# Knowledge in Natural Science – and in Medicine

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"Medicine is not only a science; it is also an art. It does not consist of compounding pills and plasters; it deals with the very processes of life, which must be understood before they may be guided." (Theophrastus Phillippus Aureolus Bombastus von Hohenheim )

# A Brief Outline

- The Scientific Revolution: what or whom do you trust
- Aim of science: relational invariances
- From mathemtical and mechanical philosophy to experimental science
- Science and Medicine: Eernst Mayr and living systems
- The two goals of science: cognitive understanding and practical utility; basic science and applied science
- Crucial: mechanisms that are responsible for diseases

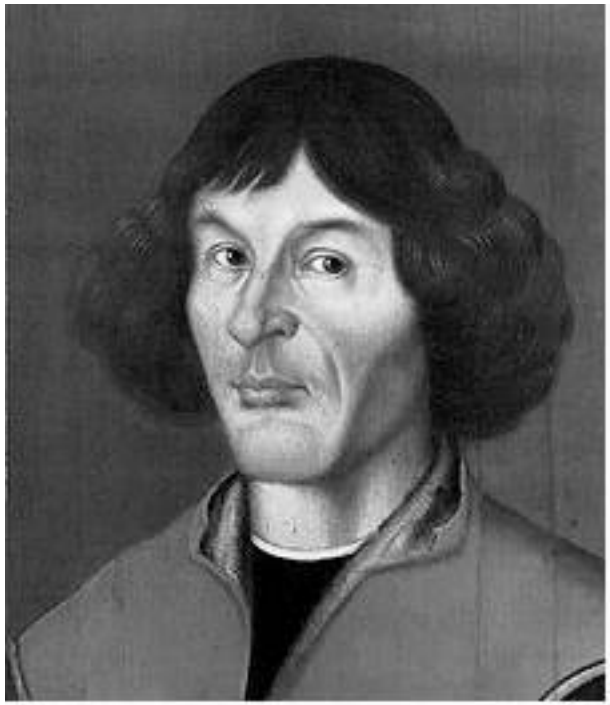
# De revolutionibus orbium coelestium – the Copernican Revolution

- 1st Edition in Nürnberg in 1543
- Challenged the received and canonised wisdom of the Prolemaic system
- Book 1: the heliocentric theory
- Book 2: a theoretical account
- Book 3: Describes the apparent motion of the moon
- Book4: Descrives the movement of earth
- 5, ja 6.: give e.g. the means of calculating the positions of heavenly bodies


NICOLAI
COPERNICI TO-
RINENSIS DE REVOLVTIONI-
bus orbium cœlestium,
Libri VI.
IN QVIBVS STELLARVM ET FI-
XARVM ET ERRATICARVM MOTVS, EX VETE-
ribus atq; recentibus observationibus, restituit hic autor.
Præterea tabulas expeditas luculentasq; addidit, ex quibus eosdem motus ad quodeis tempus Mathe-
maticum studiosus facillime calcu-
lare poterit.
ITEM, DE LIBRIS REVOLVTIONVM NICOLAI
Copernici Narratio prima per M. Georgium Ioachi-
mum Rheticum ad D. Ioan. Schonerum scripta.
Cum Gratia & Priuilegio Cæs. Maiest.
BASILEAE, EX OFFICINA
HENRICPETRINA.

# De Revolutionibus: The Fake Foreword

- Defends the book agaist those who might be offended by the new hypothesis
- Astronomers are allowed to ascribe the observed movements any causes they wish, and they might end up with those that are easy to understand
- To the extent they enable reliable calculations, they need not be taken as philosophical truths
- But his Foreward was fake – and written by Osiander, not Kopernicus who wished to stick to literal truth



