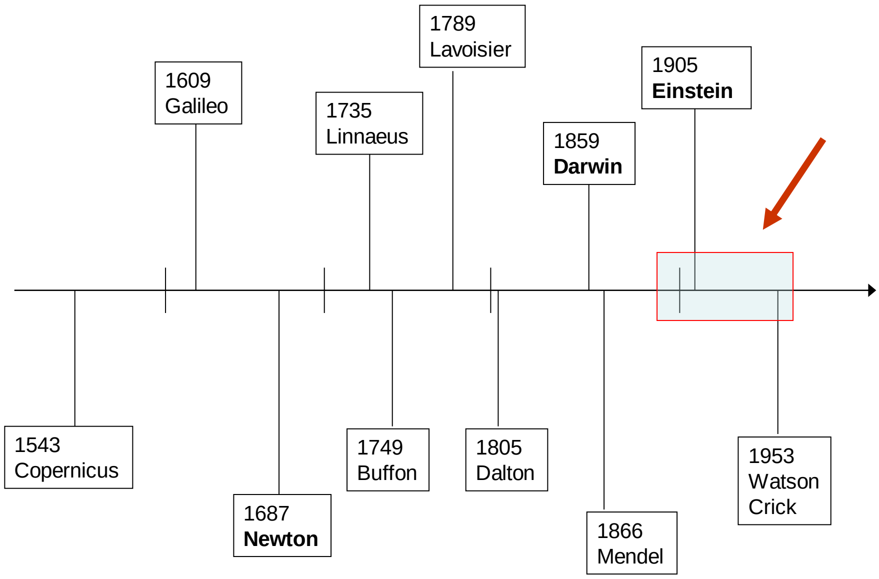
HISTORICAL & SOCIAL ASPECTS OF PHYSICS:

Algemeen:

- Examen: readers niet in detail kennen
- write a short essay about one of the 5 topics
    - +/- 1 page (+/- 400 words)
    - 5 punten
    - afgeven op het examen ?!
- Examen = mondeling met schriftelijke voorbereiding

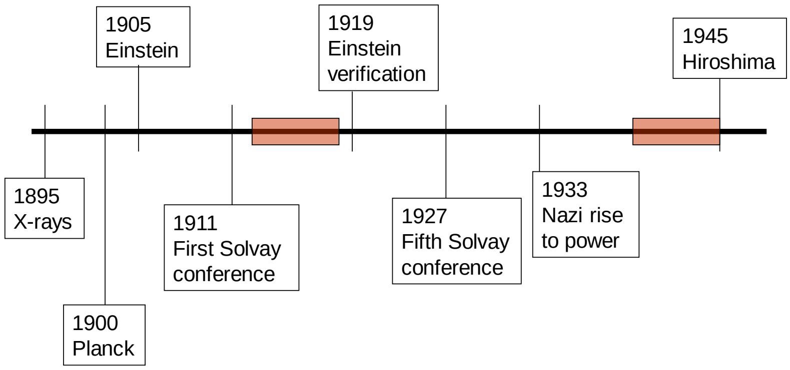
Inleiding



- Copernicus
- Galileo
    - filosofie → physics
    - know mathematics to know how the world works
- Newton: phylospher

19th century: chemistry was very important!
←→ biology was especially (vooral) linked to medicine & linked to the effect of colonialism (in de colonies de dieren gaan onderzoeken, bv)
➔ physics = just the start of your study, because everything was already known in physics (dacht men)

This course: re emerge (weer opleveren) of physics: Einstein, Watson & Crick
→ physics ı mirror of the reality: mathematical formula
➔ models (in our mind) = the mirror of physics
= science



- 1900: quantum hypothesis (A hypothesis that some physical quantity can assume only a certain discrete set of values; examples are Planck's law, and the condition in the Bohr-Sommerfeld theory that the action integral of a system must be an integral multiple of Planck's constant)
- 1927-1933: war!!
  ➔ Jews may not exercise their profession
- Solvay conference:
  - first: subject: radiation and the quanta
  - fifth: electrons and photons
  - There exists a 6th conference about quantum mechanics & Schrödinger
- 1945: you can make everything if you have the money for
  → forget about fundamental physics

I. How many revolutions?

a) Conceptual revolution

Fundamental characteristic features of classic physics = abonned

- Relativity
- Quantum mechanics

b) Professional revolution

- Identity of 'the physicist'
  Before the revolution: philosophy
  Opm.: frech: "savant" = scientist & wise man
  → "physics"
  → then especially: teaching of physics
  1) especially experimental physics (only a little mathematics)
  2) teach the students how to do measurements
  BUT: students were not interested in it

attendance (opkomst) of theoretical physics (after the 19th century)

- theoretical physics = beyond Newton
- BUT: Nobelprices were then only given to things that were usefull for the human being
  eg: Zeemann & Lorenz: Zeemann = experimentalist, only him gets the Nobelprice

- Institutional changes
  Physics = an individual job
  After Manhattan project: team work (= very important during the war)
    (The Manhattan Project was a research and development program, led by the United States with participation from the United Kingdom and Canada, that produced the first atomic bomb during World War II. From 1942 to 1946, the project was under the direction of Major General Leslie Groves of the US Army Corps of Engineers. The Army component of the project was designated the Manhattan District; "Manhattan" gradually superseded the official codename, "Development of Substitute Materials", for the entire project. Along the way, the Manhattan Project absorbed its earlier British counterpart, Tube Alloys.)

- Migration towards US
  First: here in Europe they didn't know what they are doing in the US
  BUT: US received the leading role after the war

c) Social revolution

- Impact on warfare and society

    - heat machines: difference between theoretical aspects and real realization
      ←→industry: on basis of engineers
      eg steel industry: has nothing to do with physics
      ➔ physics has a low impact on the society
    - eg radio (WOI), X-rays (WOI), radar (WOII)

- Emergence of science policy (opkomst van het wetenschapsbeleid)

  First: best science = done by geniuses
  BUT, then: politics navigate science: SCIENCE POLICY (MONEY!!)
  → taxpayer pays science
    ➔ science has to do something for the taxpayer

II. Social aspects

- factors that promoted the progress of physics
- relationship between physics and other sciences
- social perception of physics
- material support of physics
- evolution of research practices

Opm.:

- Germany: inflation, no jobs, loosers of the war, BUT: however, still the invention of quantum mechanics (Schrödinger) → stimutlation
- Physics places are full: go to: economics, biology..
- Why do you want to study physics? Why would you pay for physical research?

H1. Classical physics in the 19th century

Boltzmann, 1899:
Die Aufgabe der Physik schien sich für alle Zukunft darauf zu reduzieren, das Wirkungsgesetz der zwischen je zwei Atomen tätigen Fernkraft festzustellen und dann die aus allen diesen Wechselwirkungen folgenden Gleichungen unter den entsprechenden Anfangsbedingungen zu integrieren.
Was hat sich seitdem alles verändert! Ich bin allein übrig geblieben von denen, die das Alte noch mit voller Seele umfaßten. Ich stelle mich Ihnen daher vor als einen Reaktionär, einen Zurückgebliebenen, der gegenüber den Neuerern für das Alte, Klassische schwärmt.

Comments: Germany: 1895-1950

- Wirkungsgesetz = law of force
  → between atoms
    →leads to equations & integrate overall it = PHYSICS
- atavist: throwback
- classical physics = everything
  → new things are just novalities
  eg classical physics is what it should be (Boltzmann)
  → new things must be integrated, BUT: classical physics remains everything

I. The foundations of "classical physics"

a) *Newtonian physics* (Newton = the basis)

All phenomena are to explained by the interaction of small 'particles'. These interactions are governed by Newton's three laws.

b) *Laplace*

elaboration of mathematical apparatus to formalize Newtonian physics.

- Exposition du système du monde (1796)
- Mécanique céleste (1799)
- Théorie analytique des probabilités (1812)

"Some perfect genius who knows the location and movement of all particles in the world, can predict all future (and past) events"

Opm:

- Laplace: "deterministic view of the world: if there exists a mind who knows all the positions and velocities of all the particles, you know everything (future), BUT this does not exist. So, we need probability."
- theoretical (concepts, basic laws) ˌ always the same as mathematical physics

II. Nineteenth century developments

- Rise of theoretical physics, based on advanced mathematics
  - French physicists: Laplace, Coulomb, Fresnel, Malus, Biot, Ampère, Fourier, Carnot, Poisson
  - German physicists: Gauss, Ohm, Weber, Neumann, Clausius, Kirchhoff, Helmholtz, Lorenz

    Lorenz: polarization in a plane;

    light = transverse wave = a mathematical model

  Opm: start in French: 1930: mathematical models = very important for physics, afterwards also in other countries

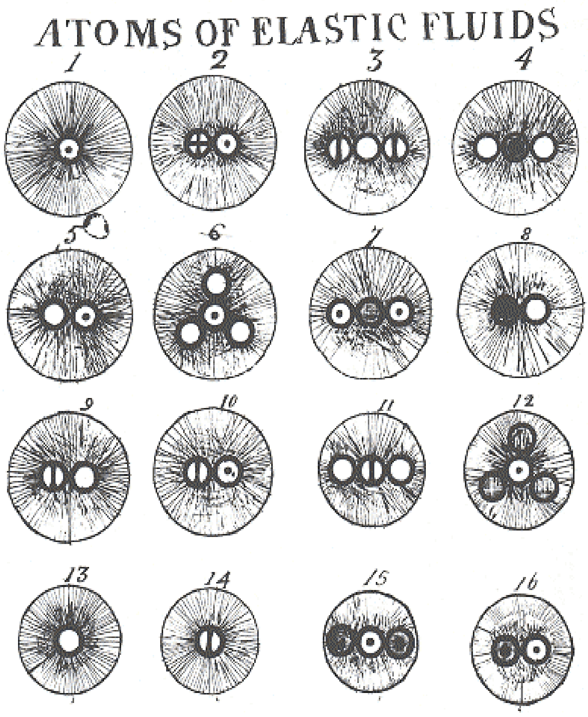
- New phenomena
  - electromagnetism = like a fluid
    - Oersted (1820): interactions between electrical & magnetics
    - Ampère (1827): mathematical models
    - Faraday (1831): field concepts
  - Thermodynamics: Carnot (after the steam engines are optimized)
    - Steam engine ➔ description of heat
- Alternative theories:
  - Field theories, wave models, ether mechanics

III. The mechanical worldview

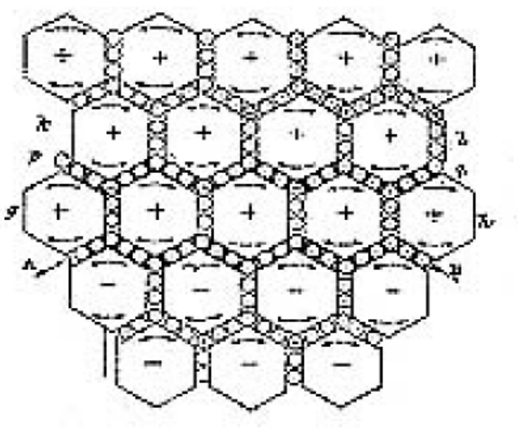
- First part of physics: Ponderabilia (particles with mass)

  → mechanics, atomism
- Second part of physics: Imponderabilia
  - Light
  - Heat
  - Electricity
  - Magnetism

Opm.: this subdivision was not very satisfactory for physics



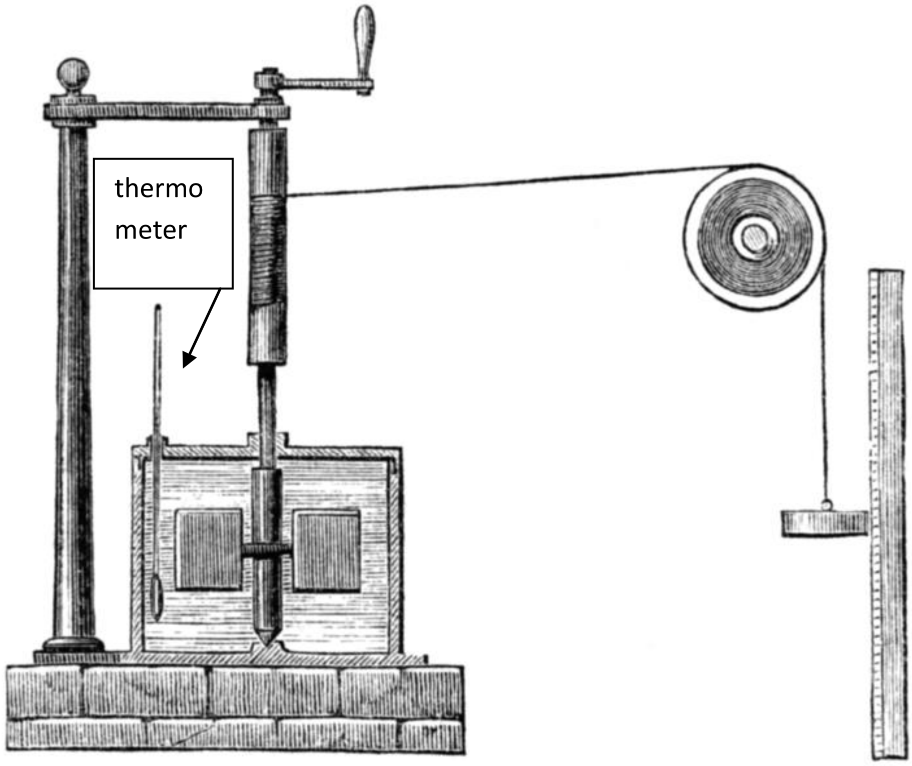
Atomic model of Dalton:
→ How is it possible that air consists of N & O that this 2 gasses remains mixed, why would the heavy particles does not go down and the light ones goes up?
→ around the nucleus: heat atmosphere
→ heat = related to the atom



Maxwell (= pure mathematical physicist ➔ equations)
= model to explain the magneto optic aspects

HEAT OR MOVEMENT?

- Lavoisier: 'calorique' (heat was an element)
  vs Rumford: movement (the more movement, the more heat it produces → heat ı fluid)
- Carnot (1824): mechanical power is generated by the transfer of heat between bodies on different temperatures (heat has something to do with energy)



- Joule (1847): mechanical equivalent of heat
- Conservation of energy including heat (Joule, Kelvin, Helmholtz, Mayer)
- Clausius: transformation of energy → second law of thermodynamics
- Kinetical theory of heat: Clausius, Maxwell, Boltzmann

(In the history of science, the theory of heat or mechanical theory of heat was a theory, introduced predominantly in 1824 by the French physicist Sadi Carnot, that heat and mechanical work are equivalent.[1] It is related to the mechanical equivalent of heat. Over the next century, with the introduction of the second law of thermodynamics in 1850 by Rudolf Clausius, this theory evolved into the science of thermodynamics. In 1851, in his "On the Dynamical Theory of Heat", William Thomson outlined the view, as based on recent experiments by those such as James Joule, that “heat is not a substance, but a dynamical form of mechanical effect, we perceive that there must be an equivalence between mechanical work and heat, as between cause and effect.”

In the years to follow, the phrase the "dynamical theory of heat" slowly evolved into the new science of thermodynamics. In 1876, for instance, American civil engineer Richard Sears McCulloh, in his Treatise on the Mechanical Theory of Heat, stated that: “the mechanical theory of heat, sometimes called thermo-dynamics, is that branch of science which treats of the phenomena of heat as effects of motion and position.”

This term was used in 19th centuries to describe a number of laws, relations, and experimental phenomenon in relation to heat; those such as thermometry, calorimetry, combustion, specific heat, and discussions as to the quantity of heat released or absorbed during the expansion or compression of a gas, etc. One of the most famous publications, in this direction, was the Scottish physicist James Clerk Maxwell’s 1871 book Theory of Heat, which introduced the world to Maxwell's demon, among others.[3] Another famous paper, preceding this one, is the 1850 article On the Motive Power of Heat, and on the Laws which can be deduced from it for the Theory of Heat by the German physicist and mathematician Rudolf Clausius in which the concept of entropy began to take from.

