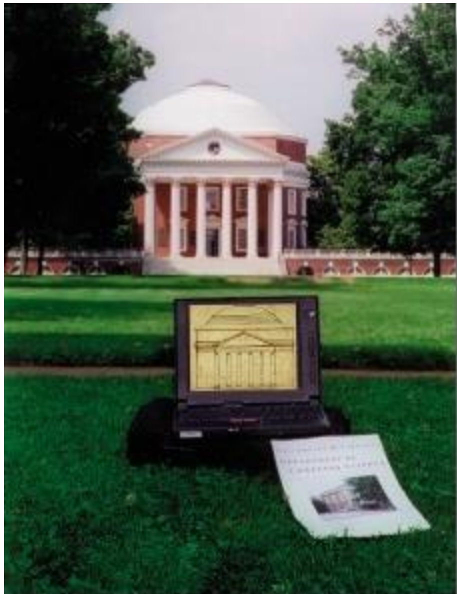


A Brief History of Computing

Gabriel Robins

Department of

Computer Science

University of Virginia

www.cs.virginia.edu/robins

Historical Perspectives

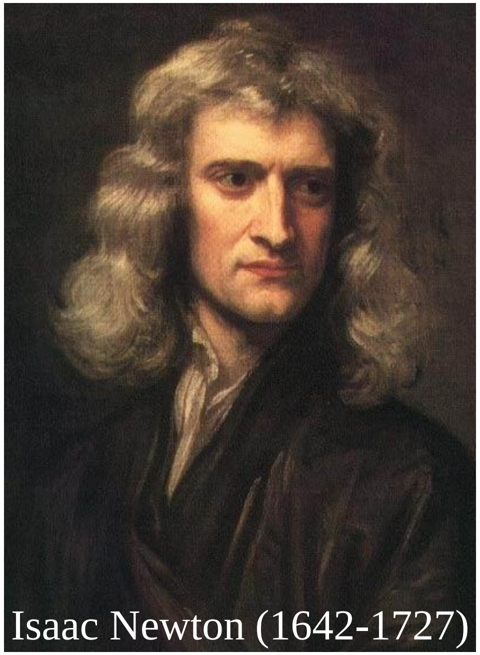
Historical Perspectives

- Knowing the "big picture" is empowering
- Science and mathematics builds heavily on past
- Often the simplest ideas are the most subtle
- Most fundamental progress was done by a few
- We learn much by observing the best minds
- Research benefits from seeing connections
- The field of computer science has many "parents"
- We get inspired and motivated by excellence
- The giants can show us what is possible to achieve
- It is fun to know these things!

"Standing on the Shoulders of Giants"

- Aristotle, Euclid, Archimedes, Eratosthenes
- Abu Ali al-Hasan ibn al-Haytham
- Fibonacci, Descartes, Fermat, Pascal
- Newton, Euler, Gauss, Hamilton
- Boole, De Morgan
- Babbage, Ada Lovelace
- Venn, Carroll


Ada Lovelace (1815-1852)

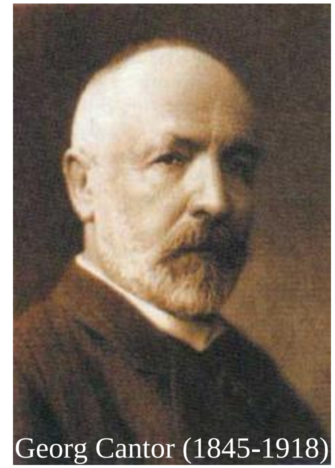

Isaac Newton (1642-1727)


Euclid (300 BC)

“Standing on the Shoulders of Giants”

- Cantor, Hilbert, Russell
- Hardy, Ramanujan, Ramsey
- Gödel, Church, Turing
- von Neumann, Shannon
- Kleene, Chomsky
- Hoare, McCarthy, Erdos
- Knuth, Backus, Dijkstra

Many others…


Georg Cantor (1845-1918)

