

Title: The Usefulness of Useless Knowledge

Date: Dec 19, 2017 02:00 PM

URL: <http://pirsa.org/17120024>

Abstract: <p>In his classic essay, “The Usefulness of Useless Knowledge,” Abraham Flexner, the founding director of the Institute for Advanced Study in Princeton and the man who helped bring Albert Einstein to the United States, describes a great paradox of scientific research. The search for answers to deep questions, motivated solely by curiosity and without concern for applications, often leads not only to the greatest scientific discoveries but also the most revolutionary technological breakthroughs. In short, no quantum mechanics, no computer chips. Robbert Dijkgraaf, the Institute’s current director, explains how Flexner’s defense of the value of “the unobstructed pursuit of useless knowledge” may be even more relevant today than it was in the early twentieth century. Dijkgraaf describes how basic research has led to major transformations in the past century and explains why it is an essential precondition of innovation and the first step in social and cultural change.</p>

# The Usefulness of Useless Knowledge



ABRAHAM FLEXNER

*With a companion essay by*  
ROBERT DIJKGRAAF

Roosevelt, the Rich Man's Alibi

October

# Harpers

## MAGAZINE

### OLD PEOPLE: A RISING NATIONAL PROBLEM

*Is Money All They Need?*

By ROY HELTON

Roosevelt, the Rich Man's Alibi . . . . .	Elmer Davis
The Strange Noise of Dr. Beldoon. <i>A Story</i> . . . . .	Morris Markey
How the Wright Brothers Began . . . . .	Fred C. Kelly
The Future of the British Empire . . . . .	C. Hartley Grattan
Why Can't We Have Perfect Teeth? . . . . .	Walter C. Alvarez, M.D.
Conscience in Wartime . . . . .	{ Lucille B. Milner { Groff Conklin
Great Hawaii . . . . .	Leonard Bacon
Why Slum Clearance May Fail . . . . .	{ Alfred Rheinstein { Henry F. Pringle
Music in Aspic . . . . .	Oscar Levant
In Defense of Ghost Writing . . . . .	Seneca Johnson
The Usefulness of Useless Knowledge . . . . .	Abraham Flexner
One Man's Meat—Dr. Townsend Himself, by E. B. White	
The Easy Chair—Meditation in Fading Sunlight, by Bernard DeVoto	
The New Books, by John Chamberlain; Personal and Otherwise	

HARPER & BROTHERS, PUBLISHERS

The Future of the British Empire



## THE USEFULNESS OF USELESS KNOWLEDGE

BY ABRAHAM FLEXNER

IT IS not a curious fact that in a world steeped in irrational hatreds which threaten civilization itself, men and women—old and young—detach themselves wholly or partly from the angry current of daily life to devote themselves to the cultivation of beauty, to the extension of knowledge, to the cure of disease, to the amelioration of suffering, just as though fanatics were not simultaneously engaged in spreading pain, ugliness, and suffering? The world has always been a sorry and confused sort of place—yet poets and artists and scientists have ignored the factors that would, if attended to, paralyze them. From a practical point of view, intellectual and spiritual life is, on the surface, a useless form of activity, in which men indulge because they procure for themselves greater satisfactions than are otherwise obtainable. In this paper I shall concern myself with the question of the extent to which the pursuit of these useless satisfactions proves unexpectedly the source from which undreamed-of utility is derived.

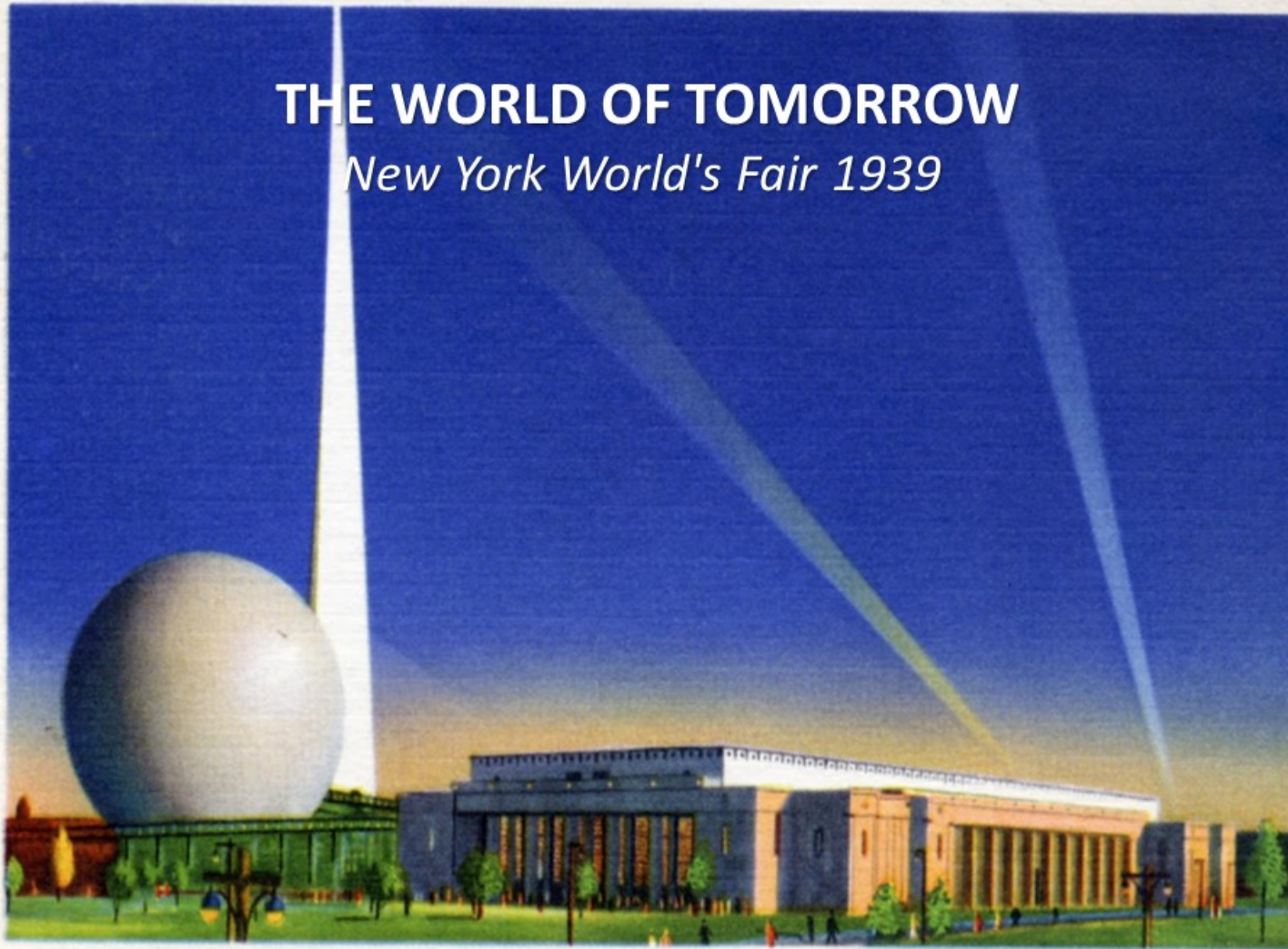
mental problems. I have no quarrel with this tendency. The world in which we live is the only world about which our senses can testify. Unless it is made a better world, a fairer world, millions will continue to go to their graves silent, saddened, and embittered. I have myself spent many years pleading that our schools should become more acutely aware of the world in which their pupils and students are destined to pass their lives. Now I sometimes wonder whether that current has not become too strong and whether there would be sufficient opportunity for a full life if the world were emptied of some of the useless things that give it spiritual significance; in other words, whether our conception of what is useful may not have become too narrow to be adequate to the roaming and capricious possibilities of the human spirit.

We may look at this question from two points of view: the scientific and the humanistic or spiritual. Let us take the scientific first. I recall a conversation

*New York City Building*

# THE WORLD OF TOMORROW

*New York World's Fair 1939*



*New York World's Fair 1939*

A-34

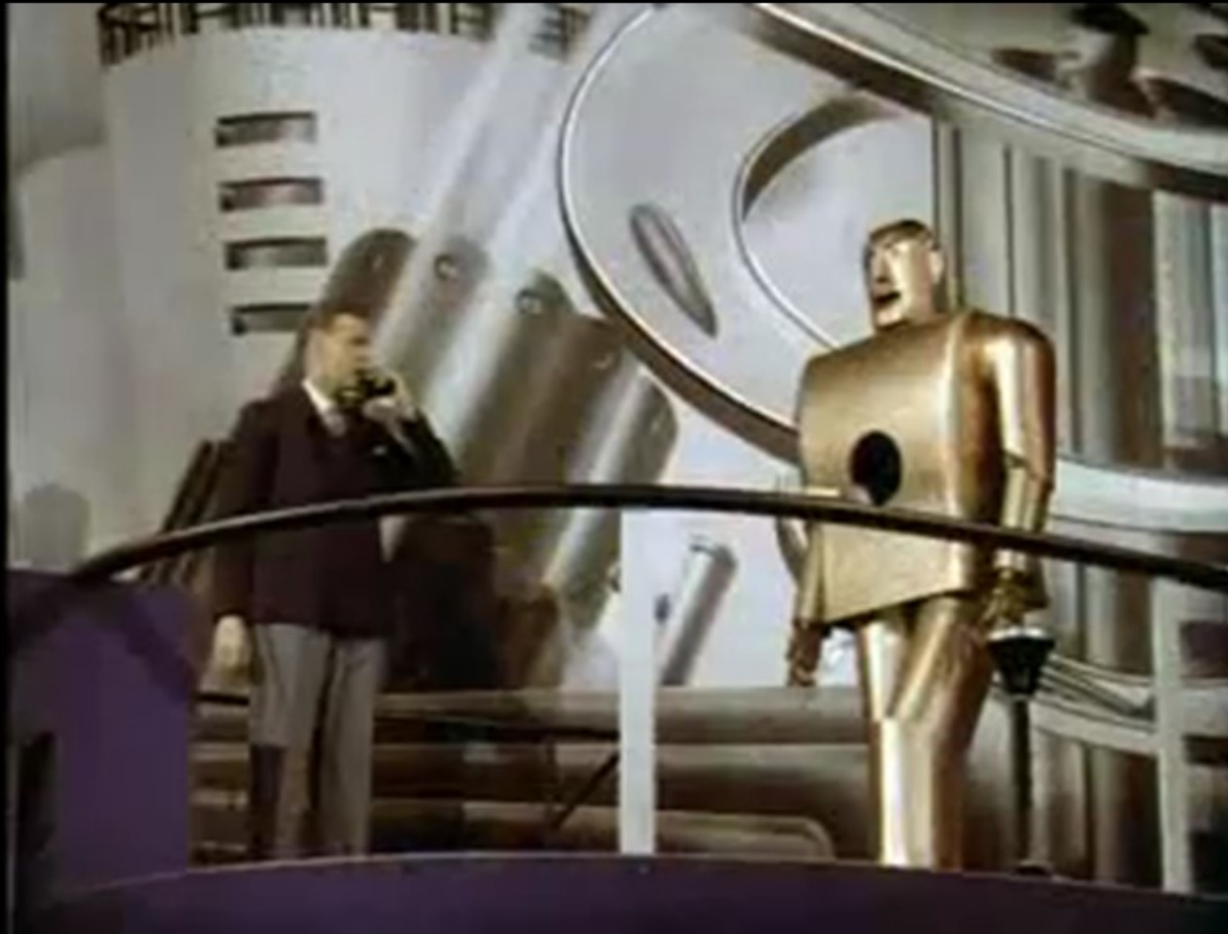
# FIRST TELEVISION

R.C.A. COMMUNICATIONS.

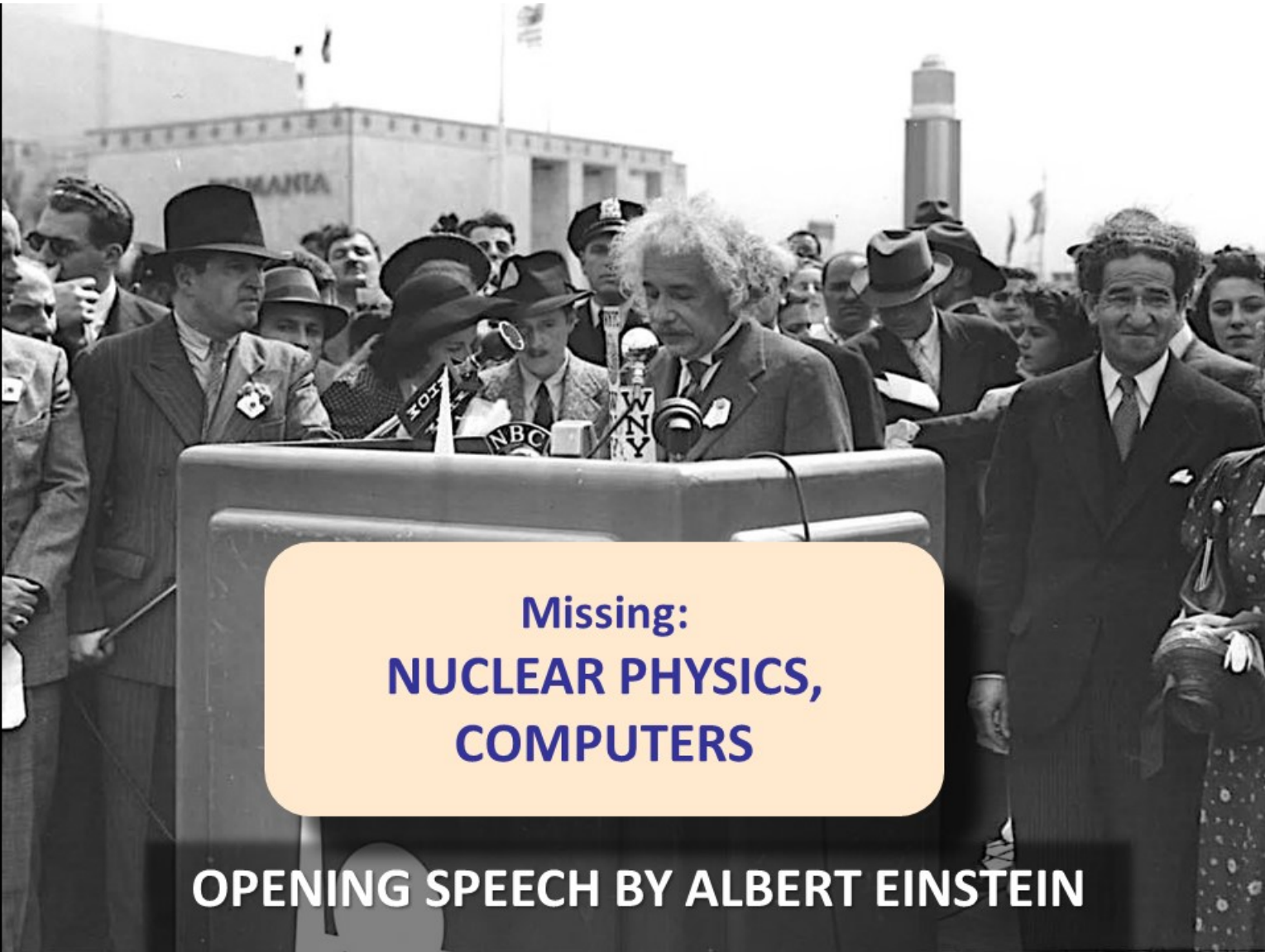


# LAST STEAM ENGINES





**ELEKTRO – THE SMOKING ROBOT**



**Missing:  
NUCLEAR PHYSICS,  
COMPUTERS**

**OPENING SPEECH BY ALBERT EINSTEIN**





**Institute for Advanced Study, Princeton**

## SEEKING ETERNAL TRUTHS IN A WORLD OF CHAOS

The Institute for Advanced Study at Princeton, founded a decade ago, frees scholars to pursue their pioneering.

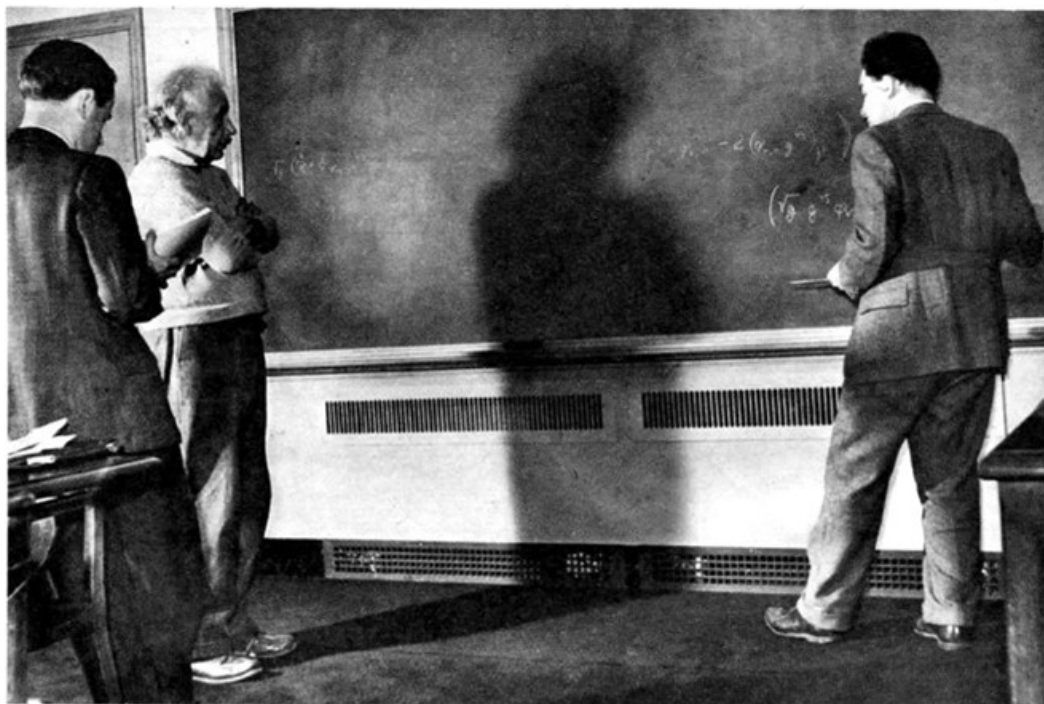
By ELEANOR KITTREDGE

"MY life here has been one of stirring adventure, and I have just time for one more adventure in the same cause." With these words Frank Aydelotte bade farewell in 1939 to students of Swarthmore College, where he had been president for nearly twenty years, and embarked upon his new role as director of the Institute for Advanced Study at Princeton.

Recently in his library in the old house in which he lives outside Princeton Dr. Aydelotte said to the writer with a smile, "We are really doing the same thing here, you and I—trying to find out what the institute is and what it may become."

The first time you see Frank Aydelotte or hear him speak you receive an impression of extraordinary moral integrity. When you hear that it was a week after he left Swarthmore that he became a member of the Society of Friends, the story becomes one of those anecdotes which light up and explain a good deal of the quality of mind and character of a man. He had waited until he had broken his official connection with the old college of the Quakers before publicly joining their ranks.