The term “theory of heat”, being associated with either vibratory motion or energy, was generally used in contrast to the caloric theory, which views heat as a fluid or a weightless gas able to move in and out of pores in solids and found between atoms. In an 1807 journal of Nicholson’s, as an example, we find: “…it is well known that Count Rumford adheres to the old theory of heat being simply a vibratory motion of the particles of bodies.” However, both these viewangles are actually compatible under the principle of energy conservation and corresponding first law of thermodynamics.

From modern perspective, the formal equivalence of heat and mechanical vibrations (or motions) does not mean they are physically identical. The fundamental difference of these two concepts shows particularly clearly in spectroscopy. While sharp spectral lines are usually associated with mechanical vibrations, the heat shows only a "random" spectrum with some distribution function (white noise, etc.))

IV. Unification of theories

= a romantic dream (end 18th and begin 19th century)
→ reaction against enlightment (= everything in the world can be explained by reason: "rationality")
→ some things we never know; eg: field = mental image, no real explanation,
BUT: emphases geniuses= someone who can look further, can do more

Only discoveries, only combining
➔ unification = a complication

- James Clerk Maxwell: mathematical unification
  - *Treatise on Electricity and Magnetism* (1873)
    - Electromagnetic field: mechanical analogies
    - Light is an electromagnetic wave (Hertz)

- Hendrik Antoon Lorentz: "I'm a theoretical physicist so an other teacher must be an experimental physicist. (Hij was de eerste prof en toen moest er moest een nieuwe prof bij)"
  - Electron theory

- Wilhelm Ostwald reform of chemistry (= abstract, general, not linked to specific elements = a new view)
  - Physical chemistry, energetics

- (Boltzmann: atomism: atoms = physics (= working with particles, interactions); the question of this atoms exist is not the point here)

V. Physics around 1900

Physics do exact measurements
Physics in 1900 = what you do in a room, with a few measurements and with a small amount of money

Alfred North Whitehead (1925)
"An age of successful scientific orthodoxy, undisturbed by much thought beyond the conventions. One of the dullest stages of thought since the time of the First Crusade."
→ orthodoxy: against the renovation
→ no shocking subjects
→ First Crusade (De Eerste Kruistocht (1096-1099) was een militaire expeditie door het Westers christendom om het Heilige Land, dat veroverd was in de moslimverovering van de Levant terug te krijgen, wat uiteindelijk resulteerde in de herovering van Jeruzalem. Het werd gestart in 1095 door Paus Urbanus II met het primaire doel te reageren op een oproep van Byzantijnse Keizer Alexios I Komnenos, die verzocht dat westerse vrijwilligers hem kwamen helpen om de binnenvallende Seltsjoeken af te weren van Anatolië. Een bijkomend doel werd al snel de voornaamste doelstelling - de christelijke herovering van de heilige stad Jeruzalem en het Heilige Land en het bevrijden van de oosterse christenen van de islamitische heerschappij.)

Sergé (1984): worked with Fermi, wrote books (quite readable)
= a macroscopic physicist; limited mathematics
"*By the end of the nineteenth century, physics had scored brilliant successes.*
All this formed essentially a physics of the macroscopic world.
The use of mathematics is relatively limited.
It also seems that physics had fewer general ideas and guidelines then than now. The skeleton was weaker and the flesh heavier.
In a dramatic series of events, the totally unexpected discovery of radioactivity, combined with [other] discoveries, opened the door to the atomic world. "

Erwin Hiebert (1900)

- no view of new physics
- no feeling that there was something wrong with physics, only unification
- discoveries in unexpected directions: find something when you are not looking for it eg.: radioactivity

"During the last two decades of the nineteenth century, scientists had witnessed an expansive growth in scope, content, practice and technological relevance of the natural sciences.
In physics, the maturity and refinement of theoretical principles was conspicuous, notably in continuum mechanics, thermodynamics and the electromagnetic theory of radiation.
In general, it was assumed that the elucidation of the most troublesome anomalies would depend less upon the discovery of new theoretical guidelines than upon successful integration into the body of what later came to be referred to as 'classical physics'.
One [trend] that merits special attention follows from the recognition that almost none of the new discoveries had been foreseen or predicted on the basis of established theoretical principles. This perception encouraged the taking of risks."

Helge Kragh, *Quantum Generation. A History of Physics in the Twentieth Century* (1999)

"The mechanical worldview was no longer considered progressive in the 1890s, and even traditionalists had to admit that it was not universally successful.

The new physics that arose in the early years of the twentieth century was not a revolt against a petrified Newtonian worldview. The basic problem of physics in the late nineteenth century was perhaps the relationship between ether and matter. Physics consisted of the physics of matter and the physics of the electromagnetic ether, and the trend to avoid the unwanted dualism was to identify matter with ether, not the other way around.

The trend of theoretical physics around 1900 […] was part of a change in worldview that had ramifications outside physics and was nourished by the particular Zeitgeist of the period, a spirit sometimes characterized as neoromantic.

One important element of this cultural configuration was a widespread antimaterialism. If matter was not the ultimate reality, but merely some manifestation of an immaterial ether, it would not seem unreasonable to challenge other established doctrines, including the laws of conservation of matter and energy."

→ mechanical view: only describe things that you see

→ ether: describes phenomena in stead of matter

  Newtonian world has to bring in in ether mechanics

→ people saw the problems, they knew that the phenomena were important

  (←→ discovery of a phenomena & forget about it)

→ "neo" = "2de period": people knew that ether & matter were different, with ether as solutions for problems

→ materialism: conviction everything on earth can reduced to matter

H2. Quantum revolution

= an internal revolution

relativity = was better known under the public, but not so popular under physicists

Quantum: it really makes a difference in physics

Physics laboratories were very different in organization and equipment from our present ones. There was usually only one professor, who often had his residence at the laboratory, and who was helped by very few assistants.

I estimate that in 1895 there were approximately a thousand physicists. They were reasonably well paid and were held in moderately high regard.

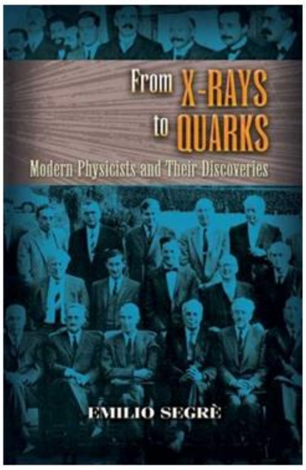


TABLE A.1
Number of Academic Physicists in 1900[a]

	Faculty						
	Senior	Junior	Privat-dozenten	Total	Assistants[b]	Research affiliates[c]	Total[c]
Austria-Hungary	26	9	13	48	(16)	(15)	79
Belgium	7	2	0	9	6	(2)	17
British Empire	40	34	12[d]	86	45[e]	(40)	171
U.K.	32	32	12	76	38	(30)	144
Other	8	2	0	10	7	(10)	27
France	27	26	0	53	52	(40)	145
Germany	38	31	34	103	42	(90)	235
T.H.	11	6	9	26	10	(10)	46
Univ.	27	25	25	77	32	(80)	189
Italy	18	7	18	43	20	(10)	73
Japan	4	2	0	6	(2)	(3)	11
Netherlands	8	1	1	10	11	(10)	31
Russia	10	8	12	30	5	(5)	40
Scandinavia	11	7	0	18	11	(5)	34
Switzerland	11	2	4	17	10	(20)	47
United States	32	31	36[f]	99	46	(50)	195
Total	232	160	130	522	266	290	1078

TABLE A.5
Posts in Theoretical and Mathematical Physics[a]

	1900				1910			Adressbuch[c] (1909)
	Senior faculty	Junior faculty[b]	Total	Percent[d]	Senior faculty	Junior faculty	Total	
Austria-Hungary	4	4	8	17	7	2	9	13
T.H.	0	0	0	0	0	0	0	
Univ.	4	4	8	22	7	2	9	
Belgium	1	0	1	10	0	2	2	2
British Empire	0	2	2	3	0	2	2	2
U.K.	0	2	2	3	0	2	2	2
Other	0	0	0	0	0	0	0	0
France	4	0	4	8	4	0	4	2
Germany	8	8	16	15	10	6	16	16
T.H.	3	1	4	15	4	0	4	
Univ.	5	7	12	16	6	6	12	
Italy	4	4	8	19	6	6	12	11
Japan	0	0	0	0	2	1	3	0
Netherlands	1	2	3	25	2	1	3	2
Russia	1	0	1	3	1	0	1	2
Scandinavia	3	1	4	20	5	2	7	4
Switzerland	2	1	3	17	2	1	3	4
United States	2	1	3	3	0	1	1	2

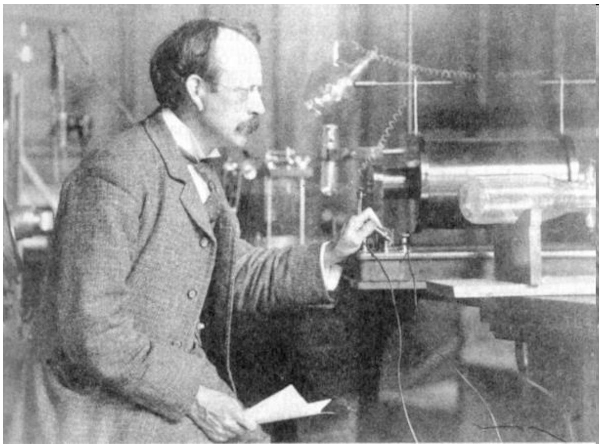
[a]Same sources as Table A.4.
[b]Including Privatdozenten.
[c]*Adressbuch der lebenden Physiker* (1909).
[d]As percent of all physics posts.

Germany!
First there were more profs in stead of students.
In the beginning there was a minority in positions of theoretical physicists.

Experimental physicist:

Röntgen: X-rays

Becquerelle: without influence of the sun, the X-rays can be captured on a photographic plate

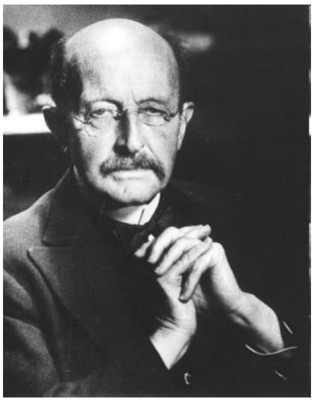


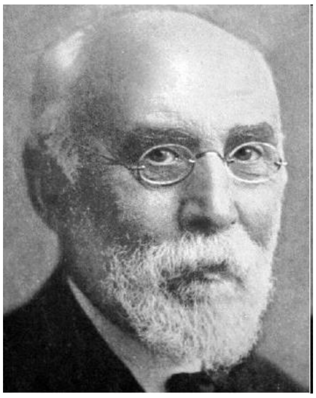
Thomson

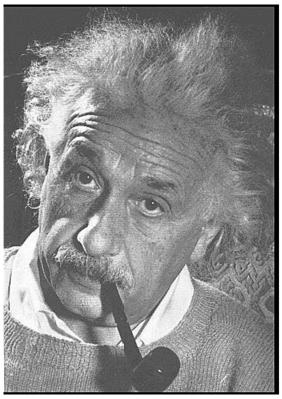
→experimental discoveries are very important

eg Barium sheets to protect yourself against the X-rays. (before: everybody worked without any security, until the discovery that you can become impotent of X-rays)

Theoretical physicists:







Planck, Lorentz, Einstein

The years from 1895 to 1897 were crucial because of four great discoveries: x-rays, the electron, the Zeeman effect, and radioactivity.

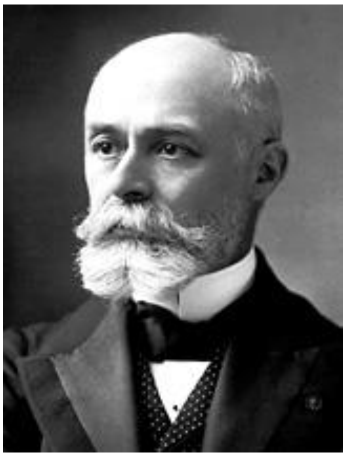
TABLE 3.1
Discovery Claims, 1895–1912, and Their Status by 1915

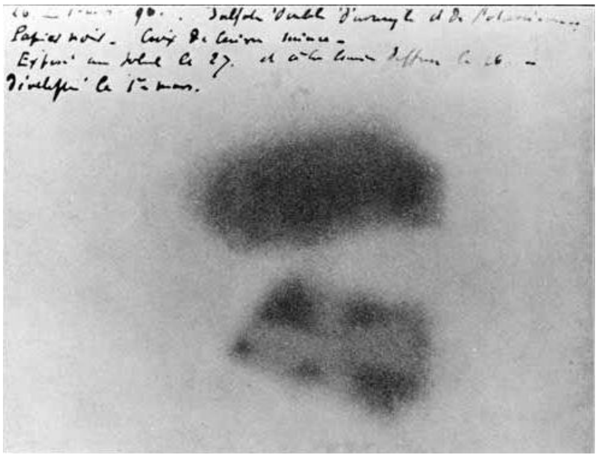
Entity	*Year*	*Scientists*	*Status, 1915*
Argon	1895	Rayleigh and W. Ramsay	accepted
X-rays	1896	W. Röntgen	accepted
Radioactivity	1896	H. Becquerel	accepted
Electron	1897	J. J. Thomson	accepted
Black light	1896	G. LeBon	rejected
Canal rays	1898	W. Wien	accepted
Etherion	1898	C. Brush	rejected
N-rays	1903	R. Blondlot	rejected
Magnetic rays	1908	A. Righi	doubted
Moser rays	1904	J. Blaas and P. Czermak	reinterpreted
Positive electrons	1908	J. Becquerel	reinterpreted
Cosmic rays	1912	V. Hess	uncertain

Note: Canal rays, or positive rays, were identified in cathode ray tubes by Eugen Goldstein in 1886; they were found to consist of positive gas ions. Etherion was the name for a chemical element consisting purely of ether that Charles Brush claimed to have discovered. Moser or metal rays, first proposed by the physicist L. F. Moser in 1847, were sometimes believed to be rays emanating from illuminated metals and other substances. The phenomenon was explained as photo- and electrochemical in nature.

theory & experiment: both are important

a) Henri Becquerel (1852–1908):





Sergé: " *The other side of physics is of equal importance. I refer to the development of theoretical ideas.*
We see the subtle play between theory and experiment that propels physics in its zig-zag progress between new facts and new theories. The ultimate goal of physics is to describe nature and predict phenomena. It is impossible to do this starting with a priori theories; on the other hand, using experiments alone, we would soon be lost in a bewildering array of disconnected facts without any hope of making sense of them. It is the combination of theory and experiment, brought about by the use of mathematics as a language, that permits the astounding results physics has attained."

Kragh: "*In the history of blackbody radiation, and hence in the birth of quantum theory, experiment was no less important than theory.*"

b) Planck:

Helge Kragh, *The Slow Rise of Quantum Theory*

Blackbody radiation defined by: Kirchhoff (1859-60)

1879: Josef Stefan – blackbody radiation varies as T^4

1884: Ludwig Boltzmann – theoretical underpinning

1894: Wilhelm Wien – displacement law

1897-1900: Planck proposes a theoretical formula to explain Wien's law

"In 1899 [Max Planck] found an expression for the entropy of an oscillator by means of which he could derive Wien's radiation law. This was what Planck had hoped for, and had it not been for the experimentalists, he might have stopped there.
In the same year as Planck derived Wien's law, experiments proved that the law was not completely correct, contrary to what Planck and most other physicists had assumed."

