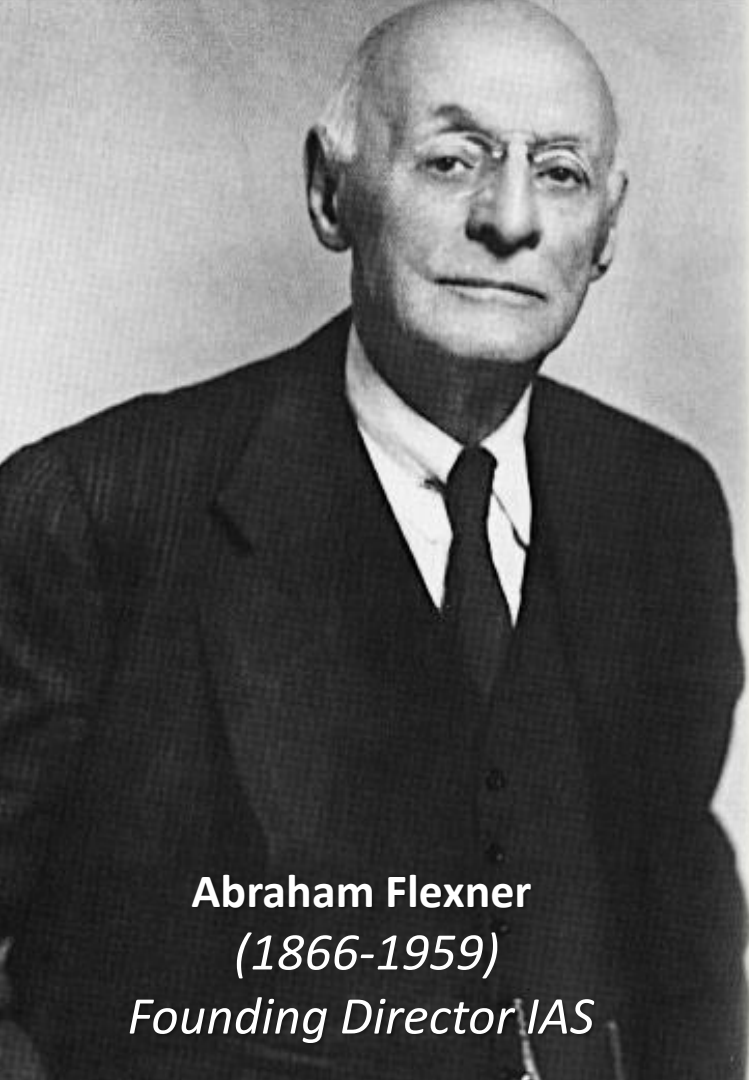


THE USEFULNESS OF USELESS KNOWLEDGE

Robbert Dijkgraaf
Institute for Advanced Study
Princeton, New Jersey

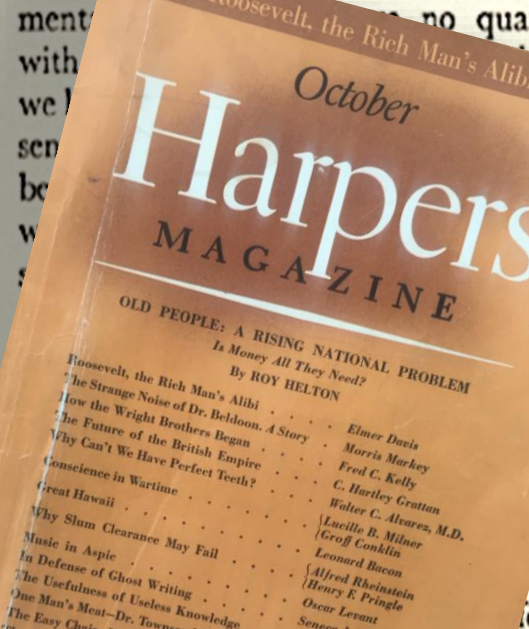


Abraham Flexner
 (1866-1959)
 Founding Director IAS

THE USEFULNESS OF USELESS KNOWLEDGE

BY 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 atten-



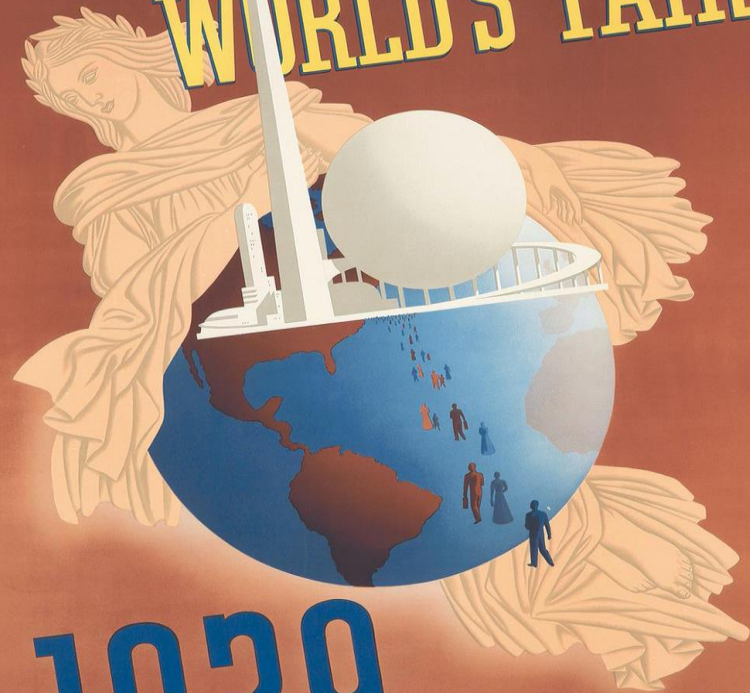
NEW YORK WORLD'S FAIR



THE WORLD OF TOMORROW

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NEW YORK WORLD'S FAIR



1939

ATREATOR

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*Flushing Meadows,
Queens, New York*

FIRST TELEVISION



OPENING SPEECH BY ALBERT EINSTEIN



Missing:
NUCLEAR PHYSICS,
COMPUTERS



Institute for Advanced Study, Princeton (1930)

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.

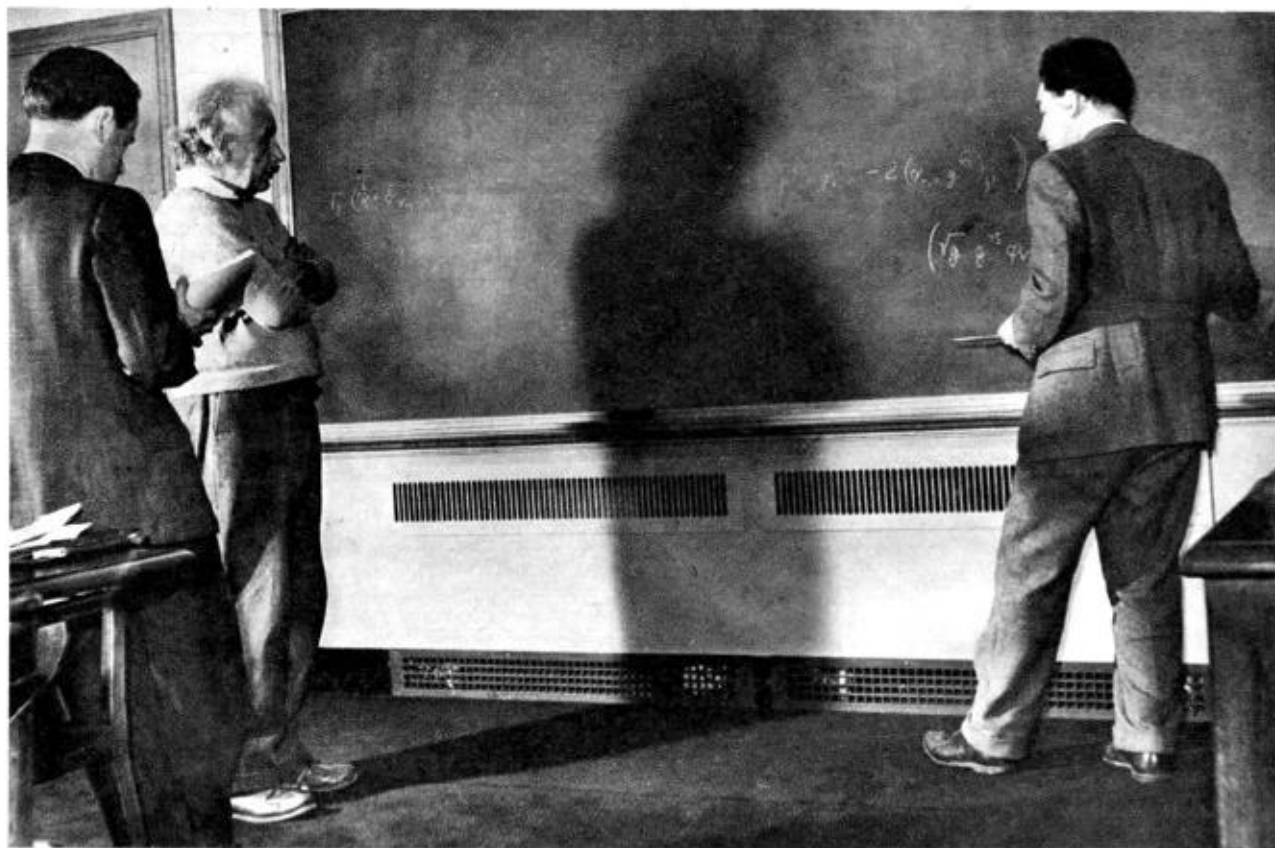
By ELEANOR KITTREDGE

"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



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

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

August 2nd, 1939

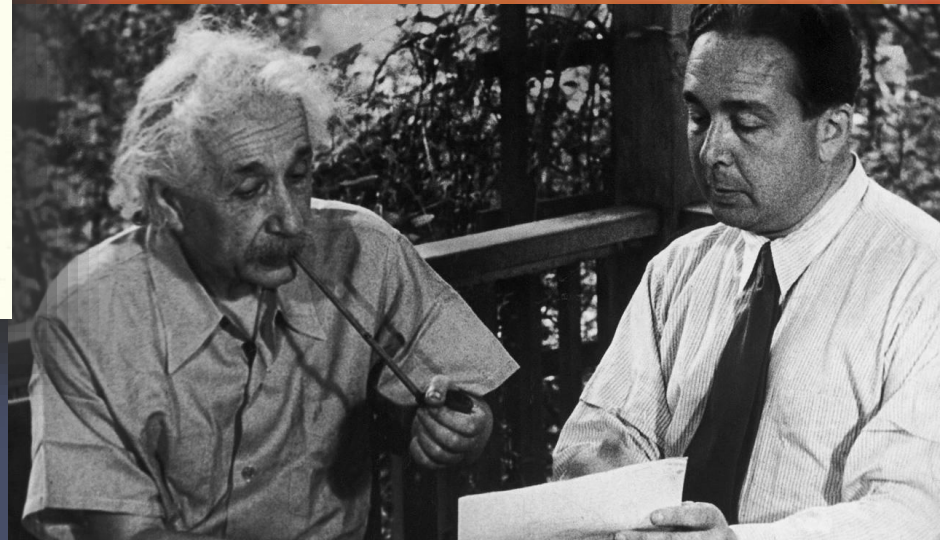
F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

