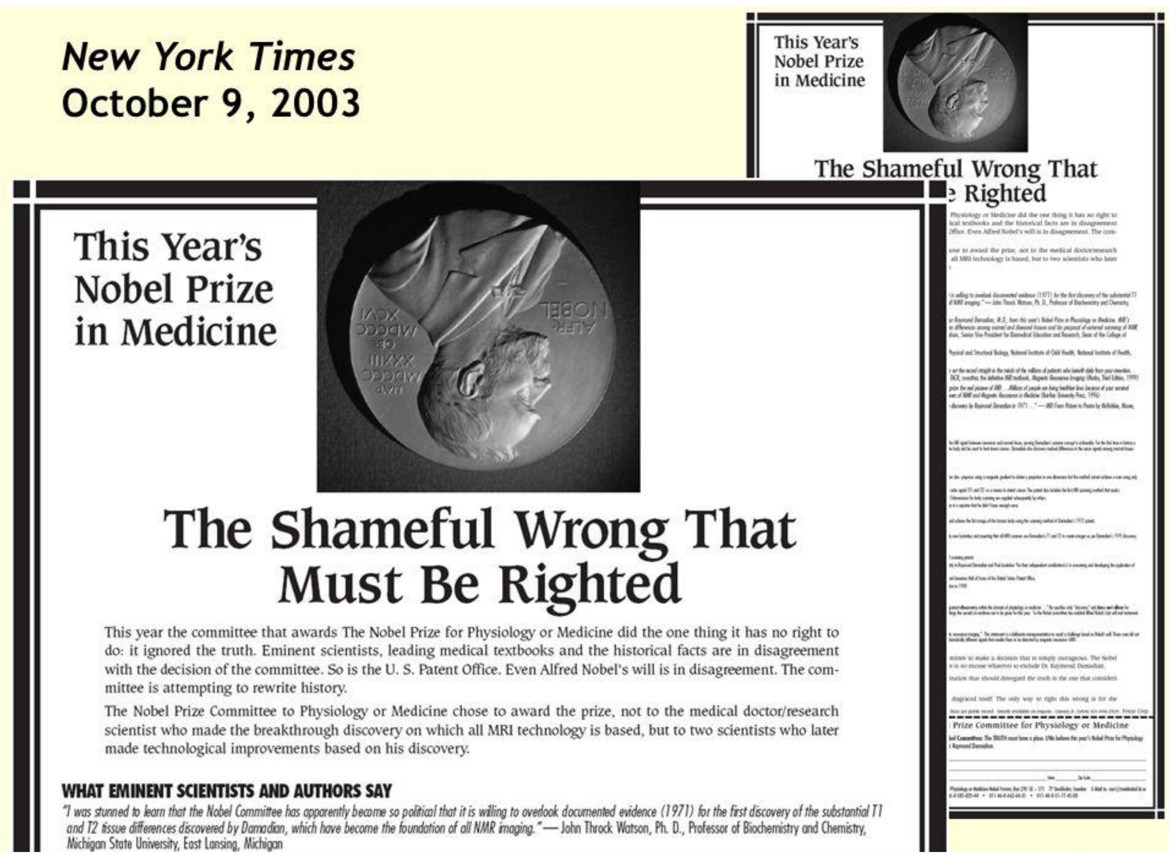
An Intresting Note !!!!

Did the Nobel Prize Committee make a wrong decision in 2003?


New York Times
October 9, 2003

This Year's Nobel Prize in Medicine

The Shameful Wrong That Must Be Righted

This year the committee that awards The Nobel Prize for Physiology or Medicine did the one thing it has no right to do: it ignored the truth. Eminent scientists, leading medical textbooks and the historical facts are in disagreement with the decision of the committee. So is the U. S. Patent Office. Even Alfred Nobel's will is in disagreement. The committee is attempting to rewrite history.

The Nobel Prize Committee to Physiology or Medicine chose to award the prize, not to the medical doctor/research scientist who made the breakthrough discovery on which all MRI technology is based, but to two scientists who later made technological improvements based on his discovery.

WHAT EMINENT SCIENTISTS AND AUTHORS SAY

"I was stunned to learn that the Nobel Committee has apparently become so political that it is willing to overlook documented evidence (1971) for the first discovery of the substantial T1 and T2 tissue differences discovered by Damadian, which have become the foundation of all NMR imaging." — John Throck Watson, Ph. D., Professor of Biochemistry and Chemistry, Michigan State University, East Lansing, Michigan

Alfred Nobel's will that prizes are not to be given out solely on the basis of improving an existing technology for commercial use.


Let's have a
COFFEE
BREAK

What is Biophysics?

What is Biophysics?

What is Biophysics?

- **Physics (Romanized: physikḗ - knowledge of nature):**
  - Is the natural science that studies matter, its motion and behavior through space and time, and the related entities of energy and force.
  - Is one of the most fundamental scientific disciplines, and its main goal is to understand how the universe behaves.
- **Biology (Romanized: bíos-logia – life to speak):**
  - Is the natural science that studies life and living organisms, including their physical structure, chemical processes, molecular interactions, physiological mechanisms, development and evolution.

❑ Biophysics:

- ❑ **Is an interdisciplinary science** that **applies approaches and methods traditionally used in physics to study biological phenomena**. (Is an interdisciplinary science somewhere between biology and physics)

- ❑ Covers all scales of biological organization, from molecular to organismic and populations.

- ❑ **Is connected to other disciplines**, such as biochemistry, molecular biology, physical chemistry, physiology, nanotechnology, bioengineering, computational biology, biomechanics, developmental biology and systems biology.

The Scope of Biophysics

- In terms of biophysics, living organisms are considered as open, self-adjusting, producing, developing and growing, heterogeneous and multi-purpose complex systems.

- Every stage of life is of interest in biophysics, from small molecules to coarse biopolymers (proteins and nucleic acids), cell organelles, cells, tissues, organs, organisms, communities and biosphere.