Portrait, 1580, Toruń Old Town City Hall

# Council of Trent 1545-1563

-Aimed at strengthening the power of Catholic Church in the divided Europe

- Declared the science was to serve religion and church

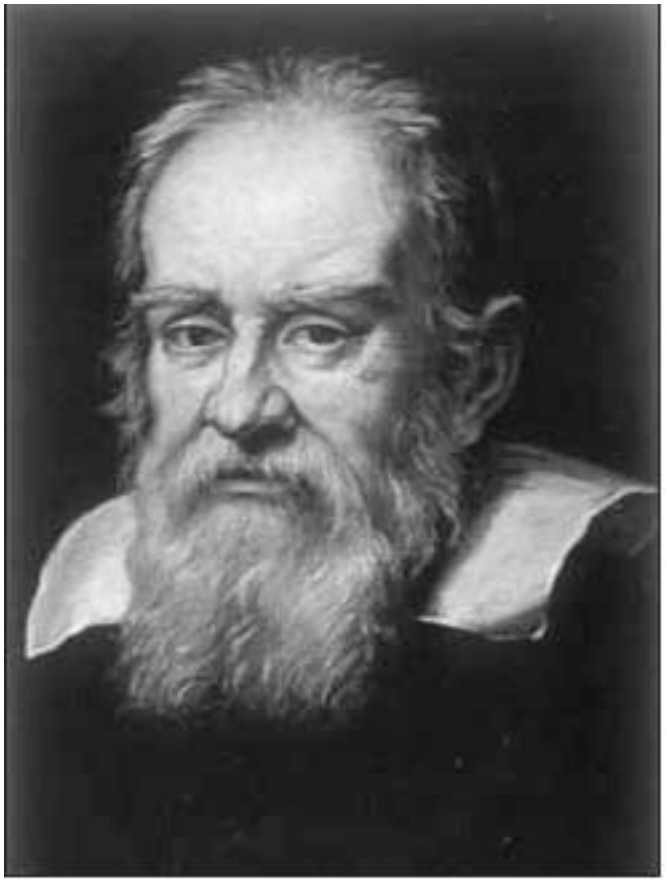
- Canonised the Ptolemaic planetary astronomy

# The Fight over Copernicus´s Theory

- 1609 the heated debate between the Copernicans and the supportes of the Ptolemaic Theory was continued and accelerated
- The problem: with observations made on earth it was difficult to give a knock-down argumen for either theory
- The problem was topical because Copernicus had stired the accepted relationships between science, religion, and everyday experience
- Would it be possible that natural philosohy (=science) and religion (=church) could be in conflict?
- Is man allowed to trust his senses and his reason?
- At any rate: the Copernican view was against the religious dogma and the Trento Consilium

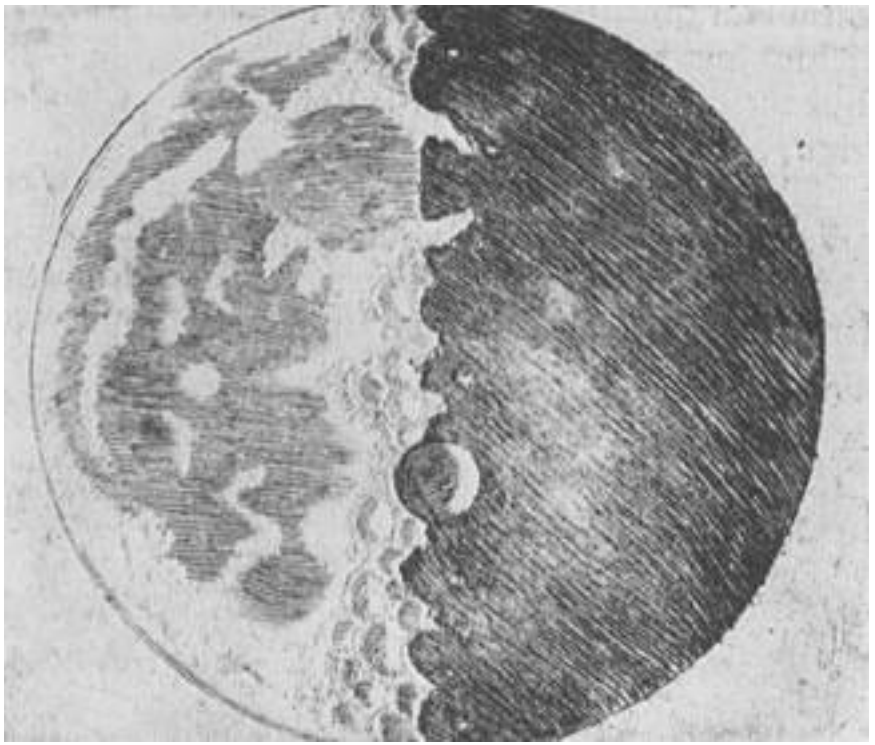
# Galileo – the Father of Modern Science

- So called because he published the first scientific publication that was based on observations made by telescope



# The surface of the moon

- Galileo was watching the moon through his telescope in the autumn of 1609 katseli kuuta – and made a revolutionary observation about the moons surface: there were ligter and darker patches
- The Aristotelian thought that the heavens are perfect and immutable, with the stars fixed in its crystal orbits, was false!
- But can you base your views on observations? What and whom do you trust?