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

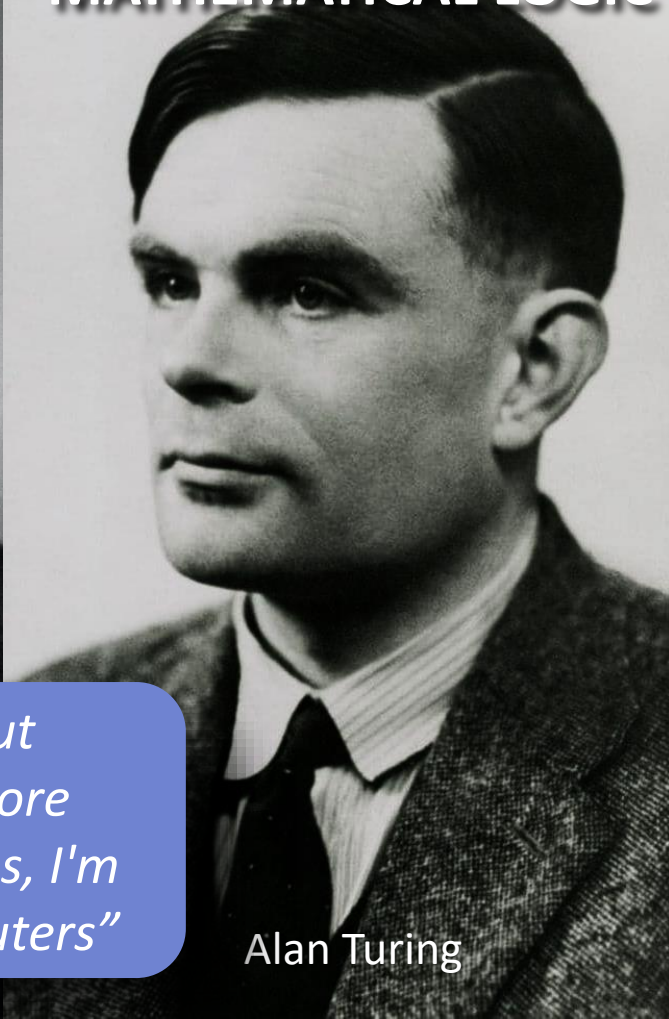


Einstein, Leo Szilard

MATHEMATICAL LOGIC



"I'm thinking about something much more important than bombs, I'm thinking about computers"

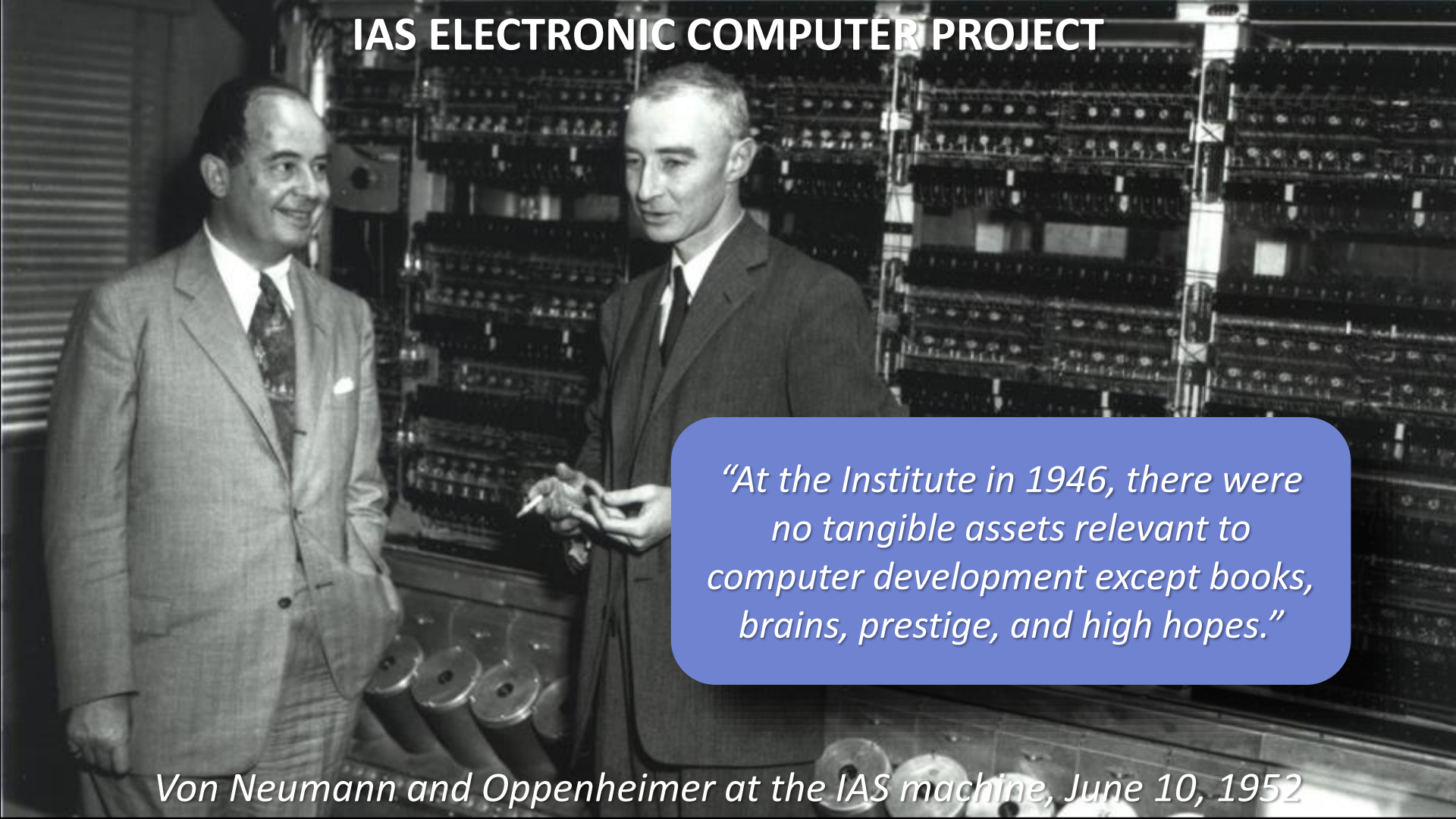


Alan Turing



Kurt Gödel

IAS ELECTRONIC COMPUTER PROJECT



“At the Institute in 1946, there were no tangible assets relevant to computer development except books, brains, prestige, and high hopes.”

Von Neumann and Oppenheimer at the IAS machine, June 10, 1952

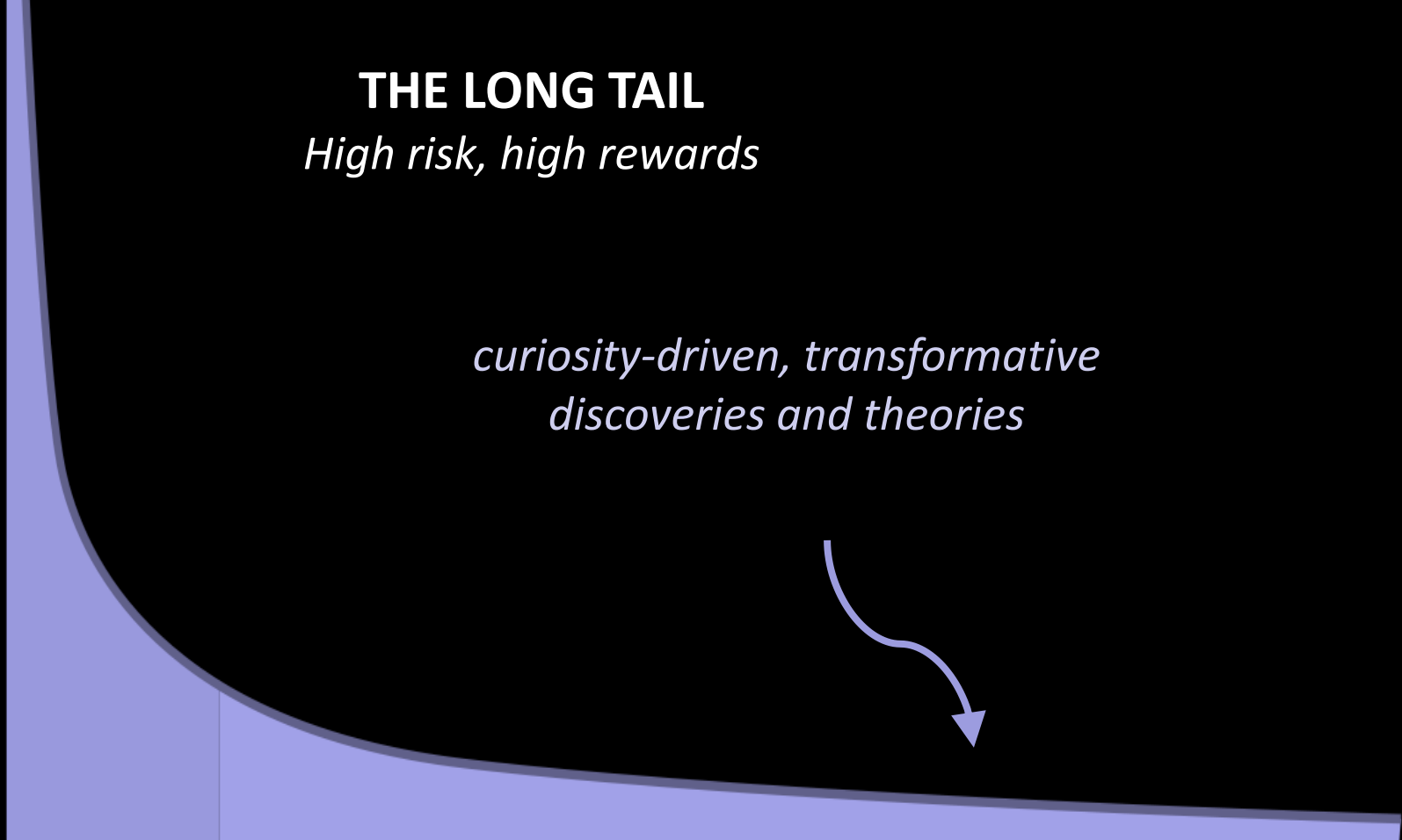
THE LONG TAIL

High risk, high rewards

*curiosity-driven, transformative
discoveries and theories*

Success rate ↑

Intellectual depth →



WHAT IS TECHNOLOGY?