Frank Aydelotte is austere and friendly at the same time, open-minded, ready to listen to the suggestions and ideas of any colleagues or students, yet he is inflexibly rooted in his own philosophy of the meaning and purpose of education. He has a passion for excellence, and his life has been spent in trying to release the



Where "class" and "faculty" are all students—An informal Institute research group led by Professor Einstein.

unknown, waiting to be discovered by the "lonely grappling" of honorable minds with intellectual problems, he makes a little of his own vision real to the most obtuse. The search, the splendor of the search for knowledge and its use for human purposes becomes of vital con-

temporary importance and he makes the among a group of people dedicated to judging time by eternity, to living by what they regard as the fundamental and the permanent in the midst of change and chance and distilling meaning from mere happenings.

methods of teaching were varied. All or nearly all were truly initiators as well as scholars. \* \* \* Alone among the various corps of teaching bodies in the next century the College de France counted in the movement of sciences, arts and ideas."

It was in 1530 that a small group of humanists in the wake of Erasmus per-

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

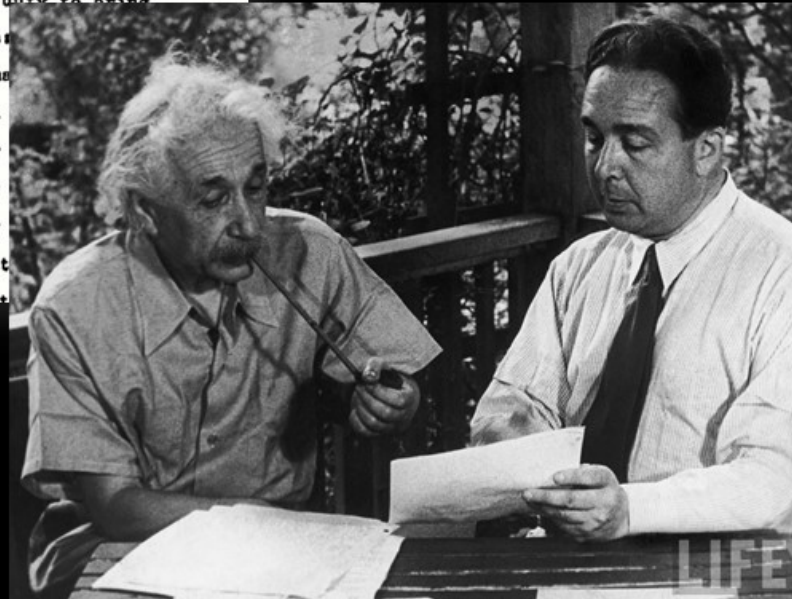
August 2nd, 1939

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 known 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 new radium-like elements would be generated. How soon this can be accomplished is almost certain that this could be achieved in the immediate future. This new phenomenon would also lead to the construction



*Einstein, Szilard*

# MATHEMATICAL LOGIC & COMPUTING

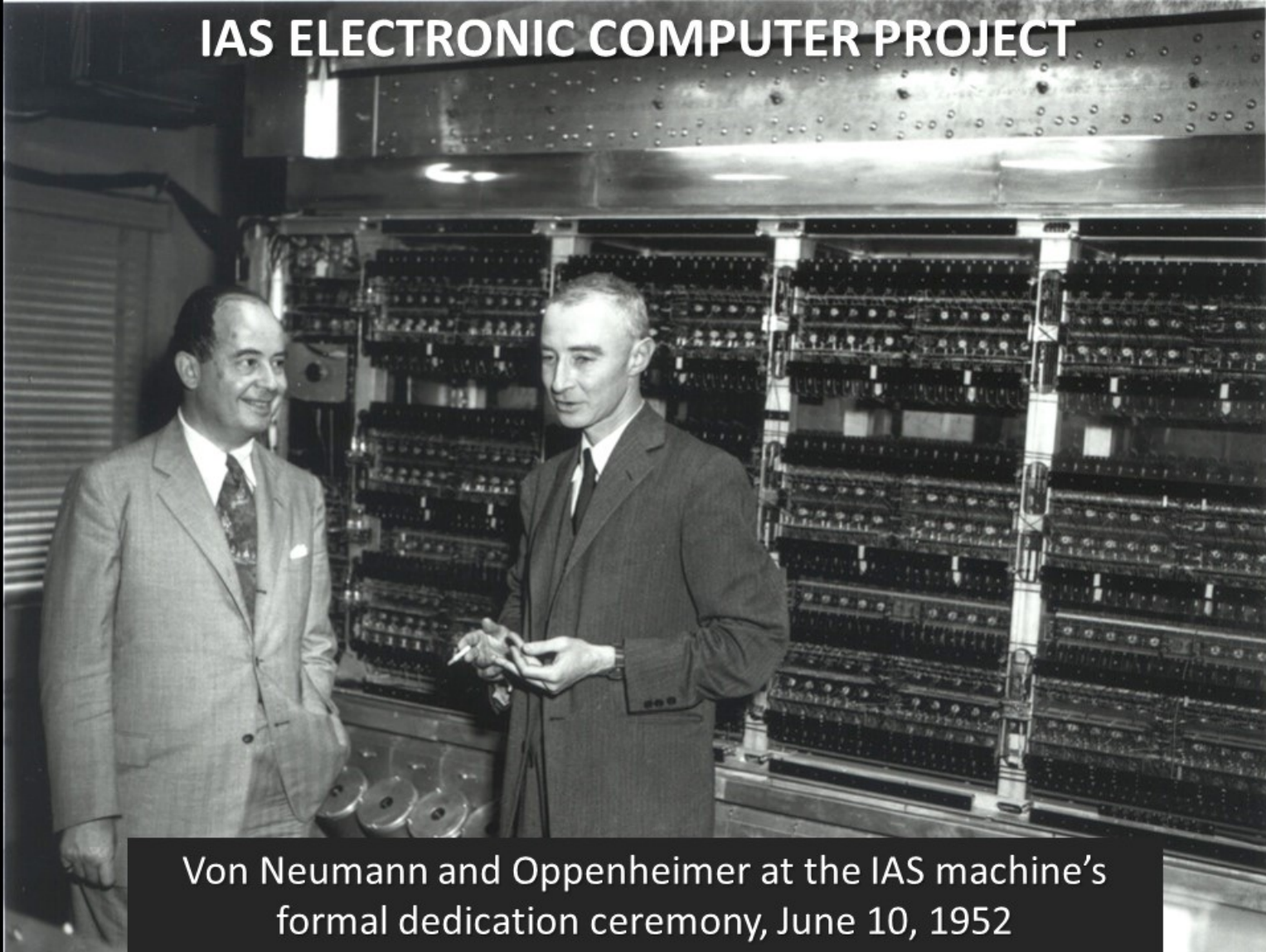


*John von Neumann*



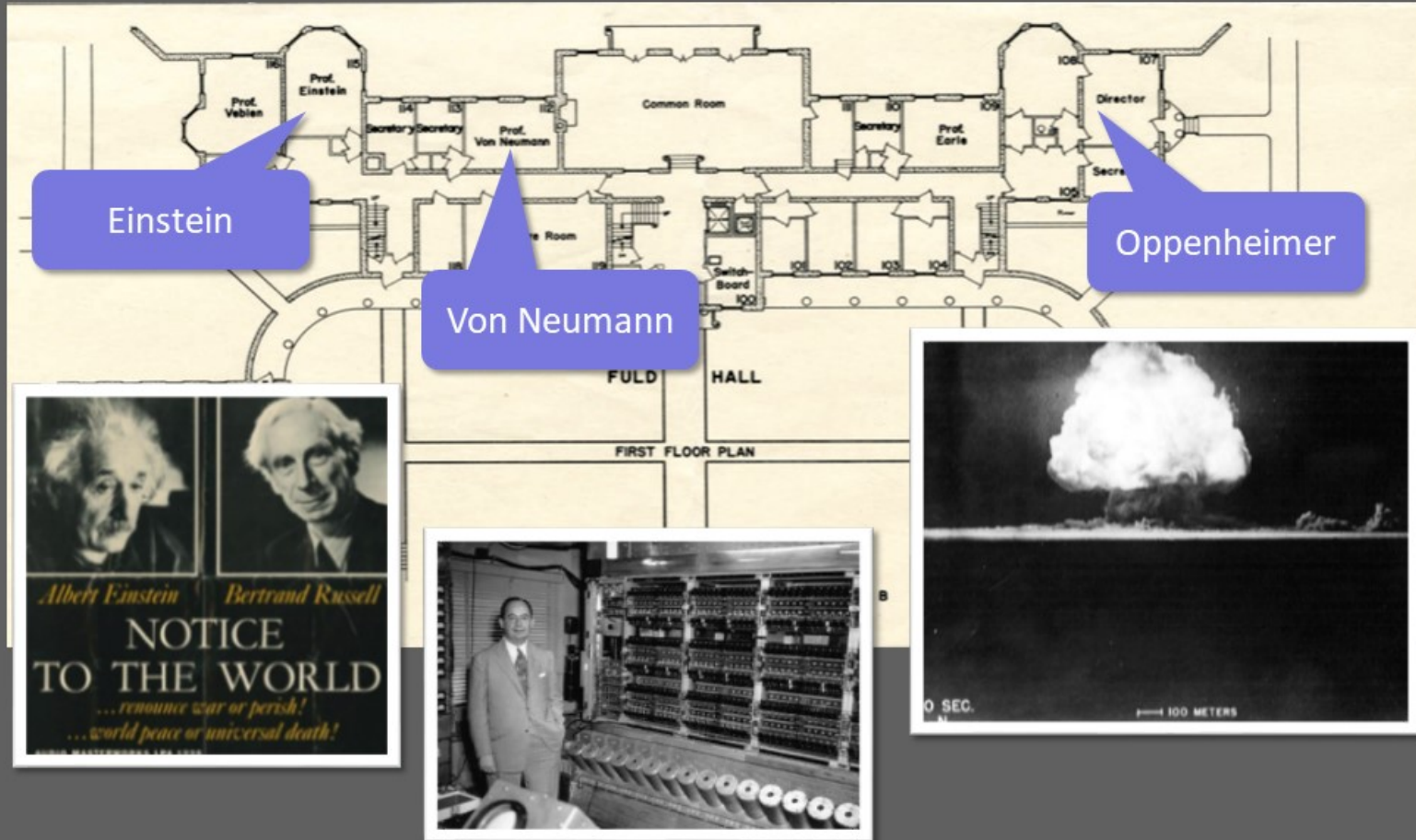
*Kurt Gödel*

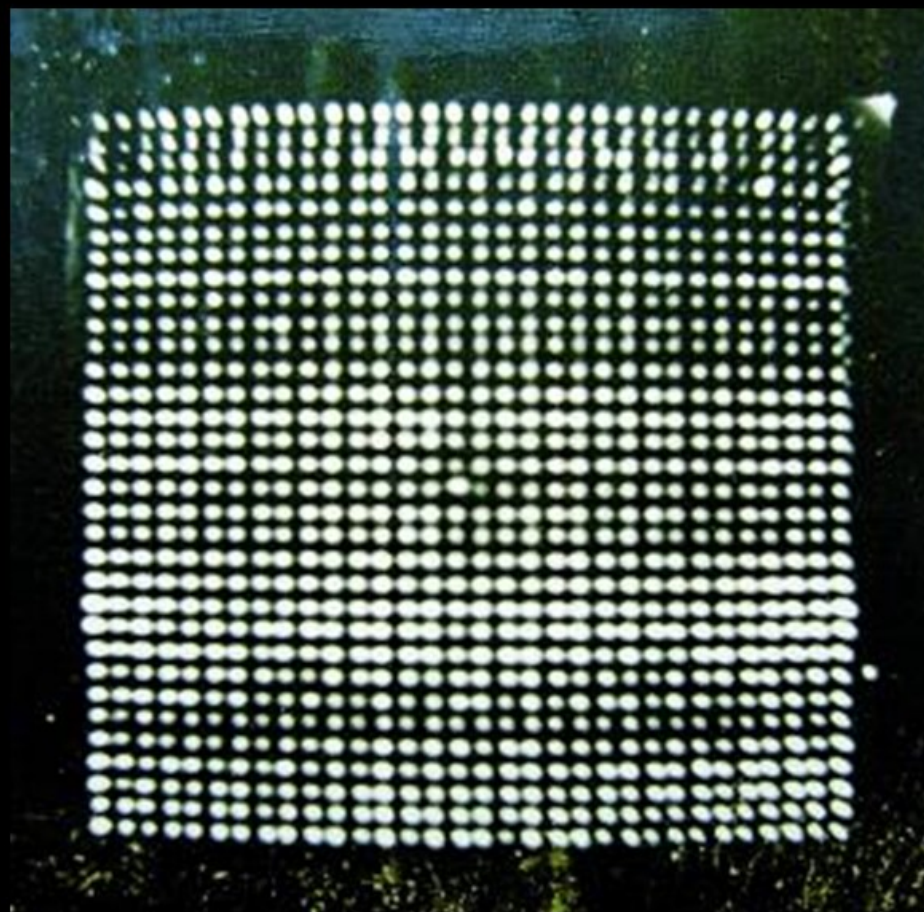
# IAS ELECTRONIC COMPUTER PROJECT



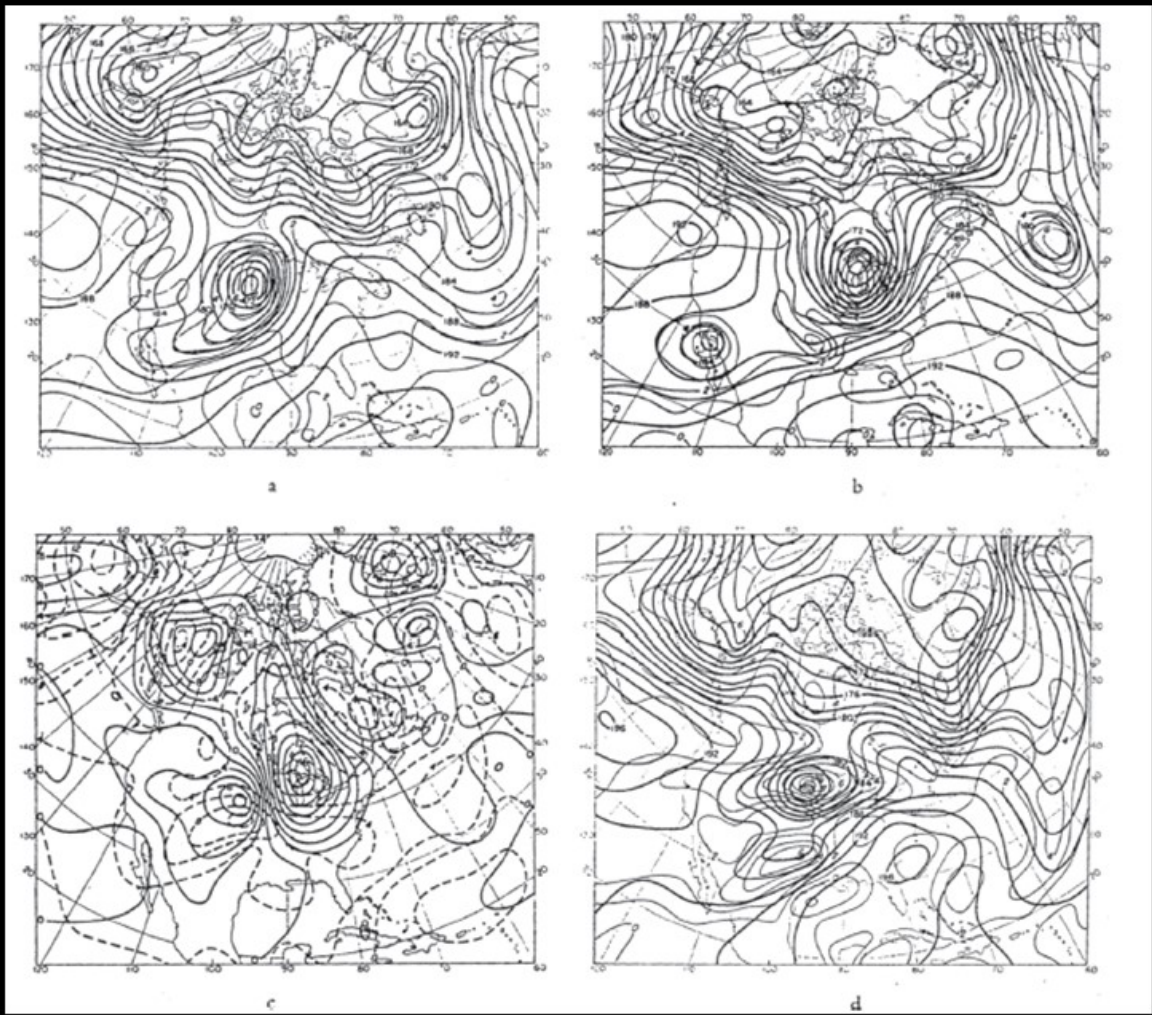
Von Neumann and Oppenheimer at the IAS machine's formal dedication ceremony, June 10, 1952

# First Floor Plan of Fuld Hall (1948)



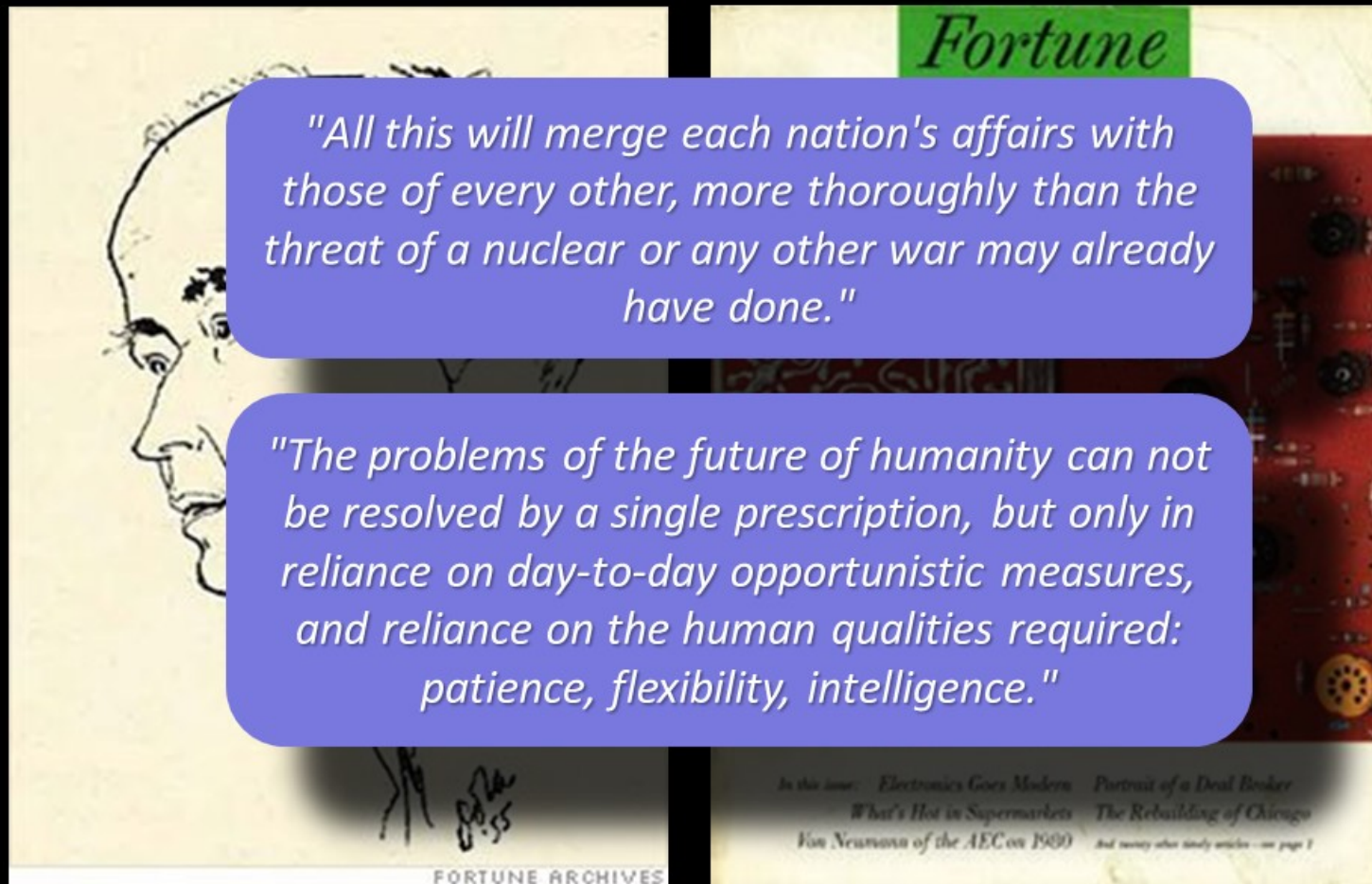


32 x 32 memory



First electronic weather forecast, 5 Jan 1949





*"All this will merge each nation's affairs with those of every other, more thoroughly than the threat of a nuclear or any other war may already have done."*