1899: Wien's law doesn't hold for large wavelengths

1900: Planck deduces a new (correct) formula, but without a theoretical (i.e. mechanical/classical) foundation

"Planck's primary interest was not to find an empirically correct law, but to derive it from first principles."
"The law [of blackbody radiation] seemed to be in complete agreement with experimental data and was, in this respect, the answer that had been sought for so long. Because the new law rested on an entropy expression that was scarcely more than an inspired guess, however, it was not theoretically satisfactory. [Planck] could not rest content before he understood the new law."

14 December 1900: hypothesis of energy quantum

"All what happened can be described as simply an act of desperation…"

- students have to pay the teachers, not the university (privatization)
  = beginning
  = waiting for a real appointment
- Planck = a very central person; it controls the journal
- negatively adviced to study physics, but do chemistry
- blackbody radiation
- interaction with matter & ether
- it is not true that a formule (that comes from a theoretical model) strokes with an experiments, that it verifies the model
  ➔ it was not bad that Planck doesn't understand its own law

Helge Kragh, *The Slow Rise of Quantum Theory*

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14 December 1900: hypothesis of energy quantum
"All what happened can be described as simply an act of desperation…"

Allerdings muss ich gestehen, dass mir die Vorlesungen [in Berlin] keinen merklichen Gewinn brachten. Helmholtz hatte zich offenbar nie richtig vorbereitet. […] Wir hatten das Gefühl, dass er sich selber bei diesem Vortrag mindestens ebenso langweilte wie wir. […]
Im Gegensatz dazu trug Kirchhoff ein sorgfältig ausgearbeitetes Kolleg frei vor. […] Infolgedessen lernten wir aber nicht viel dabei – denn man lernt nur, indem man sich Fragen stellt.

Eine neue wissenschaftliche Wahrheit pflegt sich nicht in der Weise durchzusetzen, dass ihre Gegner überzeugt werden und sich als belehrt erklären, sondern vielmehr dadurch, dass die Gegner allmählich aussterben und dass die heranwachsende Generation von vornherein mit der Wahrheit vertraut gemacht is.

Planck, *Persönliche Erinnerungen aus alten Zeiten* (1946)

I have to admit that the lectures [in Berlin] were not really useful to me. Helmholtz clearly never prepared his lecture. […] We had the feeling that he felt bored as much as we did. […] On the other hand, Kirchhoff presented a carefully prepared lecture. […] As a result, we didn't learn much – you only learn when you ask questions.
A new scientific truth usually doesn't set forth by convincing its opponents, but much more but the fact that these opponents die out, and that the new generation from the start has been familiar with the new truth.

Helge Kragh, *The Slow Rise of Quantum Theory*

“In December 1900 Planck did not recognize that the new radiation law necessitated a break with classical physics. Nor, for that matter, did other physicists.”

“If a revolution occurred in physics in December 1900, nobody seemed to notice it, least of all Planck. […] By 1908 Planck’s result was generally accepted as the correct answer. Only a handful of theorists found it worthwhile to ask why the formula was correct.”

“For most of the decade, Planck believed that his radiation law could be reconciled with classical mechanics and electrodynamics.”

“At the end of the first decade of the twentieth century, quantum theory was still badly understood and studied seriously only by a few theoretical physicists. These included Lorentz, Ehrenfest, Jeans, Einstein, Larmor, and, of course, Planck. Until 1906, Einstein was alone in realizing the radical, nonclassical nature of Planck’s theory.”

Helge Kragh, The Slow Rise of Quantum Theory

Einstein and the Photon

Einstein’s approach differed markedly from Planck’s and hardly relied at all on Planck’s radiation law and its associated quantum of action.

He reasoned that “monochromatic radiation of low density behaves – as long as Wien’s radiation formula is valid – as if it consisted of mutually independent energy quanta of magnitude.”

Einstein emphasized that this concept of light quanta was provisional. Yet he was convinced about the reality of the light quanta and eagerly tried to show that his hypothesis was empirically fruitful.

→ photo-electric effect (Lenard 1902 – Millikan 1916)

Einstein’s photoelectric equation was e truly novel prediction. Einstein’s theory was not a response to an experimental anomaly that classical theory could not accoutn for, for in 1905 the photoelectric effect was not considered problematic. It was only some years later that experimentalists took up the question of the relationship between E and ν. And when they did, it was not with the purpose of testing Einstein’s theory.

Einstein’s theory of light quanta was either ignored or rejected by experimenters and theorists alike.

The theory of specific heats [1907-1912] helped bring the quantum theory into more traditional areas of physics and make it known to the many physicists who were not interested in, or did not understand, the finer details of the theory of blackbody radiation.

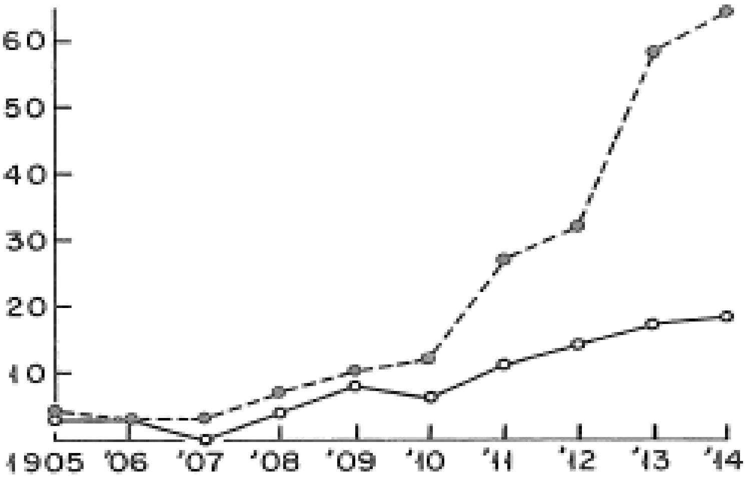


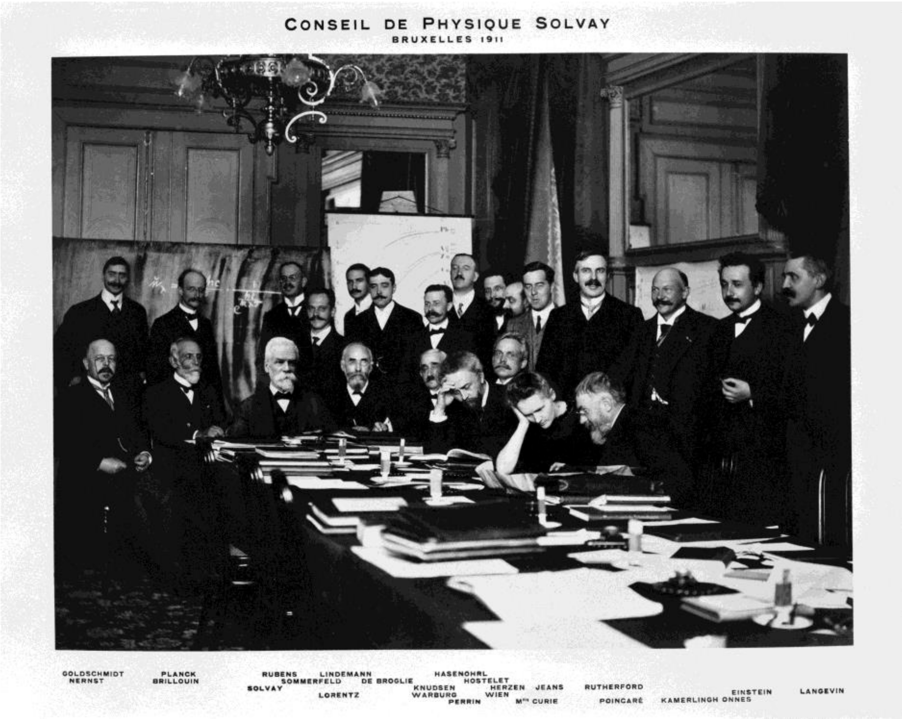
Figure 5.2. The slow rise of quantum theory. The solid circles indicate the number of authors who published on quantum topics. The open circles refer to the number of authors who dealt with blackbody theory, a subset of early quantum physics. *Source:* T. S. Kuhn, *Black-Body theory and Quantum Discontinuity*. Copyright © 1978 by Oxford University Press, Inc. Used by permission of Oxford University Press, Inc.

"slow rise of the quantum mechanics"
START: 1905: Einstein: light as a gas of particles
➔ photo electric effect

c) Einstein:

- joung men are more revolutionary
  ←→ Planck: it was not new physics, but just something new in the old physics
- QM = something really new
- discrete particles in space, not in matter
- concept of light quanta works very well
- how to verify this? fotoelekctric effect was already known + add an extra point to the theory (photon?) → but is this something new?
- Einstein found mathematical formules to describe specific heat in the quantum model
  → QM enters in microscopic physics

CONSEIL DE PHYSICQUE SOLVAY:



- Solvay:
  - = supporter of the university of Brussels
  - = millionaire
  - ≠ a scientist
- science = reflection of basic understanding of the world
  (this was not the main reason to want to organize the science world)
- Nernst: thermochemistry
  - made this large conference (conseil)
  - conference ≠ local, but was international
    - = on invitation
    - ➔ a lot of experts present
    - but no clear decisions made
- other scientists present: Curie, Rutherford, Einstein, Lorentz (=director of the conseil), Sommerfeld
- ! ½ theoretical physicists & ½ experimental physicists
  = something new,
  because # of theoretical physicists > # of experimental physicists
  → lots of them will receive a Nobel price
  → were taking about radiation, heating capacities
    → collaboration
- Maurice Debroglie: was the editor (came out the next year) of the conseil

The Solvay Congress of 1911 pointed up the significance of theoretical questions for physical research. It was the prototype of the intimate, international meetings that would increasingly attend the latest advances in physics.
The Solvay Congress was called into being because of certain troubling theoretical questions raised in recent experimental work in the physics of heat.

The presentations made a case for a dislocation of physical theory more serious than many of the members of the congress had imagined beforehand.

"It appears certain that from now on it will be necessary to introduce into our physical and chemical concepts a discontinuity, an element varying by jumps, which we had no idea of a few years ago." This was the principal lesson of the quantum theory as of 1911.
The publication [of the congress proceedings] did much to acquaint physicists with the as yet little-known quantum theory.

C. Jungnickel and R. McCormmach, *Intellectual Mastery of Nature*, vol. 2 (1986)

Solvay conference: the problems were not easy solved
➔ quantum concepts needed

The Royal Swedish Academy of Sciences has decided to award this year's Nobel Prize for Physics to Professor Dr. Hendrik Antoon Lorentz of Leiden and Professor Dr. Pieter Zeeman of Amsterdam for their pioneering work on the connection between optical and electromagnetic phenomena.
[…]
The greatest credit for the further development of the electromagnetic theory of light is due to Professor Lorentz, whose theoretical work on this subject has borne the richest fruit. […] Lorentz starts from the hypothesis that in matter extremely small particles, called electrons, are the carriers of certain specific charges. These electrons move freely in so-called conductors and thus produce an electrical current, whereas in non-conductors their movement is apparent through electrical resistance. Starting from this simple hypothesis, Lorentz has been able not only to explain everything that the older theory explained but, in addition, to overcome some of its greatest shortcomings.
[…]
Alongside the theoretical development of the electromagnetic theory of light, experimental work also continued without interruption, and attempts were made to demonstrate in every detail the analogy between electrical wave motion and light. […] Professor Zeeman has recently succeeded in solving just this problem, which has up till now been the object of fruitless exertions on the part of many perspicacious research workers. Guided by the electromagnetic theory of light, Zeeman took up Faraday's last experiment, and, after many unsuccessful attempts, finally succeeded in demonstrating that the radiation from a source of light changes its nature under the influence of magnetic forces in such a way that the different spectral dines of which it consisted were resolved into several components.
The consequences of this discovery give a magnificent example of the importance of theory to experimental research. Not only was Professor Lorentz, with the aid of his electron theory, able to explain satisfactorily the phenomena discovered by Professor Zeeman, but certain details which had hitherto escaped Professor Zeeman's attention could also be foreseen, and were afterwards confirmed by him. He showed, in fact, that the spectral lines which were split under the influence of magnetism consisted of polarized light, or in other words that the light vibrations are orientated in one particular way under the influence of the magnetic force, and in a way which varies according to the direction of the beam of light in relation to this force.

1922 - Niels Bohr
1921 - Albert Einstein
1920 - Charles Edouard Guillaume
1919 - Johannes Stark
1918 - Max Planck
1917 - Charles Glover Barkla
1915 - William Bragg, Lawrence Bragg
1914 - Max von Laue
1913 - Heike Kamerlingh Onnes
1912 - Gustaf Dalén
1911 - Wilhelm Wien
1910 - Johannes Diderik van der Waals
1909 - Guglielmo Marconi, Ferdinand Braun
1908 - Gabriel Lippmann
1907 - Albert A. Michelson
1906 - J.J. Thomson
1905 - Philipp Lenard
1904 - Lord Rayleigh
1903 - Henri Becquerel, Pierre Curie, Marie Curie
1902 - Hendrik A. Lorentz, Pieter Zeeman
1901 - Wilhelm Conrad Röntgen

1945 - Wolfgang Pauli
1944 - Isidor Isaac Rabi
1943 - Otto Stern
1939 - Ernest Lawrence
1938 - Enrico Fermi
1937 - Clinton Davisson, George Paget Thomson
1936 - Victor F. Hess, Carl D. Anderson
1935 - James Chadwick
1933 - Erwin Schrödinger, Paul A.M. Dirac
1932 - Werner Heisenberg
1930 - Sir Venkata Raman
1929 - Louis de Broglie
1928 - Owen Willans Richardson
1927 - Arthur H. Compton, C.T.R. Wilson
1926 - Jean Baptiste Perrin
1925 - James Franck, Gustav Hertz
1924 - Manne Siegbahn
1923 - Robert A. Millikan

LINKS: before the ware
RECHTS: interwar period

OPMERKING: Nobel price 1902: Lorentz & Zeeman

Lorentz = theoretical physicst
Zeeman = experimental physicst

MAAR: in 1902 was het nog niet mogelijk dat een theoretische physicus de Nobelprijs kreeg

BECAUSE: Nobel: " this price = for progess and theoretical work is this not"

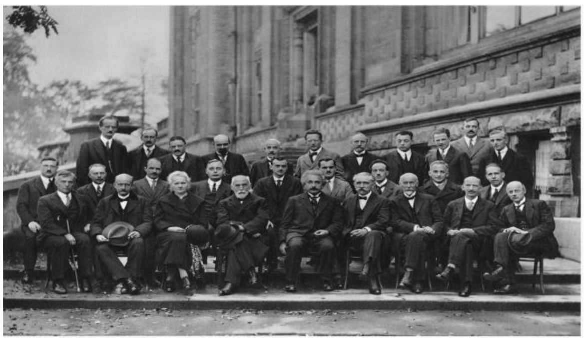
BUT: Lorentz had the basic idea

EPILOGUE:

old vs new generation:

new generation:

- new concepts = something different, evolutionary
- new concepts must not persé be integrated in the older physics
- eg Einstein, Bohr
- motto: " progress in science = due to this new generation"



H3. Weimar culture and the Forman-thesis

Forman-thesis: “ how is it possible that the quantum concept came up in German?”

German was, at that time, the country where you expect the least of progress
= Weimar republic (= name of the country before the nazi’s)

I. Quantum revolution at last

revolution = moment that you realize that you do a completely different physics.

relativity: mathematics & philosophers: interest outside the physics
←→ quantum: interest only from the physicists
= European phenomena (not American)

Europa:
- scientists = well educated people
- = philosopher look on physics

←→ America: physics only for new techniques

Compared to the theory of relativity, quantum mechanics developed rapidly, disseminated very quickly, and met almost no resistance.

Also contrary to relativity, quantum mechanics attracted little public interest.