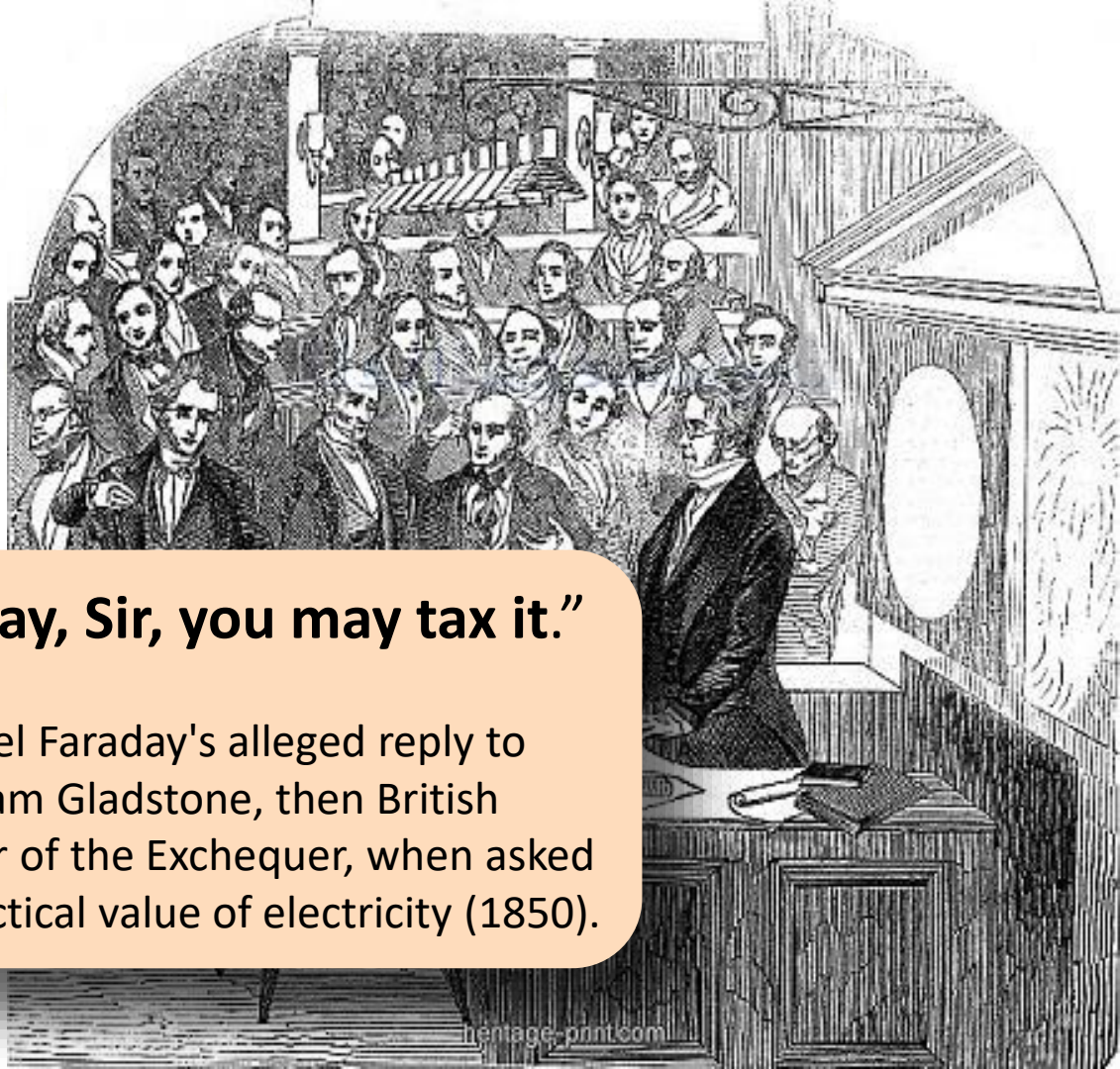
- *Everything discovered after you were born.*
- *Everything that doesn't work.*
- *The dominant force that shapes and changes both nature and culture.*
- *The future is already here—in the minds and laboratories of scientists.*



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

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

Michael Faraday



“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).

MISCELLANEOUS CITY NEWS

EDISON'S ELECTRIC LIGHT.

"THE TIMES" BUILDING ILLUMINATED BY ELECTRICITY.

Edison's central station, at No. 257 Pearl-street, was yesterday one of the busiest places down town, and Mr. Edison was by far the busiest man in the station. The giant dynamos were started up at 3 o'clock in the afternoon, and, according to Mr. Edison, they will go on forever unless stopped by an earthquake. One-third of lower district was lighted up, the territory being within the boundaries of Nassau, Pearl streets and Spruce and Wall streets. During the past few weeks the Edison Electric Illuminating Company has been engaged in completing the installations in the premises of its customers by the insertion of meters and lamps, and in procuring inspection of such premises by the Fire Underwriters. As the Board of Underwriters has but one expert, Mr. Osborne, the process has been necessarily slow, but such portions as has been inspected was supplied last night. Mr. Edison said that the work will be pushed as rapidly

T. A. EDISON.
Electric-Lamp.

No. 223,898.

Patented Jan. 27, 1880.



The whole lamp looks so much like a gas-burner surmounted by a shade that nine people out of ten would not have known the rooms were lighted by electricity, except that the light was more brilliant than gas and a hundred times steadier. To turn on the light nothing is required but to turn the thumbscrew; no matches are needed, no patent appliances. As soon as it is dark enough to need artificial light, you turn the thumbscrew and the light is there, with no nauseous smell, no flicker and no glare.



integrated circuits



nanomaterials

QUANTUM MECHANICS

30% of GDP



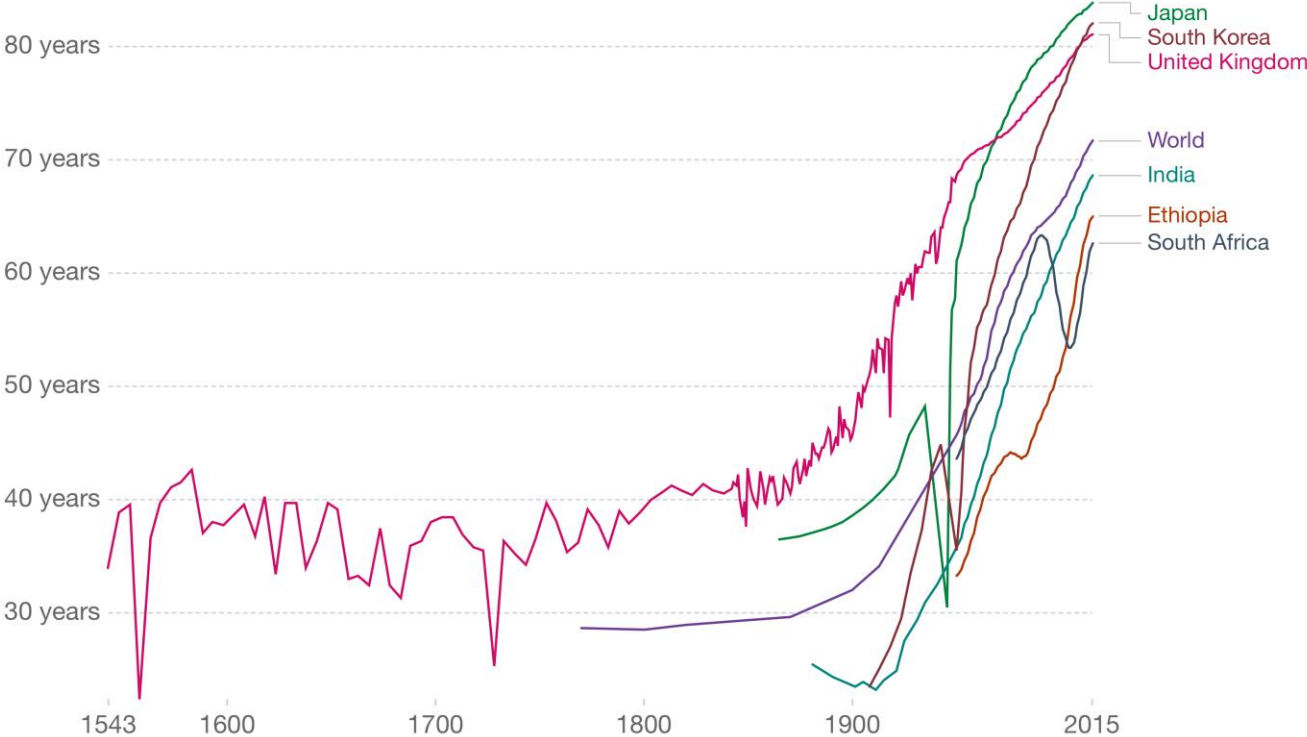
lasers



1 μm
quantum computers

DOUBLING OF LIFE EXPECTANCY IN LAST 150 YEARS

Life expectancy, 1543 to 2015



Source: Riley (2005), Clio Infra (2015), and UN Population Division (2019)

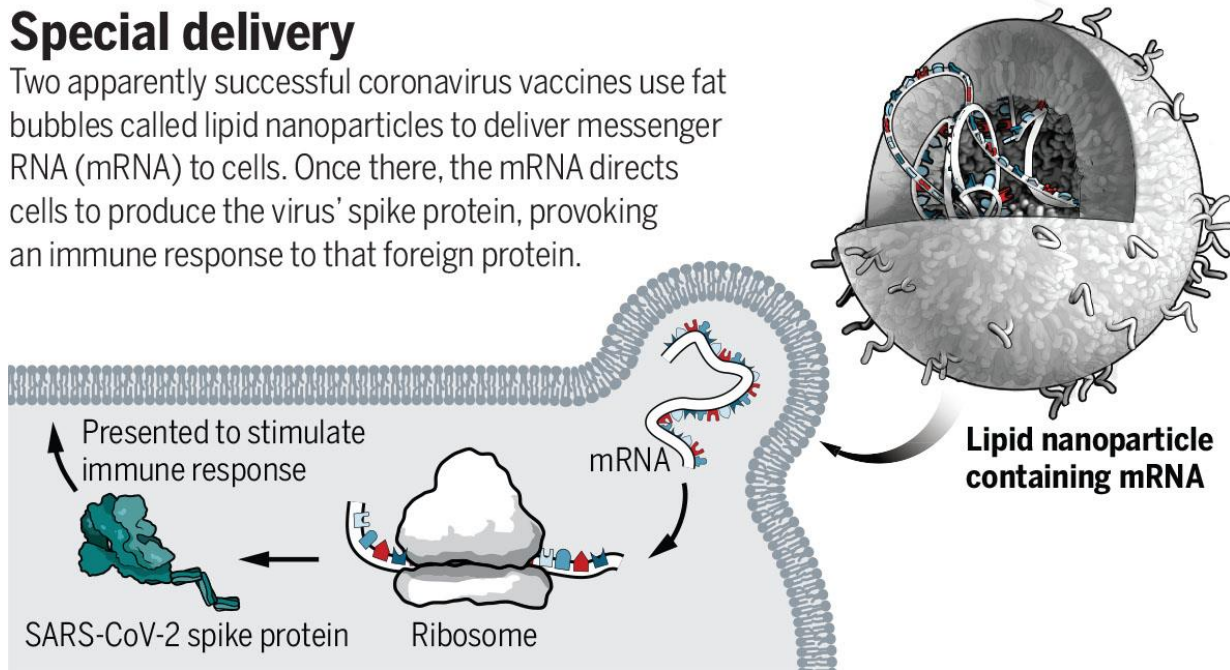
OurWorldInData.org/life-expectancy • CC BY

Note: Shown is period life expectancy at birth, the average number of years a newborn would live if the pattern of mortality in the given year were to stay the same throughout its life.