*"The problems of the future of humanity can not be resolved by a single prescription, but only in reliance on day-to-day opportunistic measures, and reliance on the human qualities required: patience, flexibility, intelligence."*

**Can we survive technology?**  
John von Neumann, *Fortune*, 1955



**Moritz & Esther Flexner**



**Simon Flexner**  
(1863-1946)



**Bernard Flexner**  
(1865-1945)



**Abraham Flexner**  
(1866-1959)

**MEDICAL EDUCATION  
IN THE  
UNITED STATES AND CANADA**

A REPORT TO  
THE CARNEGIE FOUNDATION  
FOR THE ADVANCEMENT OF TEACHING

BY  
ABRAHAM FLEXNER

WITH AN INTRODUCTION BY  
HENRY S. FRITCHETT  
PRESIDENT OF THE FOUNDATION

BULLETIN NUMBER FOUR

# UNIVERSITIES

AMERICAN ENGLISH  
GERMAN

BY  
ABRAHAM FLEXNER

OXFORD UNIVERSITY PRESS  
NEW YORK · LONDON · TORONTO  
1930

## THE IDEA OF A MODERN UNIVERSITY

### I

SEVENTY-FIVE years ago, an eminent Oxonian, Cardinal Newman, published a book entitled *The Idea of a University*. I have adopted in a modified form the title of that volume. I am undertaking in this chapter to discuss the idea of a *modern* university. In inserting the word "modern" I am endeavouring to indicate in the most explicit fashion that a university, like all other human institutions — like the church, like governments, like philanthropic organizations — is not outside, but inside the general social fabric of a given era. It is not something apart, something historic, something that yields as little as possible to forces and influences that are more or less new. It is, on the contrary — so I shall assume — an expression of the age, as well as an influence operating upon both present and future. I propose to elaborate this point of view and, as I proceed, to ask myself to what extent and in what ways universities in America, in England, and in Germany have made themselves part of the modern world, where they have failed to do so, where they have made hurtful concessions, and where they are wholesome and creative influences in shaping society towards rational ends.

Quite obviously I am assuming that to some extent, however slight, we are masters of our fate. The modern world is developing under the pressure of forces that reason cannot readily control. Pitted against

[3]

Is there any "service" that Columbia University will shirk? From the heart of the national metropolis, it has announced its readiness to organize an institute of rural life. It offers a course on the merchandising of drug products, running into such details as the "individually owned rural drug store" and "variety stores." The city of skyscrapers must, of course, have a course in "building management," separate divisions of which are devoted to "office buildings" with special attention to "janitor service," "apartment houses," "loft buildings," "financial buildings," etc. On the other hand, situated in the City of New York where there is scarcely an inch of open space, Columbia offers to resident extension students, by way of adjusting a modern university to its environment, courses in "practical poultry raising," "bee keeping," and "home vegetable and fruit growing." No wonder then that it has proposed systematic instruction on part time in "fire insurance" and a two weeks' institute at which commercial leaders may discuss the "problems created by the high degree of prosperity." The latter announcement was made some two years ago. In view of the recent speculative panic, the "institute" might now turn its attention for a fortnight in precisely the opposite direction! And so Columbia, has indeed done. On the heels of the recent stock market crash, the University issued the following printed circular:

# Evening News

WEATHER: Fair tomorrow.

**CITY-COUNTY  
EDITION**  
**WALL ST. COMPLETE**  
Pages 2\*, 3\*, 4\*, 5\*

Entered as second-class matter, September 11, 1883, at the Post-office at Newark, New Jersey, under the Act of March 3, 1879.

SATURDAY, JUNE 7, 1930—40 PAGES

215-221 Market St., Newark, N. J.  
Daily, Except Sunday

TWO CENTS

Place

Had Run-  
and Home  
orts

Police rudely de-  
treat for knight's  
of the Ivy Hill  
afternoon. An  
ipped with a bed  
automobile bodies  
lements by auto  
together, with all  
home, including  
roaring fireplace,  
giant Kabis and  
Wetreich and Mo-

en received that  
housewives by  
food. Yesterday  
descended on the  
ix men brewing a  
n" over an open  
g on trees. Botes  
nches contained  
oods. A spring  
y supplied the  
hometake  
ting Judge Cro-  
net Court today  
hemselves as Al-  
street, South Or-  
no home; James  
street, Steward  
y, John J. Woods,  
mas O'Brien, 18  
nnelly sentenced  
sch.

Gets

## Louis Bamberger and Mrs. Fuld Give \$5,000,000 to Establish Institute of Advanced Learning

*Donors of Institute Fund*



### Initial Endowment Announced For Graduate Foundation In Newark or Vicinity

The gift of \$5,000,000 by Louis Bamberger and his sister, Mrs. Felix Fuld, to establish an educational foundation to be called the Institute for Advanced Study was announced today. It will be located "in Newark or its vicinity."

Exclusively for post-graduate work and scientific research, the first of its kind in this country, the institute will bring Newark to the forefront among world educational centers.

The \$5,000,000 will be placed by Mr. Bamberger and Mrs. Fuld at the disposal of a distinguished board of trustees as the initial endowment of

### Cites "Duress"


Refugees	Placed	Absorbed
Kurt Gödel	Notre Dame	---
I. J. Schoenberg		Colby College
Richard Brauer		Toronto
Reinhold Baer		University of Illinois
Otto F. G. Schilling		University of Chicago
Stanislaw W. Ulam	Harvard College	---
Peter G. Bergmann		University of North Carolina
Herbert Busemann		Armour Institute, Chicago
Witold Hurewicz		University of North Carolina
Leopold Infeld		Toronto University
Edward J. Jurji		Princeton Theological Seminary
Rupert Wildt		Princeton University
Richard Ettinghausen		University of Michigan
Claude Chevalley		Princeton University
John H. Herz	Trinity College	---
Doro Levi	Princeton University	---
J. Rummy		Newark University

Refugees	Institute for Advanced Study
Professors - Albert Einstein	
John von Neumann	
Hermann Weyl	
Ernst Herzfeld	
Erwin Panofsky	
Associate - Walther Mayer	
Assistants, research, etc.	
Hanns Swarzenski	
Kurt Weitzmann	
Alfred T. Brauer	
Valentin Bargmann	
Kei-won Chung	

## Emergency Committee in Aid of Displaced Foreign Scholars

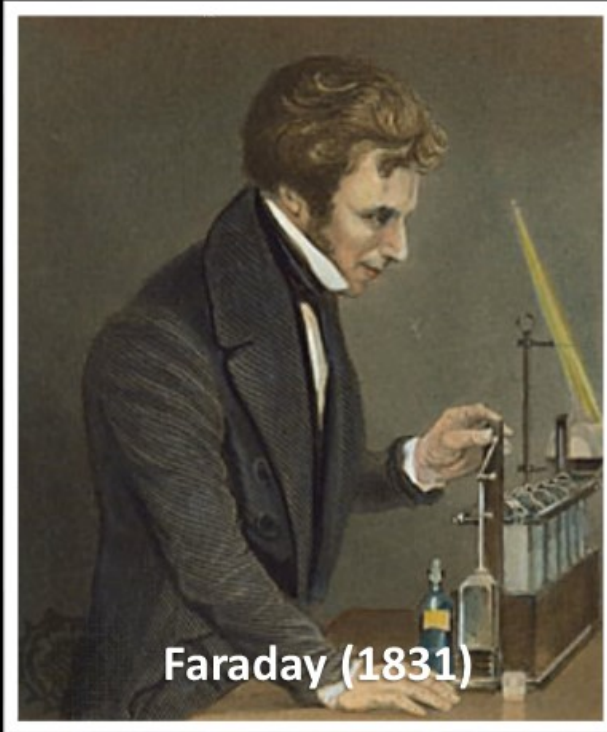
REFUGEES	2
<u>Dr. Paul Tedesco</u> , Austrian (taken out first papers) Aged 42 Ph.D., University of Vienna, 1920; first rank of Iranists, a distinguished scholar in Oriental studies - Balkoslavie, Iranian, Sanskrit or Comparative Linguistics; has published many papers; at work on linguistic researches; highly recommended by Prof. Franklin Edgerton of Yale; has worked with Prof. Herzfeld at Institute.	\$2,000.00
<u>Dr. Kurt Weitzmann</u> , German Dr. Phil., University of Berlin, 1929 Best of young Byzantinists, indispensable to research project of Corpus of Illustration of the Old Testament in Greek Mss., Index of Christian Art, Princeton University, now at work on Studies in Manuscript-Illumination, illustrated Greek sythographers, illustrated lectionaries on Mount Athos, discovered and photographed by him in 1935 and 1936, works also with Professor Panofsky.	4,500.00
<u>Dr. Valentin Bargmann</u> , German Ph.D., University of Zürich, 1936 At work on problems in relativity under guidance of Professor Einstein.	1,500.00
<u>Dr. Alfred T. Brauer</u> , German Aged 46 Ph.D., 1938, University of Berlin; assistant, University of Berlin, 1926-35; studying at Institute with Professor Hermann Weyl.	1,800.00
<u>Dr. Kurt Gödel</u> , Austrian Aged 34 Ph.D., 1930, University of Vienna; Venia legendi, University of Vienna, 1939; universally conceded to be the most brilliant mathematical logician in the world.	4,000.00
<u>Prof. Carl L. Siegel</u> , German Aged 44 Dr. Phil., 1920, University of Göttingen; lecturer, Hamburg University, 1920; assistant, University of Göttingen, 1921; professor, University of Frankfurt, University of Göttingen, 1922-1940; a mathematician of the first rank who remained in Germany until recently, largely in order to try to protect some of his Jewish colleagues.	3,000.00
<u>Prof. Walther Mayer</u> , Austrian now an American citizen Ph.D., 1914, University of Vienna; docent University of Vienna, 1926-31, A.O. Professor, University of Vienna, 1931-33; assisted Professor Einstein; has given certain courses on calculus of variations and related subjects; published papers for mathematical journals.	4,500.00
<u>Miss Valentine F. Tschobotareff</u> , Russian born First papers Aged 31 Ph.D., University of Berlin, 1934; worked on Russian economics at Deutsche Volkswirt, Berlin; author of articles and translator of papers on allied subjects; working with Professors Warren and Stewart on Notes on War Finance, and Economic Importance of the West Indies.	1,800.00
<u>Dr. Kei-won Chung</u> , Korean Aged 38 Ph.D., Princeton University, 1938 Work in linguistics, Sanskrit, written Chinese, spoken and written Japanese, work in Manchu, Mongol, Tibet, interest in Greek assisting him in Russian languages, studying at Gest Oriental Library.	1,200.00



A black and white portrait of Leonard Flexner, an elderly man with glasses, wearing a suit and tie. The portrait is centered in the upper half of the slide.

*“Fifty years from now the historian looking backward will, if we act with courage and imagination, report that during our time the center of gravity in scholarship moved across the Atlantic Ocean to the United States.”*

Flexner, May, 1939.

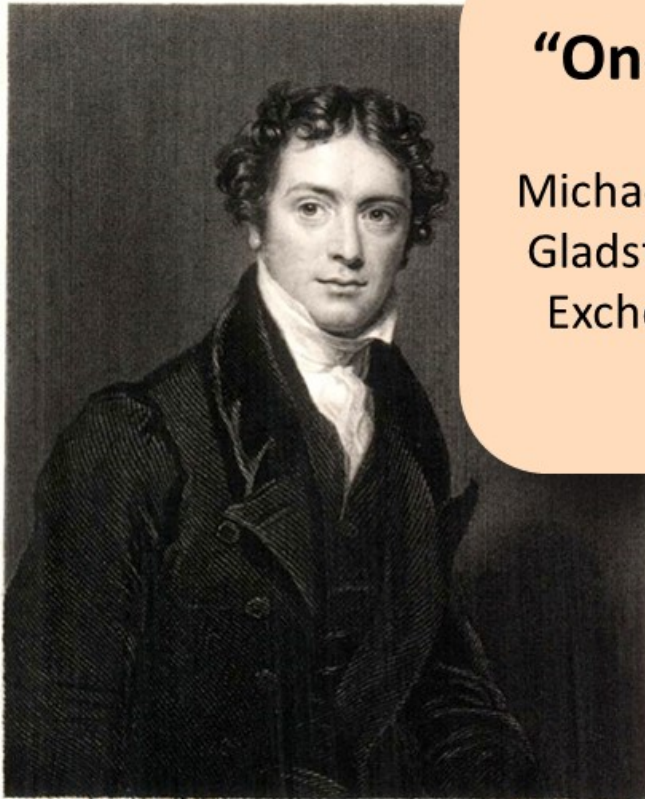


**Electricity**  
100% of present industry



**“One day, Sir, you may tax it.”**

Michael Faraday's alleged reply to William Gladstone, then British Chancellor of the Exchequer, when asked of the practical value of **electricity** (1850).



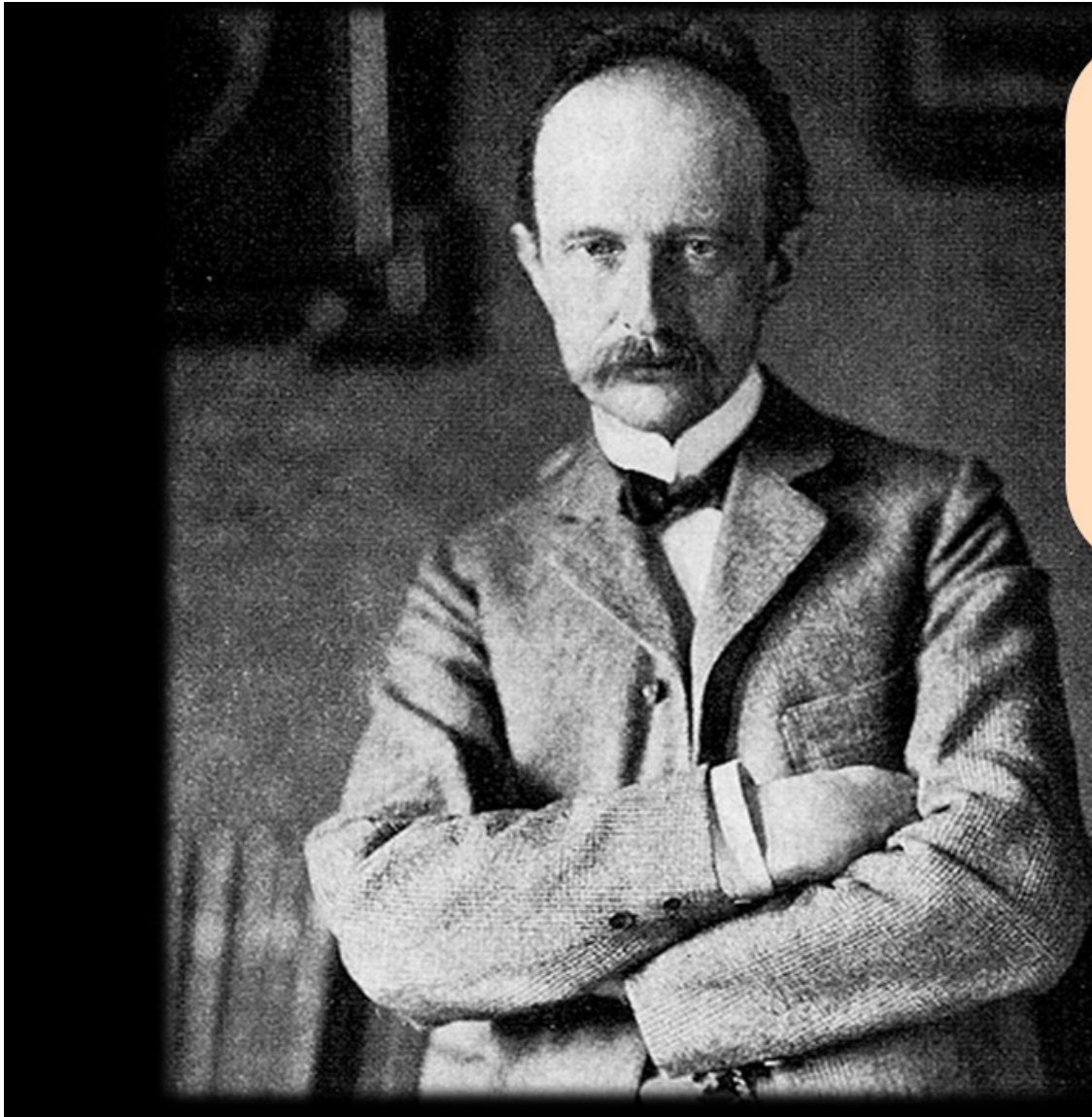
Painted by H.W. Pickershill, Esq. R. A.

Engraved by J. Crotchley.

MICHAEL FARADAY, ESQ. F.R.S. M.R.I. F.G.S. &c.