Although quantum mechanics was no less counterintuitive than relativity, there was no quantum counterpart to the antirelativistic literature that flourished in the 1920s.

Many European physicists were deeply occupied with the philosophical implications of the new mechanics and devoted much time to discussing the broader meaning of the theory’s strange nonclassical features. Do physical properties come into existence only as a result of measurements? If so, is the observed world real and objective? Can the object and subject be distinguished or do they form an indissoluble whole? Can the lessons of quantum mechanics be extrapolated to society and culture?

For Bohr, Einstein, Heisenberg, Jordan, and others, it was as important to understand these features as it was to calculate physical problems with the new technique.

II. Niels Bohr (1885-1962)

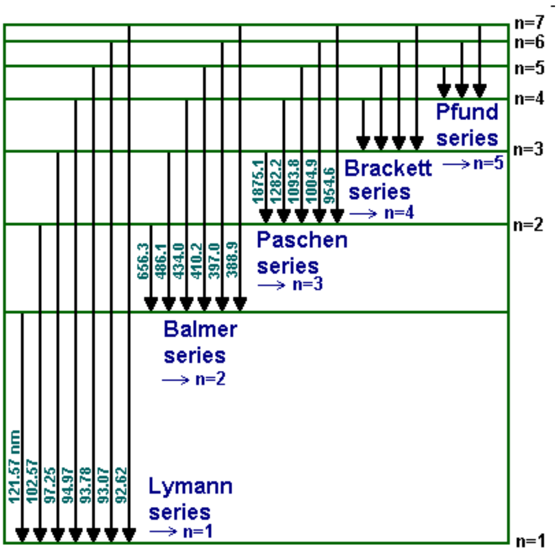
• Introduction

- Bohr = hero of the QM
  ←→ Einstein: nonconventional
  ←→ Planck: reliable
- Bohr = open
- kan omgaan met iedereen
- impressive: gives very good lectures
- similar to Einstein: because of the not mathematical, but intuitive concepts
- atomic model cannot be explained by classical physics

• 1913: "On the Constitution of Atoms and Molecules"

1. energy is not radiated continuously, but only during transitions from one stationary condition to another
2. The dynamic equilibrium of a stationary system is determined by the laws of mechanics; these laws do not apply to transitions between stationary conditions
3. During a transition homogenous radiation is emitted, of which the energy is given by E = h*ν*

• 1914



Lyman-series
Pickering series (helium)

III. Experimental confirmation on Borh's theory

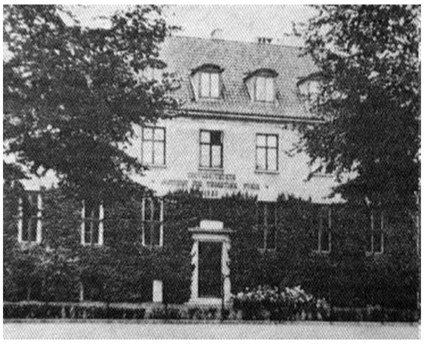
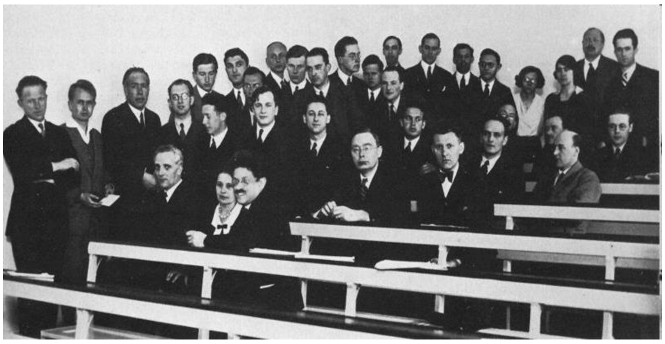
Kragh: "The strength of Bohr's theory was not its theoretical foundation, which to many seemed unconvincing and even bizarre, but its experimental confirmation over a wide range of phenomena.
For example, in 1913-1914 the young British physicist Henry Moseley studied the characteristic x-rays emitted by different elements and showed that the square root of the frequencies related proportionally to the atomic number. Mosely's mechanism of x-ray emission rested on Bohr's theory.
Another important confirmation was the experiments with electron bombardment of mercury vapor that James Franck and Gustav Hertz made between 1913 and 1916. It was soon realized that the experiments brilliantly confirmed Bohr's theory. Ironically, Franck and Hertz did not originally relate their experiments to Bohr's theory […] but in 1915 Bohr argued that they had misinterpreted their results.
The red line of the hydrogen spectrum has a double structure. Bohr seems to have been unaware of this phenomenon, for which there was no room in his theory. But once again an apparent anomaly was turned into a confirmation, although this time it required a major extension of the theory, made by Arnold Sommerfeld. The remarkable agreement between theory and experiment was considered a great success of the Bohr-Sommerfeld theory. To the majority of physicists the work of Sommerfeld looked like a striking confirmation of Bohr's quantum theory of atoms."

IV. Spectroscopy

Remark: physicists in spectroscopy worked - before the invention of Borh's model - especially on technical applications.

Sergé: "After Bohr's fundamental work, atoms and molecules moved to the center of attention for both experimental and theoretical physicists. Before Bohr spectroscopy was an almost empirical topic that did not go much beyond the cataloging of many spectral lines. The study of electric discharges in gases was also chiefly empirical. The new atomic theory provided a guide to the understanding of many phenomena and to the prediction of new ones.
The thriving intellectual activity that ultimately led to quantum mechanics centered in Germany. The leading journal was probably *Zeitschrift für Physik*, which was founded after the war. In Germany two schools were particularly important in theoretical physics; one in Munich led by Sommerfeld, and one in Göttingen led by Max Born.
A third center was in Copenhagen with Bohr. The best German students often made the pilgrimage from Munich to Göttingen, and finally to Copenhagen.
Other centers existed elsewhere in Germany, in England, in France, in Holland, and in the Scandinavian countries. After 1927 Rome started to gain importance when Fermi was called to a chair there."

V. Intellectual centres:

- quantum = now a big thing
- collaborations

- Munich
- Copenhagen!!
    - place of Bohr
    - you can come to there for a long or short period
    - REMEMBER:
      boycott the German science after their defeat (nederlaag) of the war
      = until 1926
      → only countries that were neutral during the war can openly communicate with German physicists
      ➔ Copenhagen was a meeting place for all physicists (also German one), because Denenmarken was neutral during the war

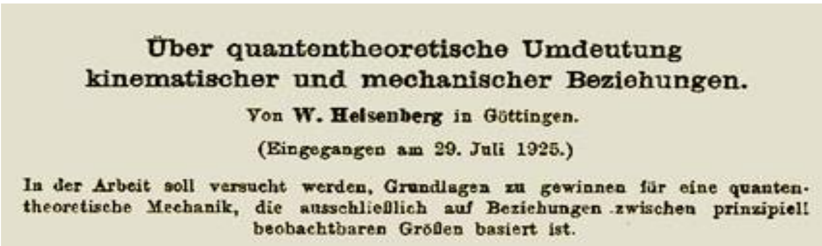
VI. Knabenphysic

- = young, new generation of physicists: boys
- because of the war: there was a gap in the age of persons (a lot of the people were dead in the war)
  ➔ creation of a real feeling of a new generation
- feeling of arrogance and superiority: wanted to make a revolution

Pauli once referred to quantum mechanics as Knabenphysik – boys' physics – because so many of the main contributors were still in their twenties.
For example, in September 1925 Heisenberg was 23 years old, Pauli 25, Jordan 22, and Dirac had just turned 22.
Many of these bright young physicists felt, arrogantly, that quantum mechanics belonged to them and that most elder physicists were just incapable of mastering the theory.
Friedrich von Weizsäcker, in 1932 a twenty-year old member of the new-generation gang [recalled] "I feel that that the general attitude was just an attitude of […] an immense 'Hochmut', an immense feeling of superiority, as compared to old professors of theoretical physics, to every experimental physicist, to every philosopher, to politicians, and to whatever sorts of people you might find in the world, because we had understood the thing and they didn't know what we were speaking about."

VII. Heisenberg-Schrödinger

a) Heisenberg:



Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen.

Von **W. Heisenberg** in Göttingen.

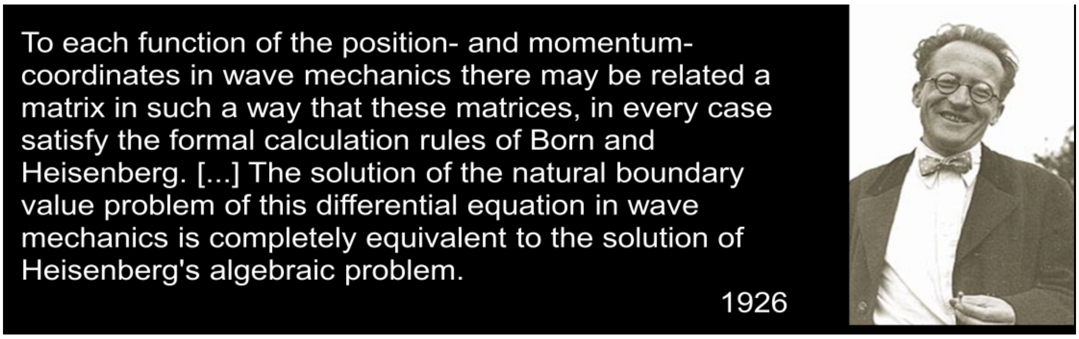
(Eingegangen am 29. Juli 1925.)

In der Arbeit soll versucht werden, Grundlagen zu gewinnen für eine quantentheoretische Mechanik, die ausschließlich auf Beziehungen zwischen prinzipiell beobachtbaren Größen basiert ist.

- ambitious
- summarize, remake in mathematics (matrix) of what was already known
  → it was just a reformulation

Heisenberg's new "reinterpretation" of mechanics was highly abstract and not easily understood, not even by Heisenberg himself.
The new quantum mechanics was more impressive from a mathematical than from an empirical point of view. Many physicists were skeptical because of the theory's lack of visualizability and its unfamiliar mathematical formalism.

b) Schrödinger:



- Schrödinger = an old guy
- did the same as Heisenberg did, but not with matrix mechanics, but with wave mechanics (continuous)

Schrödinger’s wave mechanics had great advantages over the competing systems of quantum mechanics. In particular, it built on mathematical concepts and operations well known from other areas of theoretical physics and was therefore much easier to use in practical calculations.
In addition to facilitating calculations, wave mechanics was also less abstract than matrix mechanics, and, according to many physicists, preferably from a conceptual point of view.

c) Copenhagen showdown

- (Heisenberg wants a good position in the university of Munich)

- Copenhagen showdown = what is the best description of matter?
  - Heisenberg or Schrödinger?
  - Heisenberg was not so popular
    ←→ Schrödinger: wave can be visualized

Heisenberg had just begun his job as Niels Bohr's assistant in Copenhagen when Schrödinger came to town in October 1926 to debate the alternative theories with Bohr.
The intense debates in Copenhagen proved inconclusive. They showed only that neither interpretation of atomic events could be considered satisfactory. Both sides began searching for a satisfactory physical interpretation of the quantum mechanics equations in line with their own preferences.
Up until the advent of quantum mechanics, everyone thought that the precision of any measurement was limited only by the accuracy of the instruments the experimenter used. Heisenberg showed that no matter how accurate the instruments used, quantum mechanics limits the precision when two properties are measured at the same time.

Schrödinger’s wave mechanics was initially received with some scepticism, and sometimes even hostility, by the quantum theorists in Göttingen and Copenhagen. They tended to consider the emphasis on classical virtues such as spatio-temporal continuity and visulizability a retrograde step. Most physicists were slow to accept "matrix mechanics" because of its abstract nature and its unfamiliar mathematics. They gladly welcomed Schrödinger's alternative wave mechanics when it appeared in early 1926, since it entailed more familiar concepts and equations, and it seemed to do away with quantum jumps and discontinuities.

Sergé: “Why was Schrödinger’s success so immediate and universal compared with the more modest acceptance of Heisenberg’s earlier work?
One reason was certainly that Schrödinger’s mathematics was of a type familiar to physicists and that his whole method was not mathematically different from classical wave theory.
Another reason is that Schrödinger’s methods could be applied to concrete practical problems much more easily than Heisenberg’s methods, and thus they could be compared with experiments.
A big hurdle was successfully overcome when Schrödinger and others independently recognized that Heisenberg’s en Schrödinger’s theories were mathematically equivalent.“

d) Uncerntainty:

Heisenberg, 1927
“If one wants to make clear what is meant by the words ‘position of an object,’ for example of an electron […] the one has to describe definite experiments by means of which the ‘position of an electron’ can be measured; otherwise the term has no meaning at all.”
→ uncertainty relations
Since all experiments obey the quantum laws and, consequently, the uncertainty relations, the incorrectness of the law of causality is a definitely established consequence of quantum mechancis itself.
Physics must confine itself to the description of the correlations between perceptions.

uncertainty = important discovery of Heisenberg (due to “observing”)
➔ there could not be a deterministic universe
➔ no causality
➔ you cannot predict the future

Heisenberg: it was good that nobody could understand its theory

e) Interpretation (= pas gegeven in 1950)

“For Bohr, the uncertainty relations arose not merely from the quantum equations and the use of particles and discontinuity. Waves and particles had to be taken equally into account, and the scattering of light waves by the electron was also crucial.
In Bohr's words, the wave and particle pictures, or the visual and causal representations, are "complementary" to each other. That is, they are mutually exclusive, yet jointly essential for a complete description of quantum events.
Obviously in an experiment in the everyday world an object cannot be both a wave and a particle at the same time; it must be either one or the other, depending upon the situation. In later refinements of this interpretation the wave function of the unobserved object is a mixture of both the wave and particle pictures until the experimenter chooses what to observe in a given experiment. By choosing either the wave or the particle picture, the experimenter disturbs untouched nature.
Complementarity, uncertainty, and the statistical interpretation of Schrödinger's wave function were all related. Together they formed a logical interpretation of the physical meaning of quantum mechanics known as the "Copenhagen interpretation."

Bohr: we can only make science of things we see
→ where does the uncertainty come from?
➔ 2 descriptions of the universe
the descriptions = which you choose
= depending on the experiment you do
➔complementary = vaag
ꜝ bad, because in the 1920-30: especially new particle physics

"We had understood the mathematical scheme, and we also had understood that certainly we need the discrete energy levels, and the quantum jumps, and so on. But we could not even explain how such a thing as an orbit of an electron in a cloud chamber comes about, because they would see the orbit, but still we had no notion of the orbit in our mathematical scheme.
And at that time I remembered a long discussion which I had with Einstein about a year [before] - it was my first meeting with Einstein - I had given a talk on quantum mechanics in the Berlin colloquium. And Einstein had taken me to his room, and he first asked me about this idea which I had said in my lecture, that one should only use observable quantities in the mathematical scheme. And he said, he understood the ideas of Mach, Mach's philosophy, but whether I really believed in it, he couldn't see. Well, I told him that I had understood that he has produced his theory of relativity just on this philosophical basis, as everybody knew. Well, he said, that may be so, but still it's nonsense. And that of course was quite surprising to me.
Then he explained that what can be observed is really determined by the theory. He said, you cannot first know what can be observed, but you must first know a theory, or produce a theory, and then you can define what can be observed....
And could it not be the other way around? Namely, could it not be true that nature only allows for such situations which can be described with a mathematical scheme? Up to that moment, we had asked the opposite question. We had asked, given the situations in nature like the orbit in a cloud chamber, how can it be described with a mathematical scheme? But that wouldn't work, because by using such a word like "orbit", we of course assumed already that the electron had a position and had a velocity. But by turning it around, one could at once see that now it's possible, if I say nature only allows such situations as can be described with a mathematical scheme, then you can say, well, this orbit is really not a complete orbit. Actually, at every moment the electron has only an inaccurate position and an inaccurate velocity, and between these two inaccuracies there is this uncertainty relation. And only by this idea it was possible to say what such an orbit was. "

f) Reception

Formalism of quantum was accepted (more these of Schrödinger than these of Heisenberg)

Heisenberg: had an idea: “finally we have a revolution”, but the other physicists do not care anymore.