CORONAVIRUS VACCINES

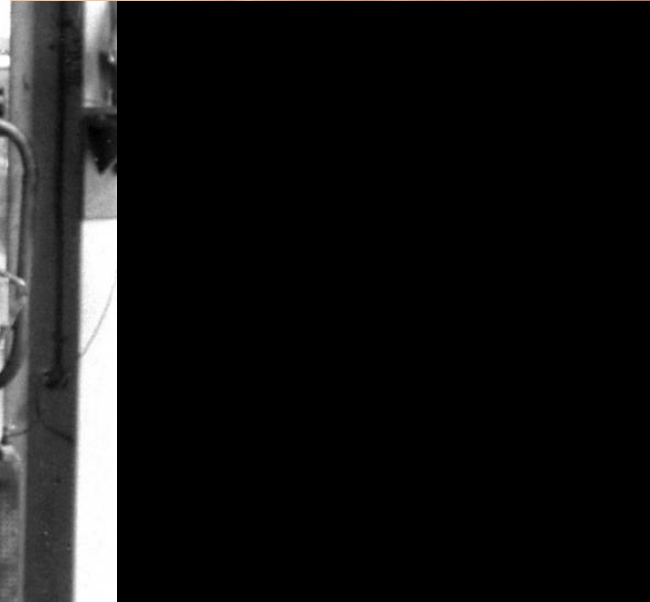
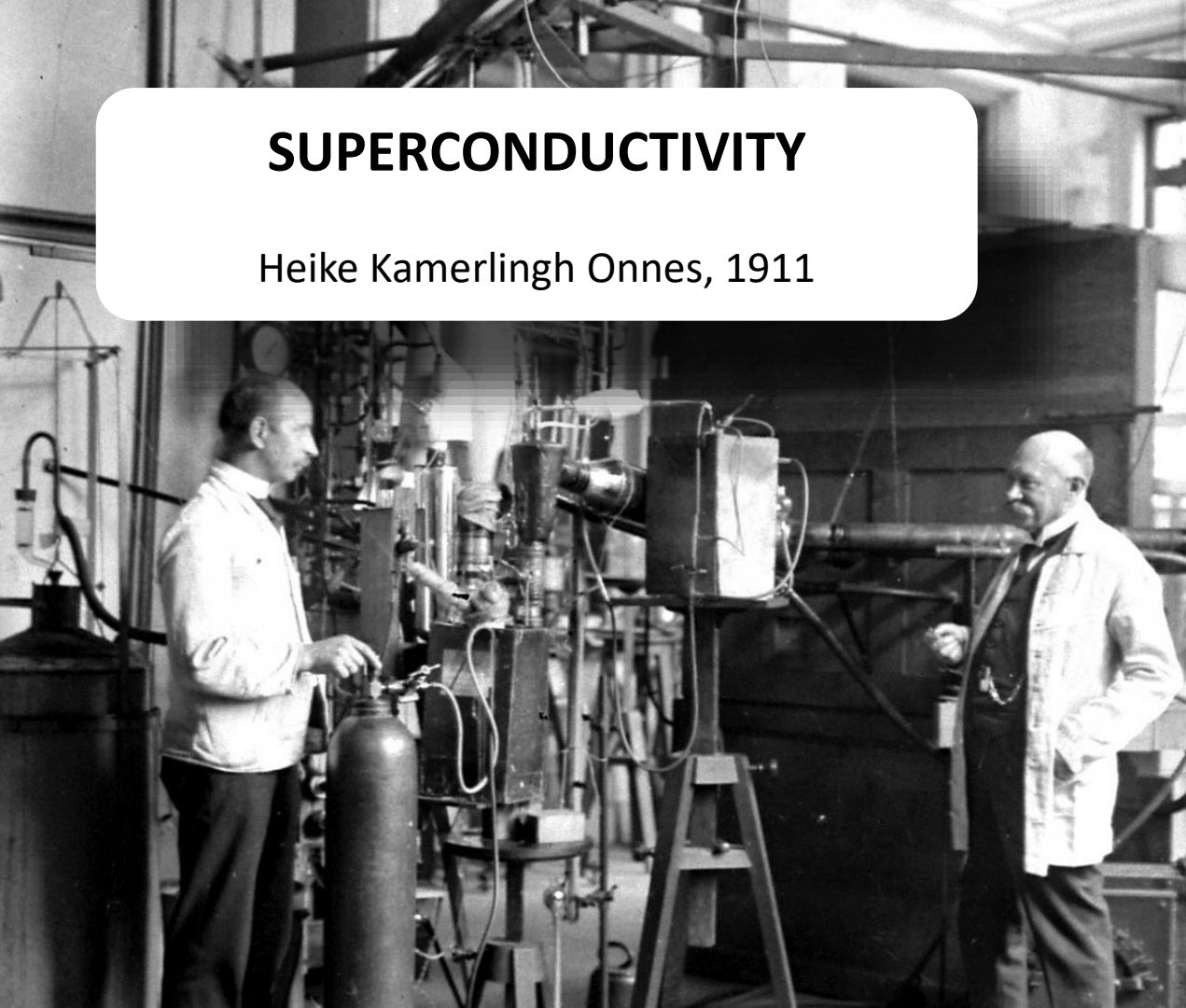
Special delivery

Two apparently successful coronavirus vaccines use fat bubbles called lipid nanoparticles to deliver messenger RNA (mRNA) to cells. Once there, the mRNA directs cells to produce the virus' spike protein, provoking an immune response to that foreign protein.



SUPERCONDUCTIVITY

Heike Kamerlingh Onnes, 1911



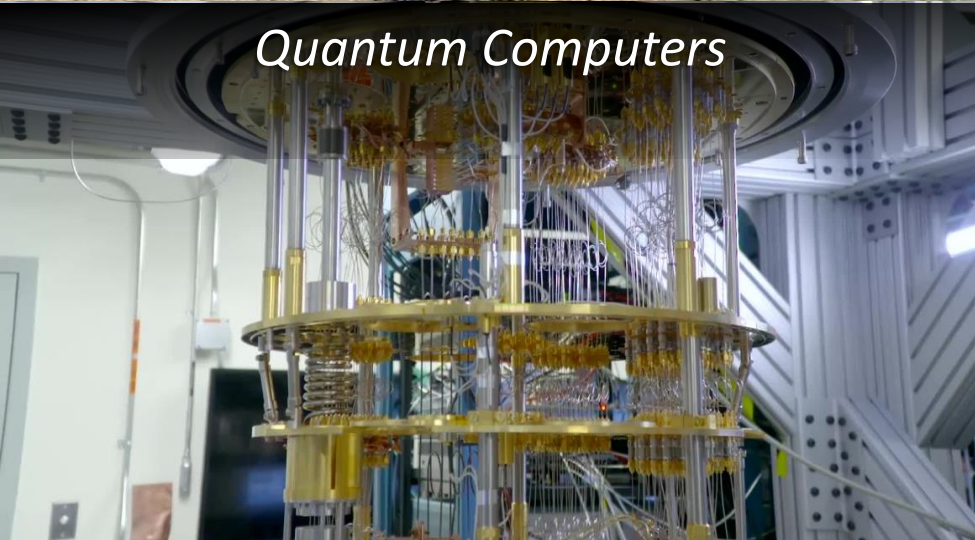
Maglev



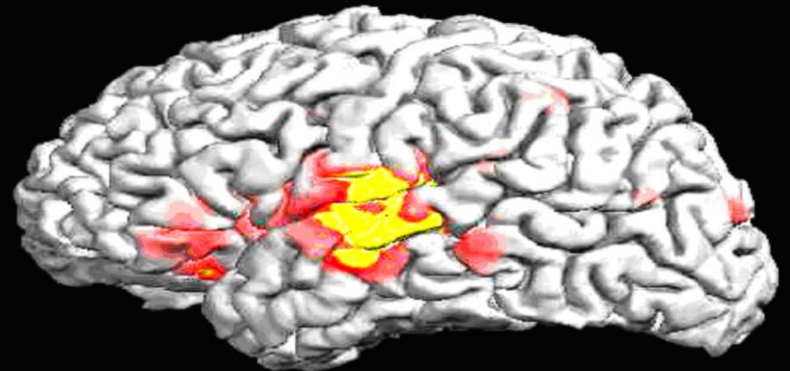
Fmri Scanners

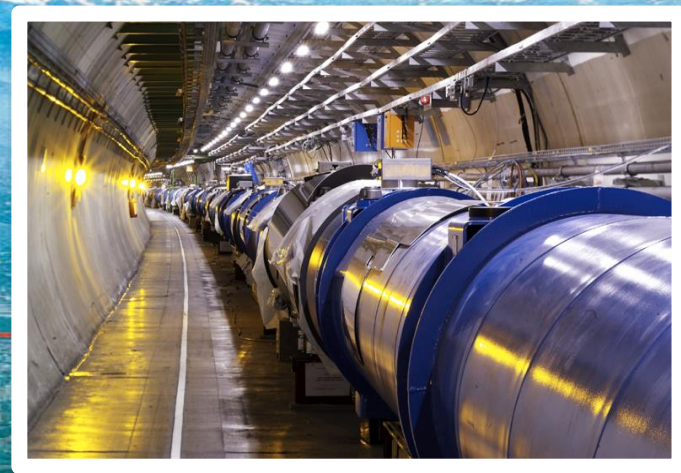
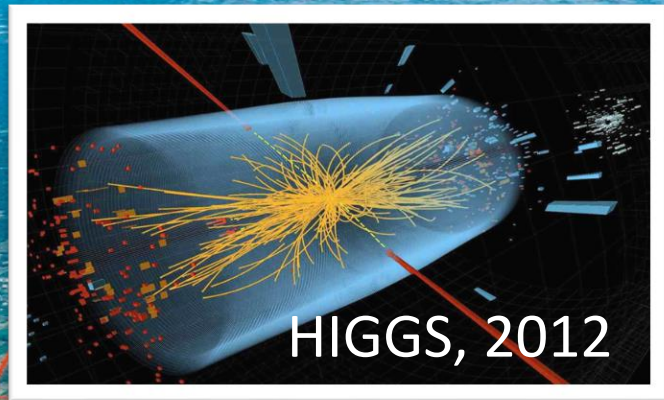


Quantum Computers



Neuroscience





SUPERCONDUCTING MAGNETS

Large Hadron Collider, CERN

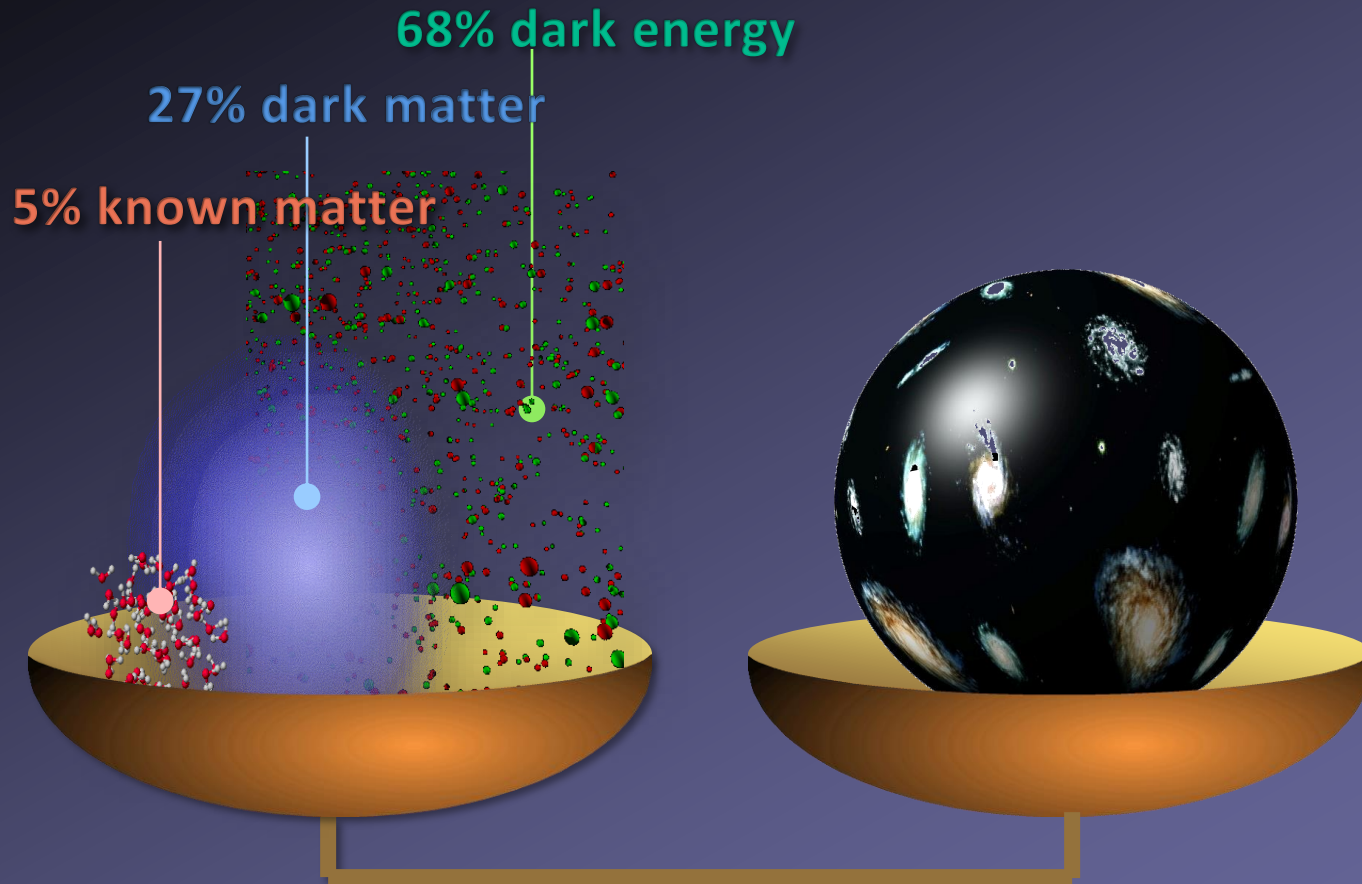
DARK KNOWLEDGE

HIC SUNT DRACONES

Do we know what we don't know?