*Michael Faraday*

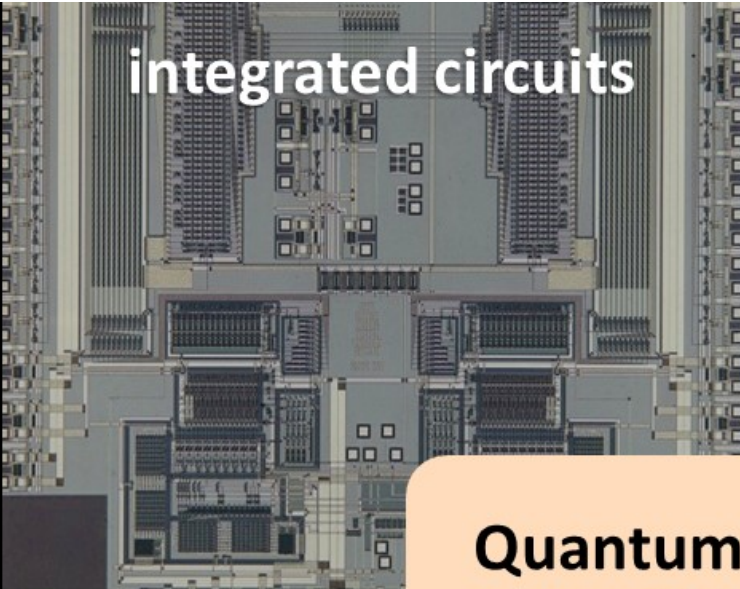




**“An act of desperation**  
[ ...] I was willing to  
make any offer to the  
principles in physics  
that I then held. “

**Max Planck**

**Quantum Mechanics**  
(1900)



integrated circuits



nanomaterials

**Quantum Mechanics**  
30% of GDP



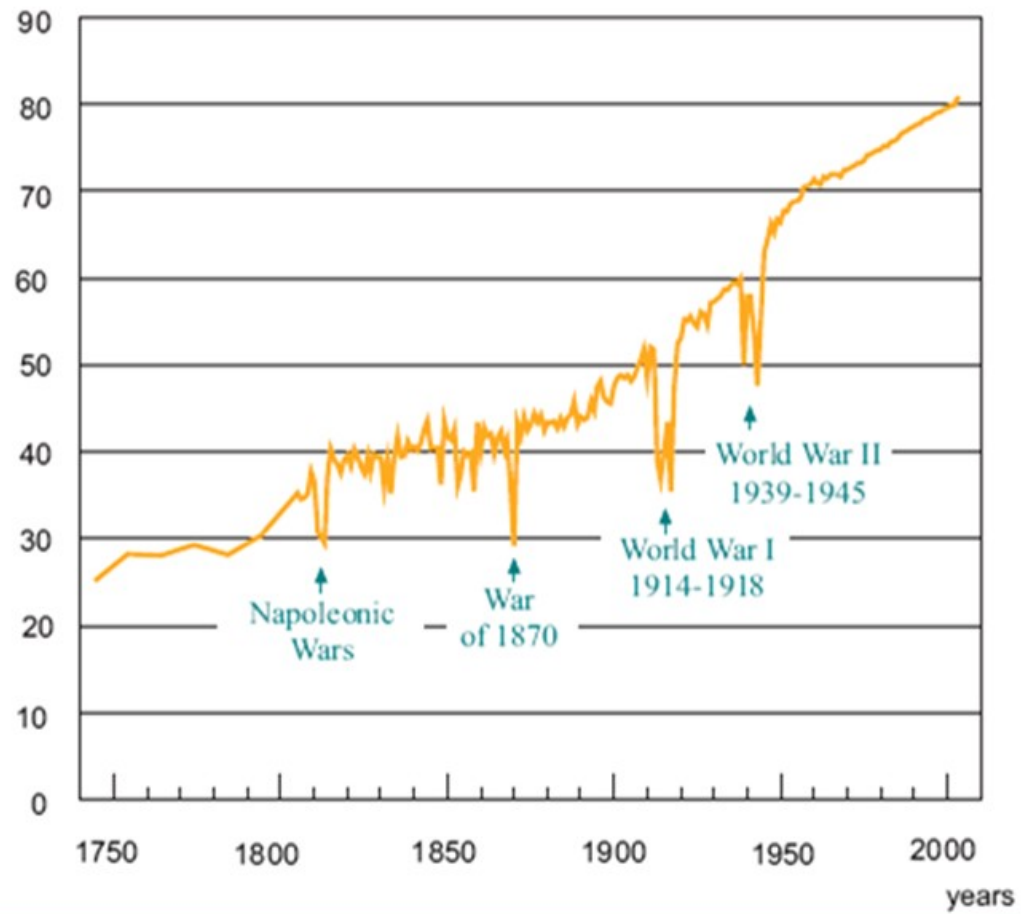
lasers



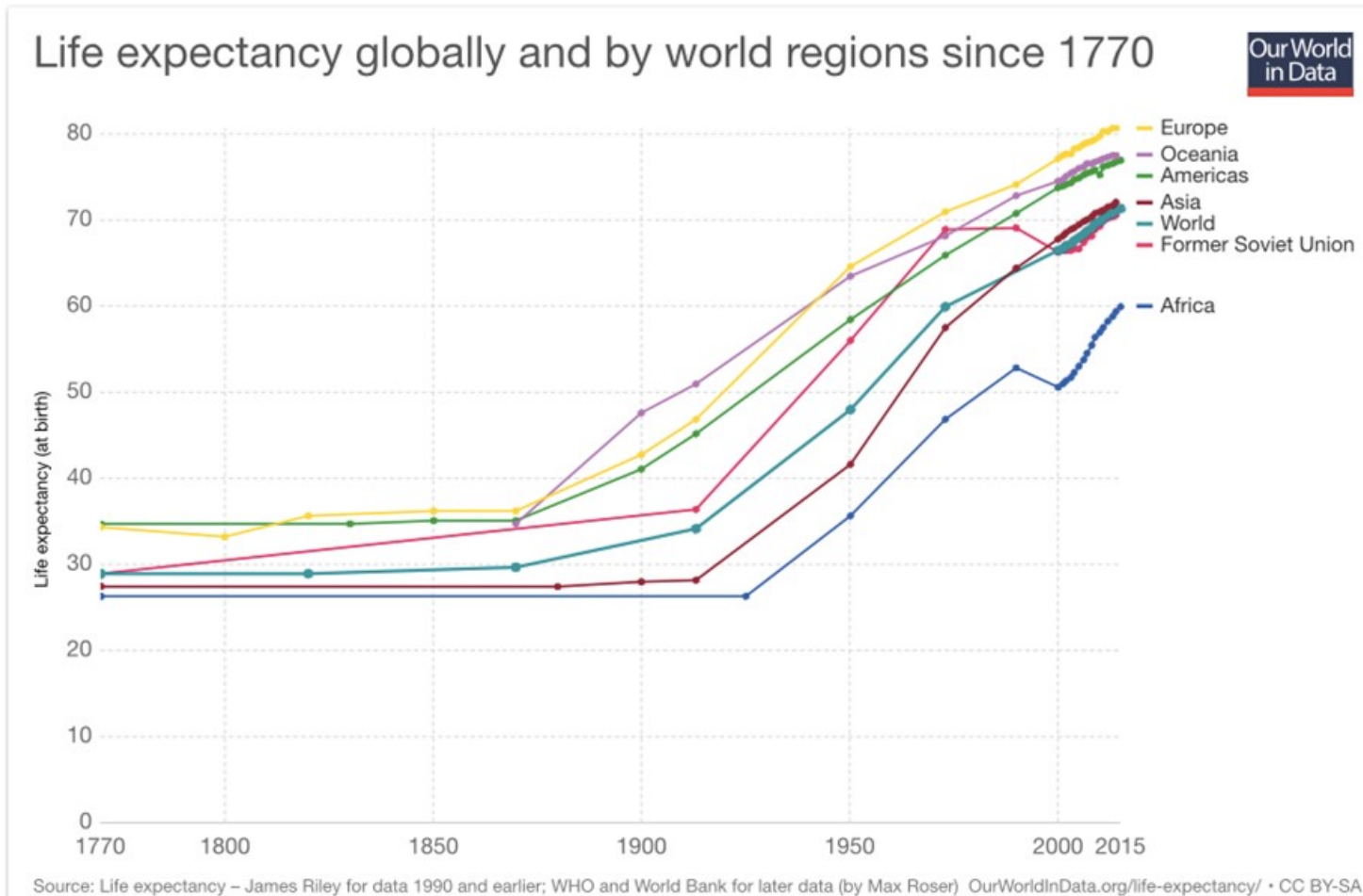
1  $\mu\text{m}$   
quantum computers

## Life expectancy in France from 1740 to 2005

Life expectancy  
at birth (years)



# Tripling Life Expectancy



# What is Technology?

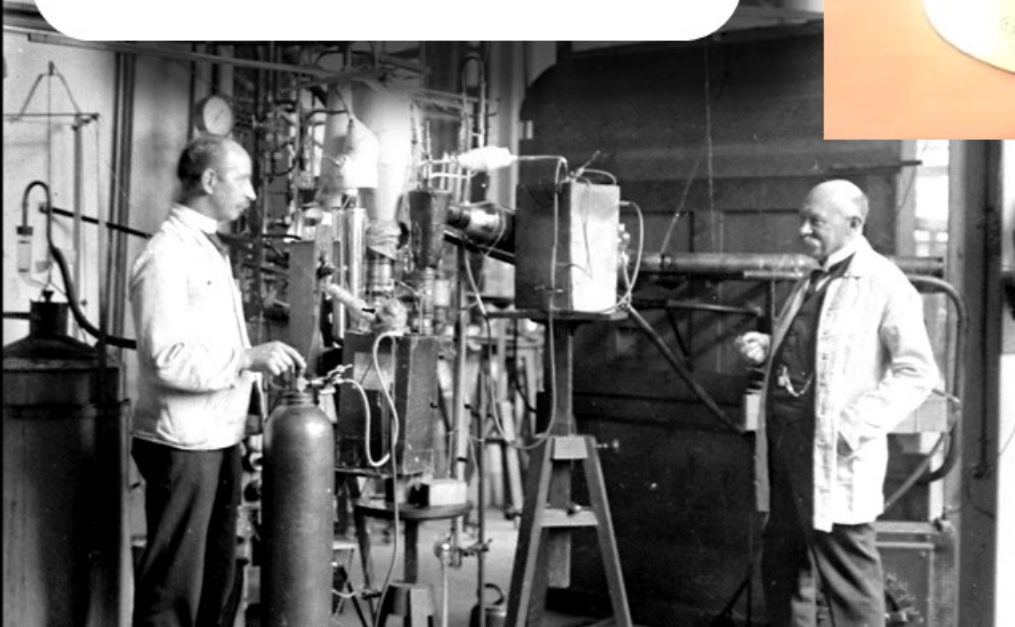
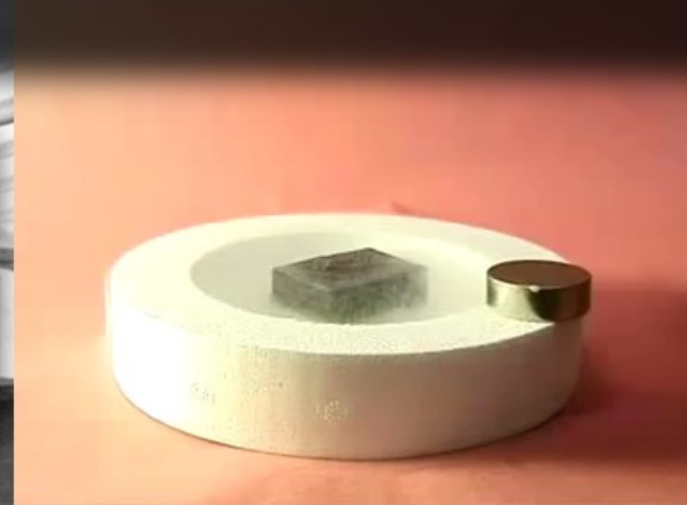
- *Everything discovered after you were born.*
- *Everything that doesn't work.*
- *The dominant force that shapes and changes both nature and culture.*



# The Uselessness of the Usefulness of Useless Knowledge

## SUPERCONDUCTIVITY

Heike Kamerlingh Onnes  
Leiden, 1911





**Lab Assistants School, Leiden**

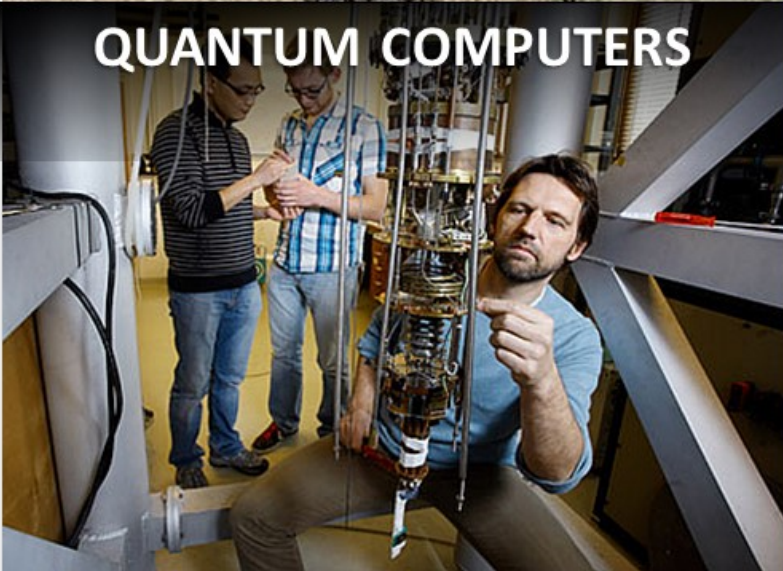
**MAGLEV**



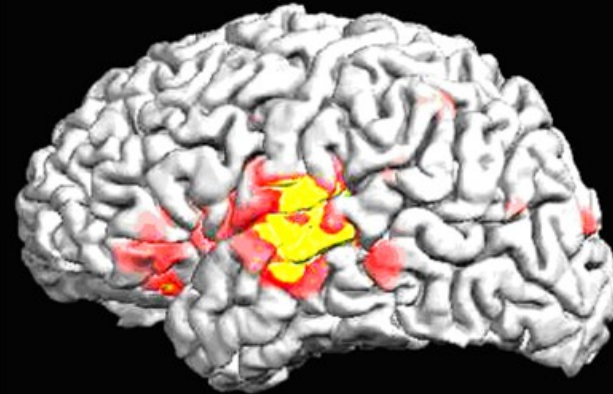
**FMRI SCANNERS**



**QUANTUM COMPUTERS**



**NEUROSCIENCE**





**SUPERCONDUCTING MAGNETS**

Large Hadron Collider, -CERN

**Wilczek**  
**Gross**  
**Paper 1973**  
**Nobel 2004**

**'t Hooft**  
**Paper 1971**  
**Nobel 1999**

**Higgs Englert**  
**Paper 1964**  
**Nobel 2013**



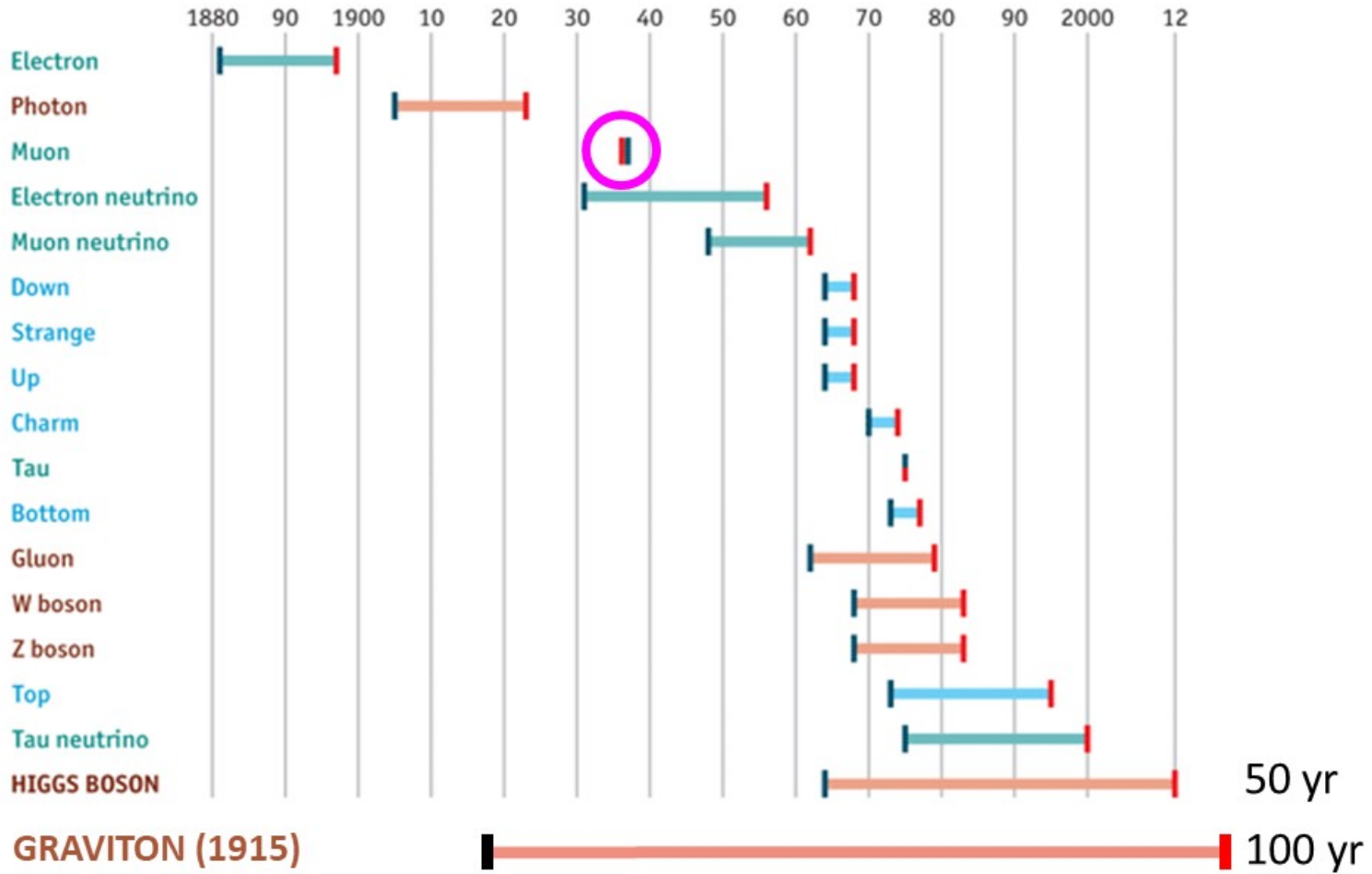
**A 50-Year Prediction**

# The Standard Model of particle physics

Years from concept to discovery

Leptons  
Bosons  
Quarks

Theorised/explained  
Discovered



# A 100 YEAR PREDICTION

LIGO: Gravitational Wave Detection, 14 Sept 2015

**LIGHTS ALL ASKEW  
IN THE HEAVENS**

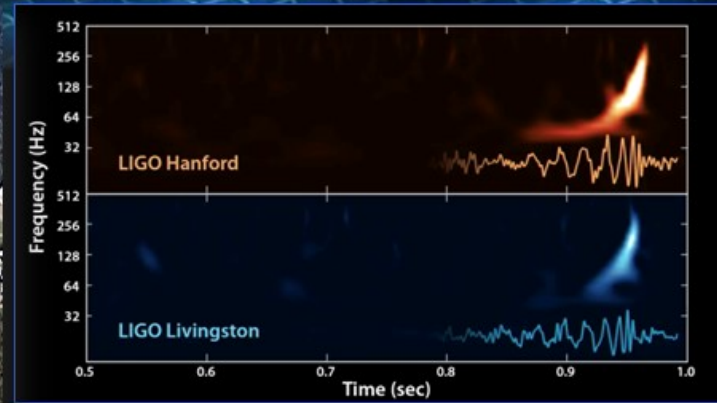
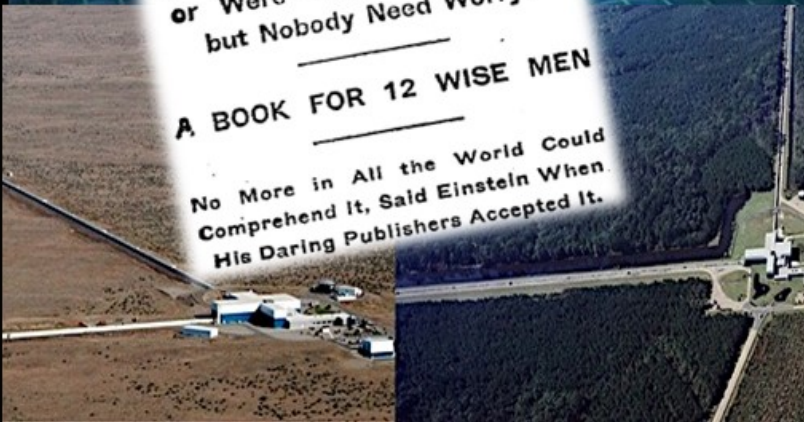
Men of Science More or Less  
Agog Over Results of Eclipse  
Observations.