It is noteworthy that almost all the physicists who explicitly adopted Bohr’s viewpoint had personal contacts to Bohr and had been visitors to his institute.
Outside the Copenhagen circle, the reception of the complementarity philosophy was considerably cooler, either politely indifferent, or, in a few cases, hostile.
In the United States […] problems that were “nearly philosophical” were not considered attractive. American physicsts had a more pragmatic and less philosophical attitude to physics than many of Bohr’s associates.
In spite of the fact that a large part of the world’s physicsts did not endorse the Copenhagen interpretation, or rather did not care about it, the opposition to it was weak and scattered. By the mid-1930s, Bohr had been remarkably successful in establishing the Copenhagen view as the dominant philosophy of quantum mechanics.
Einstein did not take much interest in the new theory at first. His general attitude was skeptical and he denied, more on philosophical than on scientific grounds, that the microworld could only be described statistically.
The general impression was that Bohr countered Einstein’s objections satisfactorily [and] confirmed to mainstream quantum physicists what they had always thought, namely that Einstein and his allies – “the conservative, old gentlemen” – were hopelessly out of tune with the development.

VIII. Weigmar culture

= marked by an afterwar period

very large inflation
➔ people don't want to think about the future

Special type of art:

After the war:

- The institutes ware still there, but there was no money
- Sense of being on their own
  ("we are the best scientists, artists: PROUD")
- science becomes something were you can be proud of
  ➔ scientists give lectures
  ➔ scientists care about the world view

a) Science and Weimar culture

The German scientific community remained intact after the war, but it was a poor community in desperate search of money.

From 1919 to about 1928, German science was subject to an international boycott, in the sense that German scientists were not allowed to attend many international conferences.

What was left to carry the nation on to new honor and dignity? According to many scientists, the answer was science. Science should be seen as a bearer of culture, a Kulturträger.

Science was seen as a means for the restoration of national dignity, and Germany's famous scientists became instruments of national and international cultural policy on par with the country's poets, composers, and artists.

b) The Physics Community

Right-wing physics:

- no new physics
- back to classical experiments
- = science were we are good in

New age physics:

- younger generation
- “the older generation was responsible for the war”
- new kind of authority = needed
- “we make our own physics ˈ classical”

From 1919 to about 1928, German science was subject to an international boycott, in the sense that German scientists were not allowed to attend many international conferences.
In the early 1920s the German physics community was split up in questions of science, politics, and ideology.
The right-wing physicists largely shared the same political views, including chauvinism, ultracaonservatism, and opposition to the Weimar republic. Anti-Semitism, too, was common to most of them.
The scientific views of the right-wing physicists were, to a considerable extent parallel with their political views, both being conservative. They stuck to the worldview of classical mechanicism and electrodynamicism, including such notions as the ether, determinism, causality, and objectivity. The standards of the right wing manifested themselves in a more or less direct dissociation from quantum and relativity theories and a preoccupation with experiments at the expense of theory. […] On the other hand, many right-wing physicists were eager to apply their science for technical purposes.
To some extent, the division between ‘progressives’ and ‘reactionaries’ reflected the tension between the powerful Berlin physicists and the physics institutes at the provincial universities. To many physicists ‘Berling’ came to signify abstract theory, Jewish intellectualism, arrogance, and bad taste.

Max Jammer, *The Conceptual Development of Quantum Mechanics* (1966) “Certain philosophical ideas of the late nineteenth century not only prepared the intellectual climate for, but contributed decisively to, the formation of the new conceptions of the modern quantum theory. […] United in rejecting causality though on different grounds, these currents of thought prepared, so to speak, the philosophical background to quantum mechanics. They contributed with suggestions to the formative stage of the new conceptual scheme and subsequently promoted its acceptance.”

Paul Forman, 'Weimar Culture, causality, and quantum theory, 1918-27' (1971)
The result is […] overwhelming evidence that in the years after the end fo the First World War but before the development of an acausal quantum mechanics, under the influence of 'currents of thought', large numbers of German physicists, for reasons only incidentally related to the developments in their own discipline, distanced themselves from, or explicitly repudiated causality in physics.
Thus the most important of Jammer's theses – that extrinsic influences led physicists to ardently hope for, actively search for, and willingly embrace an acausal quantum mechanics – is here demonstrated for, but only for, the German cultural sphere.

Kragh: *"During the decade following 1918, physics in Germany faced not only economic difficulties, but also a changed intellectual environment that in many ways was hostile to the traditional values of physics.*
Physics, and science in general, was no increasingly being accused of being soulless, mechanistic, and contrary to human values.
Non- or antiscientific attitudes were popular in philosophy, psychology, and sociology, and astrology, cabalism, and other brands of mysticism flourished.
Many scientists felt that the Zeitgeist of the period was basically antagonistic to their science and that what counted to the educated public were ideas foreign to the scientific mind.
Given that this antirationalistc and antipositivistic climate dominated a large part of the Weimar culture, and given that it questioned the very legitimacy of traditional science, it was only natural that physicists felt forced to respond to the new ideas. One result of the adaptation was that many physicists abstained from justifying their science by utility and instead stressed that physics is essentially culture.
In the early 1920s several German physicists addressed the questino of crisis in physics and argued that the principle of causality could no longer be considered a foundation of physical theories. This repudation of causality was not rooted in specific experimetnalism or theoretical developments in physics."

c) There are good reasons to reject the suggestion of a strong connection between the socio-ideological circumstances of the young Weimar republic and the introduction of an acausal quantum mechanics.
    1) → general audiences, but not in scientific papers
    2) adaptation concerned with values, not with content
    3) only a very small proportion of German physicists seem to have rejected causality before 1925-26
    4) Sommerfeld, Einstein, Born, Planck criticized the Zeitgeist explicitly
    5) the recognition of some kind of crisis in atomic physics was widespread around 1924, primarily because of anomalies that the existing atomic theory could not explain.
    6) The first acausal theory in atomic physics was not received uniformly positively among German physicists. The theory's element of acausality was not seen as its most interesting feature. Moreover, the theory had its origin in Copenhagen, and was proposed by a Dane (Bohr), a Dutchman (Kramers) and an American (Slater).
    7) Among the pioneers of acausal quantum mechanics were Bohr, Pauli, and Dirac, none of whom was influenced by the Weimar Zeitgeist. The young German physicists were more

interested in their scientific careers, and sought deliberately to isolate themselves from what went on in society.

H4. German Physics

Remember:

- Solvay gave Schrödinger an opportunity to talk about his uncertainty principle
- Einstein: "God has not play dice"

German = destroyed after the war: not really the country, but the economics and the social life.

Older physicists: you have to return to the old physics (= before the war), because it was good.

Newer physicists: the old people were responsible for losing the war
→ causality was abonded
→uncertainty was added
→microscopic world ←→quantum world
→complementary: wave vs particle

After the war: boycott on German: you may not collaborate with German physicists
= ended in 1926

→ Solvay Conference in 1927, 2de 1930

Idea (after 1930): "everything is already known"

Bohr: basic idea: in physics: the most things are known
new world was opened by going into microscopic: quantum
→ new field: molecular biology + economics
→new laws can be derived
eg: discovery of the dubble helix structure: DNA

1933: 7th Solvay Conferency

Einstein was not on the picture (1933): Hitler came into power (Einstein was Jewish)

I. Nuclear physics

Nuclear physics = a new trend (started at 1930)
→ "the nucleus": less and more easier mathematics involved

II. Discorvery of the neutron

In February 1932, after experimenting for only about two weeks, Chadwick published a paper titled "The Possible Existence of a Neutron," in which he proposed that the evidence favored the neutron rather than the gamma ray photons as the correct interpretation of the mysterious radiation. Then a few months later, in May 1932, Chadwick submitted the more definite paper titled "The Existence of a Neutron."

James Chadwick (1891-1874)
Nobelprize 1935

Chadwick: neutral particle with same mass of the proton
= needed to explain the quantum effect of the gamma ray photon
→ neutron in β decay

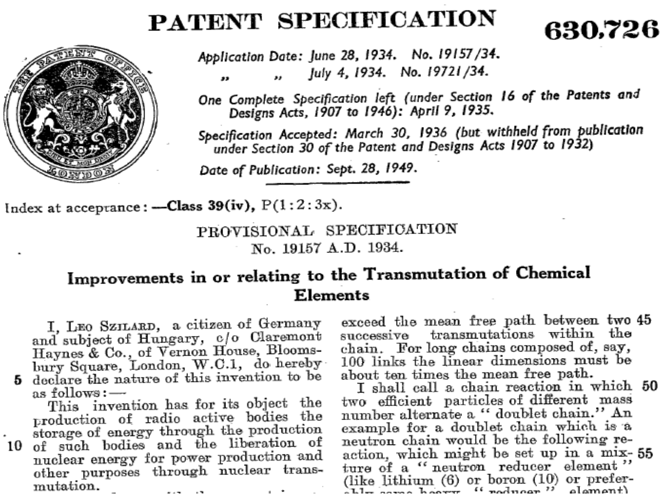
III. Nuclear chain reaction

Leo Szilard (1898-1964) (Hungary)
(Oxford, 1936)

- new radiation
- radiate a nonradiative material becomes radioactive

IV. Patent

Patent was not really for using, but it was more as a political statement



PATENT SPECIFICATION 630,726

Application Date: June 28, 1934. No. 19157/34.
" " July 4, 1934. No. 19721/34.

One Complete Specification left (under Section 16 of the Patents and Designs Acts, 1907 to 1946): April 9, 1935.

Specification Accepted: March 30, 1936 (but withheld from publication under Section 30 of the Patent and Designs Acts 1907 to 1932)

Date of Publication: Sept. 28, 1949.

Index at acceptance:—Class 39(iv), P(1:2:3x).

PROVISIONAL SPECIFICATION
No. 19157 A.D. 1934.

Improvements in or relating to the Transmutation of Chemical Elements

I, LEO SZILARD, a citizen of Germany and subject of Hungary, c/o Claremont Haynes & Co., of Vernon House, Bloomsbury Square, London, W.C.1, do hereby declare the nature of this invention to be as follows:—

This invention has for its object the production of radio active bodies the storage of energy through the production of such bodies and the liberation of nuclear energy for power production and other purposes through nuclear transmutation.

exceed the mean free path between two successive transmutations within the chain. For long chains composed of, say, 100 links the linear dimensions must be about ten times the mean free path.

I shall call a chain reaction in which two efficient particles of different mass number alternate a "doublet chain." An example for a doublet chain which is a neutron chain would be the following reaction, which might be set up in a mixture of a "neutron reducer element" (like lithium (6) or boron (10) or prefer-

V. Working places

a) Cambridge

Chadwick: nuclear bombardment, decay, radiation

b) Paris

Curie (= the daughter of Marie Curie)

Marie Curie:

- studied her children at home
- helped in the war with X-rays (medical), together with her daughter
- were (military) communist
  → because in Russia: science was promoted a lot (= until 1950; = before Stalin)

Both died very early due to radiations in the laboratory

BUT: are not always good in explaining the phenomena

c) Rome



Working in Rome: Enrico Fermi (wanted leave Italy because his wife was Jewish)
Italy had no developed Physics community
→ wanted also a good physics community
→ studied the properties of uranium & transuranium elements
(Musolini: named the elements (in a Latin name of a place))

= first place where German physicists were allowed

d) Berlin


(vrouw = Meitner)

Kaize Willhelm gezelftschaft for chemistry, physics and biology
= place where work could go on

VI. Transuranic elements

Sergé: "In the spring of 1934 we irradiated the heaviest element then known- uranium. We found several radioactive periods and substances. We then thought that we had produced transuranic elements. In this we were in error, at least in part; while it was true that transuranic elements were formed, what we had observed was something quite different.
Our experiments were repeated and extended by Curie and Joliot in Paris, and by Hahn en Meitner in Berlin. They confirmed most of our results but, by extending the investigation, found more and more substances and were forced to consider ever more complicated possible paths of decay.
It became increasingly difficult to make sensible hypotheses on the genetic relationships between the substances formed and to locate them at the end of the periodic system.
Fermi consistently refused to name the new hypothetical elements because he felt uneasy about the interpretation of the experiments. Only in 1938, in his Nobel speech, did Fermi put forward tentative names for the new elements. The moment was unfortunate; at that very time Hahn and Strassmann were discovering nuclear fission."

VII. Lise Meitner

1905: PhD Vienna
1909: Berlin
1912: Kaiser Wilhelm Institute
1938 → Groningen → Stockholm
1960 Cambridge

Hahn and Meitner met clandestinely in Copenhagen in November 1938 to plan a new round of experiments; in this regard they subsequently exchanged a series of letters. Hahn then performed the difficult experiments which isolated the evidence for nuclear fission at his laboratory in Berlin. The surviving correspondence shows that Hahn recognized that fission was the only explanation for the barium, but, baffled by this remarkable conclusion, he wrote to Meitner.

The possibility that uranium nuclei might break up under neutron bombardment had been suggested years before, notably by Ida Noddack in 1934. However, Meitner and Frisch were the first to articulate a theory of how the nucleus of an atom could be split into smaller parts: uranium nuclei had split to form barium and krypton, accompanied by the ejection of several neutrons and a large amount of energy.

Meitner also first realized that Einstein's famous equation, $E = mc^2$, explained the source of the tremendous releases of energy seen in atomic decay, by the conversion of the mass-defect into energy.

- For a woman it was difficult to make name (husband took name of her discoveries)

- 1909: Planck was not willing to love her:
  - Meitner get a place down in the basements
  - Meitner was Jewish, but Austrian
    → ze mocht langer blijven, maar als German Oostenrijk binnenviel, dan moest ze weg
      → Gronningen (=easiest border)
      → Stockholm: Meitner was not well received there, because Meitner was good (en dus dachten ze dat ze een plaats van iemand anders zou innemen :-s)

- Fission (1938): Meitner gave the explanantion in Copenhagen in Borh's institute
  (she was omitted from the paper, because it was not allowed to mention a Jewish)

VIII. Einstein Turm

1933: Einstein ejected from his country (because he was Jewish)

Theoretical physics was not so obstructed by the outsending of Jewish scientists,
because you can teach relativity and theoretical physics without even mention Einstein
(you may not copy Jewish physics)

BUT: Jewish's physicists must go away
➔ there will be a shortage on good physicists (als je de beste wegneemt, dan komen de 2de beste)

German scientific quality is not recovered
➔ return to classical, traditional physics

IX. Exodus

Naam	*Nobelprijs*		*Jaar van vertrek*	*Geboorteland*	*Instelling die ze verlieten*
Albert Einstein	Fysica	1921	1933	Duitsland	Pruisische Academie
James Franck	Fysica	1925	1933	Duitsland	Göttingen
Gustav Hertz*	Fysica	1925	1935	Duitsland	TH Berlijn
Erwin Schrödinger	Fysica	1933	1933	Oostenrijk	Berlijn
			1938		Graz
Viktor Hess**	Fysica	1936	1938	Oostenrijk	Graz
Otto Stern	Fysica	1943	1933	Duitsland	Hamburg
Felix Bloch	Fysica	1952	1933	Zwitserland	Leipzig
Max Born	Fysica	1954	1933	Duitsland	Göttingen
Eugene Wigner	Fysica	1963	1933	Hongarije	TH Berlijn
Hans Bethe	Fysica	1967	1933	Duitsland	Tübingen
Dennis Gábor	Fysica	1971	1933	Hongarije	Siemens, Berlijn
Fritz Haber	Chemie	1918	1933	Duitsland	KW Instituut voor Fysische Chemie, Berlijn
Peter Debye**	Chemie	1936	1940	Nederland	KW Instituut voor Fysica, Berlijn
George de Hevesy	Chemie	1943	1934	Hongarije	Freiburg
FGerhard Herzberg**	Chemie	1971	1935	Duitsland	TH Darmstadt
Otto Meyerhof	Medicijnen	1922	1938	Duitsland	KW Instituut voor Geneeskunde, Heidelberg
Otto Loewi	Medicijnen	1936	1938	Duitsland	Graz
Boris Chain	Medicijnen	1945	1933	Duitsland	Charité Ziekenhuis, Berlijn
Hans A. Krebs	Medicijnen	1953	1933	Duitsland	Thannhauser Kliniek, Freiburg
Max Delbrück**	Medicijnen	1969	1937	Duitsland	KW Instituut voor Chemie, Berlijn

ron: Verzameld door de auteur in de eerste plaats uit *American Men of Science*, necrologieën, brieven van een aantal van de hoofdpersonen an de auteur en correspondentie met de Research Foundation for Jewish Immigration in New York.