- **Kenneth Stewart Cole (1900 − 1984) summarizes the scope of biophysics** as "**includes everything that is interesting and excludes everything trivial**."

Subfields of Biophysics

- **Biology and Molecular Biology**: Almost all forms of biophysics efforts are included in some biology department somewhere. To include some: gene regulation, single protein dynamics, bioenergetics, patch clamping, biomechanics.

- **Structural Biology**: Ångstrom-resolution structures of proteins, nucleic acids, lipids, carbohydrates, and complexes thereof.

- **Biochemistry and Chemistry**: Biomolecular structure, siRNA, nucleic acid structure, structure-activity relationships.

- **Computer Science**: Neural networks, biomolecular and drug databases.

- **Computational Chemistry**: Molecular dynamics simulation, molecular docking, quantum chemistry

- **Bioinformatics**: Sequence alignment, structural alignment, protein structure prediction
- **Mathematics**: Graph/network theory, population modeling, dynamical systems, phylogenetics.
- **Medicine and Neuroscience**: Tackling neural networks experimentally (brain slicing) as well as theoretically (computer models), membrane permitivity, gene therapy, understanding tumors.
- **Pharmacology and Physiology**: Channel biology, biomolecular interactions, cellular membranes, polyketides.
- **Physics**: Biomolecular free energy, stochastic processes, covering dynamics.
- **Quantum Biophysics**: involves quantum information processing of coherent states, entanglement between coherent protons and transcriptase components, and replication of decohered isomers to yield time-dependent base substitutions. These studies imply applications in quantum computing.

Research Topics in Biophysics-I

- Macromolecular X-ray Crystallography
- Protein (Multidimensional) NMR
- Mass Spectroscopy
- Atomic Force Microscopy
- Electron Microscopy
- Cryoelectron Microscopy
- Dynamic Light Scattering (DLS)
- Fluorescence Resonance Energy Transfer (FRET)
- **Electrophysiology**
- Bioenergetics
- Radioisotope Dating Technologies
- Biomolecular Hydrodynamics (Biology At Low Reynolds Numbers)
- Molecular Resonance İmaging (MRI)
- Quantum Biology
- Quantum-coherent Electronic Energy Transfer (QCEET)
- Organismal Magnetoreception

Research Topics in Biophysics-II

- Orchestrated Objective Reduction (Orchor)
- Electron Paramagnetic (Spin) Resonance (EPR/ESR)
- **Membrane Biophysics**
- **Medical Biophysics**
- Astrobiology
- Fluorescence Correlation Spectroscopy (FCS)
- Fourirer Transform Infra-red (FTIR) Spectroscopy & Microscopy
- Raman Spectroscopy & Microscopy
- Optical Luminescence Dating Technology
- Confocal Fluorescence Microscopy
- High-resolution Transmission Electron Microscopy (HRTEM)
- Macromolecular Simulation
- Magnetic Proteins
- Optical & Magnetic Tweezers
- **Biomechanics**
- Microscale Thermophoresis (MST)

Research Topics in Biophysics-III

- ❑ Neutron Spin Echospectroscopy (NSES)
- ❑ Cytological Patch Clamping
- ❑ Dual Polarization İnterferometry
- ❑ Biophotonics
- ❑ Light-activated Drugs
- ❑ Biomembrane Electrostatics
- ❑ Biomolecular Nonlinear Optics (NLO)
- ❑ X-ray Micro-tomography
- ❑ Fluorescence Nanoscopy (STED, FPALM, Etc.)

International System of Units (SI)

base unit	symbol	defining constants	symbol	Value
kilogram	kg	Planck constant	h	$6.626\,070\,15 \times 10^{-34}$ J s
metre	m	speed of light in a vacuum	c	299 792 458 m/s
second	s	hyperfine transition frequency of caesium atom	$\Delta\nu_{Cs}$	9 192 631 770 Hz
ampere	A	elementary charge	e	$1.602\,176\,634 \times 10^{-19}$ C
kelvin	K	Boltzmann constant	k	$1.380\,649 \times 10^{-23}$ J/K
mole	mol	Avogadro constant	N_A	$6.022\,140\,76 \times 10^{23}$ /mol
candela	cd	luminous efficacy of monochromatic radiation of frequency 540 THz	K_{cd}	683 lm/W

Unit	Symbol	Quantity
kilogram	kg	mass
metre	m	length
second	s	time
ampere	A	electric current
kelvin	K	temperature
mole	mol	amount of substance
candela	cd	luminous intensity

SI derived units				
Name	**Symbol**	**Quantity**	**Expression in terms of other units**	**Expression in terms of SI base units**
hertz	Hz	frequency	1/s	s^{-1}
radian	rad	angle	$m \cdot m^{-1}$	dimensionless
steradian	sr	solid angle	$m^2 \cdot m^{-2}$	dimensionless
newton	N	force, weight	$m \cdot kg/s^2$	$m \cdot kg \cdot s^{-2}$
pascal	Pa	pressure, stresss	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
joule	J	energy, work, heat	$N \cdot m = C \cdot V = W \cdot s$	$m^2 \cdot kg \cdot s^{-2}$
watt	W	power, radiant flux	$J/s = V \cdot A$	$m^2 \cdot kg \cdot s^{-3}$
coulomb	C	electric charge or electric flux	$s \cdot A$	$s \cdot A$
volt	V	voltage, electrical potential difference, electromotive force	$W/A = J/C$	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
farad	F	electric capacitance	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
ohm	Ω	electric resistance, impedance, reactane	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
siemens	S	electrical conductance	$1/\Omega$	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
weber	Wb	magnetic flux	J/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
tesla	T	magnetic field strength, magnetic flux density	$V \cdot s/m^2 = Wb/m^2 = N/(A \cdot m)$	$kg \cdot s^{-2} \cdot A^{-1}$
henry	H	inductance	$V \cdot s/A = Wb/A$	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
degree Celsius	°C	temperature	*K − 273.15*	*K − 273.15*
lumen	lm	luminous flux	$lx \cdot m^2$	$cd \cdot sr$
lux	lx	illuminance	lm/m^2	$m^{-2} \cdot cd \cdot sr$
ecquerel	Bq	radioactivity	1/s	s^{-1}
gray	Gy	absorbed dose of ionizing radiation	J/kg	$m^2 \cdot s^{-2}$
sievert	Sv	equivalent dose of ionizing radiation	J/kg	$m^2 \cdot s^{-2}$
katal	kat	Catalytic activity	mol/s	$s^{-1} \cdot mol$