# Galileo´ Arguments

- However, Galileo also had arguments
- When the light proceeds, the white patches increases, just as happens on earth when the sun rises
- So: this observation supported the conclusion that the moon´s surface was uneven, with craters, valleys and mountains; morever, you could calculate their relative hights, at least
- So: the Philosopher was wrong
- The real bomb against the received world view was this: the universe does not divide into two separate realms, with two kinds of entities and lawlikeness
- The question is: given this, shouldn´t we also think that exactly the same kinds of causes operate in the sub- and superlunar worlds?

# The Method of Science

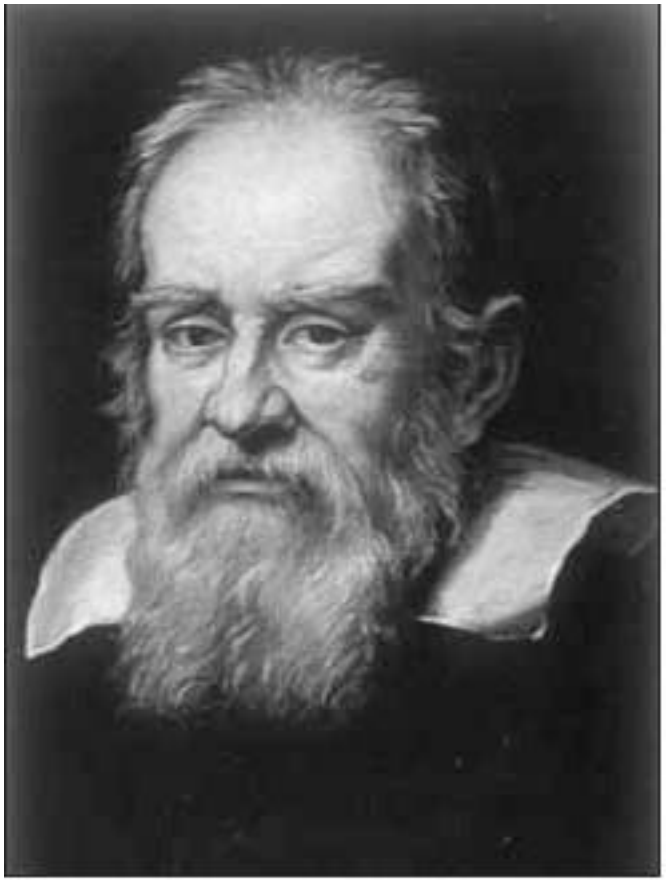
- More revolutionary evidence was to come, such as the moons of Jupiter
- It soon became evident that the received view was beyond pale
- Since then, scientific progress has been based on a number of highly general methodological assumptions that could be summed up as the Method of Science: theorising must be based on evidence and reason; if hypothese are not in accordance with the deliverances of observations, they must go
- Another phenomenon: the instrumental or material aspect of science is all-important; scientific progress depends on our capacity to extend overvations in two directions: to the skies and into structure of matter

# Goals of the New Science:

- Aristotelian world view was descriptive and qualitative
- Movement was change in the moving bodies
- The carrier of the identity of a thing was the unchanging substance
- Bottomline: it subscribed to substance of thing invariaice

# Relational Invariance

- Galilean science: the focus was not on the perceivable qualities (primary or secondary) but the unchanging relationships between phenomena
- Galileo (and later Leibniz) raised the notion of relational invariance above subtance invariance
- The Book of Nature is written in mathematical symbols
- The goal: physical (or philosophical) truth expressedn in mathematical equations