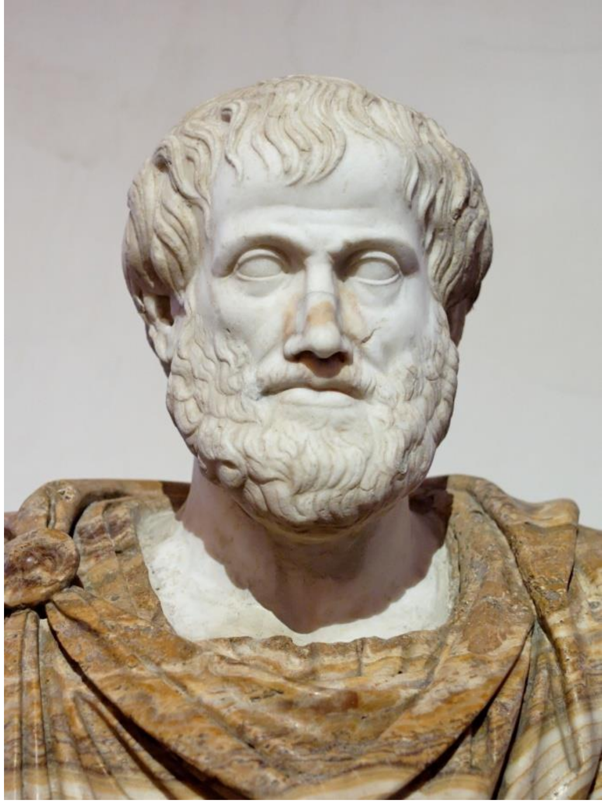

Bertrand Russell (1872-1970)


David Hilbert (1862-1943)


Kurt Gödel (1906-1978)

MAKING PHILOSOPHY ACCESSIBLE: POP-UP PLATO

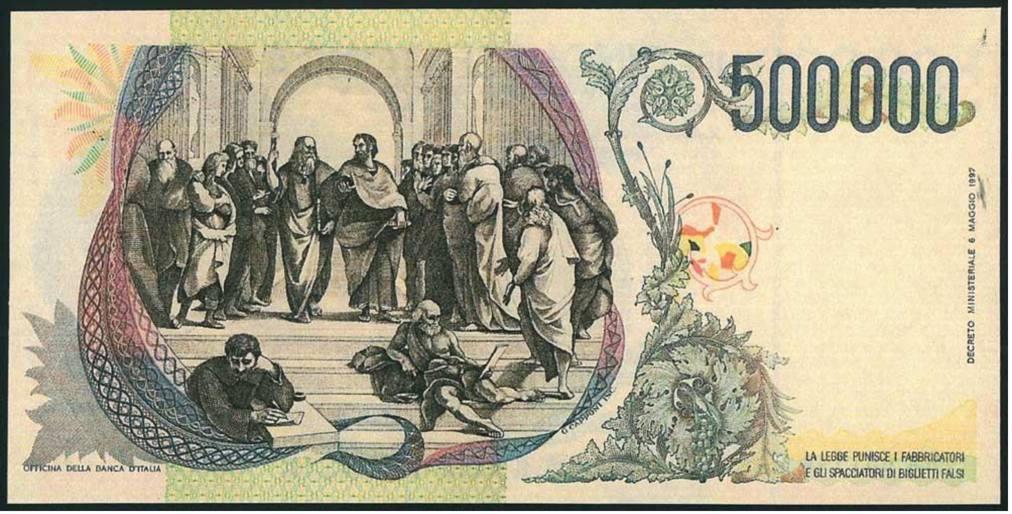
Historical Perspectives

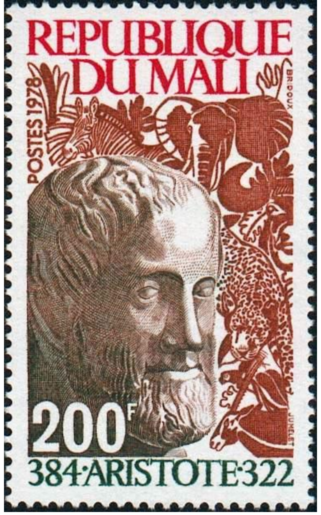


Aristotle (384BC-322BC)

- Founded Western philosophy
- Student of Plato
- Taught Alexander the Great
- "Aristotelianism"
- Developed the "scientific method"
- One of the most influential people ever
- Wrote on physics, theatre, poetry, music, logic, rhetoric, politics, government, ethics, biology, zoology, morality, optics, science, aesthetics, psychology, metaphysics, …
- Last person to know everything known in his own time!