Prefix	Symbol	Multiplier	Exponential	Name
yotta	Y	1,000,000,000,000,000,000,000,000	10^{24}	Septillion
zetta	Z	1,000,000,000,000,000,000,000	10^{21}	Sextillion
exa	E	1,000,000,000,000,000,000	10^{18}	Quintillion
peta	P	1,000,000,000,000,000	10^{15}	Quadrillion
tera	T	1,000,000,000,000	10^{12}	Trillion
giga	G	1,000,000,000	10^{9}	Billion
mega	M	1,000,000	10^{6}	Million
kilo	k	1,000	10^{3}	Thousand
hecto	h	100	10^{2}	Hundred
deca	da	10	10^{1}	Ten
		1	10^{0}	One
deci	d	0.1	10^{-1}	Tenth
centi	c	0.01	10^{-2}	Hundredth
milli	m	0.001	10^{-3}	Thousandth
micro	µ	0.000001	10^{-6}	Millionth
nano	n	0.000000001	10^{-9}	Billionth
pico	p	0.000000000001	10^{-12}	Trillionth
femto	f	0.000000000000001	10^{-15}	Quadrillionth
atto	a	0.000000000000000001	10^{-18}	Quintillionth
zepto	z	0.000000000000000000001	10^{-21}	Sextillionth
yocto	y	0.000000000000000000000001	10^{-24}	Septillionth

Chapter 1: System Concept

- The term "***system***" can be defined as "**an orderly arrangement of a set of interrelated and interdependent element that operate collectively to accompolish some common purpose or goal**".
- **The study of system concepts has three basic implications:**
  - A system must be designed to achieve pre-determined objective,
  - Interrelationships and interdependencies must exist among components,
  - Objectives of organization has higher priority than objectives of subsystems.
- The properties of a system are determined by the types, numbers of its parts or elements, and the interactions among the elements.

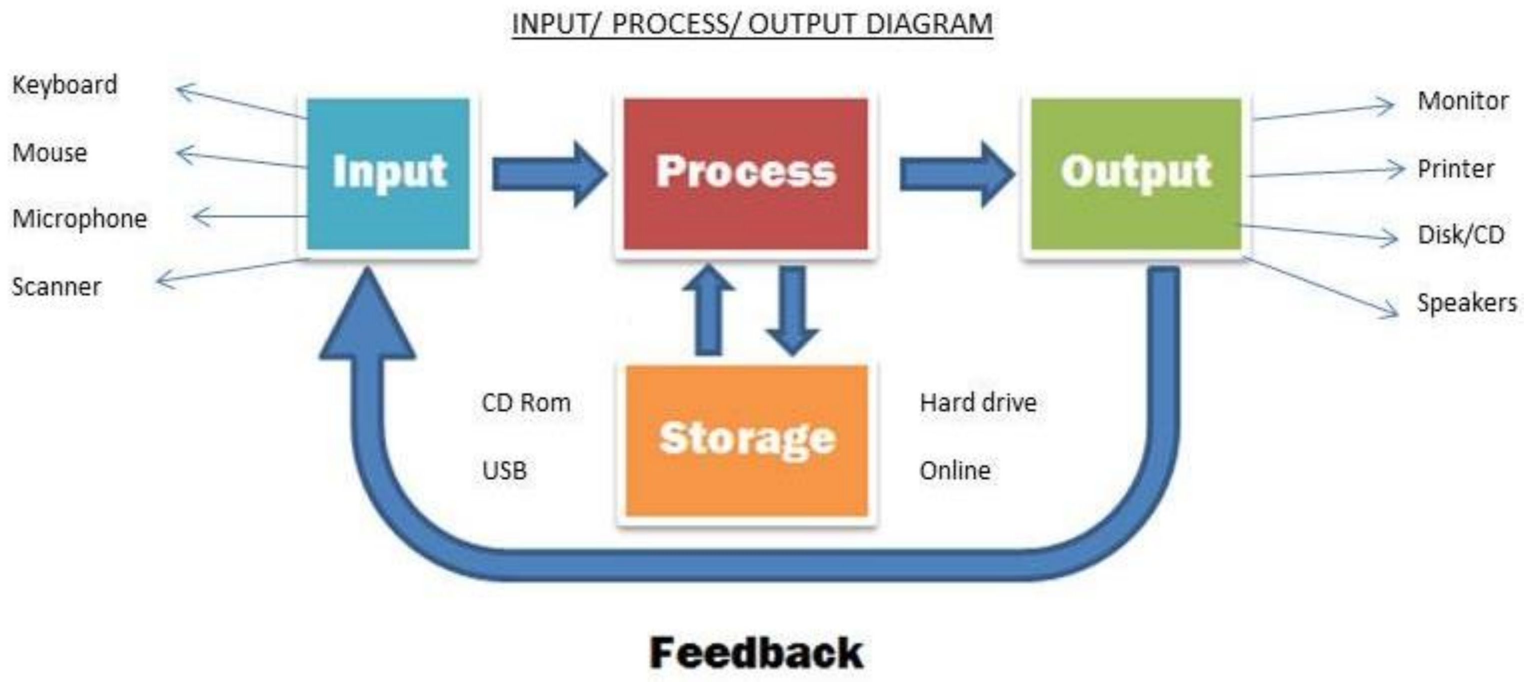
❑ Characteristics of a system:

- ✓ Organization **(Implies structure and order, Is the arrangement of components that helps to achieve objectives.)**
- ✓ Interaction **(Refers to the manner in which each component functions with other components of the system.)**
- ✓ Interdependence **(Means that parts of the organization or computer system depend on one another. One subsystem depends on the output of another subsystem for proper functioning.)**
- ✓ Integration **(Refers to the holism of systems, Is concerned with how a system is tied together)**
- ✓ Central objective **(A system should have a central objective. Objectives may be real or stated. The important point is that users must know the central objective of a system early in the analysis for a successful design and conversion.)**

❑ Elements of a system:

- ✓ Input(s) and Output(s) **(What data the system receives to produce a certain output / What goes out from the system after being processed)**
- ✓ Processors (operational component) **(The process involved to transform input into output)**
- ✓ Control **(In order to get the desired results, it is essential to monitor and control the input)**
- ✓ Feedback (cybernetic procedure; positive or negative, routine or informational) **(Output is checked with the desired standards of the output set and the necessary steps are taken for achieving the output as per the standards)**
- ✓ Environment **(The things outside the boundary of the system are known as environment. Change in the environment affects the working of the system)**
- ✓ Boundaries and Interfaces (limits of the elements) **(Setting up boundaries helps for better concentration of the actives carried in the system / The interconnections and the interactions between the sub-systems)**

E.g… Computers



Input- this is taking information that is external to the system and entering it into the system. For example keyboard or mouse

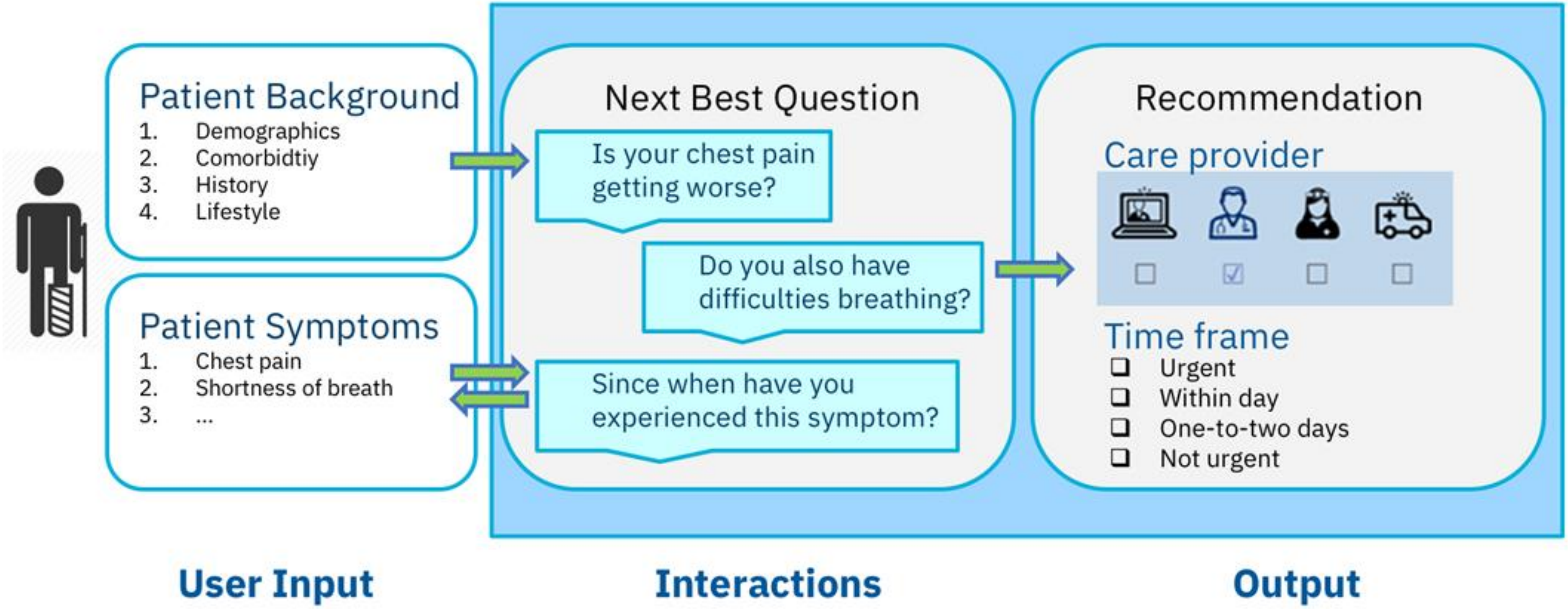
Processing- this is an action performed on the data. This includes sorting, searching or performing calculations on the data.

Storage- this is where data is held. It may be that data has been input.

Output- this is taking information that was in the system. For example disk/CD

Feedback- this is where the output from the system forms part of the input to the system. Usually used in real-time situations.

E.g… Patient Evaluation

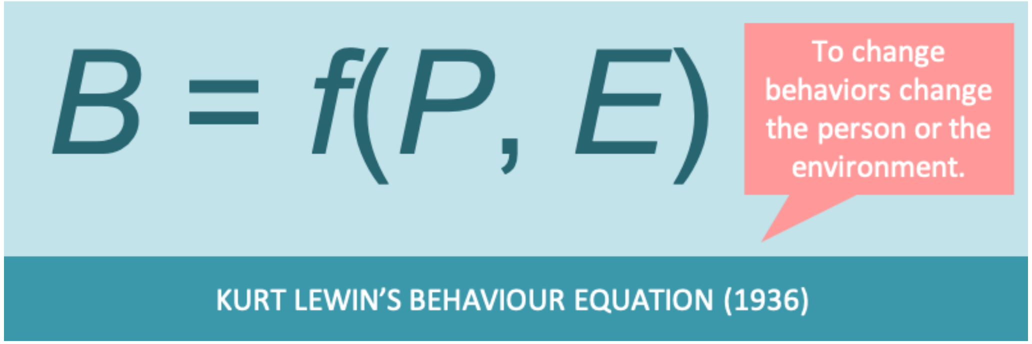


Lewin's Equation
(Behavior Equation, 1936)

- ❑ Is a heuristic formula proposed by Kurt Lewin, as an explanation of what determines behavior.
- ❑ States that an individual's behavior (B)
  - ❑ Is a function (f) of the person (P), including their history, personality and motivation,

  and

  - ❑ Their environment (E), which includes both their physical and social surroundings.