**EINSTEIN THEORY TRIUMPHS**

Stars Not Where They Seemed  
or Were Calculated to be,  
but Nobody Need Worry.

**A BOOK FOR 12 WISE MEN**

No More in All the World Could  
Comprehend It, Said Einstein When  
His Daring Publishers Accepted It.

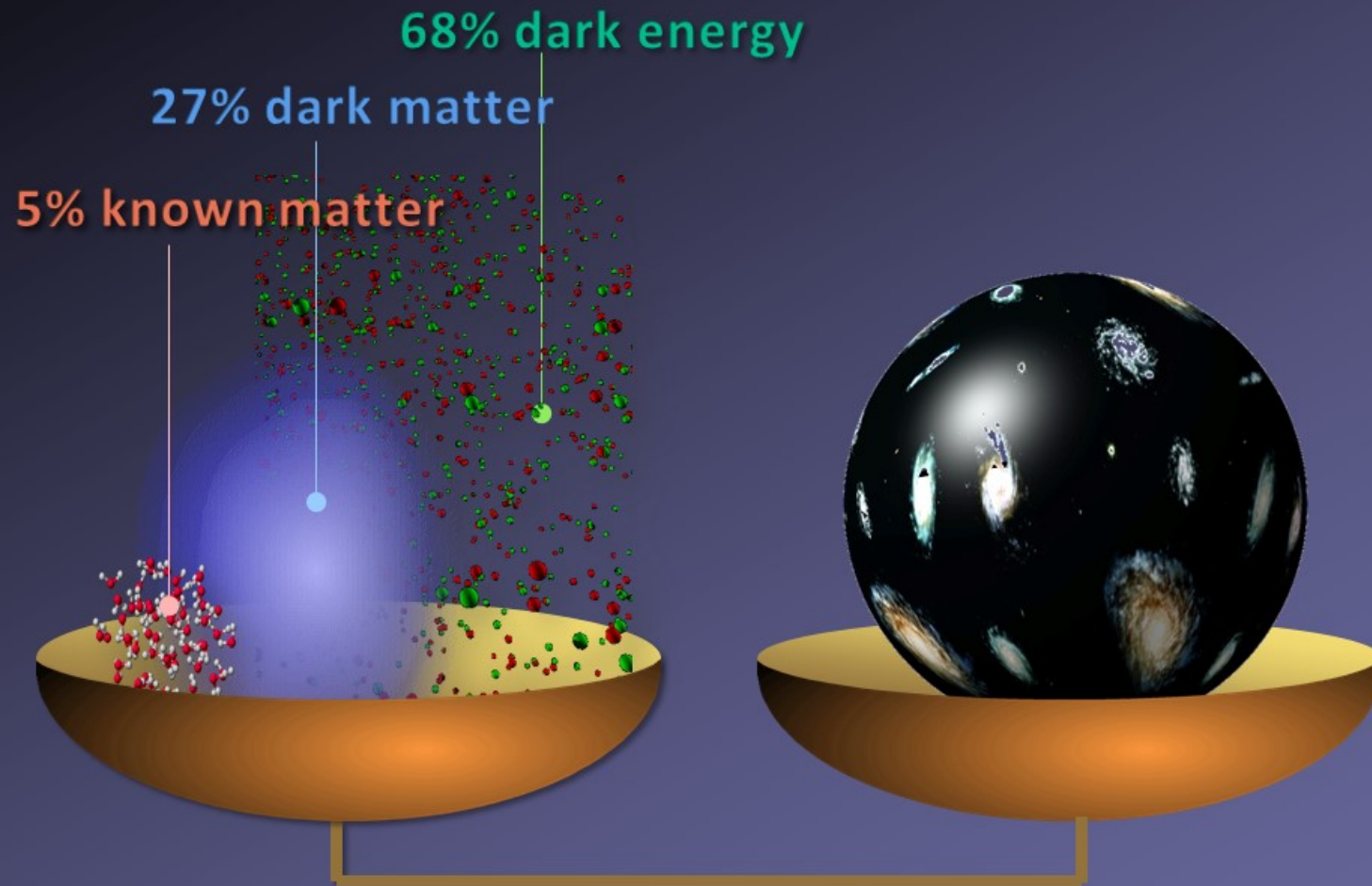




**Feb 11, 1800 – Sir Frederick William Herschel (1738 – 1822)**

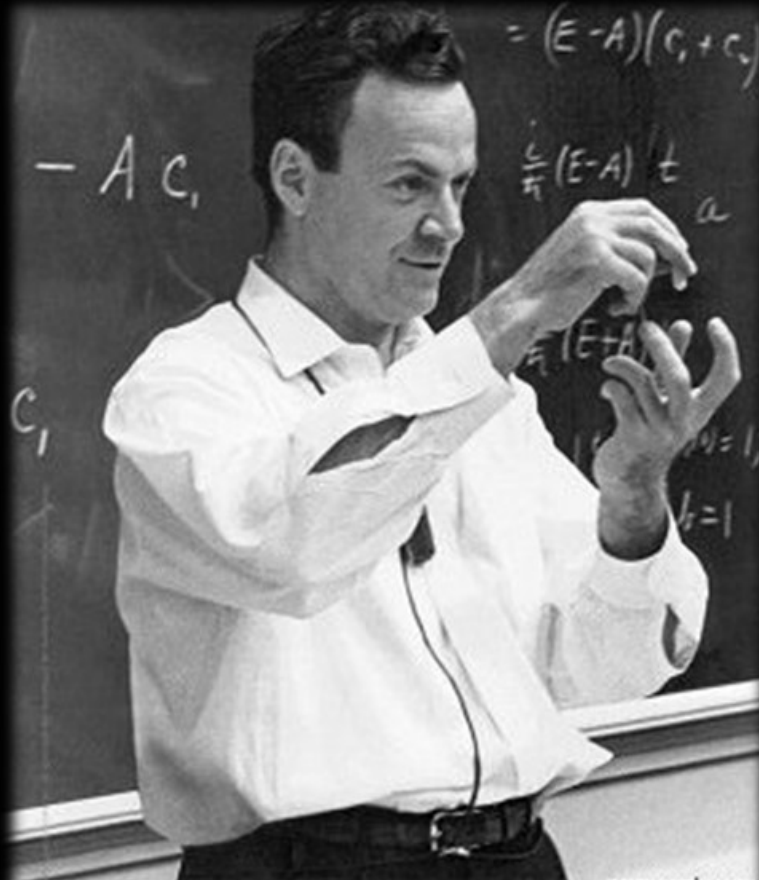






**WEIGHT OF THE UNIVERSE: 95% UNKNOWN**

## Science as the belief in the ignorance of experts



*"We have found it of paramount importance that in order to progress we must recognize the ignorance and leave room for doubt. Scientific knowledge is a body of statements of varying degrees of certainty -- some most unsure, some nearly sure, none absolutely certain."*

**Richard Feynman**

## Science as organized skepticism

*“Any theory that can account for all of the facts is wrong, because some of the facts are always wrong.”*



**Francis Crick**

*“Every law of physics, pushed to the extreme,  
will be found to be statistical and approximate,  
not mathematical perfect and precise.”*

**John Wheeler**



# Cracked it! Woman finds six double yolk eggs in one box beating trillion-to-one odds

By DAILY MAIL REPORTER  
Last updated at 12:08 AM on 3rd February 2011

[Comments \(80\)](#) | [Add to My Stories](#)

The chances of cracking open a double yolke per cent in fact.

So imagine the odds of going through a half-do finding that all of them had two yolks.

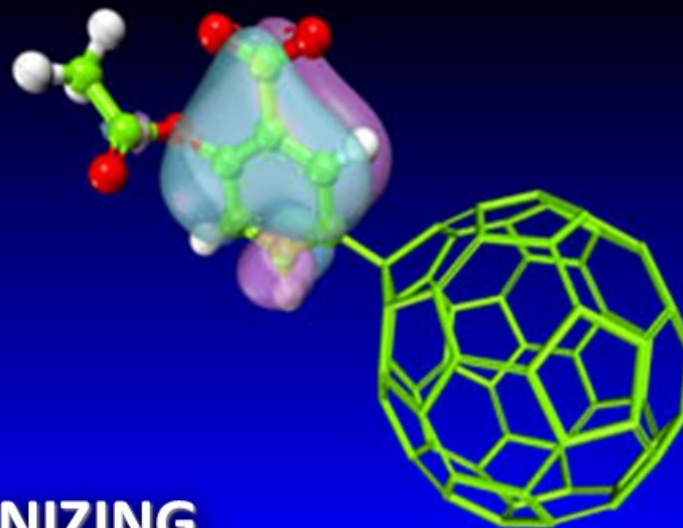
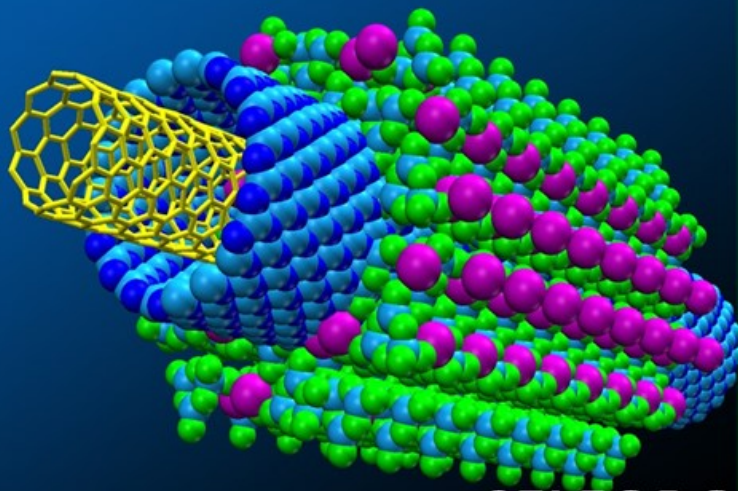
Fiona Exon has done exactly that. The art gallery owner was preparing scrambled eggs for Sunday breakfast when she started cracking the eggs.

Probability of  
1 : 1,000,000,000,000,000,000

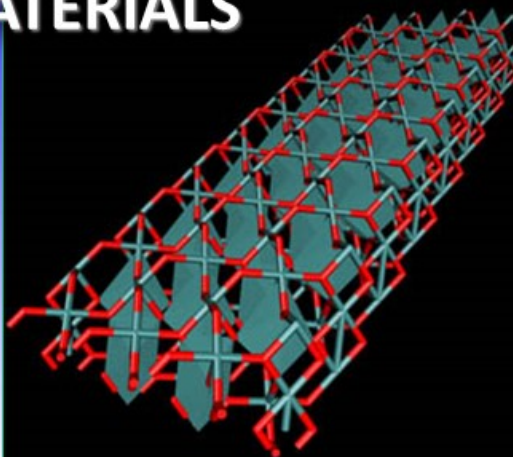
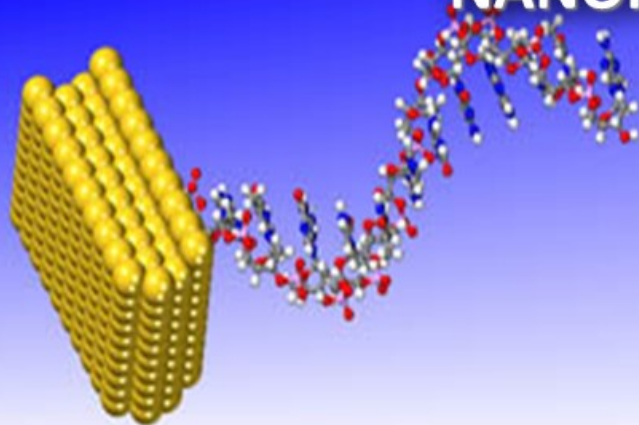


# FROM BUILDING BLOCKS TO DESIGN

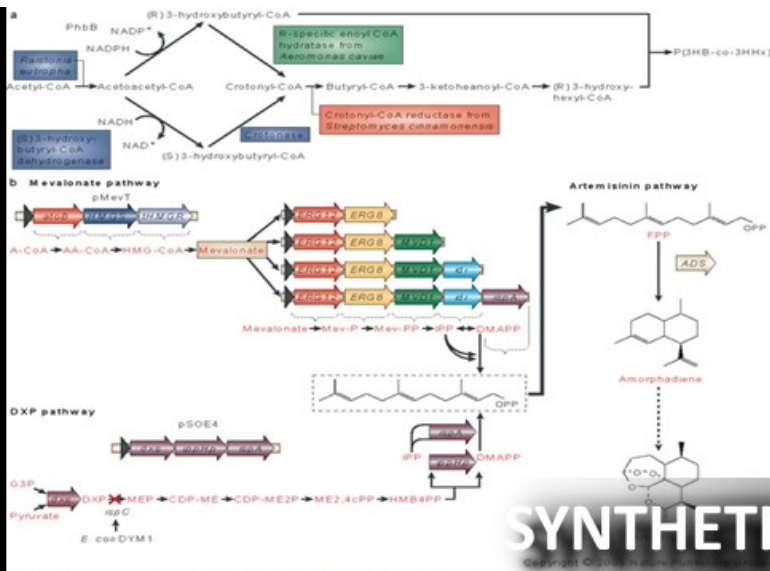




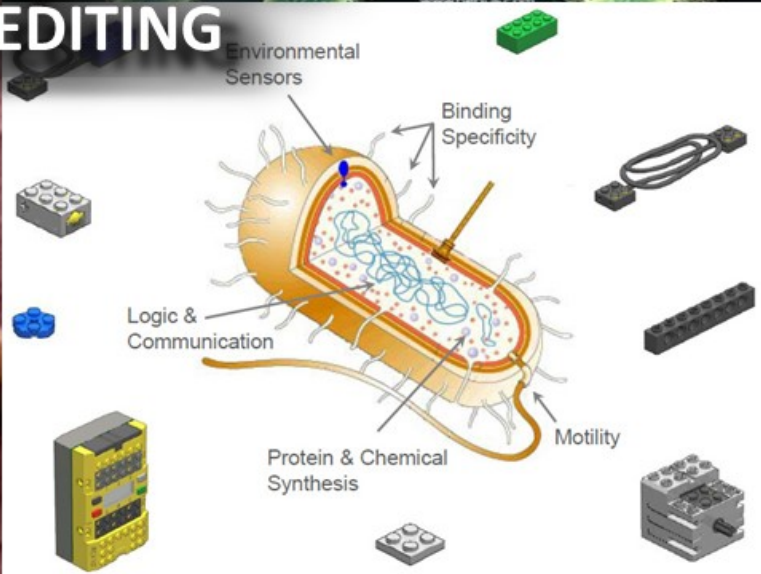
**SELFORGANIZING  
NANOMATERIALS**

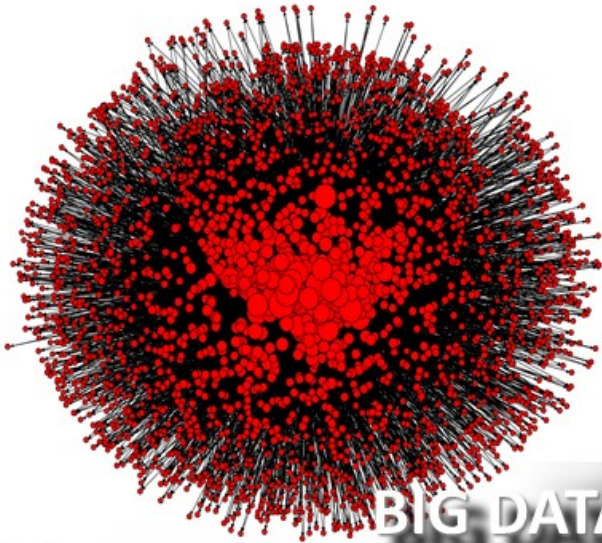




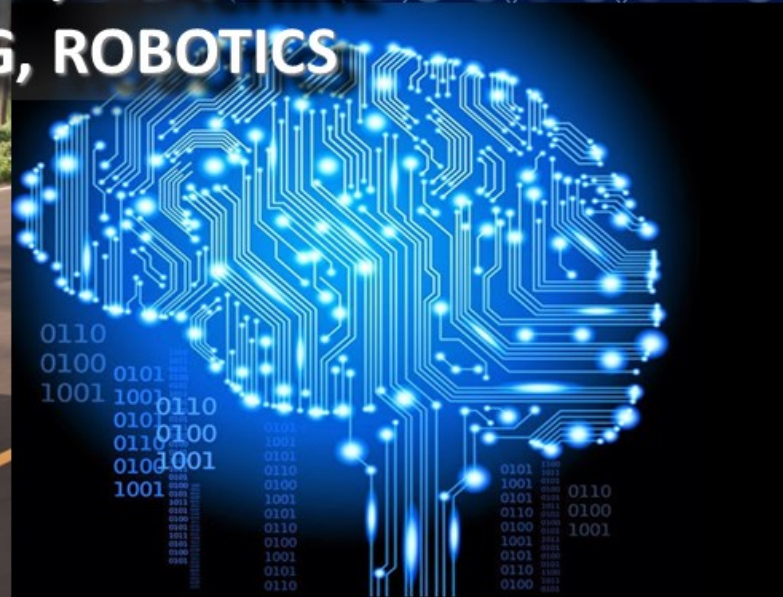


# SYNTHETIC BIOLOGY GENE EDITING





# BIG DATA, AI, MACHINE LEARNING, ROBOTICS



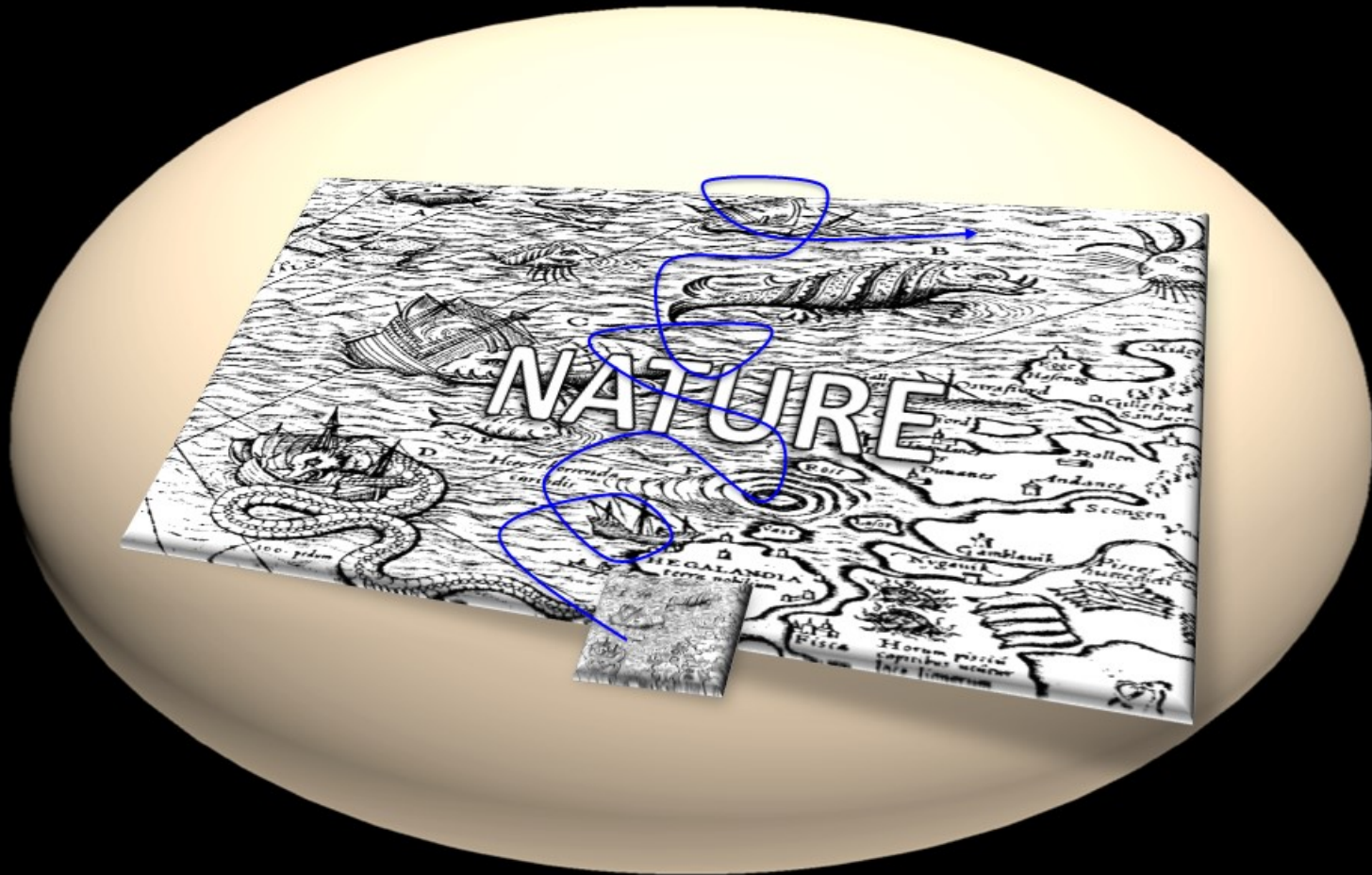
What we know we don't know




**NATURE**

What we know

# What we can make





## The Usefulness of Basic Research

- Produces **knowledge** in and of itself
- Generates **transformative** ideas and technologies
- Develops new **tools and techniques**
- Attracts the **best minds**
- Drives innovation and **startups**
- Is a truly (inter)national **public good**

# R&D and Economic Growth

MIT: generated *30,000* companies with  
*4.6M* employees, including Texas Instruments,  
McDonnell Douglas and Genentech  
Annual revenue: *\$2 trillion* > GDP 10<sup>th</sup> economy.