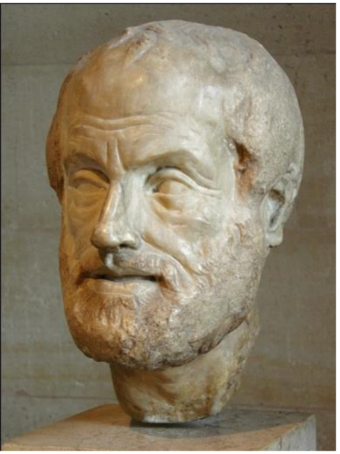
"Almost every serious intellectual advance has had to begin with an attack on some Aristotelian doctrine." – Bertrand Russell

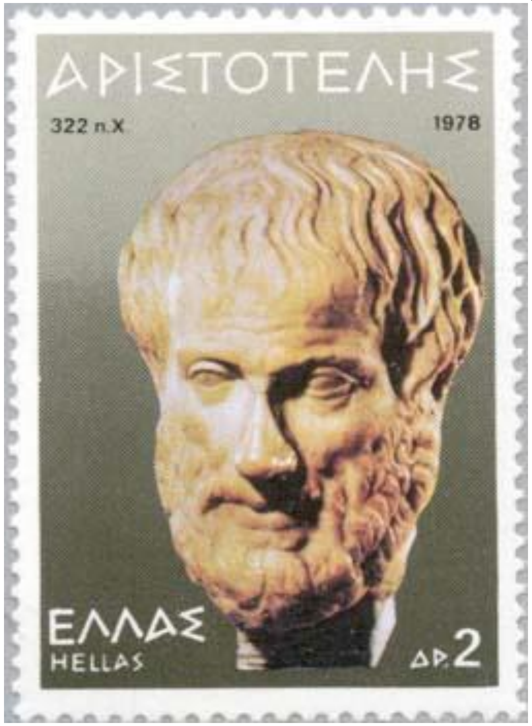


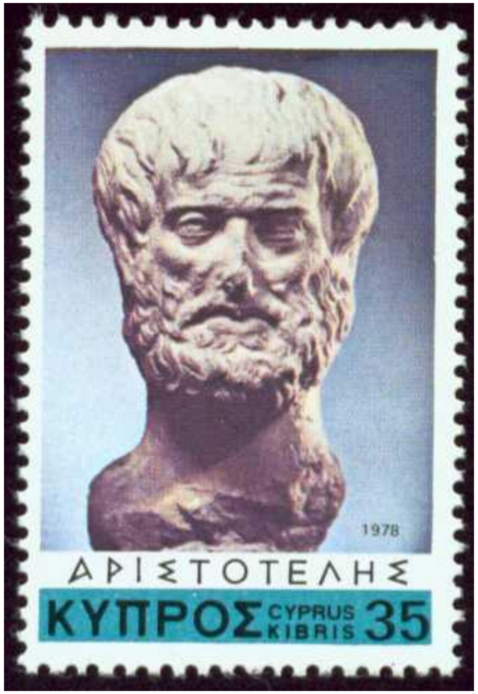


"Wit is educated insolence."

- Aristotle (384-322 B.C.)