Hertz is niet geëmigreerd, maar hij ging werken bij Siemens in Berlijn.
* Niet-joods. Hess en Herzberg hadden beiden een joodse vrouw.

BUT: There was still science left

For science: the emigration (= also with the family) is not really a problem
But: the language can be a problem: Deutsch = universal language of science in Europe, but not in America

(Jewish scientists thought it was temporal)

X. German physics

Philip Lenard (1862-1847)
Professor Breslau (1894), Aachen (1895), Heidelberg (1896), Kiel (1898) and Heidelberg (1907)
1905: Nobelprize Physics for cathoderays

- *Grosse Naturforscher. Eine Geschichte der Naturforschung in Lebensbeschreibungen* (1919)
- *Deutsche Physik* (4 volumes, 1936-37)

  - Experimental physics: photoelectric effect
  - Deutsch physics (is not international, is not Jewish)

Remark: getting a Nobelprice now = different than getting it in the beginning of that price (you could pick someone in the period before the beginning of the price)

Johannes Stark (1874-1957)
Professor Aachen (1909-1917), Greifswald (1917-1920) and Würzburg (1920-22)
1919: Nobelprize physics for the discovery of the Stark-effect (1913)
1933-1939: president Physikalisch Technische Reichsanstalt

- *Die gegenwärtige Krisis in der deutschen Physik* (1922)
- *Adolf Hitler und die deutsche Forschung* (1934)
- *Jüdische und deutsche Physik* (1941)

  - younger
  - more ambitious
  - anti-Semitism (even before Hitler)
    (Antisemitisme is de discriminatie van Joden gebaseerd op hun etniciteit of religie. Het antisemitisme kenmerkt zich door een vijandige houding en vooroordelen jegens Joden.)

XI. German, gotic writing (= in nazi's time: "only we can discover it")

Vorwort.

Das Vorwort entstammt dem Kampf der Zeit,
Das Werk sucht Werte der Ewigkeit.

„Deutsche Physik?" wird man fragen. — Ich hätte auch arische Physik oder Physik der nordisch gearteten Menschen sagen können, Physik der Wirklichkeits-Ergründer, der Wahrheit-Suchenden, Physik derjenigen, die Naturforschung begründet haben. — „Die Wissenschaft ist und bleibt international!" wird man mir einwenden wollen. Dem liegt aber immer ein Irrtum zugrunde. In Wirklichkeit ist die Wissenschaft, wie alles was Menschen hervorbringen, rassisch, blutmäßig bedingt. Ein Anschein von Internationalität kann entstehen, wenn aus der Allgemeingültigkeit der Ergebnisse der Naturwissenschaft zu Unrecht auf allgemeinen Ursprung geschlossen wird oder wenn übersehen wird, daß die Völker verschiedener Länder, die Wissenschaft gleicher oder verwandter Art geliefert haben wie das deutsche Volk, dies nur deshalb und insofern konnten, weil sie ebenfalls vorwiegend nordischer Rassenmischung sind oder waren. Völker anderer Rassenmischung haben eine andere Art, Wissenschaft zu treiben.

You may ask "German Physics?". I might have said equally Aryan Physics or Physics of the Nordic races, physics of people investigating reality, lookingfor truth, physics of those who have founded our research of nature. "But physics is and remains internationa!" one could object. But this is based on a mistake. In reality, science is, as all things produced by man, a product of race and blood.

XII. Stark

Explanation of doing 2 trends in the physics

- Pragmantic physics
  - reality
  - looking at the phenomena first

- German genius had a feeling of nature
  → intuitive approach of nature: feeling (no start of the intellect)
- reality is not in the world, it is in the phenomena
- stimulation comes from experiments (= guided by intuition)
- you will use mathematics (is not real)
  = only a method of representing the knowledge
  → must be as easiest as possible
- Mach: "Mathematics = just a summary of science: formulate in a short form"
  → you can invent 4 dimension

- Dogmatic physics: theoretical
  - start with ideas (no intuition) (could be from mathematics)
  - formula
  - apply on results of experiments
    - link you formulas to a physical meaning
    - prove that the results are correct

770 NATURE April 30, 1938, Vol. 141

The Pragmatic and the Dogmatic Spirit in Physics

By Prof. J. Stark, President of the Physikalisch-Technischen Reichanstalt, Berlin-Charlottenburg

The pragmatic spirit, from which have sprung the creations of successful discoverers both past and present, is directed towards reality; its aim is to ascertain the laws governing already known phenomena and to discover new phenomena and bodies as yet unknown. Even before they tackle a particular problem, physicists of this school of thought have acquired a certain feeling of the reality of the phenomena to be investigated, by giving careful attention to all previously ascertained facts connected with their problem. On the basis of this feeling they form a conception as to what the body or process to be investigated may be like in reality. For them, however, such a conception is solely the means to the end of devising experimental arrangements for the empirical formulation of their question to reality itself. If the observations made with the apparatus chosen do not confirm the initial conception, as very frequently happens, they reject it without hesitation and seek stimulation from experience for a new conception for the purpose of new experiments. Their final goal is always to establish reality, whether they gain new knowledge or are led to obscure and still unexplored features of the phenomena investigated. The mathematically formulated theory is to physicists of the pragmatic spirit not an end in itself, but solely a method for the purpose either of presenting the knowledge gained from experience in a quantitative manner and as briefly and simply as possible, or of deriving mathematically for special cases results which follow from general laws obtained from experiment.

The physicist of the dogmatic school operates in quite a different manner in the field of physics. He starts out from ideas that have arisen primarily in his own brain, or from arbitrary definitions of relationships between symbols to which a general and so also a physical significance can be ascribed. By logical and mathematical operations he combines them and so derives results in the form of mathematical formulæ. He then seeks to give these a physical meaning by applying them to the results of experience. In so far as they are found to be in accord with experience, he underlines this agreement with the greatest of emphasis, and makes it appear as though the results of experience have been established and have gained scientific importance only by virtue of his theory. If there are any experimental results available that are not embraced by this theory or which stand in contradiction to it, he doubts their validity or considers them so unimportant that he does not deign to mention them. Dogmatic physicists further present things as though their theories and formulæ exhaustively covered the whole range of phenomena treated by them; they can see no further problems in this field, and thought and inquiry are ice-bound in their formulæ.

Not men like Lenard and Rutherford, but Einstein and his dogmatic imitators were held up to them as models for scientific thought and work. I have taken the field against the dogmatic spirit in Germany because I have been able to observe repeatedly its crippling and damaging effect on the development of physical research in this country. In this conflict I have also directed my efforts against the damaging influence of Jews in German science, because I regard them as the chief exponents and propagandists of the dogmatic spirit.

This reference brings me to the national aspects of the mental outlook of men of science in research. It can be adduced from the history of physics that the founders of research in physics, and the great discoverers from Galileo and Newton to the physical pioneers of our own time, were almost exclusively Aryans, predominantly of the Nordic race. From this we may conclude that the predisposition towards pragmatic thinking occurs most frequently in men of the Nordic race. If we examine the originators, representatives and propagandists of modern dogmatic theories, we find amongst them a preponderance of men of Jewish descent. If we remember, in addition, that Jews played a decisive part in the foundation of theological dogmatism, and that the authors and propagandists of Marxian and communistic dogmas are for the most part Jews, we must establish and recognize the fact that the natural inclination to dogmatic thought appears with especial frequency in people of Jewish origin.

XIII. Link to German physics

Rutherford: experimentalist (not German)

(imitator = Einstein)

→ Dogmatic = Jewish way of doing thing

"Quantum, mathematics could be dangerous, it could be done by Jewish
→ experimental = oké "

XIV. About Heisenberg (dogmatic)

Heisenberg war in der Physik genial, in der Politik naiv. Bei seinen Kollegen sah es nicht viel besser aus.

Wirklich gekümmert um die politischen Vorgänge und die Zielsetzungen der Parteien hatte sich kaum ein Physiker. Man solle sich nicht in die politischen Auseinandersetzungen hineinziehen lassen, meinte man allgemein.

Typisch war die Auffassung Laues, wie er sie in einem Brief an Einstein äusserte: "Der politische Kampf fordert andere Methoden und andere Naturen als die wissenschaftliche Forschung."

Mit Recht hielt Einstein seinem Freund Laue im Mai 1933 entgegen, dass die politische Abstinenz der geistig führenden Schichten die Machtergreifung erst ermöglicht hatte. Einstein bescheinigte den deutschen Intellektuellen "Mangel an Verantwortungsgefühl".

Armin Hermann, "Physik und Physiker im Dritten Reich",
In: Erwin Neuenschwander (Hsg.), *Wissenschaft, Gesellschaft und politische Macht* (1993) 105-125.

Heisenberg was a genius in physics, but naive in Politics. Many of his colleagues were no better.
There was barely a physicst who cared about the political events or the goals of the political parties. There was a general feeling that one should not meddle with these political squabbles.
What Laue wrote to Einstein, was typical: "the political struggle needs different methods and different characters than scientific research."
Einstein correctly answered his friend in 1933 that political abstinence had made possible the political coup [of Hitler]. Einstein confirmed the lack of sense of responsibility of the German intellectual.

- no experiments
- he was not Jewish
- BUT: "hidden Jew": worked, talked like a Jew (but was not a Jew)

Naar Leipzig:

→Atomic bomb: (but not succeed in making one)

After the war: prisoned in England

Remark:

- Planck, Einstein: did react on the government
- Heisenberg: (new generation): does not care from where the money come: no care on politics

H5. ICON

Remember: Weimar culture:
☺ discovery of new physics
☹ attendance (opkomst) of the nazi's

Einstein:

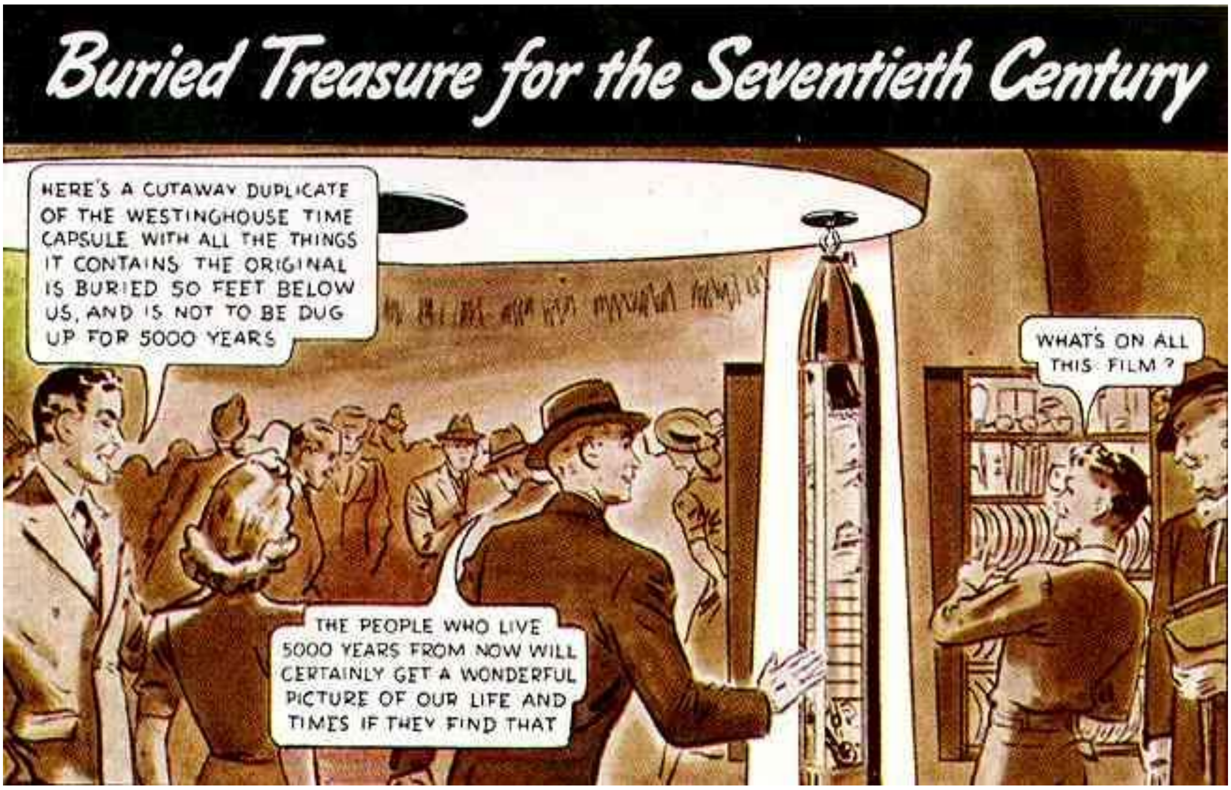
- has an influence on the society, on the public opinion

- = an exception, because there were not so much scientists with such a role:
  - ←→Newton doesn't give public interviews
  - ←→Darwin
    - went to a trip around the world
    - married a welty woman ➔ he doesn't need to work anymore, so he just wrote books
    - BUT no public appierence
      (after him, the scientists import "Darwinism")

- used al new communication media to spread his view

- (Alxander Vonhumbolt = someone like Einstein, but is now totally forgotten)

I. Introduction



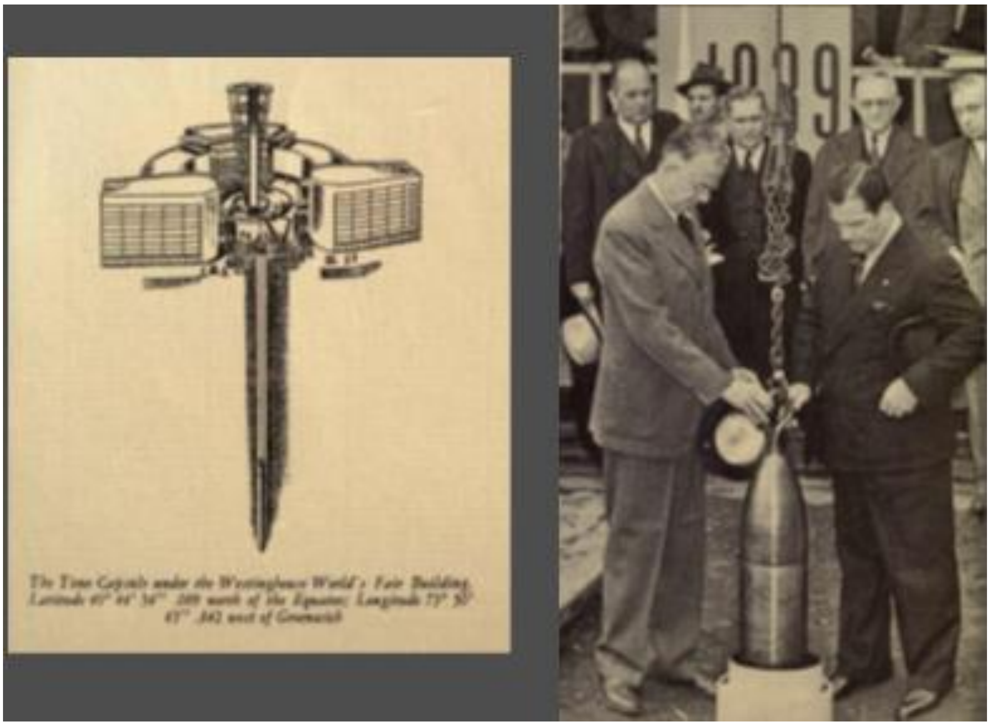
Cultural climate = behind development:

→ movements: from Europe to the US & from pure science to technologies

Einstein proposed a scientific view of previous centuries

Science must be something of a leader
=clear after WOI
→ idea: we can't go to better times → wolrds expo's

Picture (prent):
- idea that civilization only will be there for 5000 years
- timecapsule



Timecapsule: 1939: they where amazing about their own life, they wanted to share it.