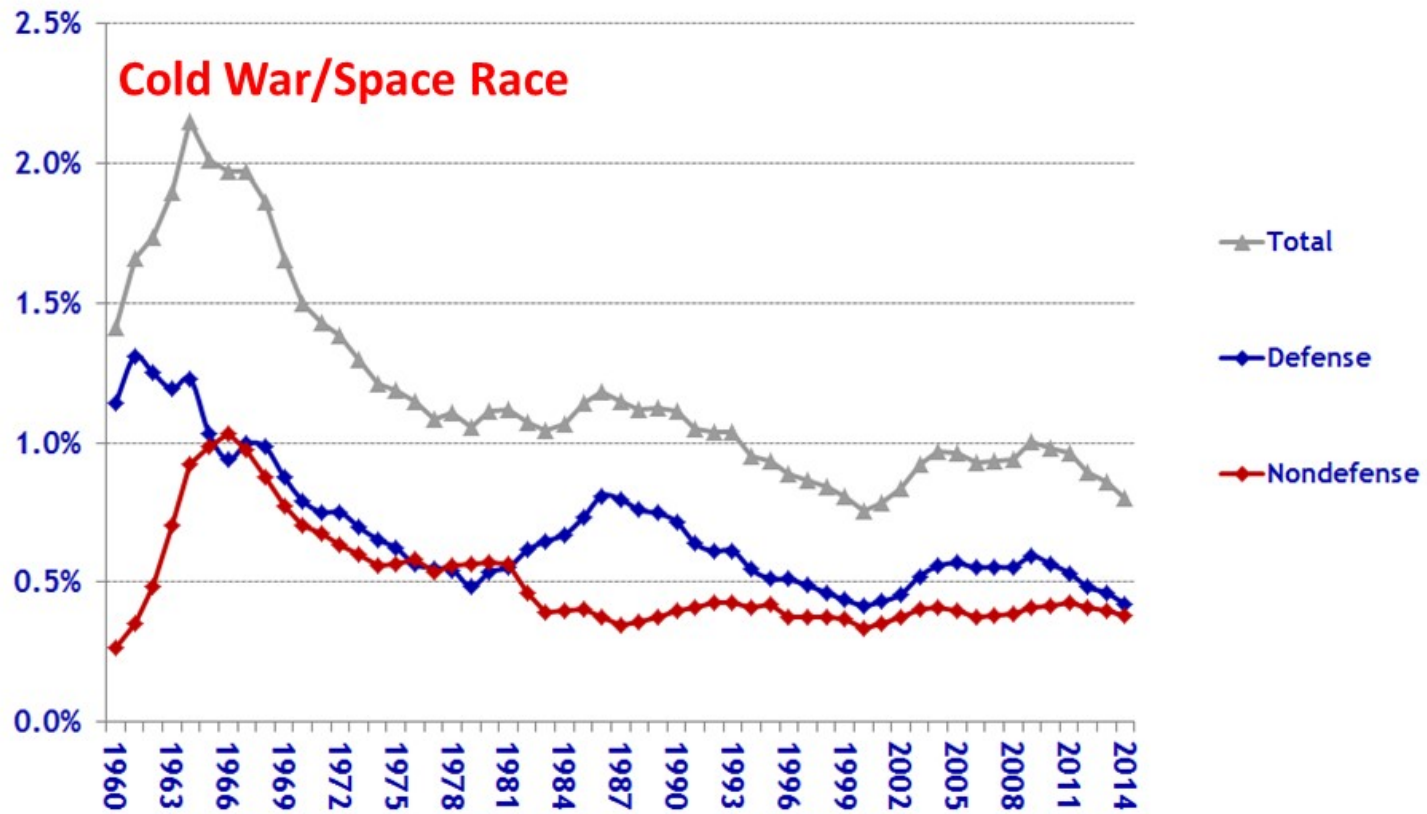
to 1.1-1.4% increase GDP.

**A multiplier of 5-7x**

*\$4.5M* NSF Digital Libraries Initiative grant to Stanford  
-> Google (Alphabet) current market cap *\$712B*  
**Multiplier 160,000x**

# Federal Research As a Share of GDP

(percent of GDP - excludes R&D plant)

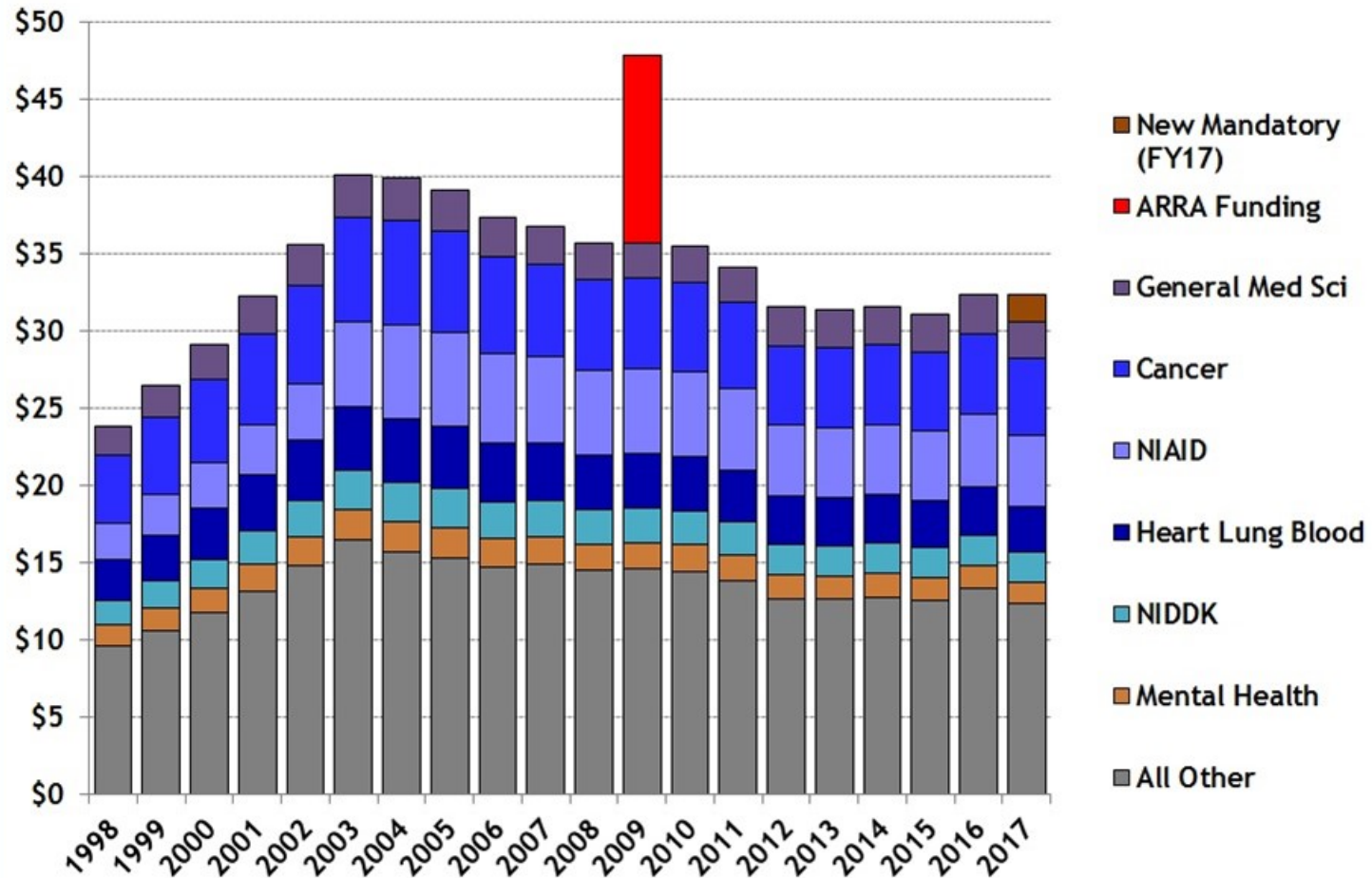


Source: *Budget of the United States Government, FY 2014*.  
FY 2013 data do not yet reflect final appropriations or sequestration.  
© 2013 AAAS



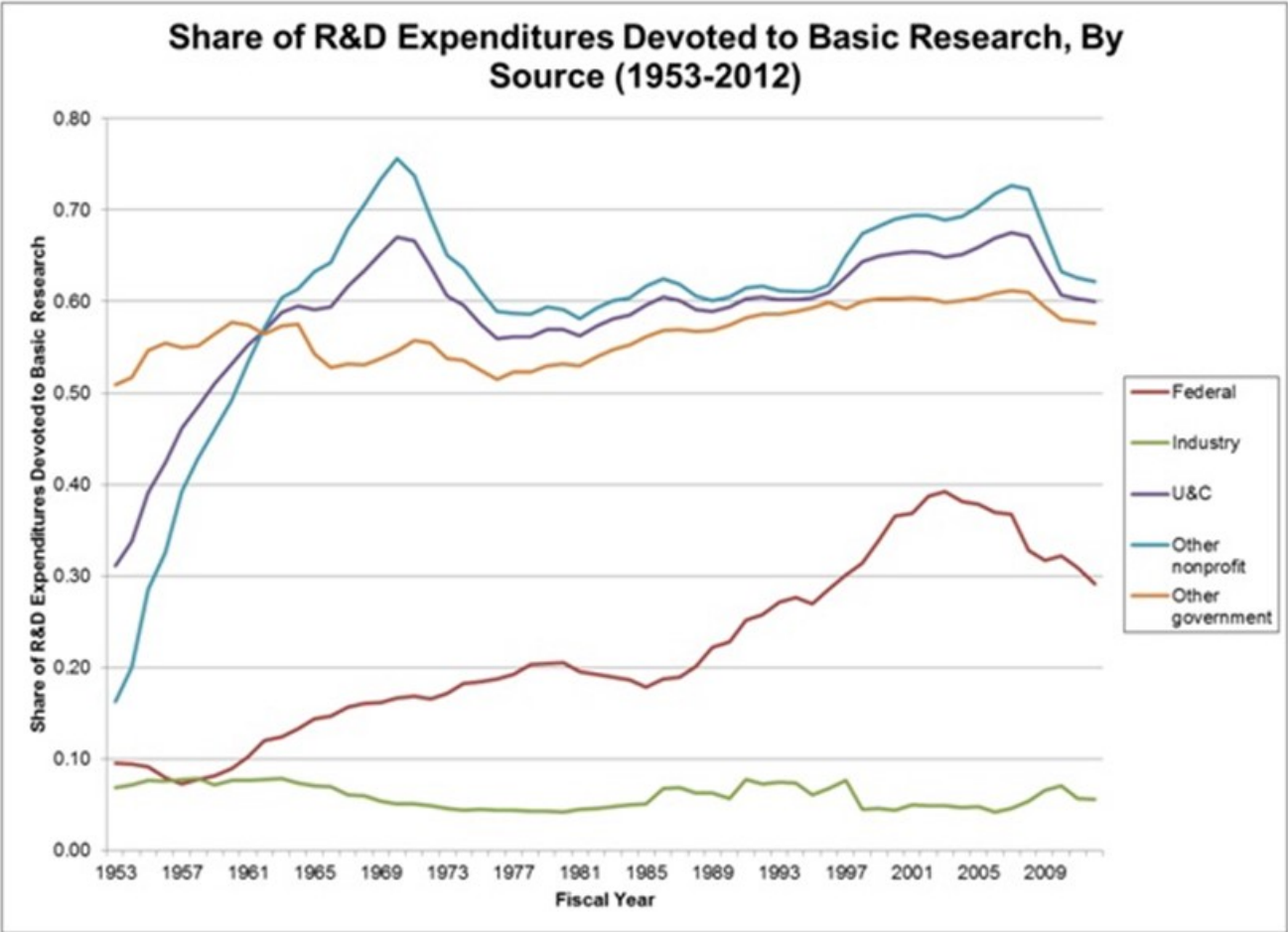
# National Institutes of Health Budget, 1998-2017

budget authority in billions of constant FY 2016 dollars



Source: AAAS data, agency budget documents, and appropriations. Adjusted for biomedical R&D inflation rate (BRDPI). Excludes supplemental FY 2017 Zika proposal and FY 2015 Ebola funding. © 2016 AAAS







(Left to right) Dr. John Bardeen\*, Dr. William Shockley\* and Dr. Walter H. Brattain, shown at Bell Telephone Laboratories in 1948 with apparatus used in the early investigations which led to the invention of the transistor.

## Bell Telephone Laboratories Salutes Three New Nobel Prize Winners

Drs. John Bardeen, Walter H. Brattain and William Shockley are honored for accomplishments at the Laboratories

The 1956 Nobel Prize in Physics has been awarded to the three inventors of the transistor, for "investigations on semiconductors and the discovery of the transistor effect."

They made their revolutionary contribution to electronics while working at Bell Telephone Laboratories in Murray Hill, N. J. Discovery of the transistor was announced in 1948. Bell Laboratories is proud to have been able to provide the environment for this great achievement.

This is the second Nobel Prize awarded to Bell Telephone Laboratories scientists. In 1937 Dr. C. J. Davison shared a Nobel Prize for his discovery of electron diffraction.

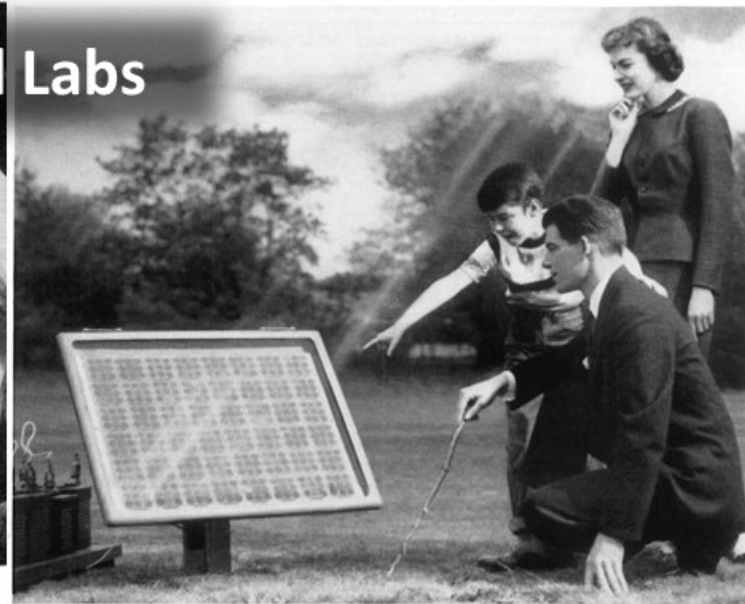
Such achievements reflect honor on all the scientists and engineers who work at Bell Telephone Laboratories. These men, doing research and development in a wide variety of fields, are contributing every day to the improvement of communications in America.

\*Dr. Bardeen is now with the University of Illinois, and Dr. Shockley is with the Shockley Semiconductor Laboratory of Beckman Instruments, Inc., Calif.



**Bell Telephone Laboratories**  
WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

February, 1957



**Something New Under the Sun.** It's the Bell Solar Battery, made of thin discs of specially treated silicon, an ingredient of common sand. It converts the sun's rays directly into usable amounts of electricity. Simple and trouble-free. (The storage batteries beside the solar battery store up its electricity for night use.)

## Bell System Solar Battery Converts Sun's Rays into Electricity!

*Bell Telephone Laboratories invention has great possibilities for telephone service and for all mankind*

Ever since Archimedes, men have been searching for the secret of the sun.

For it is known that the same kindly rays that help the flowers and the grains and the fruits to grow also send us almost limitless power. It is nearly as much every three days as in all known reserves of coal, oil and uranium.

If this energy could be put to use — there would be enough to turn every wheel and light every lamp that mankind would ever need.

The dream of ages has been brought closer by the Bell System Solar Battery. It was invented at the Bell Telephone Laboratories after

long research and first announced in 1954. Since then its efficiency has been doubled and its usefulness extended.

There's still much to be done before the battery's possibilities in telephony and for other uses are fully developed. But a good and pioneering start has been made.

The progress so far is like the opening of a door through which we can glimpse exciting new things for the future. Great benefits for telephone users and for all mankind may come from this forward step in putting the energy of the sun to practical use.

BELL TELEPHONE SYSTEM



# UNDER PRESSURE

**YOUNG RESEARCHERS ARE HAVING TO FIGHT HARDER THAN PAST GENERATIONS FOR A SMALLER SHARE OF THE ACADEMIC PIE.**

BY **BRENDAN MAHER AND MIQUEL SUREDA ANFRES**  
DESIGN BY **JASIEK KRZYSZTOFIAK**

Scientists and policymakers around the world increasingly worry about the plight of young researchers in academia, and for good reason. Competition for tenure-track

positions has surged, and some early-career researchers face tough odds in the quest for funding. As a result, many see lower pay-offs for their efforts in preparing and writing grant applications. Although everyone is under pressure, those just starting out seem to feel the impacts more acutely.