“The School of Athens” (by Raphael, 1483-1520)


ARISTOTELES
87 km
97 / 10 / 09
D=254mm f/D=10
Moon "LIGHT"
© António J. Cidadão
8
B/W QuickCam
a.cidadao@mail.telepac.pt

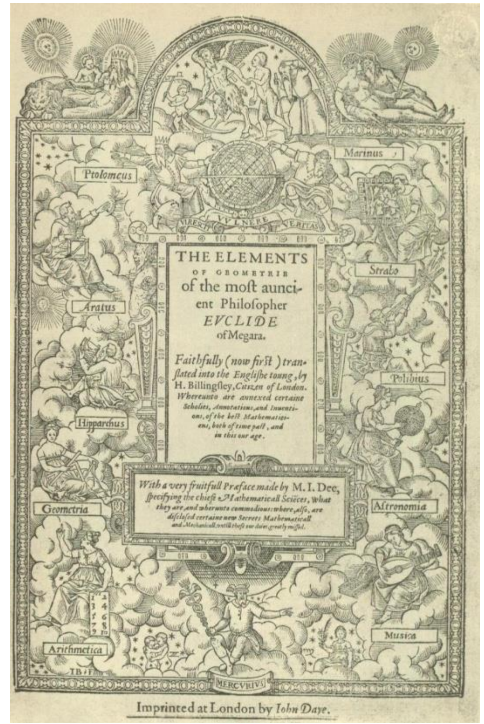

THE UNKNOWN PHILOSOPHER
WHO FIRST REALIZED LIFE IS NO PICNIC

"The periodic table."

Historical Perspectives

Euclid (325BC-265BC)

- Founder of geometry & the axiomatic method
- "Elements" – oldest and most impactful textbook
- Unified logic & math
- Introduced rigor and "Euclidean" geometry
- Influenced all other fields of science: Copernicus, Kepler, Galileo, Newton, Russell, Lincoln, Einstein & many others


THE ELEMENTS
OF GEOMETRIE
of the most aunci-
ent Philosopher
EVCLIDE
of Megara.

Faithfully (now first) tran-
slated into the Englishe toung, by
H. Billingsley, Citizen of London.
Whereunto are annexed certaine
Scholies, Annotations, and Inventi-
ons, of the best Mathematici-
ens, both of time past, and
in this our age.

With a very fruitfull Præface made by M. I. Dee,
specifying the chiefe Mathematicall Sciẽces, what
they are, and wherunto commodious: where, also, are
disclosed certaine new Secrets Mathematicall
and Mechanicall, untill these our daies, greatly missed.

Imprinted at London by Iohn Daye.


SCHOOL OF ATHENS
50c
SIERRA LEONE
500th ANNIVERSARY BIRTH OF RAPHAEL
(detail) Euclid and his pupils
1983
SCALA NEW YORK/FLORENCE