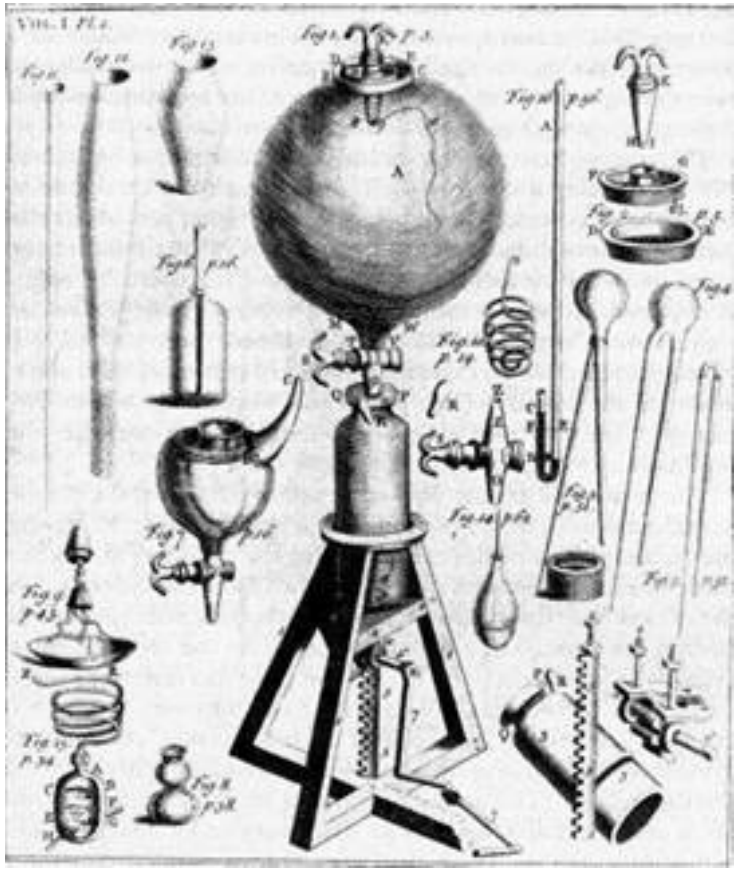
# Eino Kaila: Inhimillinen tieto (1939)

- ”If one were asked, what are the goals of human aspirations to knowledge, we could answer by one word, they are the invariances”
- ”The most important of these invariances are the so-called laws of nature, i.e., the constant relations of dependence between events. So-called physical things of bodies are another umportanat case of invariances.”
- ”All science, whether physics or psychology, is looking for these identities or similarities (p. 13)

# Robert Boyle: Mechanical Natural Philosophy

- Provided a new standard of intelligibility: what a human being has designed and created can be understood
- As a paradigm Boyle used the Strasbourg gem, the beautifully designed and orchestrated mechanism (contrivance) of the cathedras
- Its structure and functions were understood because created by a clock-maker: once it was set to motion it did not need guidance; it worked in accordance with its own principles

# The Air-Pump



- The receiver A was sucked empty through cylinder 3 erected on fame I
- The stopcock (S) was opened and bass valve (R) was closed; the wooden lether-topped piston inside the cylinder was then cranked down by a iron rack (5) and pinion (7)
- Then S was closed and R opened and the air in 3 was forced out
- Result: a vacuum in A in which experimental apparatus could be placed through aperture B-C on the top

# Robert Boyle: The Corpuscularian Philosophy

- *Sceptical Chymist* (1661):
- " . . . certain primitive and simple, or perfectly unmingled bodies; which not being made of any other bodies, or of one another, are the ingredients of which all those called perfectly mixt bodies are immediately compounded, and into which they are ultimately resolved

# The New Experimental Philosophy

- *Experiments Physico-Mechanicall, Touching the Spring of the Air and Its Effects*
- *The birth of experimental philosophy: the proper way to do philosohy is through experiments - facts are literally manufactured*
- *Engraving by François Diodati picturing Boyle at the age of 37, with the air-pump at the back*

# Robert Boyle: Disquisition about the final causes of natural things

- For there are some things in nature so curiously contrived, and so exquisitely fitted for certain operations and uses, that it seems little less than blindness to conclude, that, though they may have been designed for other (and perhaps higher) uses, yet they were designed for this use. As he, that sees the admirable fabric of the coats, humours, and muscles of the eyes, and how excellently all the parts are adapted to the making up of an organ of vision, can scarce forbearto believe, that the Author of nature intended it should serve the animal to which it belongs, to see with. (Boyle, 1688, 1968 p. 397–398)

# Robert Hook: Instruments ”inlarge the senses”

- . . . his design was rather to improve and increase the distinguishing faculties of the senses, not only in order to reduce these things, which are already sensible to our organs unassisted, to number, weight, and measure, but also in order to the inlarging the limits of their power, so as to be able to do the same things in regions of matter hitherto inaccessible, impenetrable, and imperceptible by the senses unassisted. Because this, as it inlarges the empire of the senses, so it besieges and straitens the recesses of nature: and the use of these, well plied, though but by the hands of the common soldier, will in short time force nature to yield even the most inaccessible fortress.