## PHDS RISING, JOBS FLAT

The number of graduates with advanced science and engineering degrees has been rising around the world. The Organisation for Economic Co-operation and Development (OECD) has recorded an increase in the number of science-related doctorates that would typically funnel into academic positions. The leading OECD nations in 2014 were:



**1.6%** The proportion of young people completing a doctorate of any kind in OECD member countries has doubled from 0.8% less than two decades ago.

**3,000** In most countries, however, the growth in academic jobs has not kept pace. US universities, for example, create only about 3,000 new full-time positions annually.



## FUNDING FALTERS

Government funding for research has plateaued or declined in many countries, and success rates for grants is now below 20% for some of the most important funders.



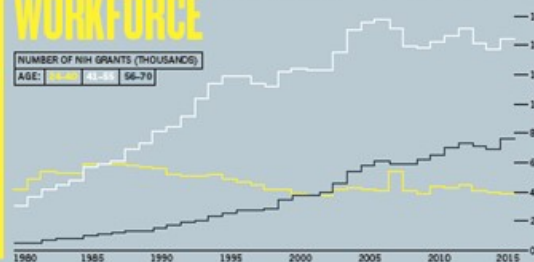
## TOUGH COMPETITION

Early-career scientists struggle to compete for grants against researchers who have a better knowledge of the system, more academic and administrative resources and richer publication lists. The Medical Research Council (MRC) — part of Research Councils UK — for example, shows lower success rates for younger scientists.



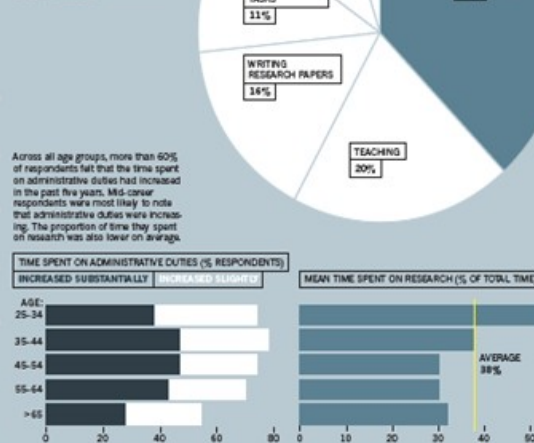
## AGEING WORKFORCE

Older scientists get the vast majority of grants, a huge change from 30 years ago. Even though the National Institutes of Health (NIH) managed to even out its success rate by giving first-time applicants a boost, the average age at which PhD scientists earn their first major grant has been around 42 since 2000.



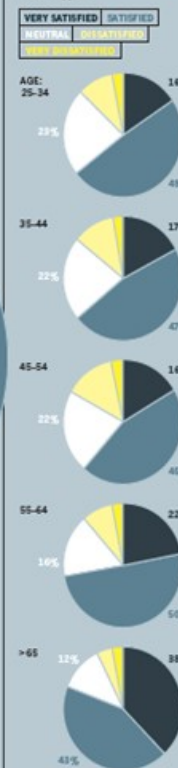
## NO TIME FOR RESEARCH

The low success rates for grants means that researchers spend a lot of time applying for them. A survey run by Nature earlier this year found that academic researchers of all ages spend only about 40% of their time on actual research.



## STRESSED BUT SATISFIED

Despite the many challenges affecting young scientists, more than 60% say that they are satisfied or very satisfied with their careers. But older scientists are the happiest.



# The Knowledge Paradox

*Infinitely far away, infinitesimally close*

**SCIENCE**

**SOCIETY**

The background of the slide is a complex, black and white fractal pattern that resembles a dense, branching structure, possibly representing a network or a complex system. A solid blue rectangular box is positioned at the top center, containing the title and subtitle. The words 'SCIENCE' and 'SOCIETY' are written in large, bold, white capital letters on either side of the fractal pattern.

# The Knowledge Paradox

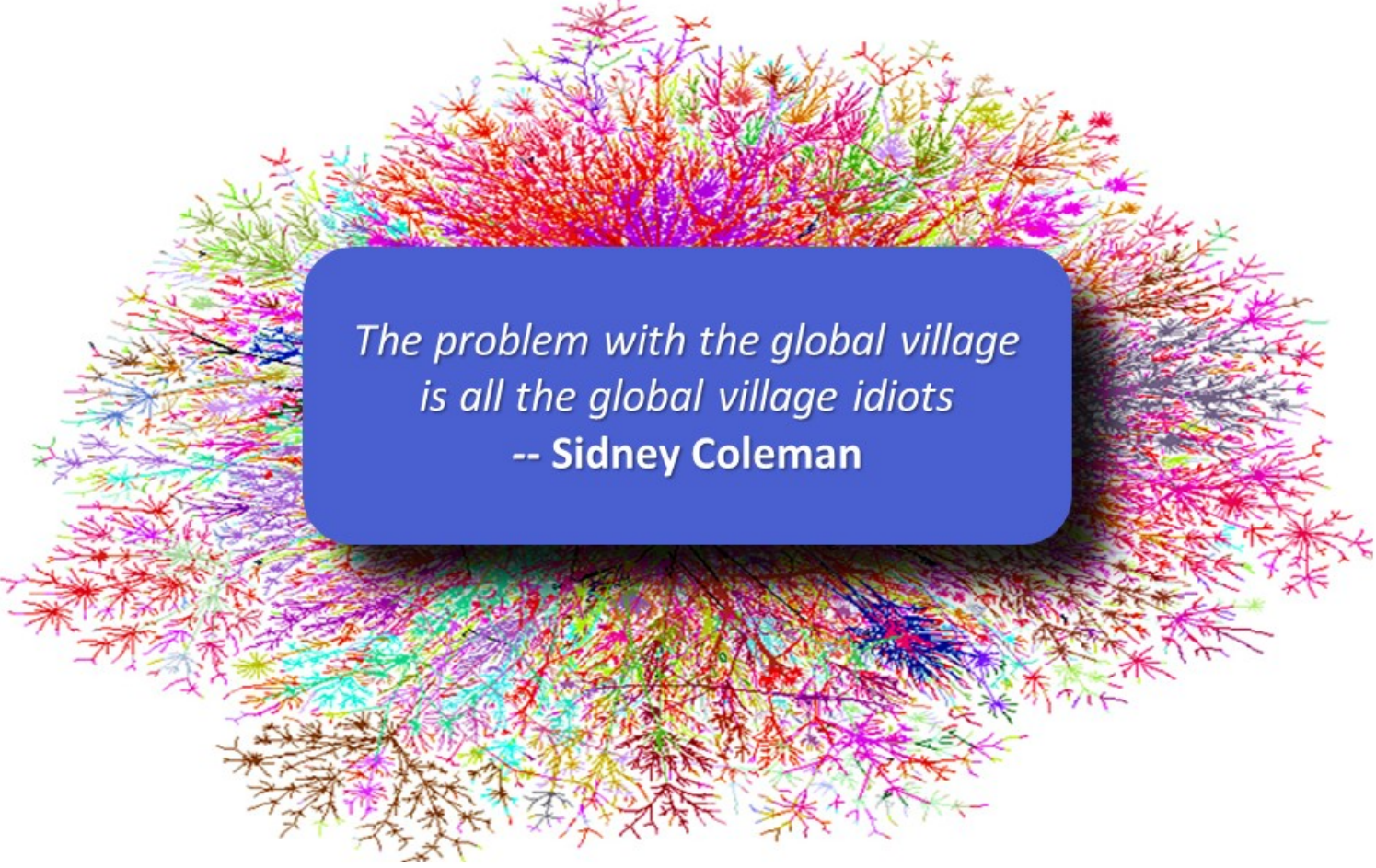
*Infinitely far away, infinitesimally close*

**SCIENCE**

**SOCIETY**

# University of Google

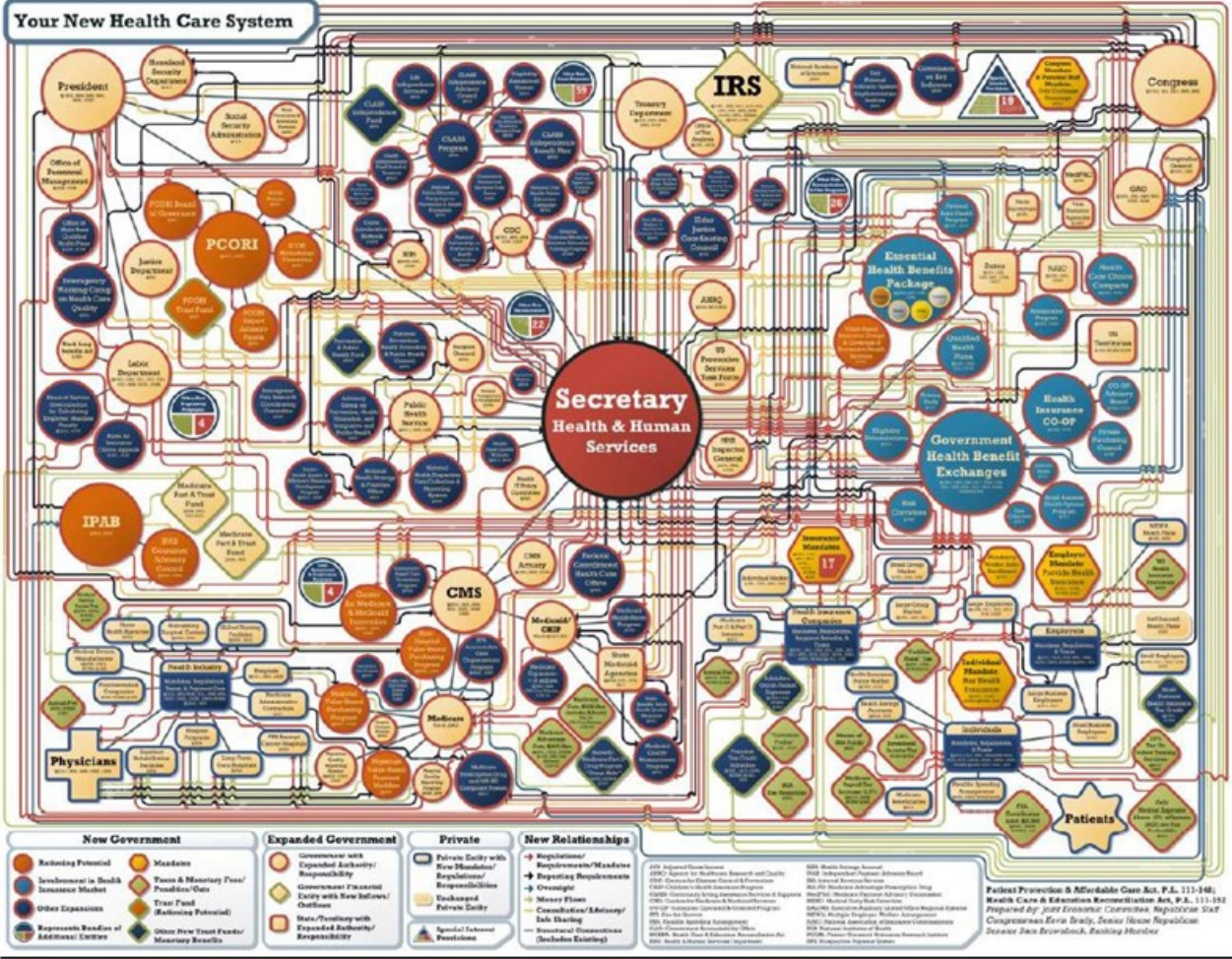
*fragmented, invalidated knowledge*



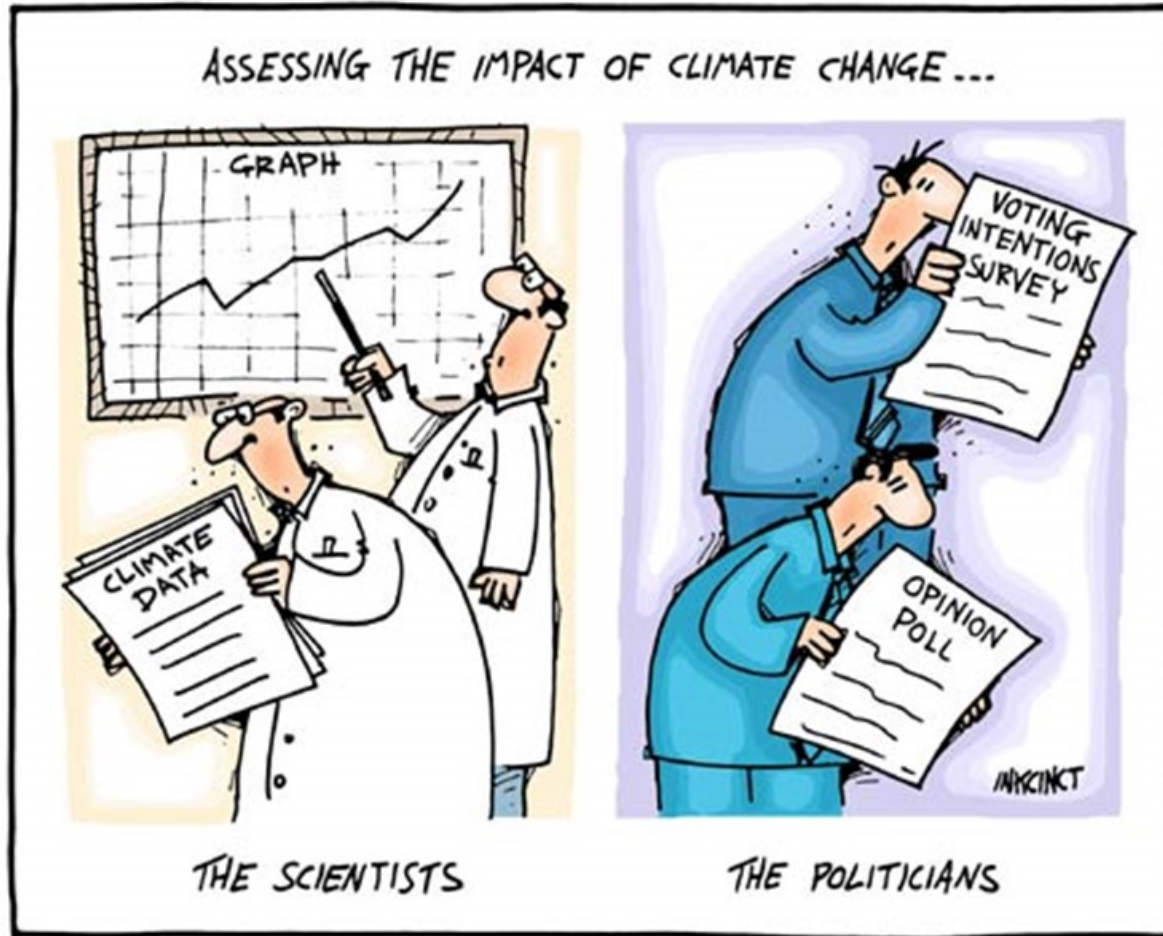
*The problem with the global village  
is all the global village idiots*  
-- Sidney Coleman

# Turning Complexity Against Science

“I’m not a scientist, but...”



# Science & Politics





## Science

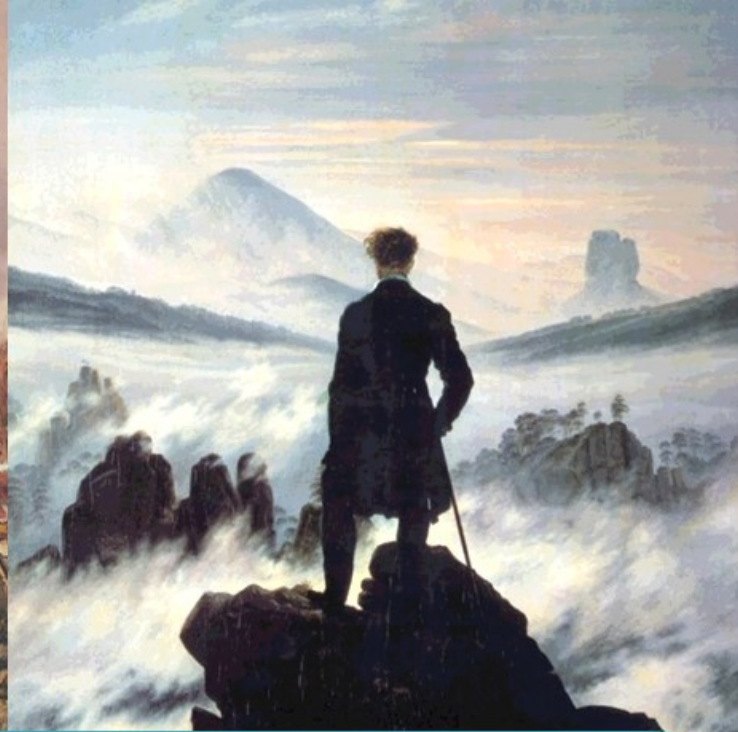
- *Universal*
- *Precise*
- *Rational*
- *Long-term*
- *Win-win*

## Politics

- *National, regional*
- *Inclusive*
- *Emotional*
- *Short-term*
- *Zero-sum*



*"Curiosity, which may or may not eventuate in something useful, is probably the outstanding characteristic of modern thinking. It is not new. It goes back to Galileo, Bacon, and to Sir Isaac Newton, and it must be absolutely unhampered."*

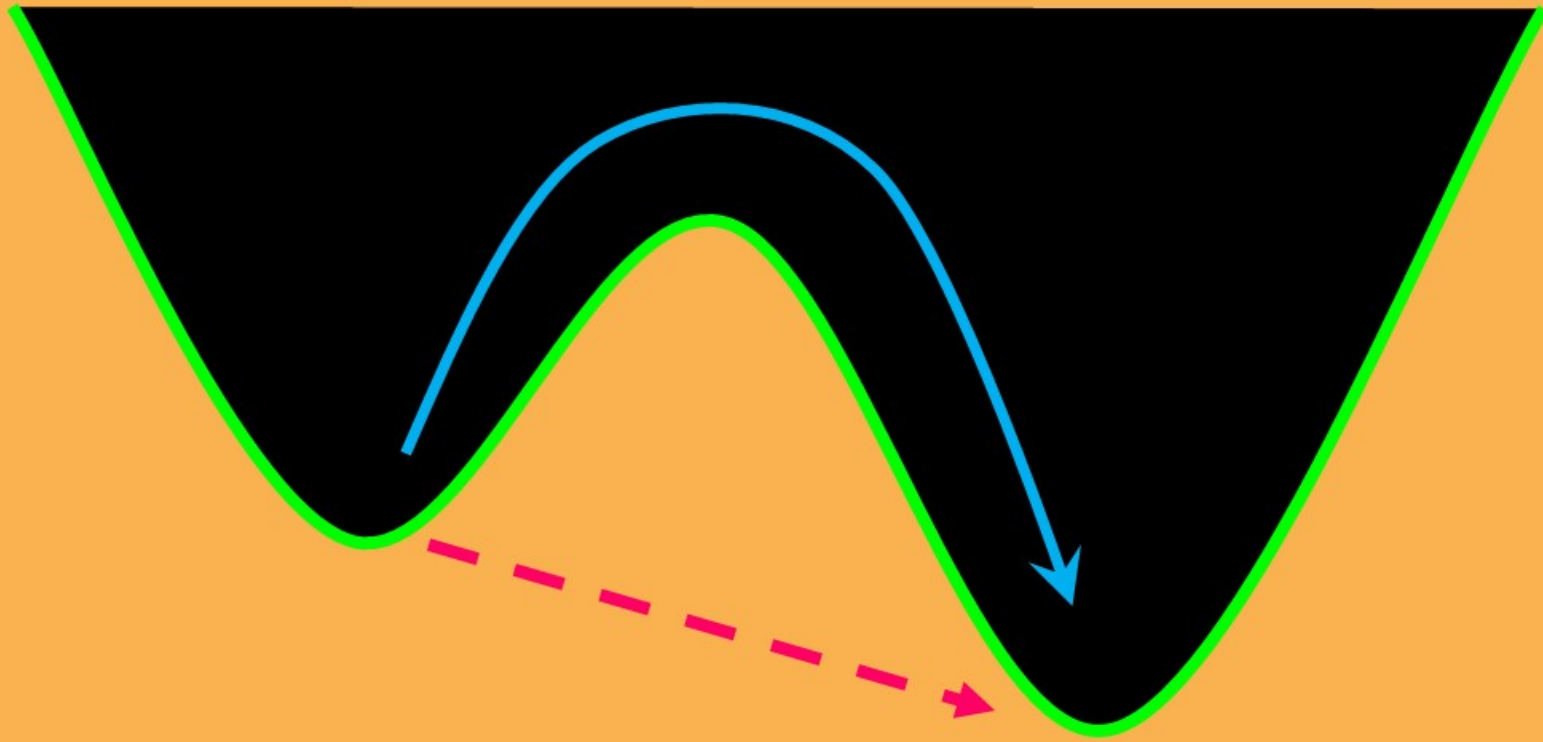


*All the business of war, and indeed all the business of life, is to endeavour to find out what you don't know by what you do; that's what I called guessing what was **at the other side of the hill.***