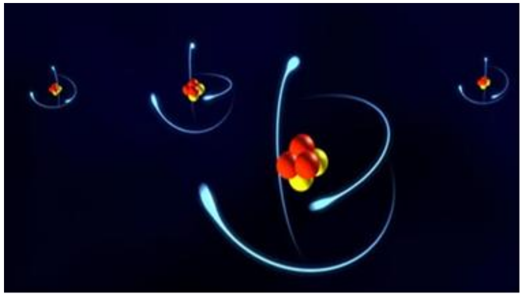


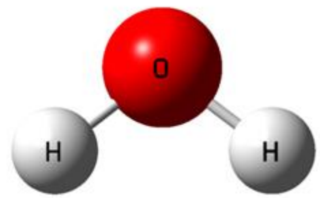
Usage of Lewin's Equation in Biophysics

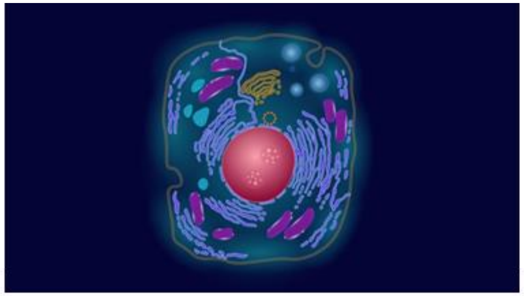
$$Y = Y(E, \alpha, t)$$

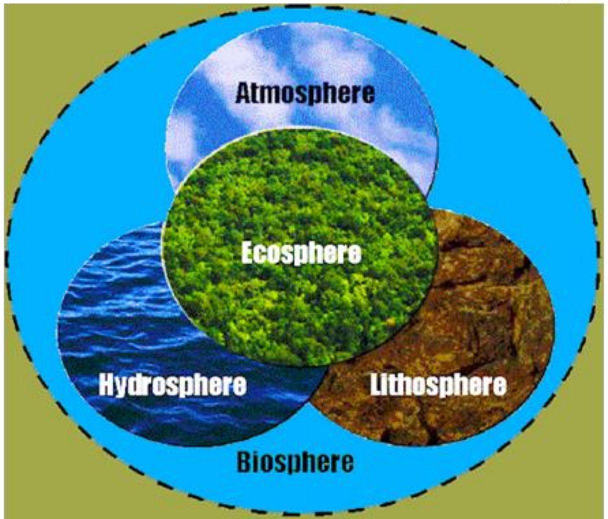
- An E effect applied from the environment can cause a response like Y in the system.
- Besides impact parameters (Force parameters; E), the behavior equation can explicitly include system parameters (α) and time (t) as well.
- A system may be subjected to many effects at the same time and generate many responses of different types.

- Any system can be divided into components in different sections and these components can also be considered as a system (or subsystem).