# The Philosophical Beef

- Birth of experimental culture which came to flourish in the Royal Society (for Gentlemen´s eyes only, and Lady Cavendish´s): facts were produced by artifacts in controlled conditions - and verified by witnesses
- Separation of experimental facts and speculation on ultimate causes
- *Everything* must be explained by reference to material corpuscles and their spatio-temporal interaction
- Pattern for all future research: a mechanism can be satudied through interacting parts
- NOTE: timing and spatial location are vital!

# From Mechanical Philosophy to Mechanistic Explanation

- 17th Century mechanical philosophy was committed to *mechanical* movement of physical bodies
- In biology this philosophy triumphed over *vitalism* in early 20th Century when developmental biologists gave up entelechies and (non-physical) *vital forces*
- But: the basic philosophy can be extended to all types of mechanisms, from clocks (early metaphor for organisms) to biological psychological and social systems
- To understand X is to see how the behaviour of X is produced by X´s parts, and this is often only possible by manipulating the parts under controlled circumstances!

# Descartes on Reflexes

- *Heat from the fire, A, starts a chain of processes that begins at the affected spot of the skin, B, and continues up the nerve tube until a pore of a cavity, F, is opened. Descartes believed that this opening allowed the animal spirits in the cavity to enter the nerve tube and eventually travel to the muscles that pull the foot from the fire. Descartes anticipated the basic idea of reflex action but his account made no anatomical distinction between sensory and motor nerves. (From Descartes, 1662)*

# Reflex action

- Descartes thought that man, but not animals, had a soul - the behaviour of animals, but not man, could be explained mechanistically,
- But involuntary behaviours in both man and animals may be explained on a common basis.
- Aanimal spirits' flowing through nerves of animals or humans had a similar function in automatic behavioural responses in man and animals or reflexes.
- The term 'reflex' comes from the flow of animal spirits produced by a stimulus which is somehow reflected by the brain into an outgoing flow which eventually produces some behaviour.

# Reflex action

- Descartes on Brutes: animals are automata that “have no intelligence at all.” Animals do not act but rather: “it is nature which acts in them according to the disposition of their organs. In the same way a clock, consisting only of wheels and springs, can count the hours and measure time...” (The Philosophical Writings , Vol I, 139)
- "I should like you to consider that these functions (including passion, memory, and imagination) follow from the mere arrangement of the machine’s organs every bit as naturally as the movements of a clock or other automaton follow from the arrangement of its counter-weights and wheels." (Descartes, Treatise on Man, p.108)

# Progress: Details being filled?

- In Mechanical Philosophy one thinks that organisms (or even higher levels) consist of hierarchically nested mechanisms
- E.g. Darwin proposed a theory of natural selection that contained blank slots: he did not know how variation came about, and he betted on the wrong candidate on how phenotypical traits are inherited
- Research programmes are entities that give rise to well defined questions: what mechanism is responsible for this or that functional feature
- Later: Mendel supposedly filled in the slot through his theory of heredity

# Mechanisms

- mechanisms consist of identifiable parts and their interaction, often given by more ore less sketchy diagrams etc
- biology is the province of mechanisms on all levels: ecology, organism, organ, organelle, cell, molecular and biochemical
- E.g. mechanisms on Mayrs *ultimate level:* how and why a trait has been born, gone to fixation and been preserved natural selection (though Darwin never called it a mechanism!)
- physiological and behavioural mechanisms on *proximate level*: how an organism works *here and now*

# Bechtel and Abrahamson 2005

"A mechanism is a structure performing a function in virtue of its component parts, component operations, and their organization. The orchestrated functioning of the mechanism is responsible for one or more phenomena" biology is the province of mechanisms on all levels: ecology, organism, organ, organelle, cell, molecular and biochemical

- First: functional decomposition - what a system does, and how it can be decomposed to simpler operations
- Then structural decomposition :what parts go into this doing, and how they operate

# Hugo de Vries: ”Rediscovering” of the Mendelian Mechanism

- Designed to explain the blending of inherited chacacter: belinding of the parental features, and the results of “use and disuse”
- In 1900 Erich Tchermack (von Seysenegg), Carl Erich Correns and Hugo de Vries published their papers where they “rediscovered” Gregor Mendel´s “laws” of heredity and hence the Mendelian Mechanism (quotes needed because Mendel didnot propose mendel´s laws, such as the law of segregation
- or independent assortment)