MALDIVES
PRINCIPLES OF GEOMETRY
EUCLID
Rf3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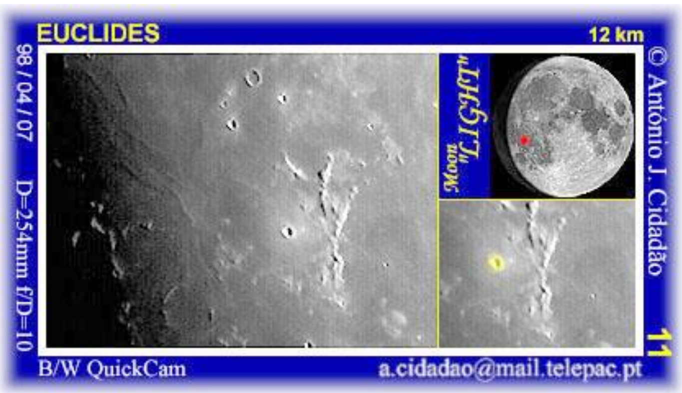
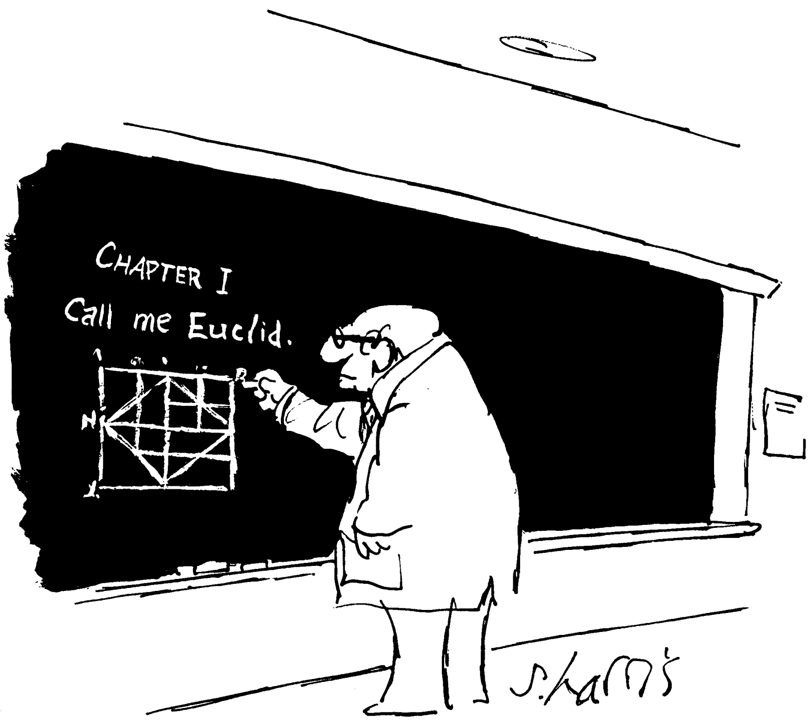
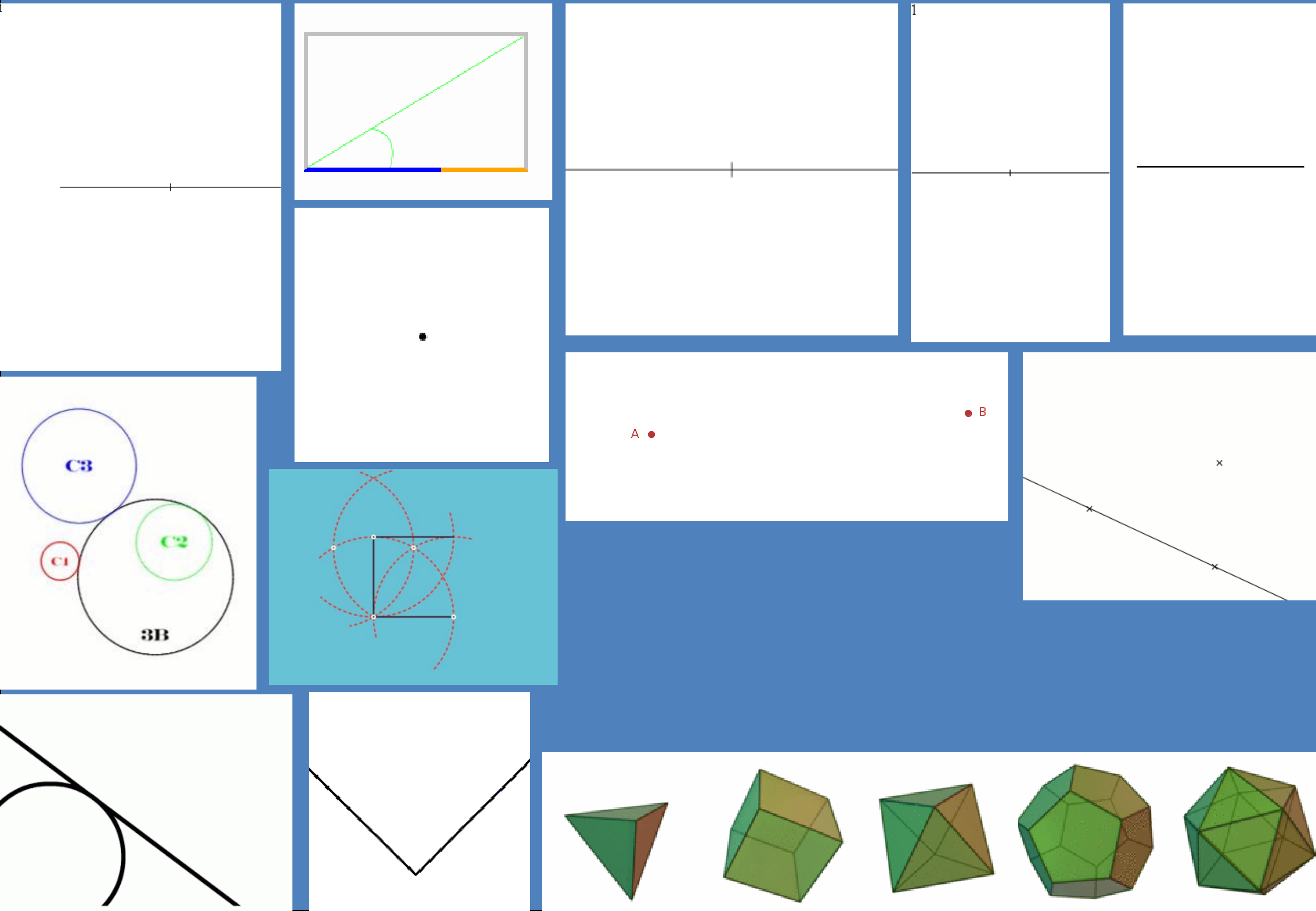
PONTIFICIA ACADEMIA SCIENTIARVM
I.P.Z.S.-ROMA-1986
P.N. ARGHITTU INC.