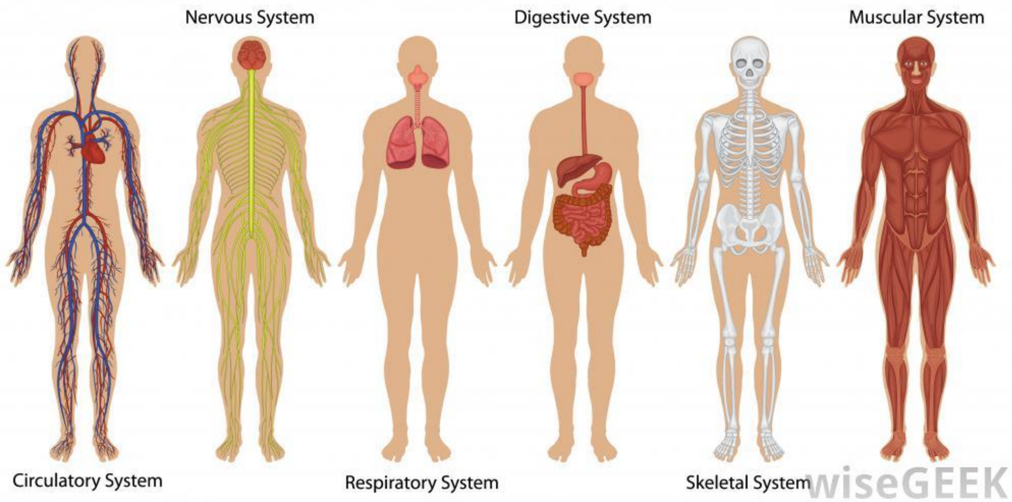
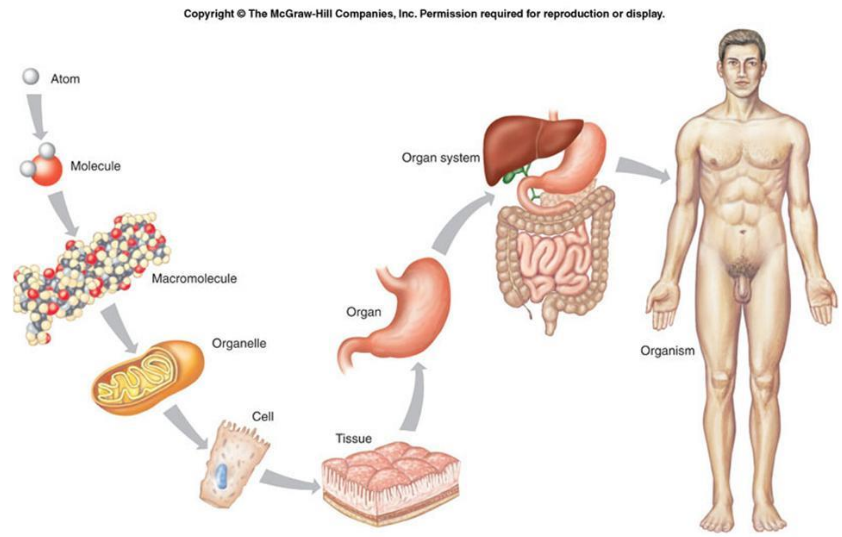
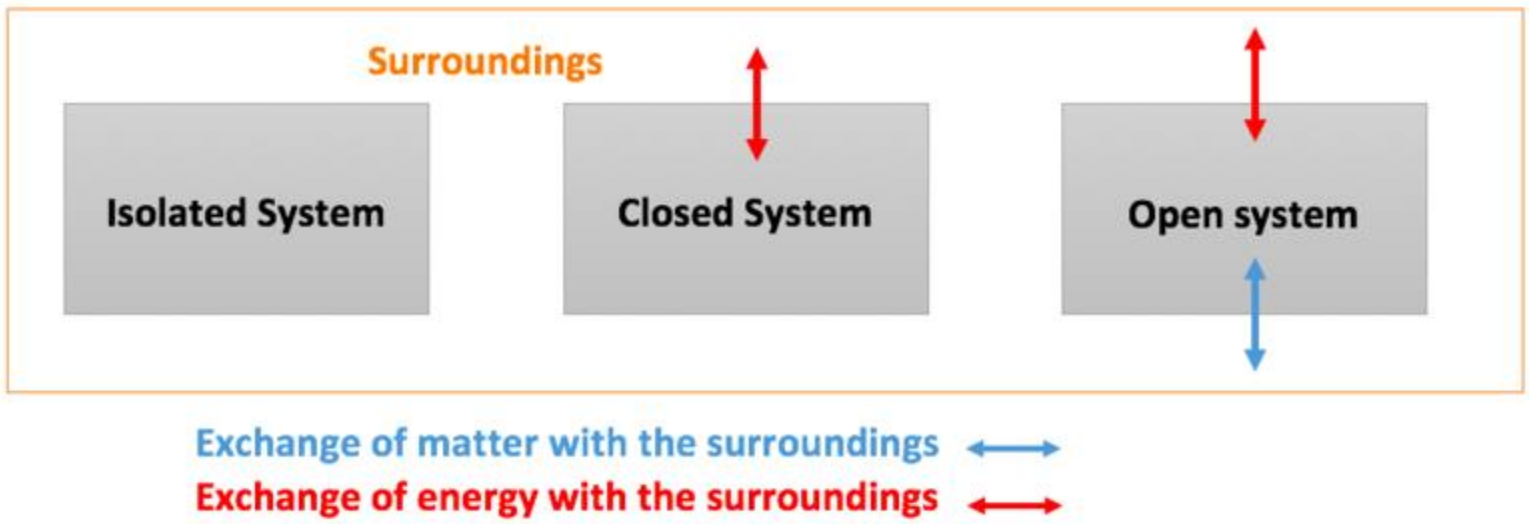