Known Science



WEIGHT OF THE UNIVERSE: 95% UNKNOWN

FROM BUILDING BLOCKS TO DESIGN

From the 20th century to the 21st century



What we know we don't know

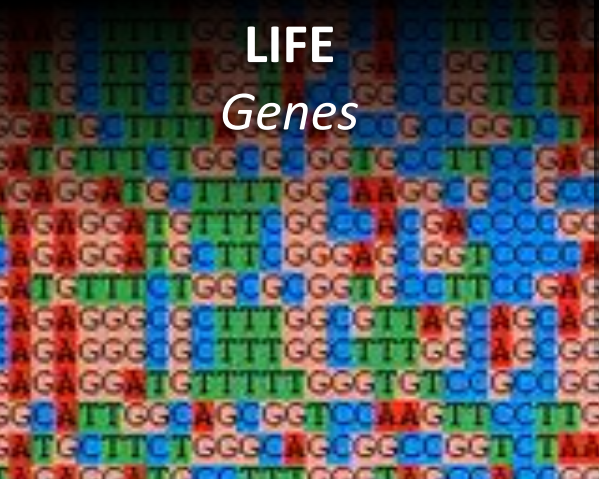


NATURE

What we know

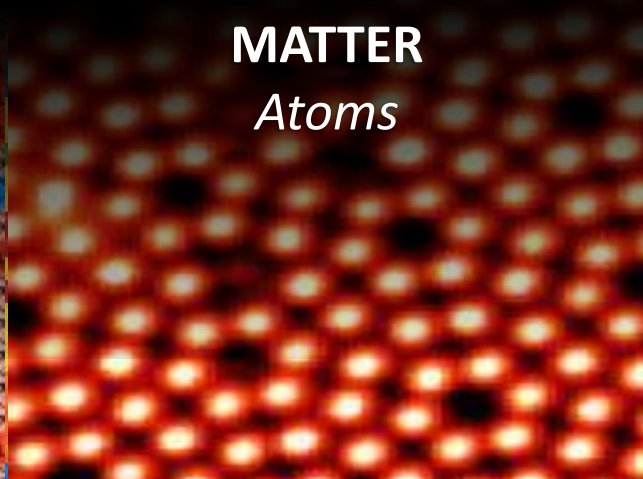
LIFE

Genes



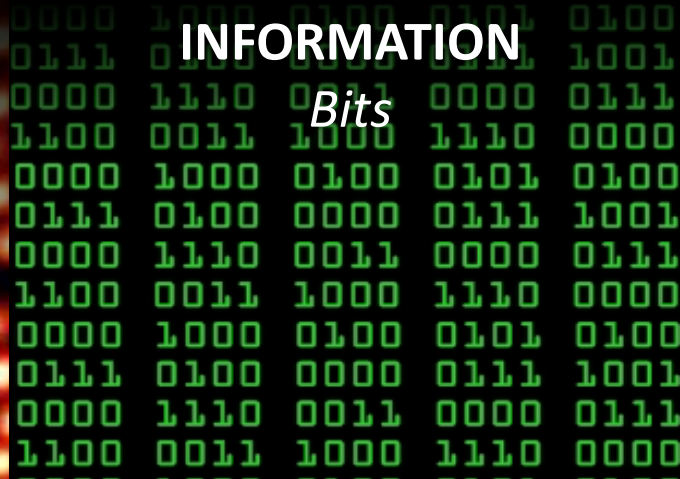
MATTER

Atoms

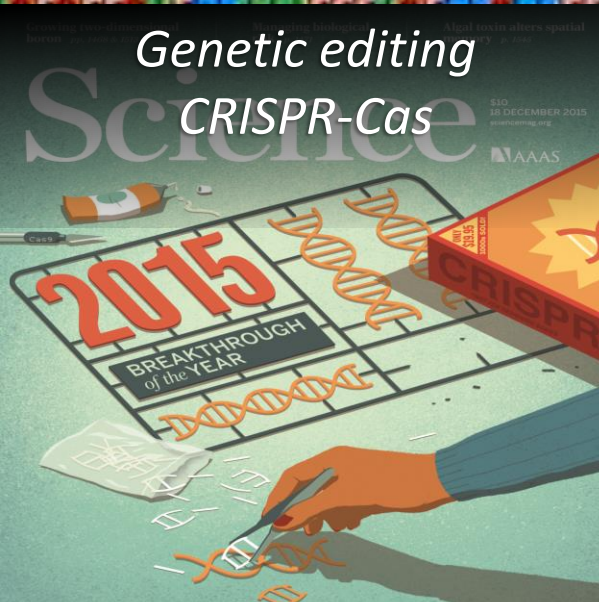


INFORMATION

Bits



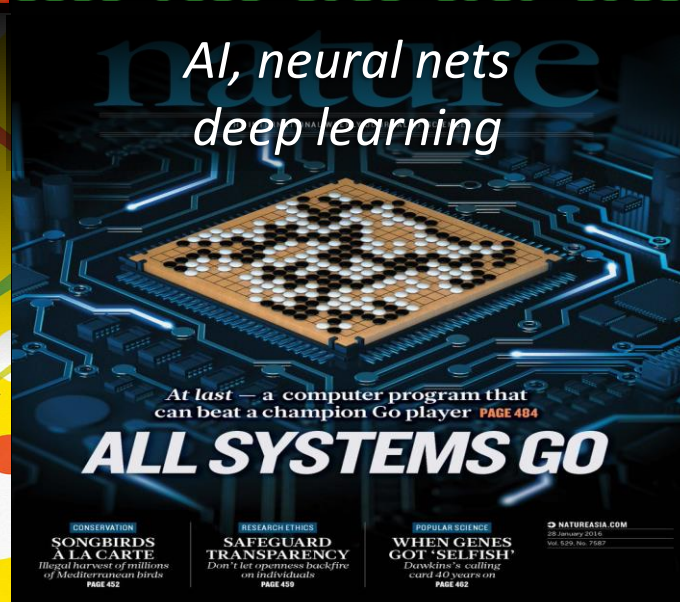
Genetic editing
CRISPR-Cas



Quantum technology
designer materials



AI, neural nets
deep learning



CONSERVATION SONGBIRDS A LA CARTE Illegal harvest of millions of Mediterranean birds PAGE 52

RESEARCH ETHICS SAFEGUARD TRANSPARENCY Don't let openness backfire on individuals PAGE 69

POPULAR SCIENCE WHEN GENES GOT 'SELFISH' Darwin's scullion card 40 years on PAGE 82

NATURE.COM/NATURE 14 November 2017 £10 Vol. 549, No. 7671

NATURE 20 January 2016 Vol. 529, No. 7587

GENETIC ENGINEERING

Personalized medicine

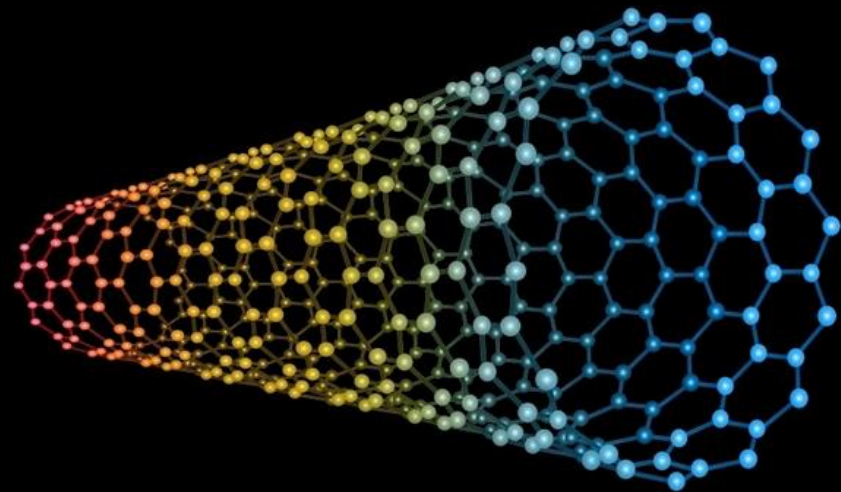
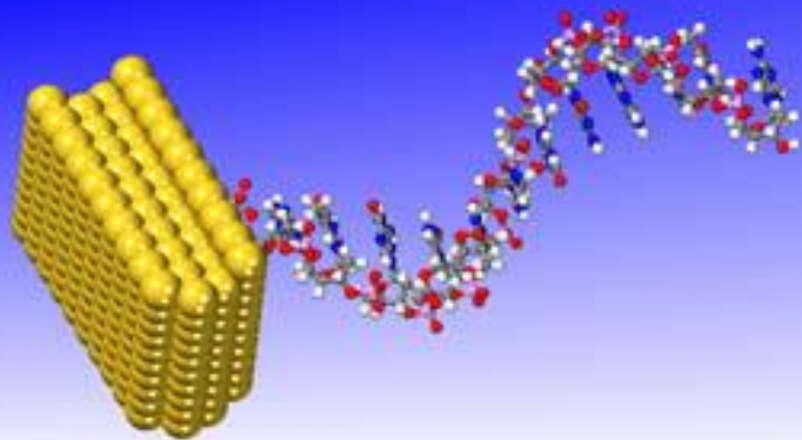
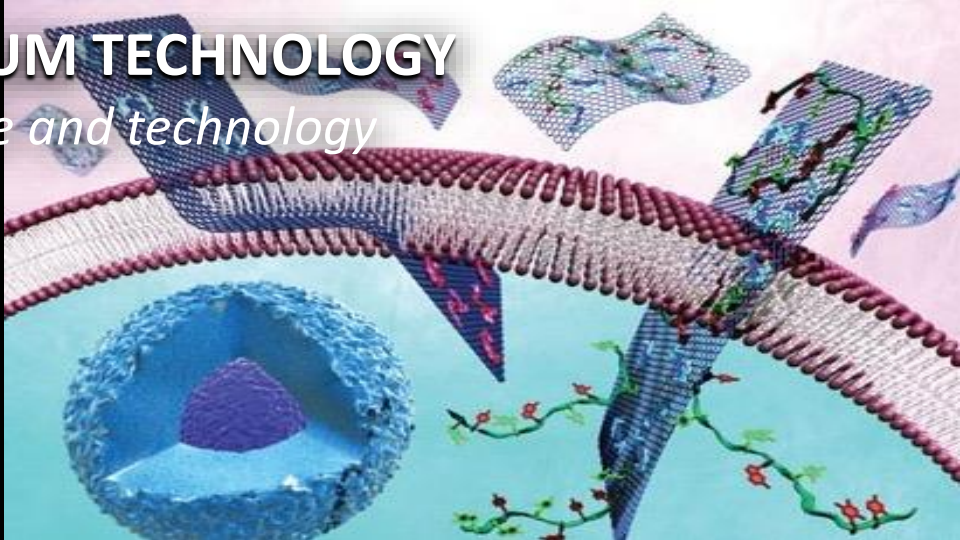
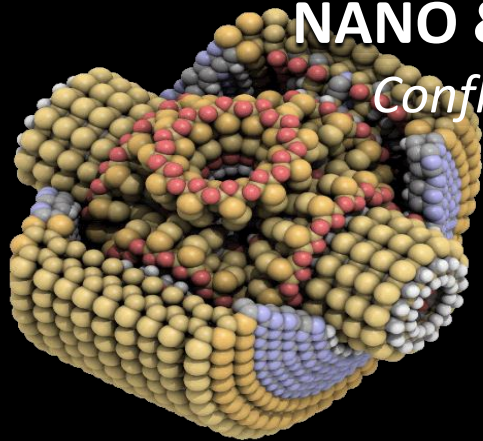
Gene therapy