-- Arthur Wellesley, the "Iron Duke" of Wellington

Imagination = Tunnel Vision

Curiosity = Urge to Explore



Jacobus Henricus van 't Hoff (1852-1911)  
*First Nobel Prize in Chemistry, 1901*



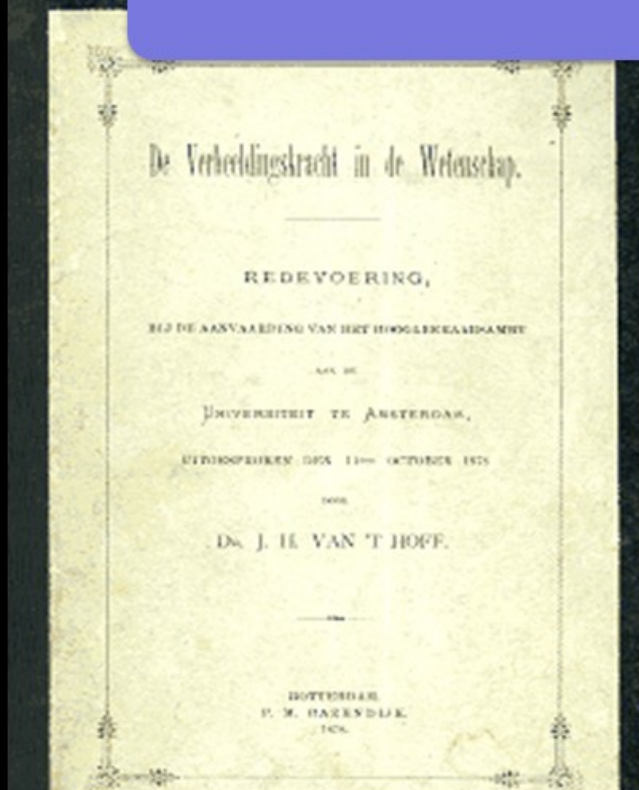
*Stereochemistry*



# Chiral Molecules



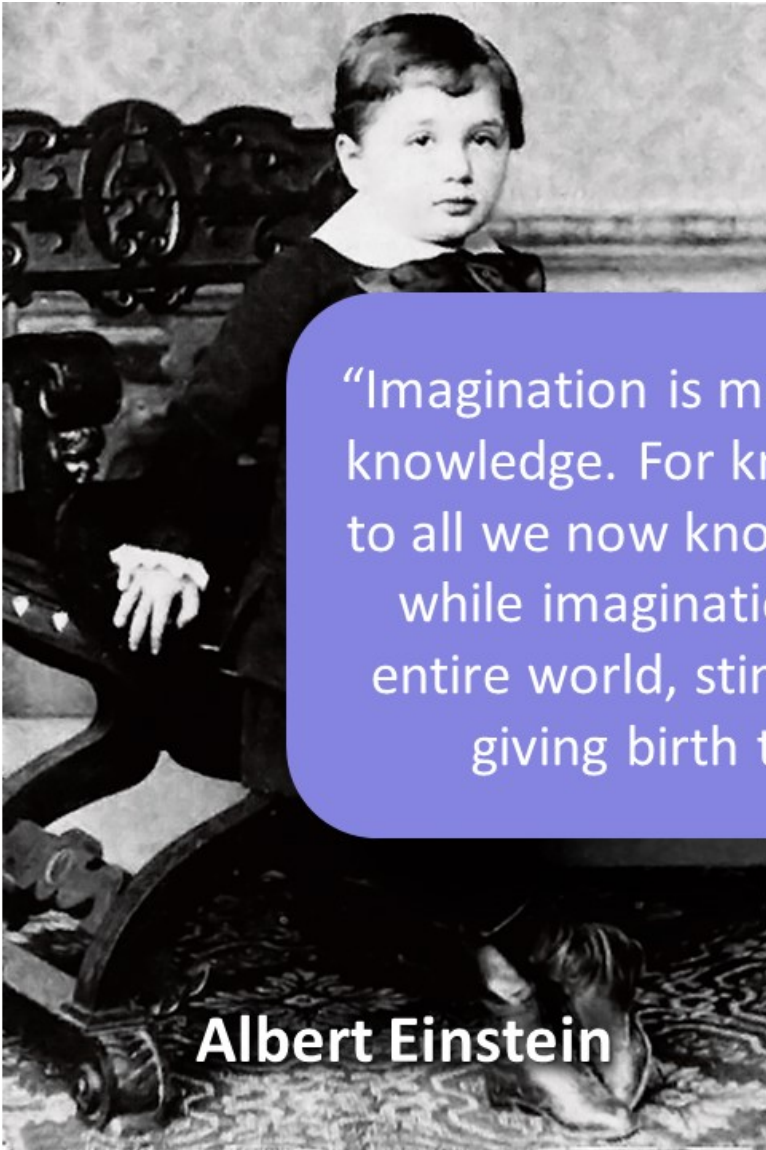
## The Power of Imagination in Science



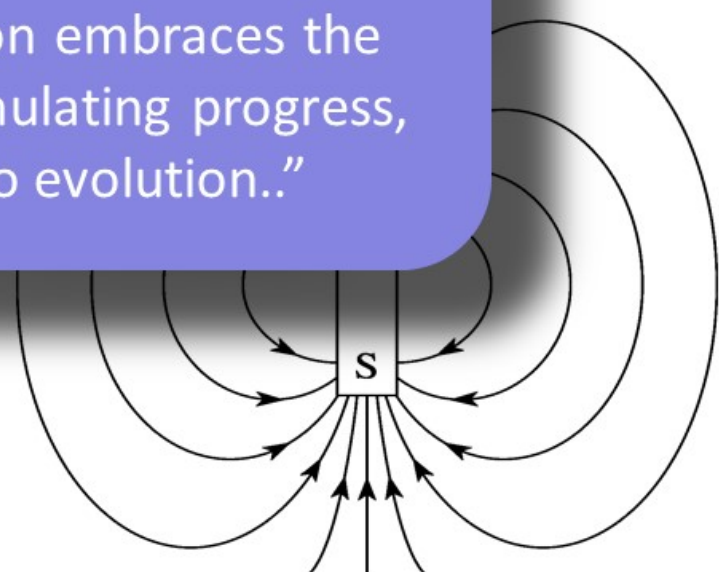
"A Dr. H. van 't Hoff of the Veterinary School at Utrecht has no liking, apparently, for exact chemical investigation. **He has considered it more comfortable to mount Pegasus** (apparently borrowed from the Veterinary School) and to proclaim in his *'La chimie dans l'espace'* how the atoms appear to him to be arranged in space, when he is on the chemical Mt. Parnassus which he has reached by bold flight."

Ampère, Bailly, Bonnet, Boyle, Crookes, Davy, Descartes, Flamsteed, Leibnitz, Newton, Priestley, Ramond, Schopenhauer, Wallace.





“Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, stimulating progress, giving birth to evolution..”



# CREATIVITY TEST



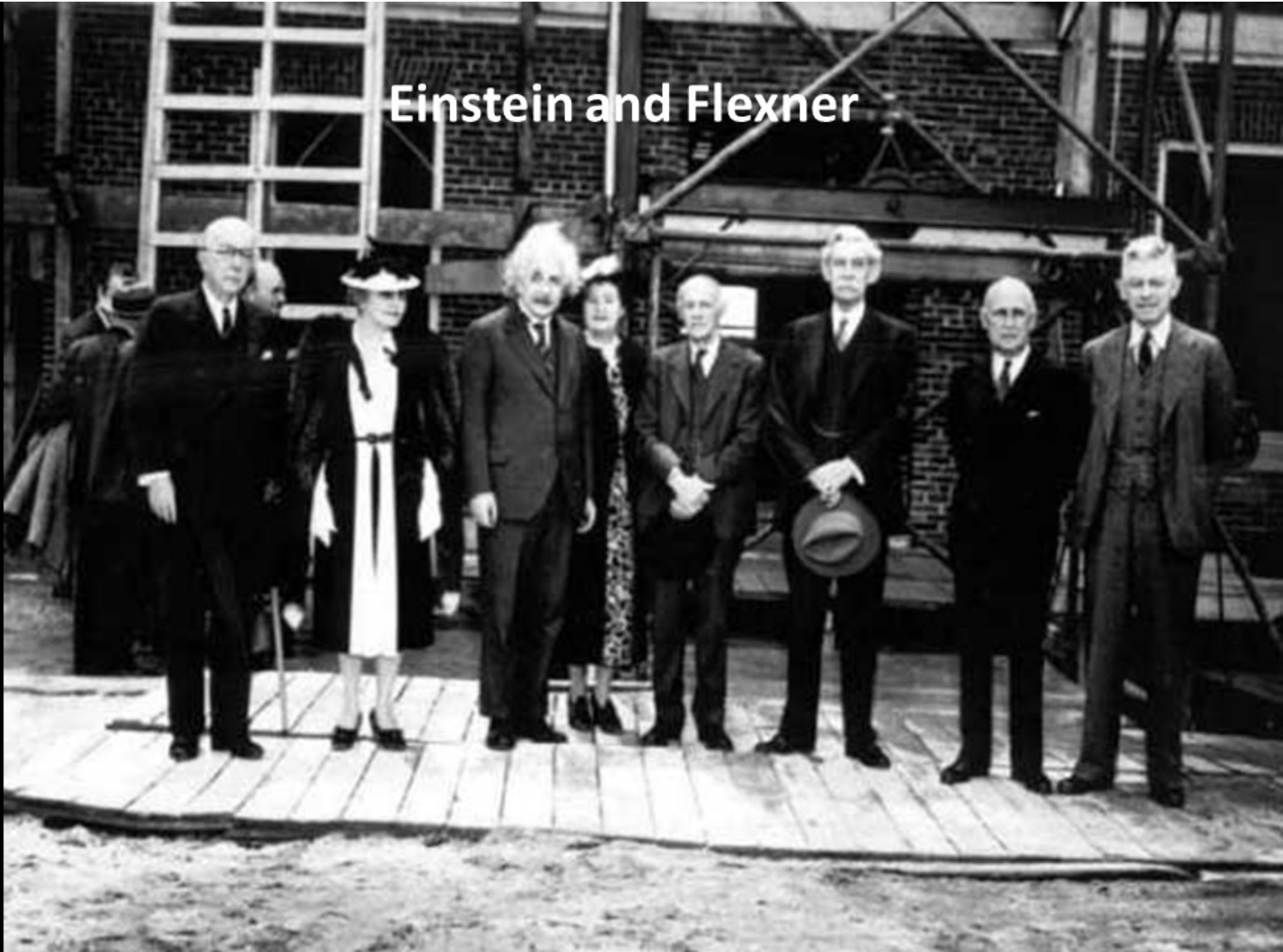
**5 YEAR 98%**

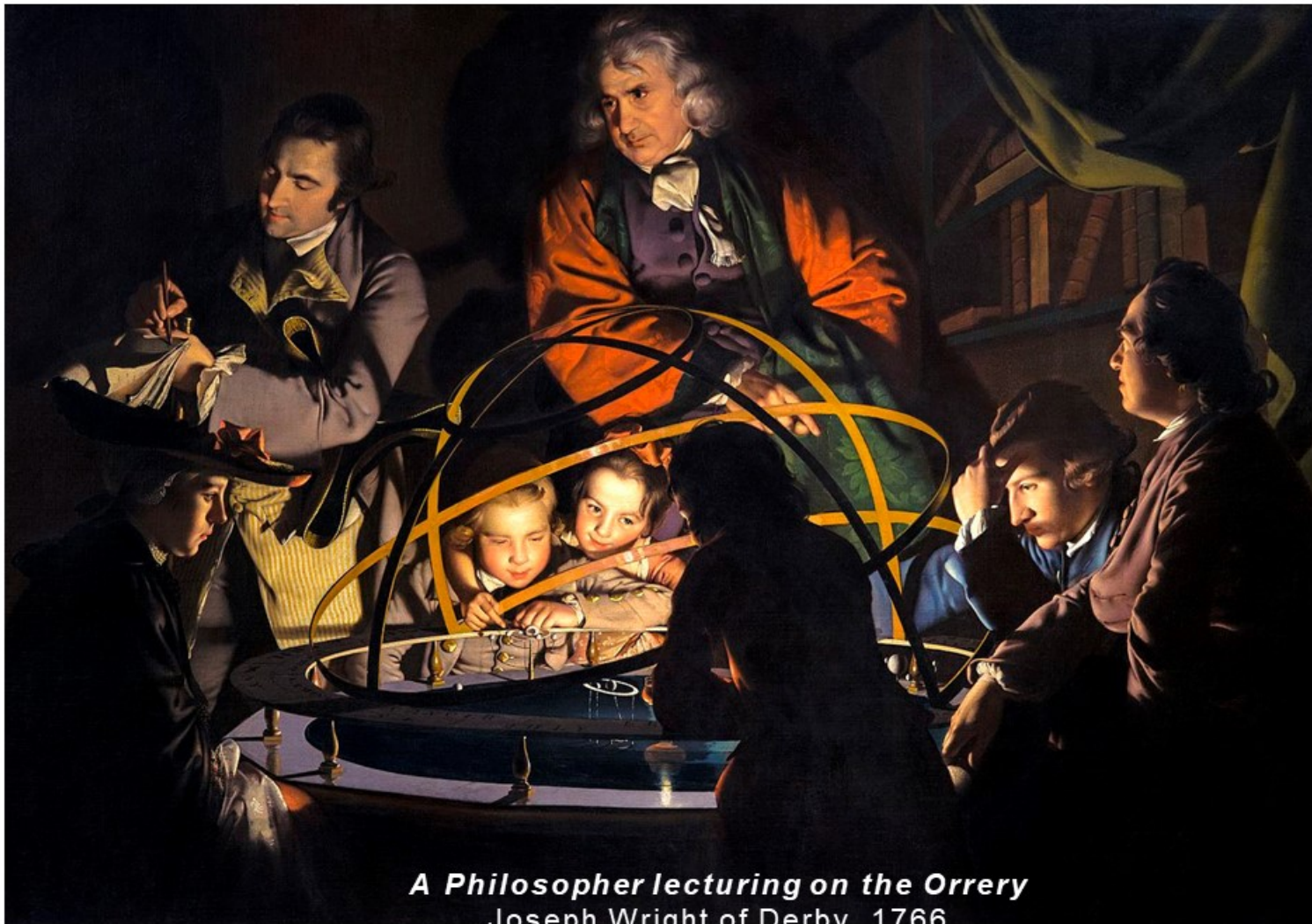
**10 YEAR 30%**

**15 YEAR 12%**

**ADULT 2%**

# Einstein and Flexner



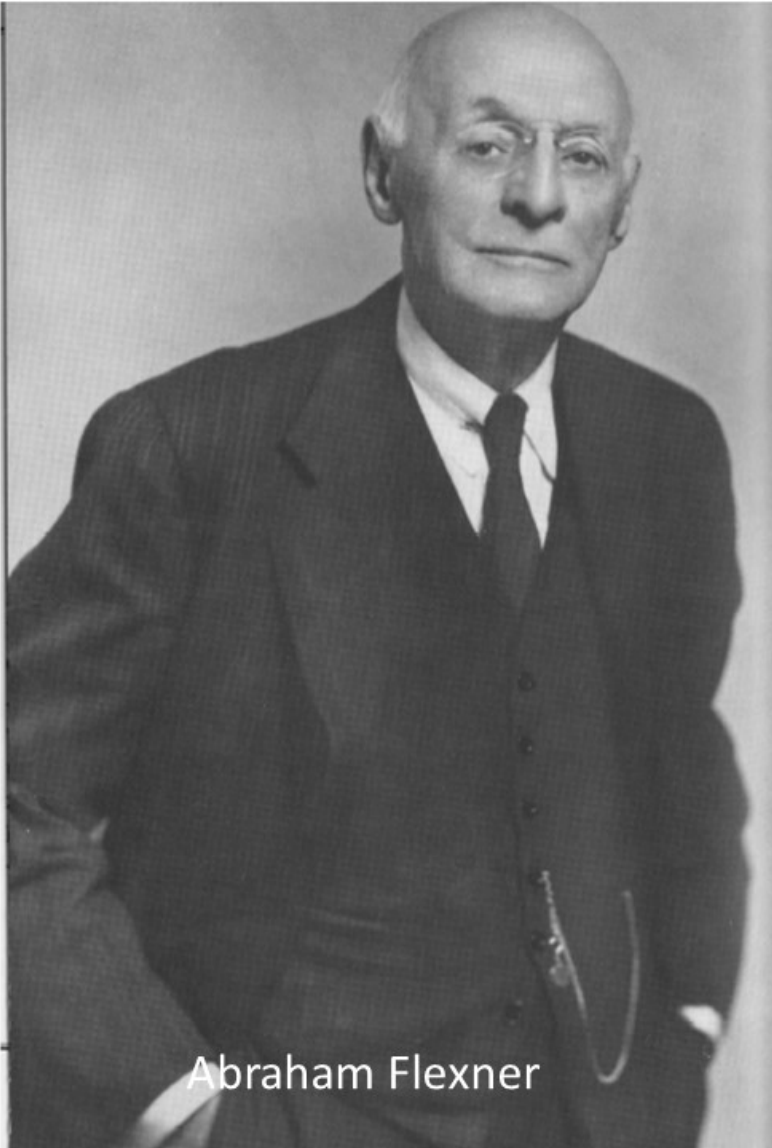


*A Philosopher lecturing on the Orrery*  
Joseph Wright of Derby, 1766

# Public Engagement

*Teaching the scientific method*





Abraham Flexner

Is it not a curious fact that in a world steeped in irrational hatreds which threaten civilization itself, men and women-old and young-detach themselves wholly or partly from the angry current of daily life to devote themselves to the cultivation of beauty, to the extension of knowledge, to the cure of disease, to the amelioration of suffering, just as though fanatics were not simultaneously engaged in spreading pain, ugliness, and suffering? The world has always been a sorry and confused sort of place-yet poets and artists and scientists have ignored the factors that would, if attended to, paralyze them.