Fig. 1.03

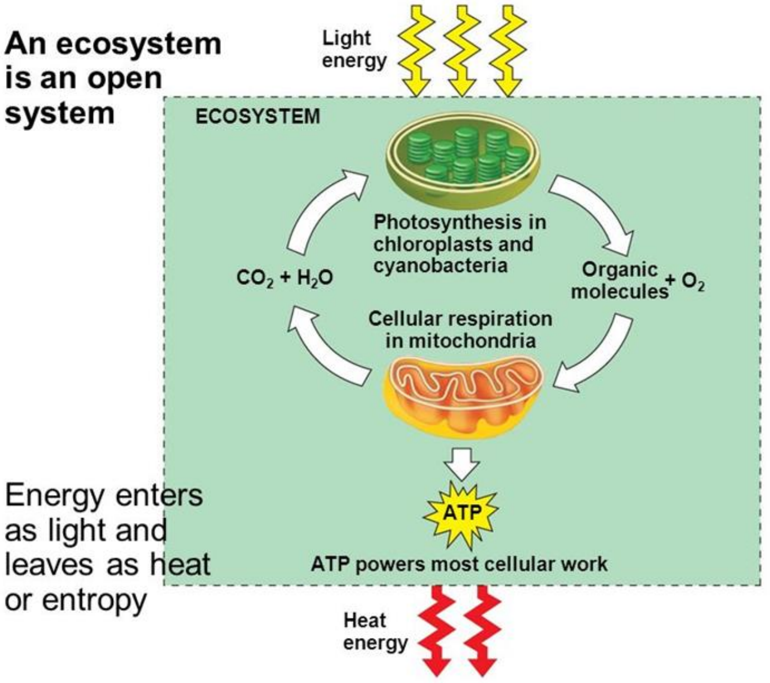


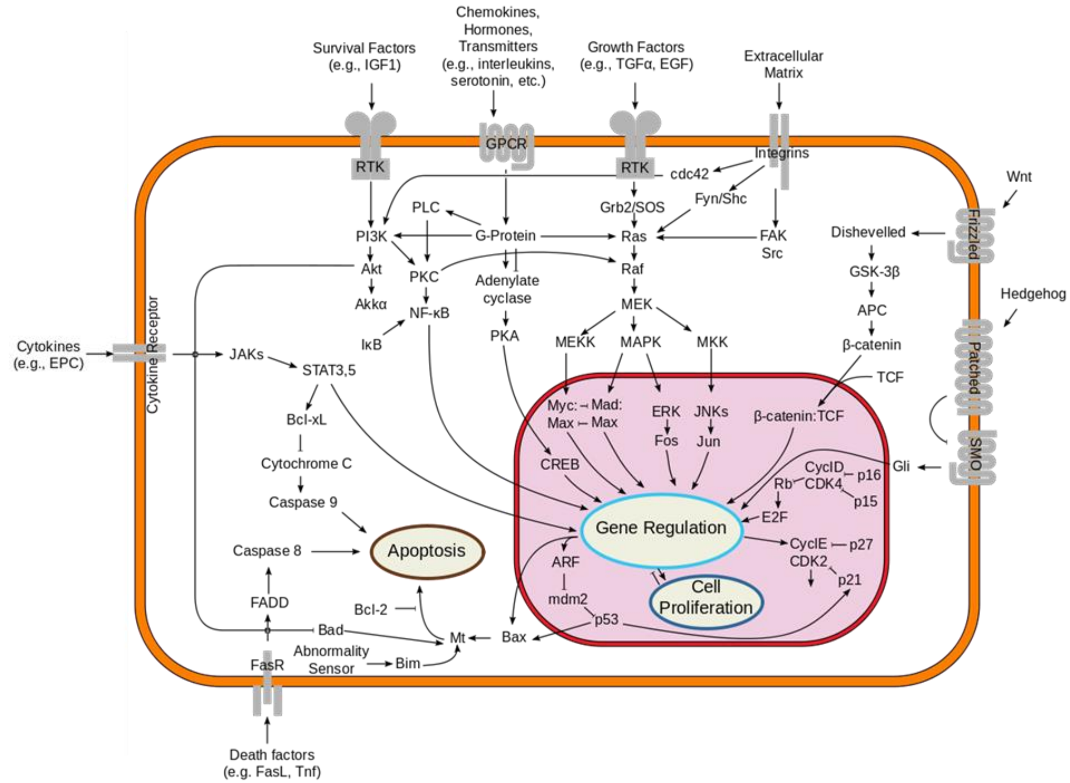
- Functionally an organism can be divided into subsystems;
  - Circulatory system, respiratory system, nervous system, digestive system, etc.
- Whether they are thought of as structurally or functionally divided subsystems, the characteristics of an organism are determined by the interaction between the subsystems as well as the properties of these subsystems.
- Disruption of one subsystem affects the behavior of all other subsystems and therefore the whole organism.

Organisms As An Open System

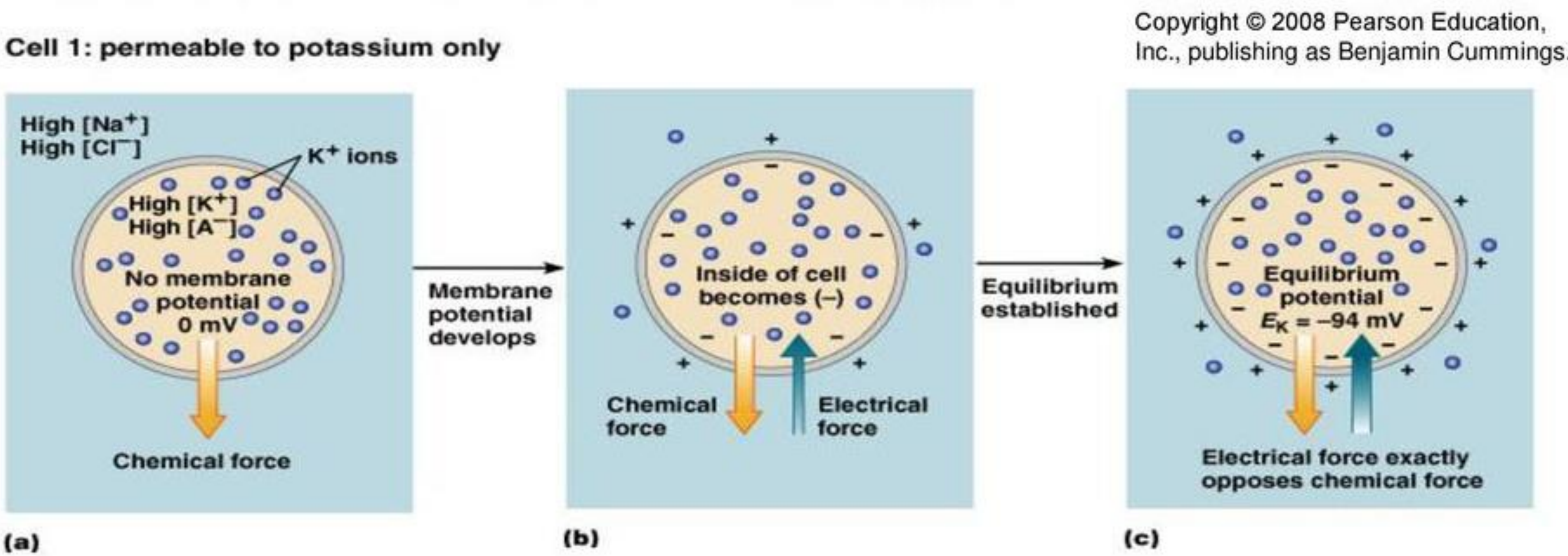


- ❑ Some events and reactions can take place in an isolated or closed system.
- ❑ However, these events end up in a situation where;
  - ❑ The system is in the most disorganized and irregular state,
  - ❑ The temperature differences are disappeared
  - ❑ The entropy is maximum (in thermodynamic concepts)
- ❑ This situation is called "***the equilibrium state***" of the system.