# Morgan, Sturtevant, Muller and Bridges (1915): The Mechanism of Mendelian Heredity

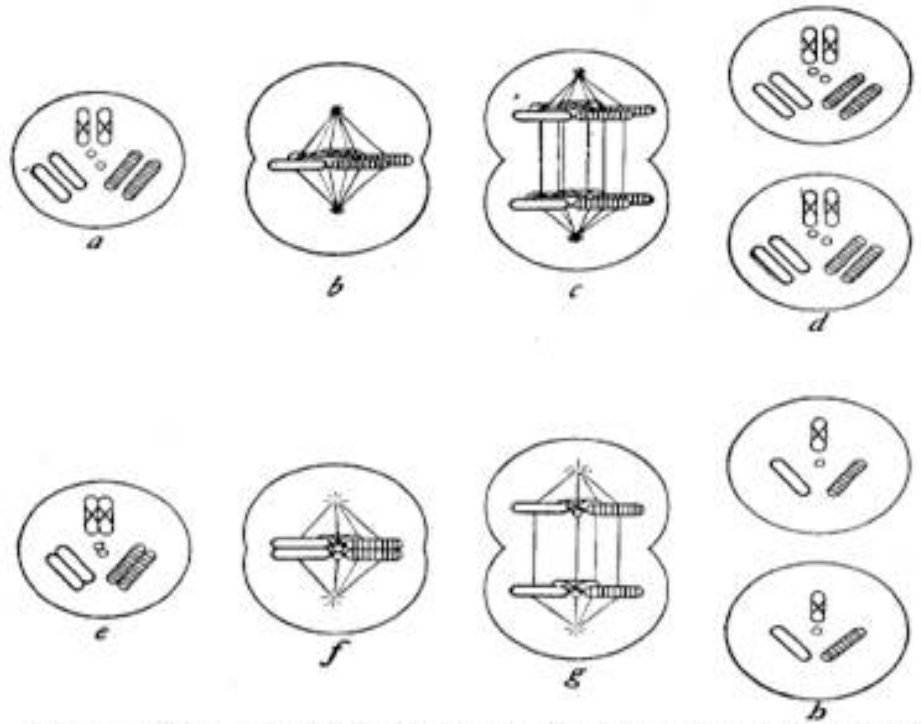
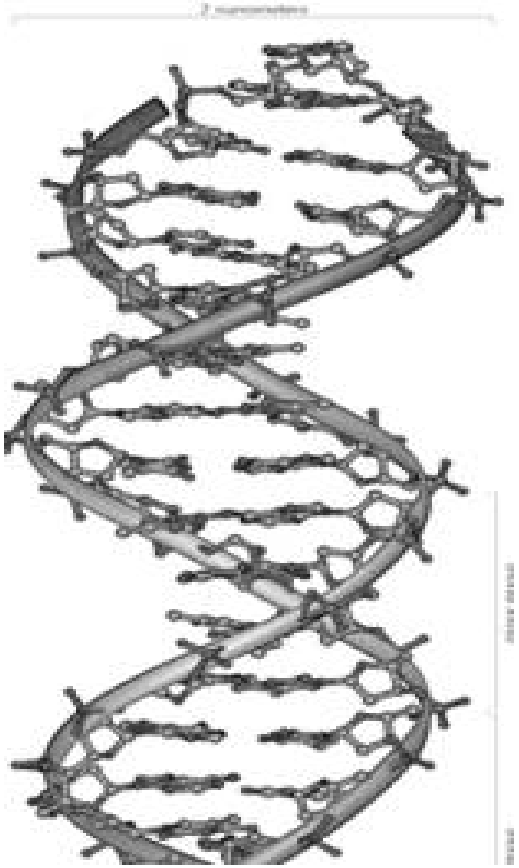



FIG. 1.—In the upper line, four stages in the division of the egg (or of a body cell) are represented. Every chromosome divides when the cell divides. In the lower line the "reduction division" of a germ cell, after the chromosomes have united in pairs, is represented. The members of each of the four pairs of chromosomes separate from each other at this division.