World fair: science & technology will lead to a better world
= leading factor to the future (not the army)
= result of reactions of WOI

Chemistry was really the future before WOI,
BUT during WOI: chemistry makes chlorine gas (=weapons)

Remark: Chlorine gas is not to kill the enemies, but permits the army to go further

Fritz Haber: invented the use of chlorine gas: very efficient, but horrible (the heavier gases that were invented later were even more horrible)

Heavy gases → stays low on the ground and stays there and so also animals that comes later on that place and are also killed.

Fritz Haber made also something to reduce the hunger in poor countries
(Zijn naam is vooral verbonden aan het Haber-Boschproces, dat gasvormig stikstof bindt aan waterstof tot ammoniak. Dit proces is de basis van de kunstmestproductie en heeft grote invloed gehad op de productiviteit van landbouwgrond over de gehele wereld. Hij kreeg er in 1918 de Nobelprijs voor.)

II. Einstein, the physicists


(Einstein & his first wife)

Einstein was born in Uhl (1979) German, Jewish

- Father went bankroot ➔ went to Italy
- Einstein went to collage in Munich
- was not a brilliant student (maybe dislectic)
- started to read after his peers (leeftijdsgenoten), so he had the time to think about a lot
- left school before he finished it → went to Italy to his family

➔ first political movement: Einstein gave in his German paspoort → so he became stateless

- finished his school in Switzerland
- met his wife in Switzerland, she was brilliant, was good in mathematics
    - 2 sons (1 was engineer, 1 was metal ill)
    - 1 daughter, but she died after a year and she was never mentioned
- was not good enough to became an assistant
- teached in in the moring in a secondary school, so in the afternoon he had a lot of time to think

1905: Einstein started to publish papers:

(1) relativity
(2) Brownian movement & determination of Avogadro's number
(3) Photo electric effet ➔ Nobelprice

He went to Praag and Zurich
Berlin: he became a member of the academi & Kaizer Wilhelm institute
→ he doesn't need to teach, he could do everything he wanted

Divorce with his first wife: he wanted to give his Nobelprice (the money) to his wife, but his wife had really nothing to do with the Nobelprice. Finally, Einstein gave only the half of his Nobelprice - money to his wife and family.

Middle: Fritz Haber: = a good friend of Einstein; took care of the divorce of Einstein with his first wife

Right: his second wife: niece; is not a physicist (agreement that Einstein may sleep with other girl)

An die Kulturwelt!

Ein Aufruf.

Der nachstehende **Aufruf** geht uns zur Veröffentlichung zu:

Wir als Vertreter deutscher Wissenschaft und Kunst erheben vor der gesamten Kulturwelt **Protest** gegen die Lügen und Verleumdungen, mit denen unsere Feinde Deutschlands reine Sache in dem ihm aufgezwungenen schweren Daseinskampfe zu beschmutzen trachten. Der eherne Mund der Ereignisse hat die Ausstreuung erdichteter deutscher Niederlagen widerlegt. Um so eifriger arbeitet man jetzt mit Entstellungen und Verdächtigungen. Gegen sie erheben wir laut unsere Stimme. Sie soll die Verkünderin der Wahrheit sein.

Es ist nicht wahr, daß Deutschland diesen Krieg verschuldet hat. Weder das Volk hat ihn gewollt noch die Regierung, noch der Kaiser. Von deutscher Seite ist das Aeußerste geschehen, ihn abzuwenden. Dafür liegen der Welt die urkundlichen Beweise vor. Oft genug hat Wilhelm II. in den 26 Jahren seiner Regierung sich als Schirmherr des Weltfriedens erwiesen; oft genug haben selbst unsere Gegner dies anerkannt. Ja, dieser nämliche Kaiser, den sie jetzt einen Attila zu nennen wagen, ist jahrzehntelang wegen seiner unerschütterlichen Friedensliebe von ihnen verspottet worden. Erst als eine schon lange an den Grenzen lauernde Uebermacht von drei Seiten über unser Volk herfiel, hat es sich erhoben wie ein Mann.

lischen Theologie Bonn; Rudolf Eucken, Professor der Philosophie Jena; Herbert Eulenberg, Kaiserswerth; Heinrich Finke, Professor der Geschichte Freiburg; Emil Fischer, Exz., Professor der Chemie, Berlin; Wilhelm Foerster, Professor der Astronomie Berlin; Ludwig Fulda, Berlin; Eduard v. Gebhardt, Düsseldorf; J. J. de Groot, Professor der Ethnographie, Berlin; Fritz Haber, Professor der Chemie, Berlin; Ernst Haeckel, Exz., Professor der Zoologie, Jena; Max Halbe, München; Professor Adolf v. Harnack, Generaldirektor der königlichen Bibliothek, Berlin; Gerhart Hauptmann, Agnetendorf; Karl Hauptmann, Schreiberhau; Gustav Hellmann, Professor der Meteorologie, Berlin; Wilhelm Herrmann, Professor der protestantischen Theologie, Marburg; Andreas Heusler, Professor der nordischen Philologie, Berlin; Adolf v. Hildebrand, München; Ludwig Hoffmann, Stadtbaumeister, Berlin; Engelbert Humperdinck, Berlin; Leopold Graf Kalckreuth, Präsident des Deutschen Künstlerbundes, Eddelsen; Arthur Kampf, Berlin; Fritz Aug. v. Kaulbach, München; Theodor Kipp, Professor der Jurisprudenz, Berlin; Felix Klein, Professor der Mathematik, Göttingen; Max Klinger, Leipzig; Alois Knoepfler, Professor der Kirchengeschichte, München; Anton Koch, Professor der katholischen Theologie, Tübingen; Paul Laband, Exz., Professor der Jurisprudenz, Straßburg; Karl Lamprecht, Professor der Geschichte, Leipzig; Philipp Lenard, Professor der Physik, Heidelberg; Maximilian Lenz, Professor der Geschichte, Hamburg; Max Liebermann, Berlin; Franz v. Liszt, Professor der Jurisprudenz, Berlin; Ludwig Manzel, Präsident der Akademie der Künste, Berlin; Josef Mausbach, Professor der katholischen Theologie, Münster; Georg v. Mayr, Professor der Staatswissenschaft, München; Sebastian Merkle Professor der katholischen Theologie, Würzburg; Eduard Meyer, Professor der Geschichte, Berlin; Heinrich Morf, Professor der romantischen Philologie, Berlin; Friedrich Naumann, Berlin; Albert Neisser, Professor der Medizin, Breslau; Walter Nernst, Professor der Physik, Berlin; Wilhelm Ostwald, Professor der Chemie, Leipzig; Bruno Paul, Direktor der Kunstgewerbeschule, Berlin; Max Planck, Professor der Physik, Berlin; Albert Plehn, Professor der Medizin, Berlin; Georg Reicke, Berlin; Professor Max Reinhardt, Direktor des Deutschen

“An der Ruturwelt”
Belgium was neutral in the war.

But German past through Belgium to go to France.

German entered a city (eg Leuven): “you have to leave your house” & than everything was burned.
(eg in Leuven de Bondgenotenlaan is tegen nu volledig verniewd)

In Leuven: the medieval library was burned: “How could German does this?”
→ respect for learning was broke down: science entered.
➔ Panflet: “An die Ruturwelt”: signed by a lot of scientists
BUT: Einstein doesn’t sign it (because he doesn’t consider himself as a German)

Measurements of the displacement of star light ➔ light = bended by mass
➔ photo: "New Copernicus"
- ➔ a new hero
- ➔ Remember: he didn't sign the the panflet during the war, so, he was good

WOI: many soldiers died
WOII: many civilest died

III. Einstein, the philosopher

After the war, there was a boycott against German,
BUT, Einstein was exempted (vrijstellen) from this boycott, but he didn't want to accept it.
Because he has the idea that every good scientist must can go to the conference

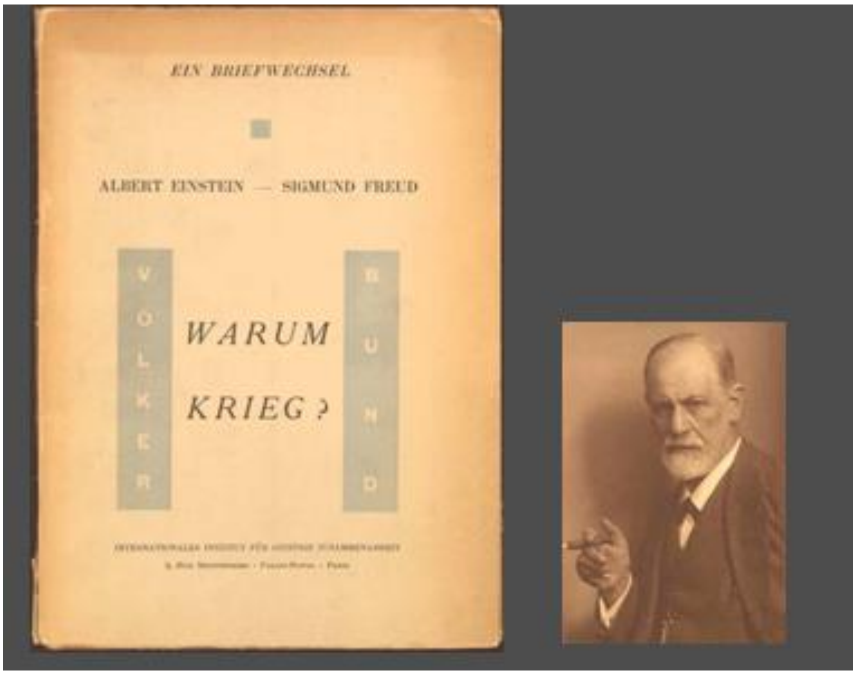
So he started to travel (and teaching): US, Barcelona, Argentinia, Tokyo and France
France was an exception, because a German was not allowed to go to eg France, so, the lecture had to take place in a very small room.

At this time, Einstein, is more giving lectures, than doing new physics.

Nobelprice

Einstein started to settle himself down and he received visits from people from all the world
→ happy period in his villa

Eistein played the violin & also a picture with his wife.



Pacifism: was linked to science = Einstein (= most well known pacifis, analogical on Ghandi)

Einstein was very often asked to write about: “how could we avoid the war”

Einstein wrote a letter to Freud about it:
Einstein thoughts: we could avoid the war with openness, intellectuals collaboration

←→ Freud: this = nonsense, because aggression = in human life
→ war = needed for survival

US (invite him to give some lectures, he didn't wanted)

Charlin Chaplin: European, Jewish

BUT:…

There came new leader in German: Hitler

- → Einstein said "freedom = gone" on the boot to his way from US back to Europe
- ➔ Einstein was not welcome in German anymore
- ➔ had to stay in Belgium (De Haan)

Many people visit / invite him to ask him to become a teacher at their university.

Important story: 2 young Belgians didn't want to be soldiers, so, they asked Einstein to defend their opinion to go the army.

→ Einstein talked to the Belgian king and queen, apparently they were convinced (overtuigd)

BUT Jewish people had to be dismissed from their positions in German
→ Einstein: "we cannot do simple nothing"
➔ preparedness (the danger = there, so be prepared)

SO: Eintein went to US:

Left: it was the only painting where Einstein was sitting as a model (1kopie hang tint geel huis)

IV. Einstein, the icon

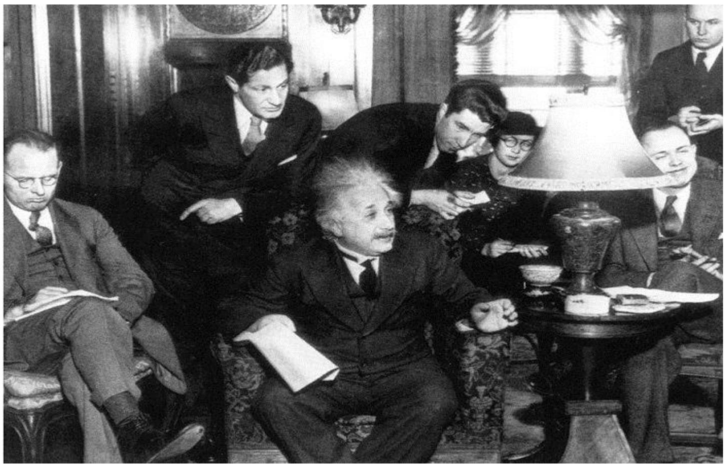
Einstein = now an older man (54)

(Eintein had accepted his German nationality when he worked at the academy, but he didn't know it, so he abonned his German nationality for the second time)

Einstein to the US and left everything in German.

In US: physics in a private institute, payed by miljonars.
Physicists get high fees & they were asked to do nothing,
Because, genius = better than other people

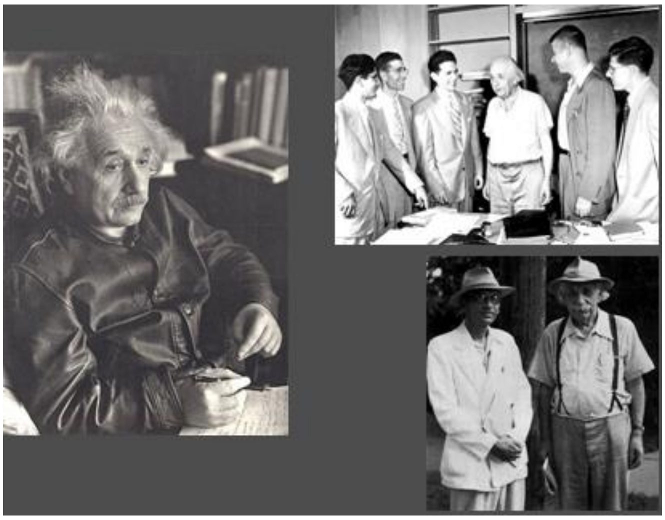
BUT: Einstein was still active:



In Priston: Einstein = still active, still writing

Göthel: Austrian mathematisn (Jewish): (Mathematics = never complete)
& Einstein asked him to become a member of Priston

Last period in his life:



Einstein was visited by a physicist: Leo Szilard

Szilard: worked with nuclear reactions
→ atomic bomb, BUT he doesn't want to make it
(he was also Jewish & against Hitler)

Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

-2-

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo.

In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity. His task might comprise the following:

a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States;

b) to speed up the experimental work, which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.

Yours very truly,
A. Einstein
(Albert Einstein)

Einstein wrote a letter to Roosevelt: "Attention: Uranium (needed to make the atomic bomb) can be found in Belgian Congo, BUT Belgian king could not anything to do about it.