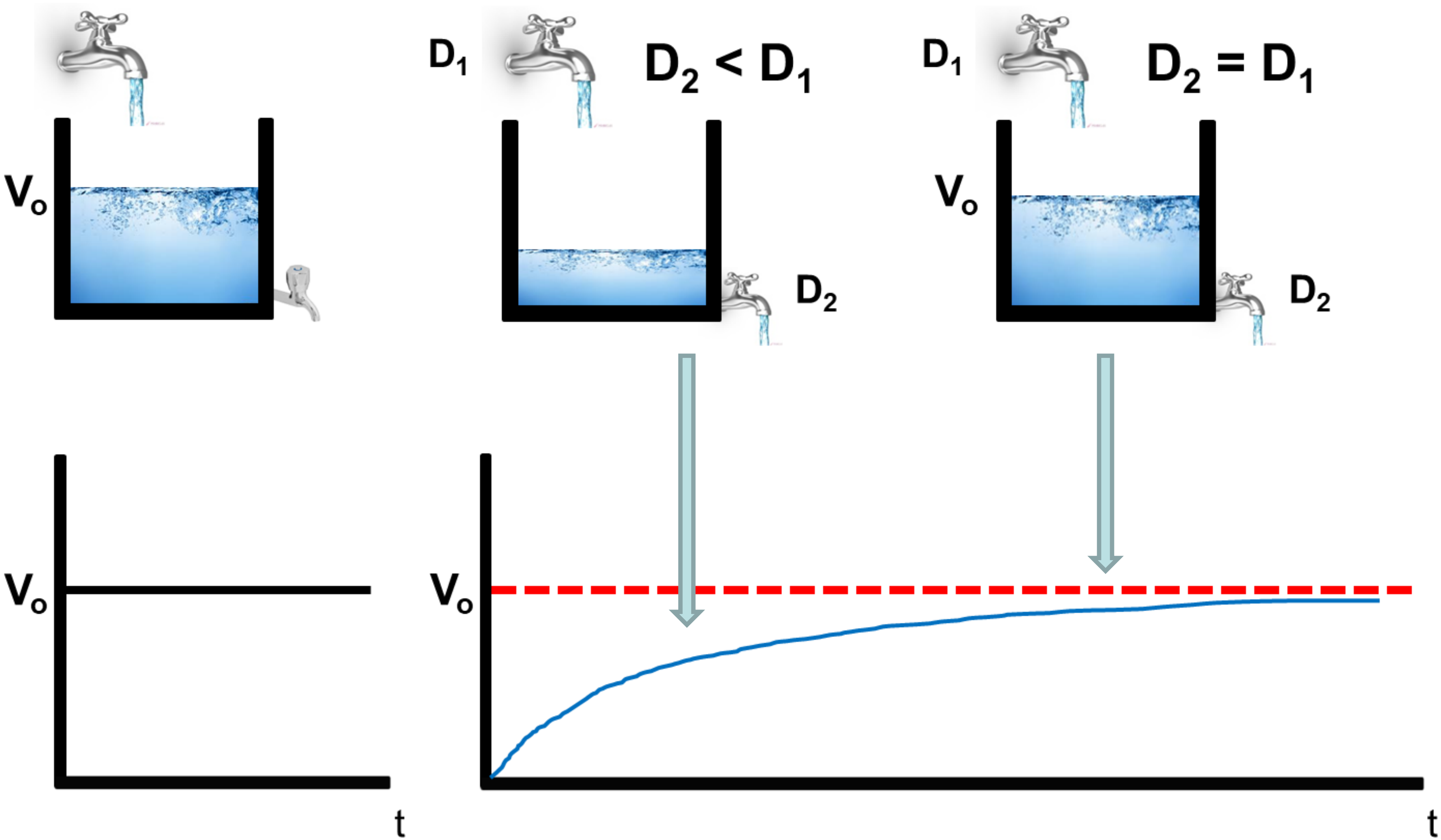




- Open systems can sustain their existence by exchanging matter and energy with their environment.
- While the components made up the open systems are produced on one hand and eliminated on the other hand.
- An open system can comprise many subsystems, each of which is also an open system.



- Open systems are generally open to change.
- In particular, however, they can reach a state in which their composition remains time-independent, while the material and energy go in and out.
- This situation in which the system does not change over time but always remains similar to itself, is called "***the steady-state***" or "***dynamic equilibrium state***".



A
Closed system in an equilibrium state

B
Steady state transition in an open system

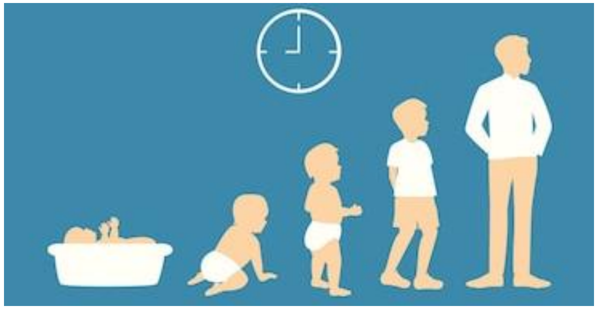
C
Steady state in an open system

Open Systems in Summary

1. Take matter and energy from the environment in the form of water, air, food, wave energy, etc.
2. Do not use the matter and energy as received as it is, makes it suitable for them.
   - E.g… break down the proteins into amino acids, then produce proteins suitable for them.
3. They export some of their products to the environment.
4. Matter and energy efficiency has a cyclic character. Some of the exported products can serve as an energy source for the renewal of the cycle.
5. They can acquire negative entropy (negentropy). **(Negentropy, the inverse of the concept of entropy, is a measure of the regularity and degree of organization of the system.)**

Open Systems in Summary

6. The input of the open systems are informative. The received matter and energy carry messages about the external environment. The acceptance of matter and energy by open systems is optional.
7. Can reach steady state. Although the exchange of matter and energy continues, the composition of the system is time-independent.
8. May change towards differentiation and specialization.
9. Characterized by the principle of equifinality. Different initial conditions may reach the same final situation in different ways.



E.g… Growth

$$Anabolism \approx \alpha \cdot L^2$$

$$Catabolism \approx \beta \cdot L^3$$

$$\frac{dm}{dt} = \alpha \cdot L^2 - \beta \cdot L^3 > 0 \Longrightarrow L_F = \frac{\alpha}{\beta}$$

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