*Bio-engineering
materials*

*Synthetic biology
Life 2.0*

NANO & QUANTUM TECHNOLOGY

Confluence of life and technology



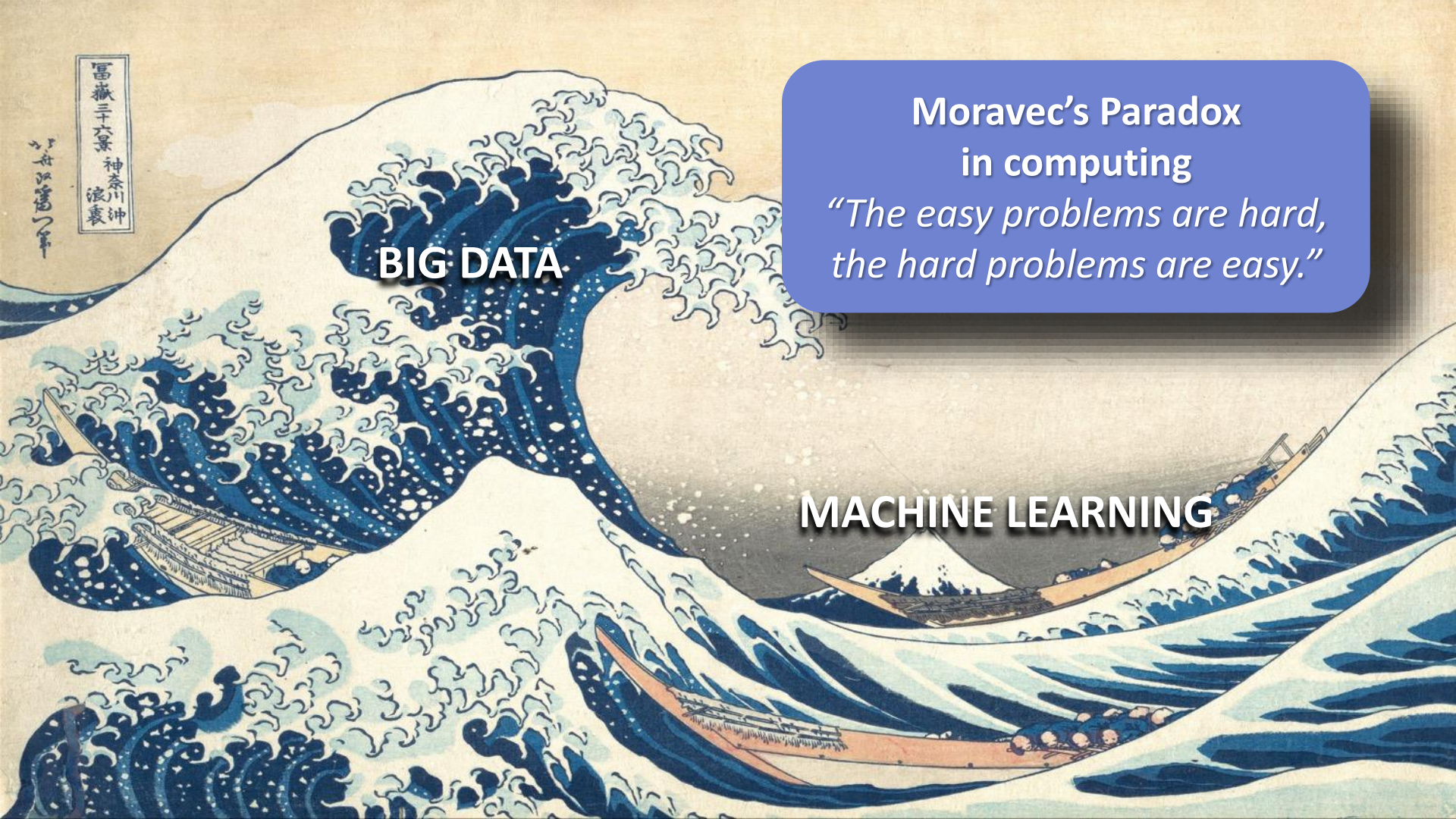
富嶽三十六景 神奈川 浪裏

葛飾 貞房 画

BIG DATA

Moravec's Paradox
in computing
*"The easy problems are hard,
the hard problems are easy."*

MACHINE LEARNING



'It will change everything': DeepMind's AI makes gigantic leap in solving protein structures

Google's deep-learning program for determining the 3D shapes of proteins stands to transform biology, say scientists.

Ewen Callaway

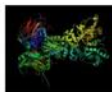


A protein's function is determined by its 3D shape. Credit: DeepMind

 [PDF version](#)

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AI protein-folding algorithms solve structures faster than ever



The revolution will not be crystallize: a new method sweeps through structural biology



The computational protein designers

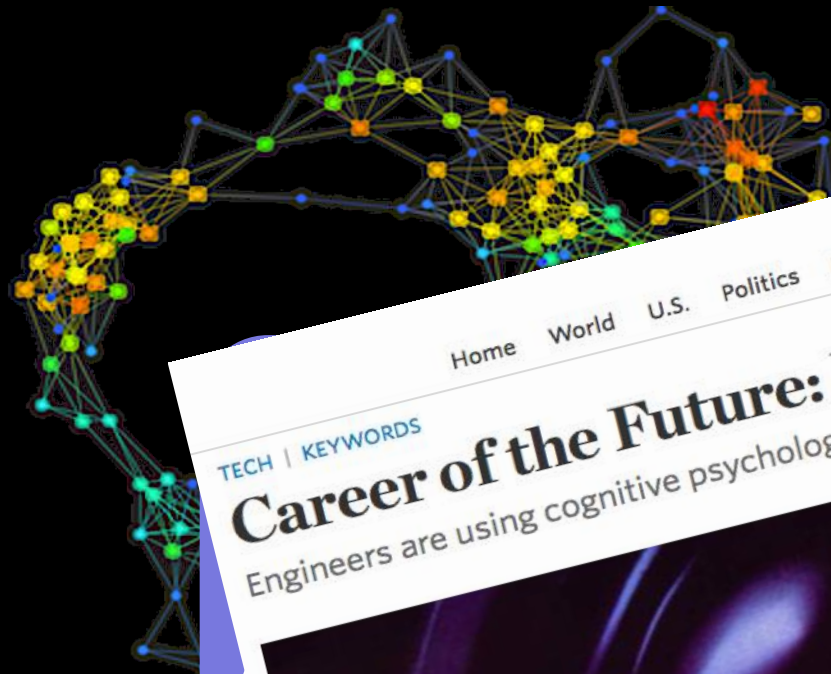


Revolutionary microscopy



DEEP LEARNING IN SCIENCE

FINDING MATHEMATICAL STRUCTURES IN COMPLEXITY



THE WALL STREET JOURNAL

Home World U.S. Politics Economy Business Tech Markets Opinion Arts Life

TECH | KEYWORDS

Career of the Future: Robot Psychologist

Engineers are using cognitive psychology to figure out how AIs think and make them more a



The eye of
Bowman, in

DEEP LEARNING:

Alchemy or Science?

IAS | INSTITUTE FOR
ADVANCED STUDY

IS AI THE NEW ALCHEMY?

LeCun vs Rahimi: Has Machine Learning Become Alchemy?

 Synced Dec 12, 2017 · 4 min read ★



Prominent AI researchers call the entire field "alchemy"

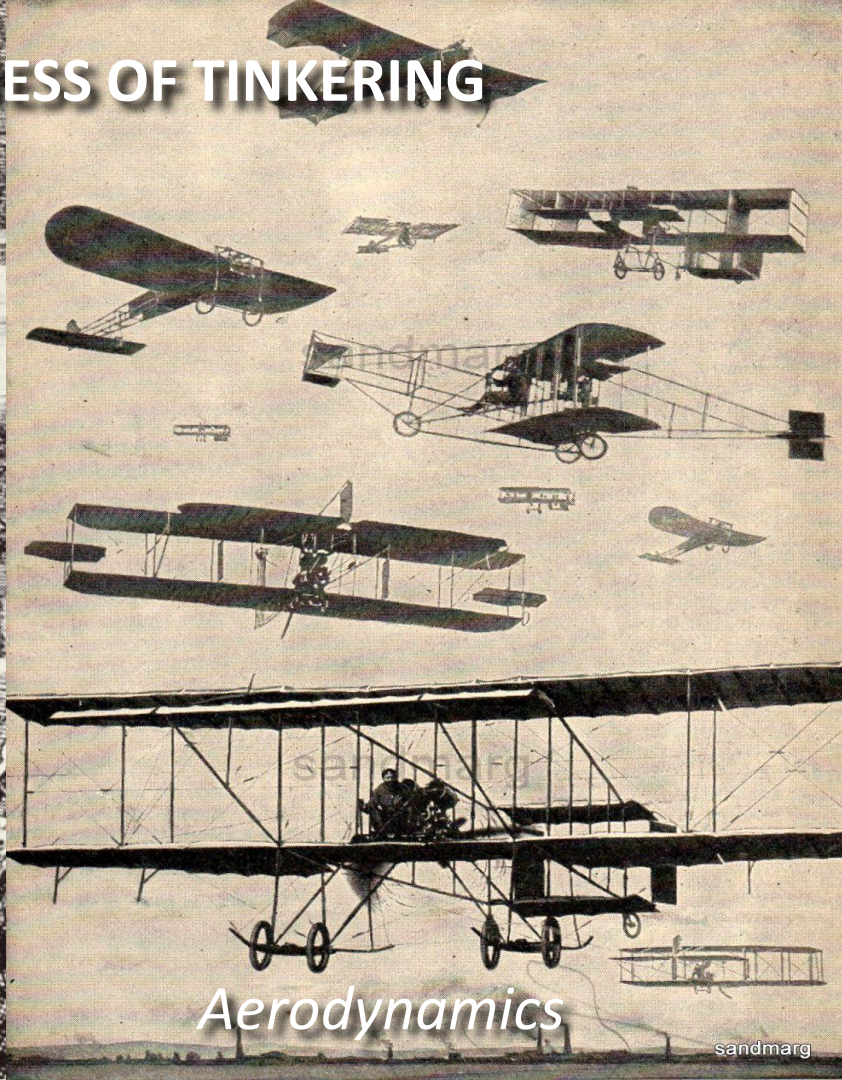
CORY DOCTOROW / 6:12 AM FRI MAY 4, 2018



THE USEFULNESS OF TINKERING



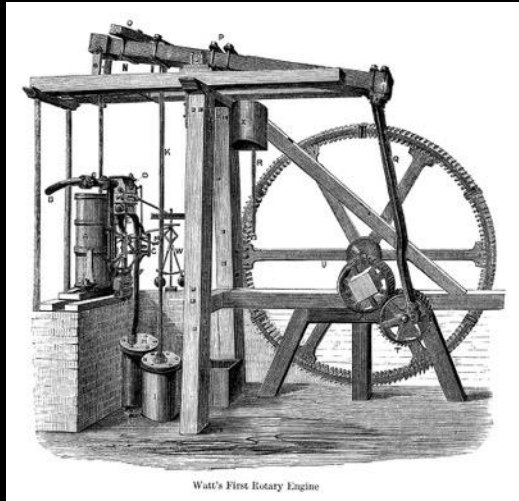
Optics



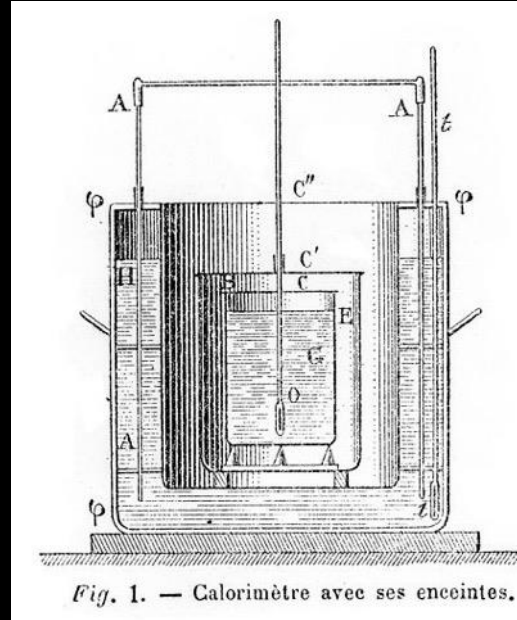
Aerodynamics

“THE USELESSNESS OF USEFUL KNOWLEDGE”