# The Molecular Revolution: Enter the Chymist

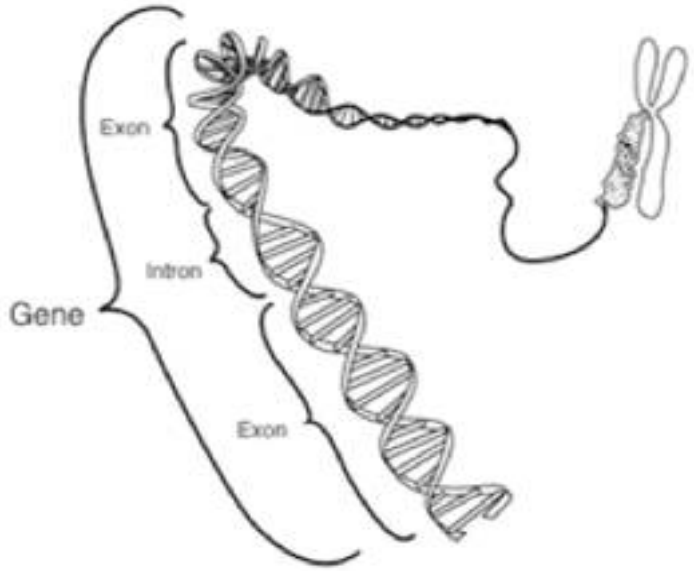
- Dissecting the mechanism(s) of inheritance in terms of molecular submechanisms
- Classical Mendelian genetics contained gaps (black boxes) that were filled with molecular mechanisms: gene expression and protein synthesis
- Darden and Maull 1977: chromosomes were associated with heredity – they were discovered around 1850 (it is argued that von Nägeli´s claim to priority is unwarrented), but the mechanism was unknown
- Watson and Crick cracked the nut: a chromosome (coloured bodies, discovered studied by staining) is a long piece of DNA, a nucleic acid that contains thr instructions for the development and functioning of all living organisms (also some viruses).

# The Double Helix



- *Chemistry (the most useful of sciences, said Samuel Parkes )* helps to tell what a cytologist sees
- *Physics* enters the picture by explaining the behaviour of the macromolecule: the hydrogen bonding explaining why and how the ”string” bends into secondary and tertiary structure, etc
- The simple idea serves as a *heuristic* for the mechanism of gene expression, filling in a gap in the Mendelian theory: protein synthesis

# So, What is A Gene?




- *A diagram showing a gene in relation to the double helix structure of DNA and to a chromosome (right). Introns are regions often found in eukaryote genes that are removed in the splicing process (after the DNA is transcribed into RNA): only the exons encode the protein. This diagram labels a region of only 40 or so bases as a gene. In reality most genes are hundreds of times larger*
- Adopeted, with Thanks, from Wikipedia!
- End of Story?

# Details being filled?

- The big picture: DNA is herited, transcribed to RNA and synthesized to proteins
- In fact genes can be understood (at least in four ways) as abstract entities, material entities, functional biological entities or generic (operational) entities (Falk 2000)
- Falk subscribes to the following: “genes are entities that refer to the hereditary input of traits (phenotypes), irrespective of whether these traits are defined in terms of behavior of the physicochemical properties of a segment of the DNA molecule” (Falk, 2000, p. 344).

# Scientist

- Natural Philosophy – Experimental, Mathematical and Mechanical – lived till the 1430´s
- Upon the request of the poet Coleridge in 1833 William Whewell invented the English word “scientist;” before this time the only terms in use were “natural philosopher” and “man of science.”
- There was"an increasing proclivity of separation and dismemberment" in the sciences; while highly specific terms proliferated—chemist, mathematician, naturalist—the broad term "philosopher" was no longer satisfactory to group together those who pursued science, without the caveats of "natural" or "experimental" philosopher.”
- "some ingenious gentleman proposed that, by analogy with *artist, they might form [the word] scientist, and added that there could be no scruple in making free with this term since we already have such words as economist, and atheist—but this was not generally palatable"*