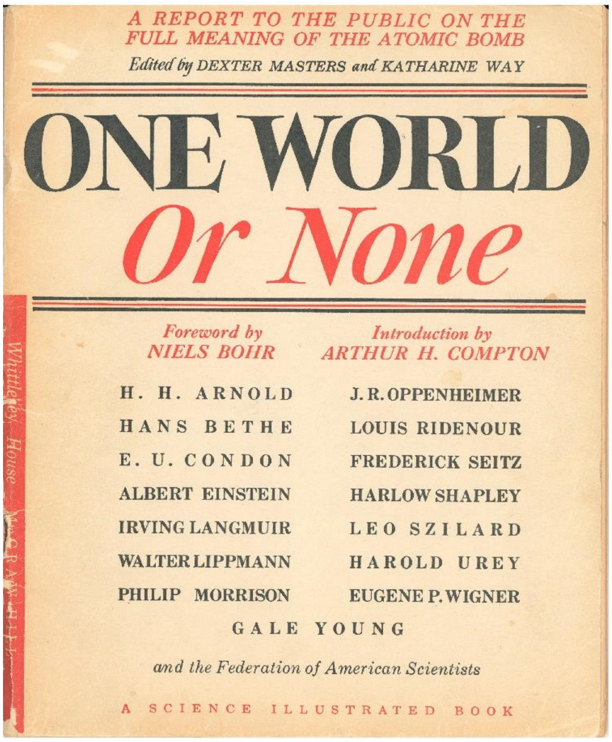
In 08/1939: Roosevelt wrote back (because US were not in the war already, so they doesn't have to hurry).

Einstein was not asked to make the atomic bomb, but volunteered (he was already old).

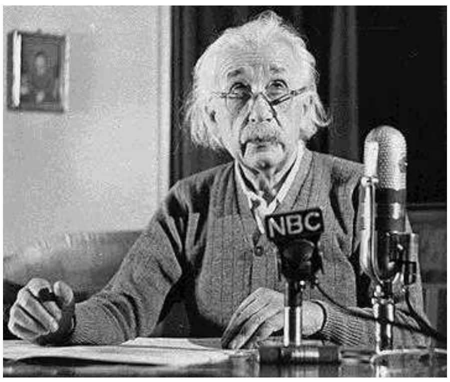
Einstein did supported to the bomb (the letter was published!)

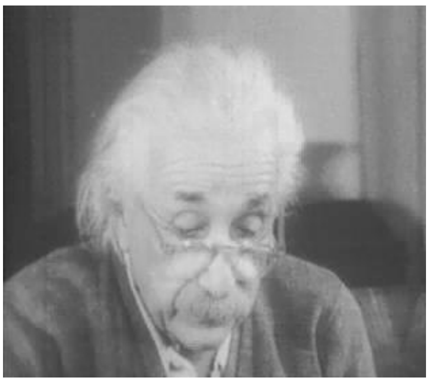
Scientists proposed to make the bomb, but not to use it ☺,
BUT the wars are almost everywhere done, but US wanted to show the other countries (especially Russia) that the bomb worked.

Atomic bomb WOII	Gas in WOI
Atomic bomb = new type of weapon, with an enormous power	You could control the gas
Used nuclear fission (one thought that is was not possible!) (Every country want such a bomb ☹)	Used simpler science



Einstein became again pacifist = only possible with one world.

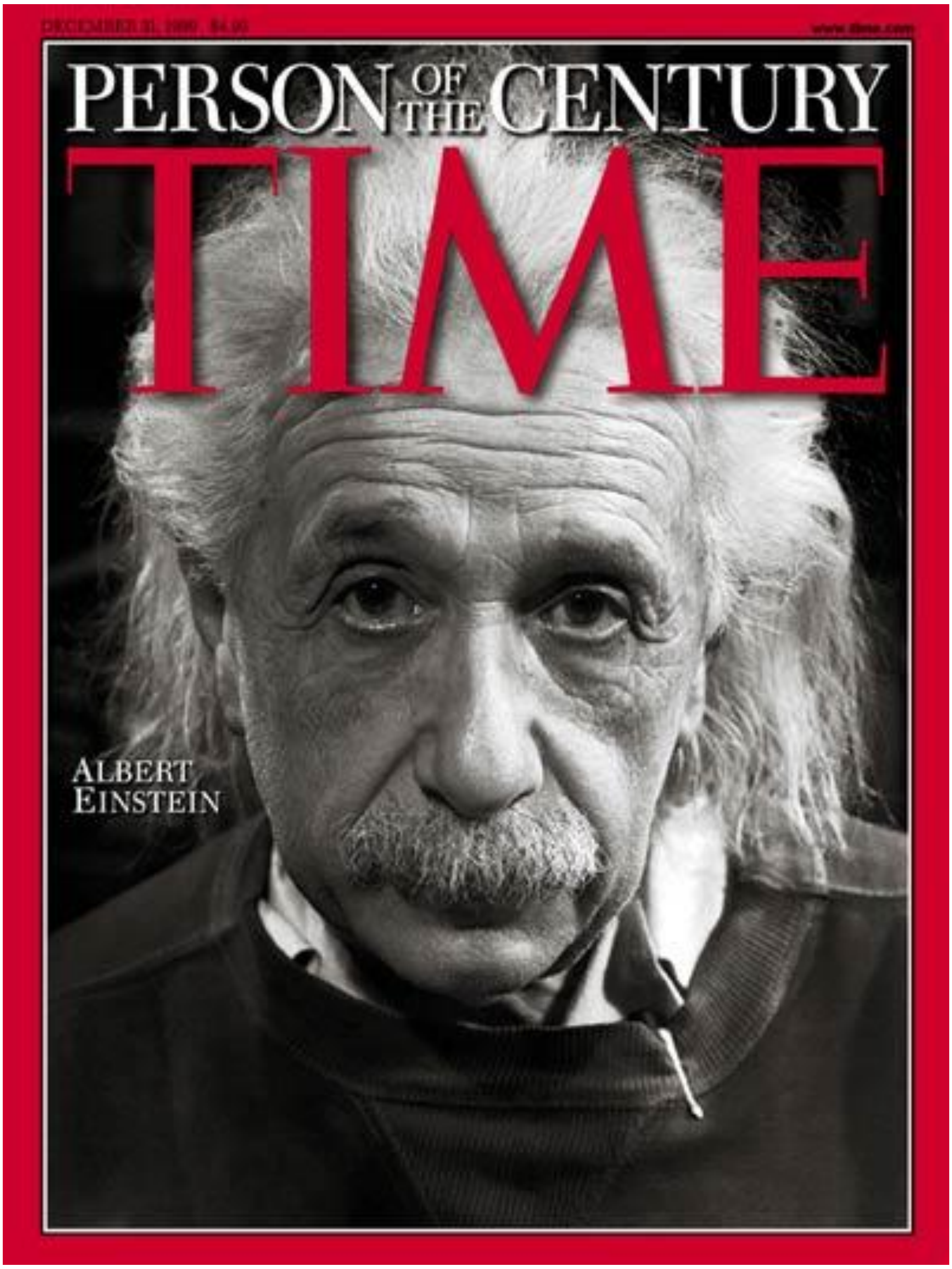




Einstein = famous

- had a very important position
- was scientist until the end of his carriers
- was a public figure: published his lectures

Physics (developed by Manhattan project) ، the physics of Einstein anymore



H6. Big science, big money

Pre war physics ended which Manhattan project (nuclear bomb)

Physics were taught to be responsible for bad things in the war

☺ physics = important: THE science

☹ physics was not about developing the nuclear bomb, not for technology

BUT, physics showed it could make new technology (military devices)

= demanded by the government

= different view: applied physics

BUT BUT, physics = to understand nature

I. Take away your billion dollars: SONG '46

Arthur Roberts: worked at the radar.

"Up on the lawns of Washington the physicists assemble
From all the land are men at hand, their wisdom to exchange.
A great man stands to speak, and with applause the rafters tremble.

"My friends," says he,
"you all can see that physics now must change.
"Now in my lab we had our plans, but these we'll now expand,
Research right now is useless, we have come to understand.
We now propose constructing at an ancient Army base,
The best electro-nuclear machine in any place.

"Oh – it will cost a billion dollars, ten billion volts 'twill give,
It will take five thousand scholars seven years to make it live.
All the generals approve it, all the money's now at hand,
And to help advance our program, teaching students now we've banned."

"We have chartered transportation, we provide a weekly dance.
Our motto's integration, there is nothing left to chance.
This machine is just a model for a bigger one of course.
That's the future road for physics, as I'm sure you'll all endorse."

And as the halls with cheers resound and praises fill the air,
one single man remains aloof and silent in his chair.
And when the room is quiet and the crowd has ceased to cheer,
he rises up and thunders forth an answer loud and clear.

"It seems that I'm a failure, just a piddling dilettante.
Within six months a mere 10,000 bucks is all I've spent.
With love and string and sealing wax was physics kept alive.
Let not the weath of Midas hide the gold for which we strive.

"Oh – take away your billion dollars, take away your tainted gold.
You can keep your damn ten billion volts; my soul will not be sold.
Take away your army generals, their kiss is death I'm sure.
Everything I build is mine, every volt I make is pure.
Take away your integration and let us learn and let us teach.
For beware this epidemic, for colitis I beseech.

"Oh, dammit – engineering isn't physics – isn't that plain?
Take, oh take your billion dollars. Let's be physicists again."

☺ enthusiasm of big money that comes to physics → future
☹ if you go to military part of physics, this leads to the dead of physics
→ integration: physics & engineering

II. US military R & D expenditure

Amazing increase in physical spending
→ it doesn't diminished after the war! but it continued
➔ money given to not military research decreases

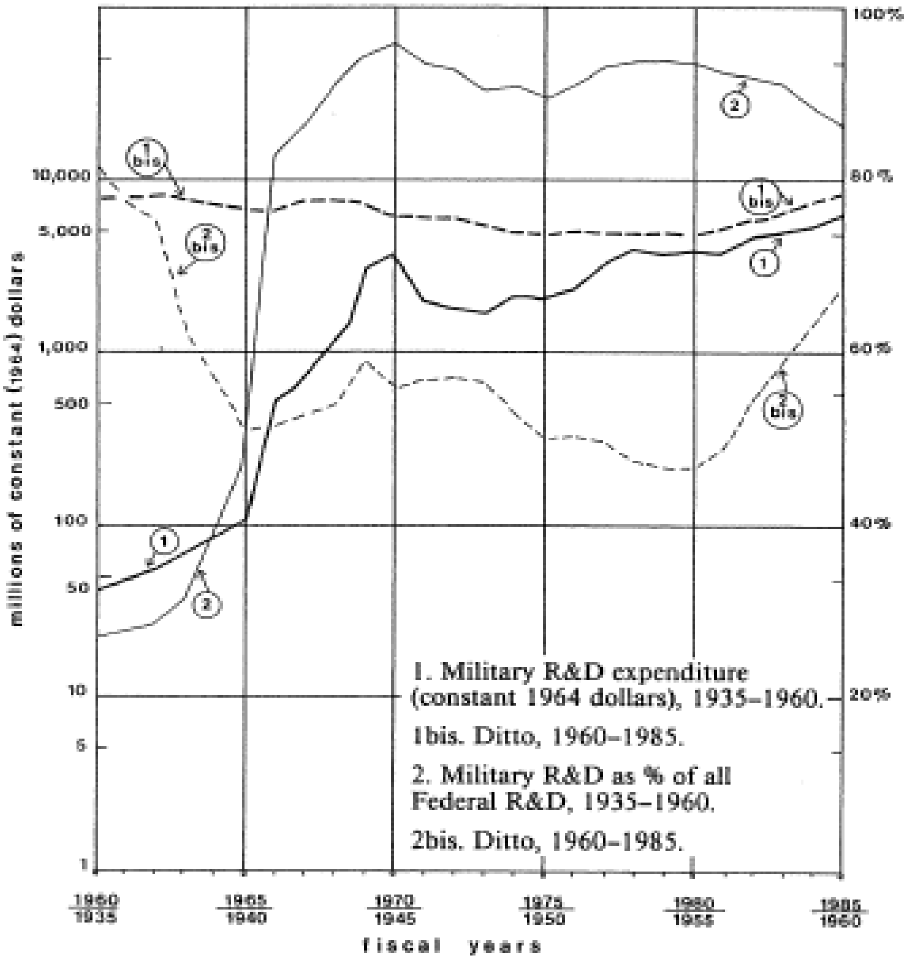
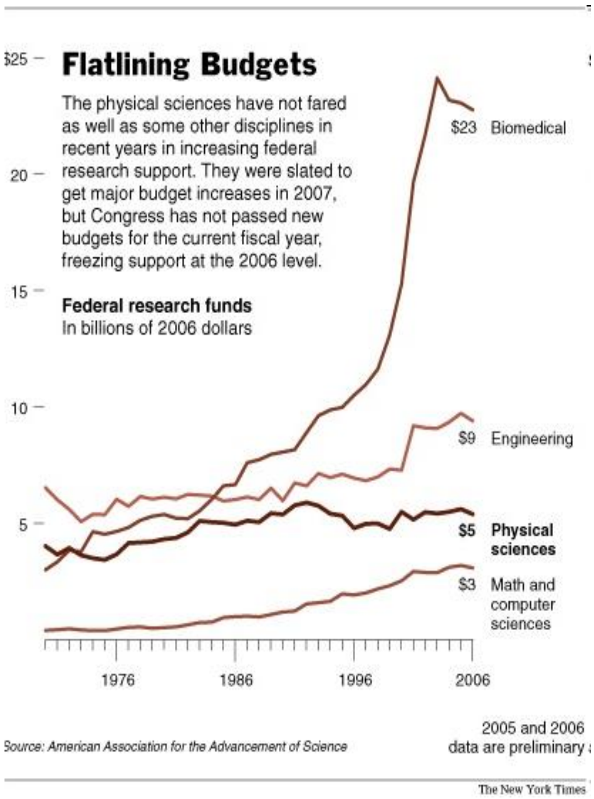


Figure 20.1. The development of U.S. military R&D expenditures, 1935–85. The figure is folded in order to facilitate a comparison between the two periods 1935–60 and 1960–85. *Source:* © 1987 by The Regents of the University of California. Reprinted from *Historical Studies in the Physical and Biological Sciences* vol. 18, figure p. 153, by permission.

And now:

- physical sciences remaining at the same line
- biomedical: funding for genetics and health increases (↑ just after the war)



III. Watershed

WORLD WAR II was in many ways a watershed for American science and scientists. It changed the nature of what it means to do science and radically altered the relationship between science and government . . . the military . . . and industry" (Forman 1987, 152). So wrote in 1984 Jerrold Zacharias, a leading physicist of the 1950s with great experience in military projects and science policy. The watershed caused by the war depended very much on a changed scale and structure of funding for science, in particular a spectacular rise in federal funding. Before the war, such funding was negligible, about $1 million for all of basic physics research in the United States. It has been estimated that the total amount of federal money allocated to basic physics in 1953 was about $42 million, or half that amount if counted in 1938 dollars.

It was no wonder that some physicists thought that their science was dangerously close to becoming just a branch of the military.

The philosophy of the NSF was to a large extent based on the ideas of Vannevar Bush in his 1945 report, *Science: The Endless Frontier*.

The bonds between the military, the defense industry, and the physicists were further reinforced after the so-called Sputnik shock in 1957.

Physicists were economically pampered indeed. In 1958, the population of U.S. physicists was 12,702, with the two largest fields being nuclear physics (2,622) and solid state physics (1,926). In terms of mere numbers, the physics community was not all that impressive. In the same year, the United States counted 35,805 chemists and 18,015 biologists; even the earth sciences, with 13,071 geologists, counted more scientists than physics. But although there were nearly three times as many chemists as physicists, chemistry received only half as much federal research support. Each physicist received an average of $11,000, while the corresponding figure for the chemist was $1,900; the average biologist received $4,900, and in geology and mathematics the amounts were $1,800 and $1,700, respectively.

US ' Europe

- → Europe: physics was a well developed field + Europe has also the leadership in other fields
- → US promotes science

IV.