From applications to experiments to theory



Steam engines



*Controlled
experiments*

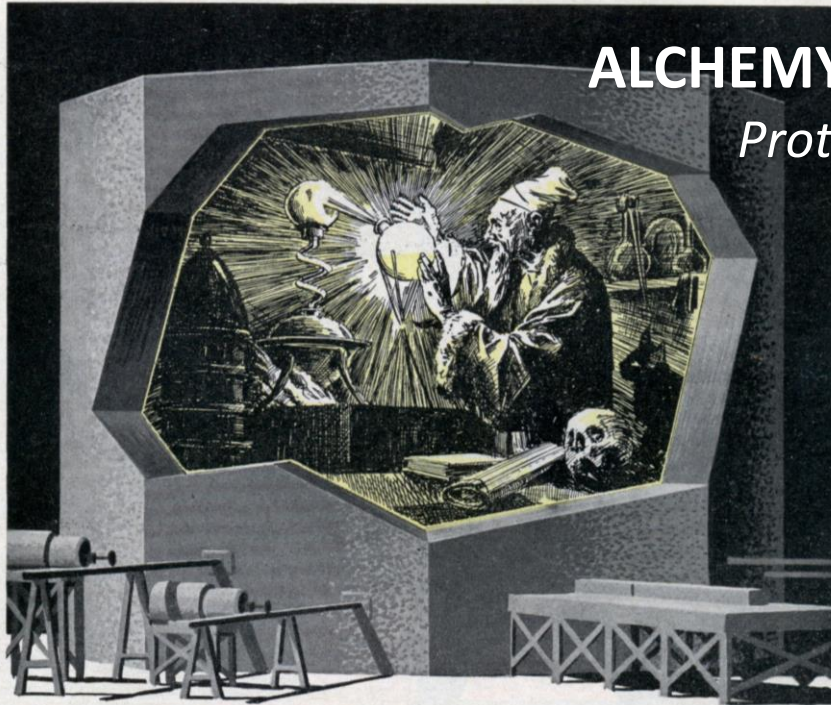


$$\Delta S \geq 0$$

*Laws of
Thermodynamics*

ALCHEMY RECONSIDERED

Proto-chemistry?



Dreams of the ancient alchemists come true in the chain-reacting pile at Oak Ridge, Tenn.

U. S. Alchemists Make Gold

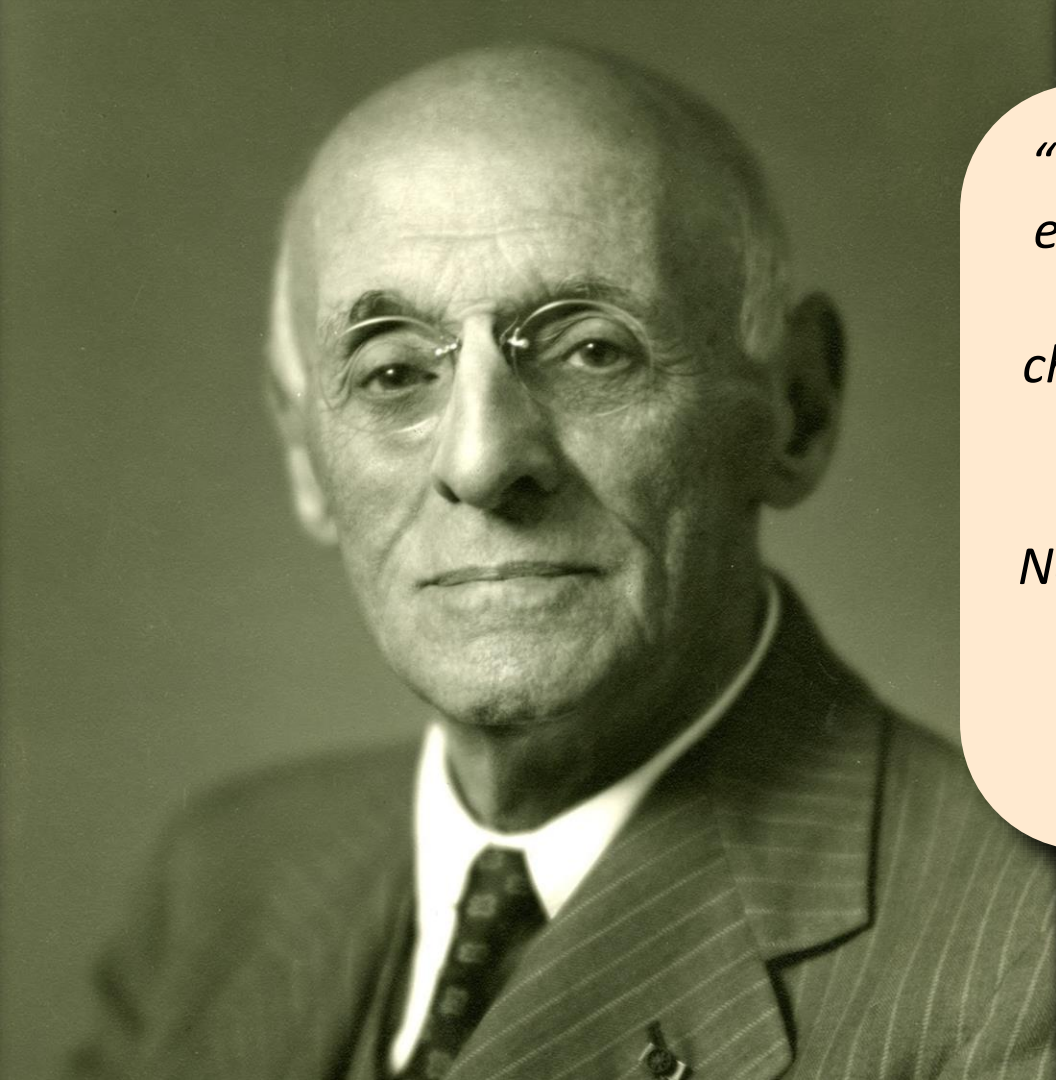
Applying atomic magic to aid medicine and research, radiochemists duplicate nature's elements and create new ones.

By Alden P. Armagnac

Drawings by Ray Pioch

Strange to say, this extraordinary way of acting actually enhances the gold's value. What makes it so desirable is the fact that it is radioactive. Hence the ray-emitting "radio-gold" offers medical men a priceless tool for treating such maladies as leukemia, lymphoma and Hodgkin's disease. At one institution, the University of Michigan, it

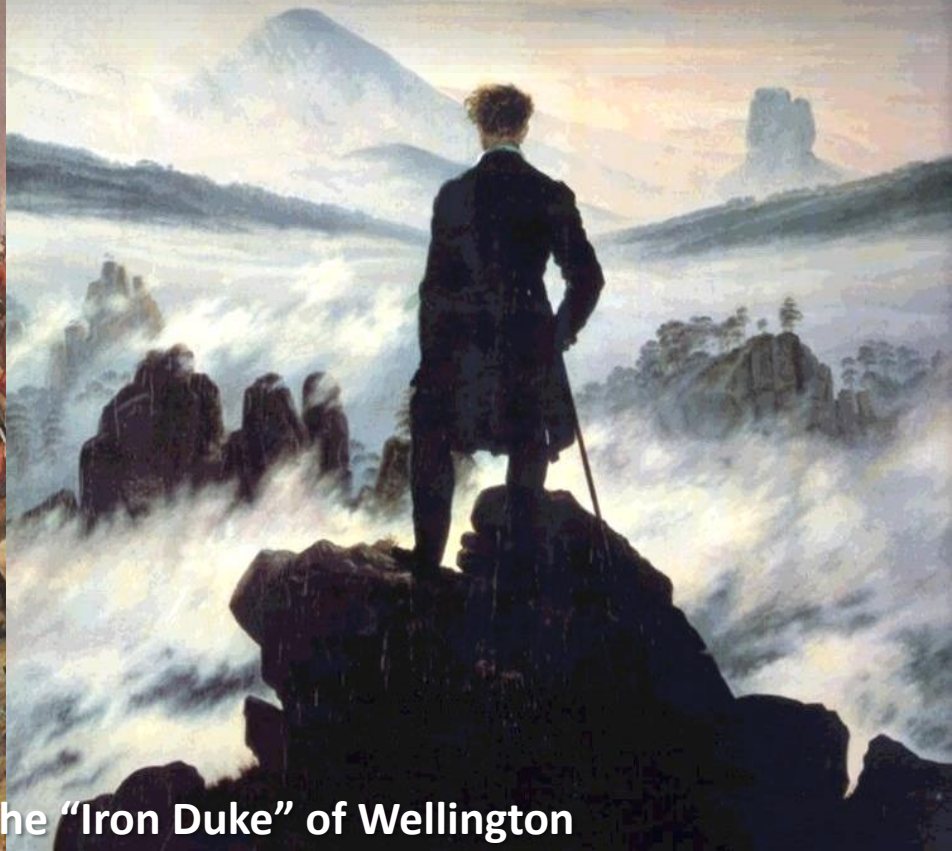
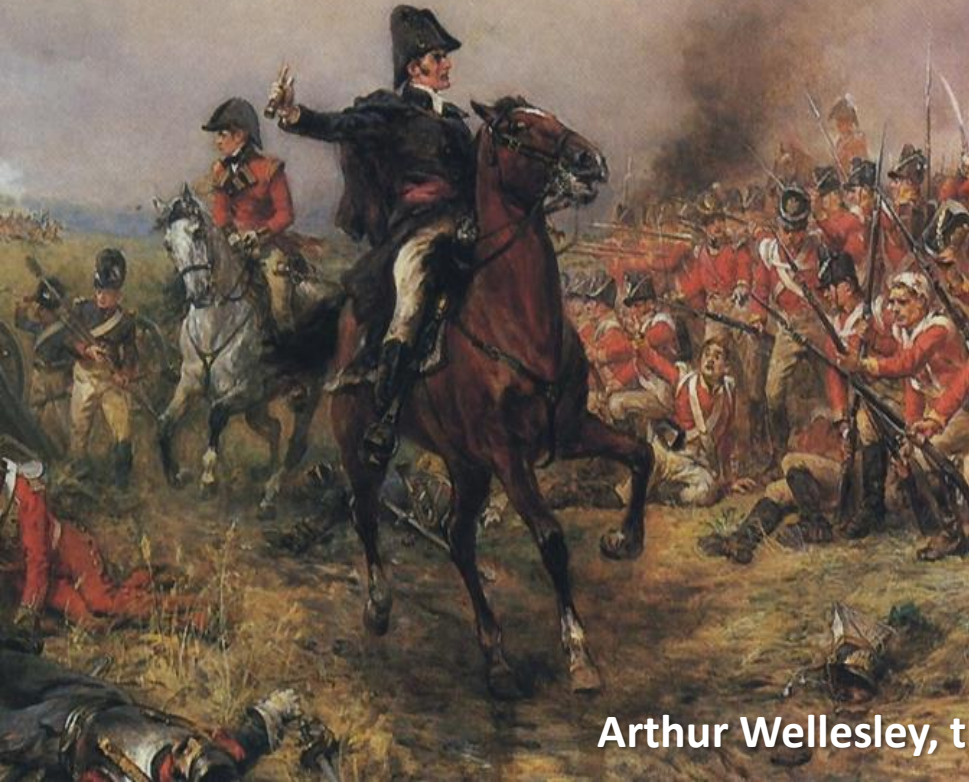




“Curiosity, which may or may not eventuate in something useful, is probably the outstanding characteristic of modern thinking. It is not new. It goes back to Galileo, Bacon, and to Sir Isaac Newton, and it must be absolutely unhampered.”