# Science and medicine

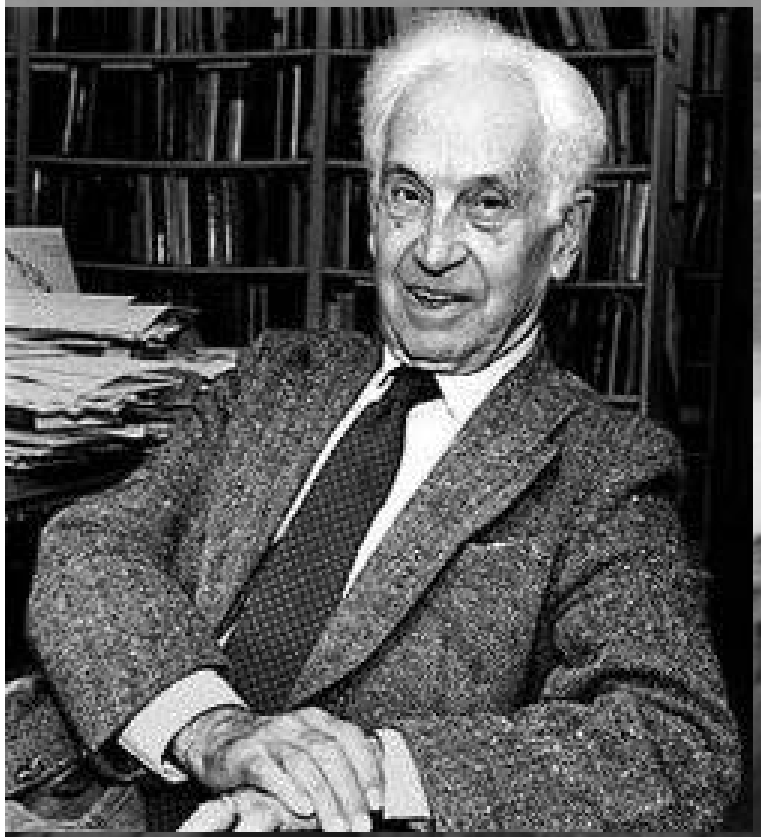
- Medicine: science and art (practice), basic and applied
- In medicine: identifying causes of diseases such as bacteria or viruses, as well as well as preventing diseases and curing illnesses
- It does not seem that there are theories of the type chased in natural science: exeptionless regularities tied in neat conceptual structures by intertheory-relations, such as reductive relationships between fields
- Crucial: mechanims that are responsible for healthy functioning of the body and mind, and causes that might break down or distort these mechanisms

# Reduction

- ontological reduction: the possibility of reducing entities at one level to lower levels
- methodological and explanatory reduction: defining theoretical terms in observational terms and by deducing lower-level laws from higher level laws
- the old positivist dream: reducing laws and theories on one level to those on a more fundamental level

# Explanatory Reduction

- Biological organisms are but physico-chemical systems (more exactly, systems of systems)
- But it does not follow that all explanations of biological traits and phenomena could be based on laws of physics and chemistry
- So the picture of the unified science based on fundamental physics need not be a threat to automomous life sceences



-The Darwin of 20th Century: Studied medicine, got interested in philosophy of science
-There was no such discipline as biology, then, only botany, zoology and experimental sciences such as physiology and genetics
-Mayr made a list of the problems that philosophers of science studied: reduction, the nature of laws, etc
-Philosophy of science, then, addressed none of the questions that interested life scientists

# Ernst Mayr (1904-2005)

# Living systems

- “The classical physical sciences, on which the classical philosophy of science was based, was dominated by a set of ideas inappropriate to the study of organisms; these include essentialism, determinism, universalism, and reductionism.
- Biology, properly understood, comprises population thinking, probability, chance, pluralism, emergence and historical narratives. What we need is a new philosophy of science that could incorporate the approaches of all sciences, including physics and biology”.

# Mayr: Reduction is Absurd!

- "The claim that every attribute of complex living systems can be explained through the study of the lowest components (molecules, genes or whatever) struck me as absurd. Living organisms form a hierarchy of ever more complex systems, from molecules, cells and tissues through whole organisms, populations and species. In each higher system, characteristics emerge that could not have been predicted from a knowledge of the components"

"Reading never made a physician. Medicine is an art, and requires practice. If it were sufficient to learn to talk Latin, Greek, and Hebrew to become a good physician, it would also be sufficient for one to read Livius to become a great commander-in-chief. “

**Philippus Aureolus Theophrastus Bombastus von Hohenheim**

**1**493 - 1541

"I began to study my art by imagining that there was not a single teacher in the world capable to teach it to me, but that I had to acquire it myself. It was the Book of Nature, written by the finger of God, which I studied not those of the scribblers… "

So Paracelsus used the new metaphor 100 year before the hight of the Scientific Revolution