Abraham Flexner

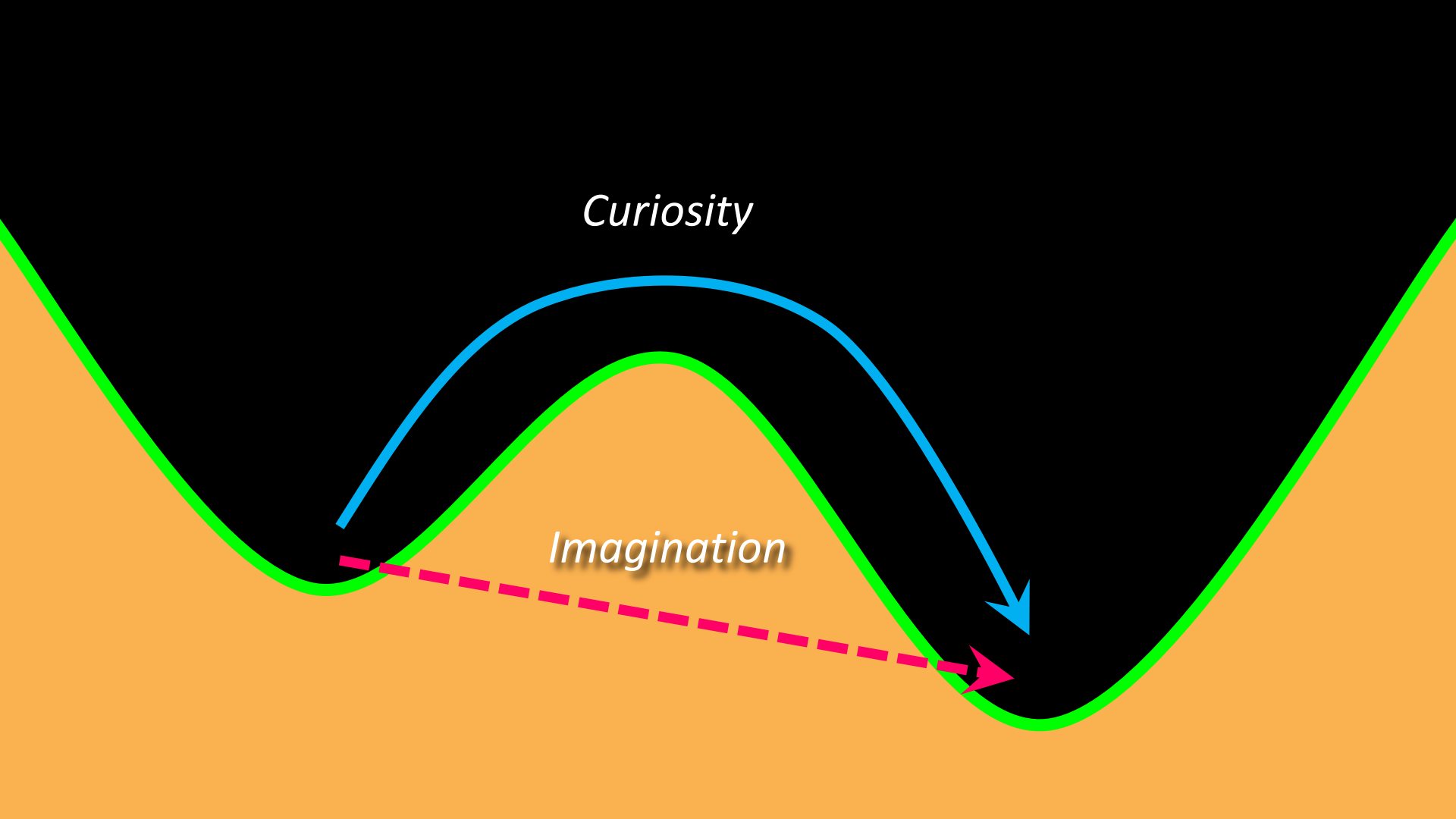
“All the business of war, and indeed all the business of life, is to endeavour to find out what you don't know by what you do; that's what I called guessing what was at the other side of the hill.”



Arthur Wellesley, the “Iron Duke” of Wellington

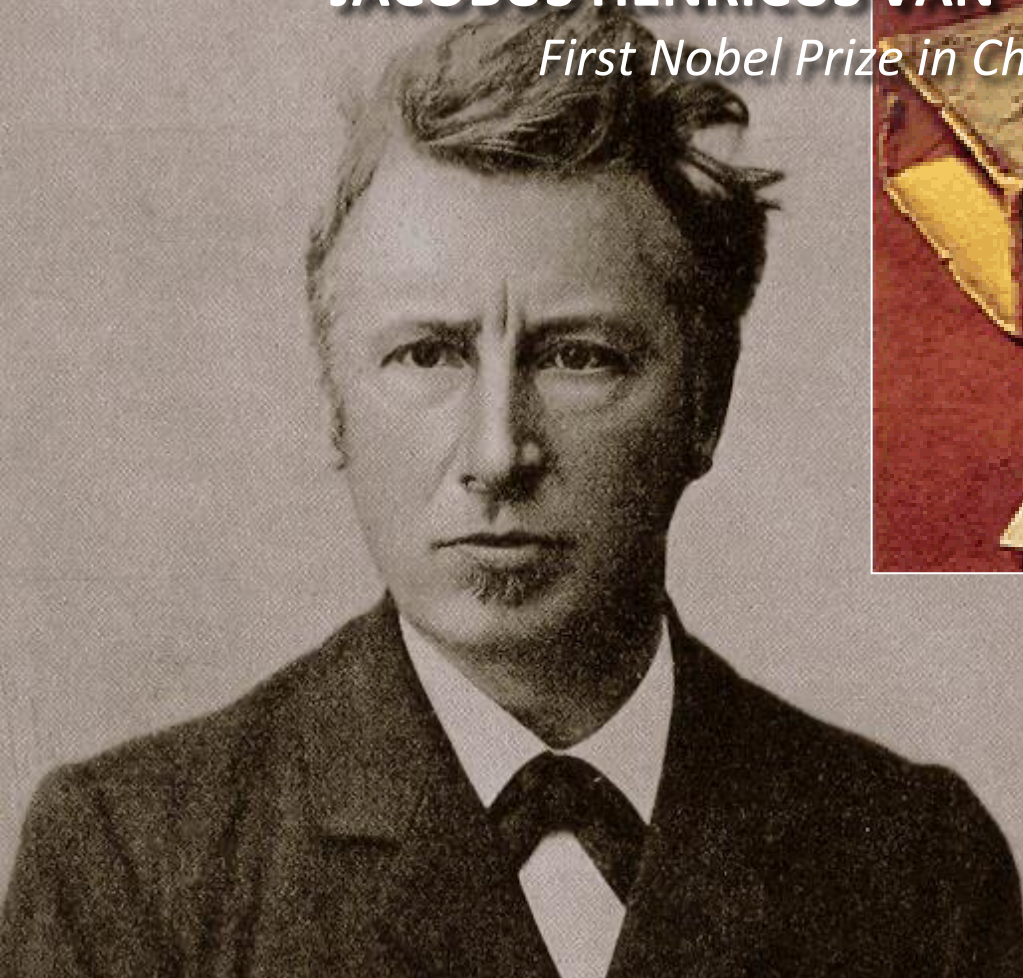
Curiosity

Imagination



JACOBUS HENRICUS VAN 'T HOFF (1852-1911)

First Nobel Prize in Chemistry, 1901



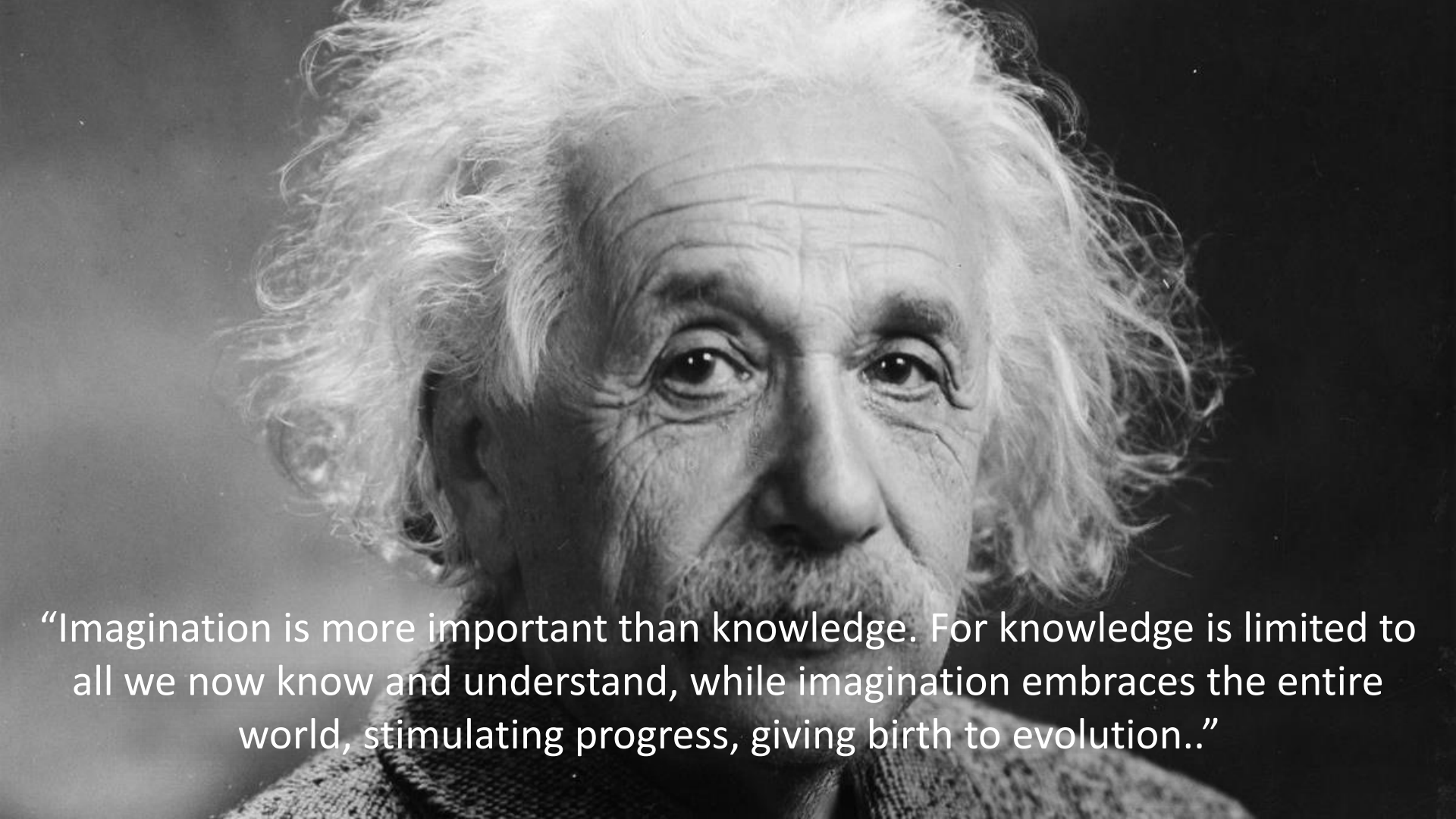
Stereochemistry

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, Baily, 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..”