EUCLIDES
12 km
98/04/07
D=254mm f/D=10
© António J. Cidadão
Moon "LIGHT"
11
B/W QuickCam
a.cidadao@mail.telepac.pt


CHAPTER I
Call me Euclid.
S. Harris

Euclid’s Straight-Edge and Compass Geometric Constructions



Euclid's Axioms

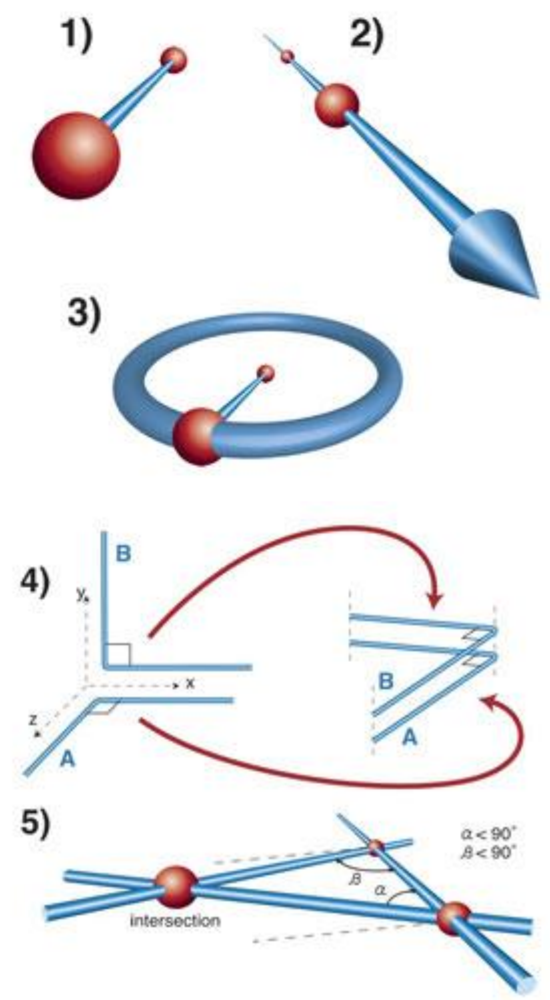
1: Any two points can be connected by exactly one straight line.

2: Any segment can be extended indefinitely into a straight line.

3: A circle exists for any given center and radius.

4: All right angles are equal to each other.

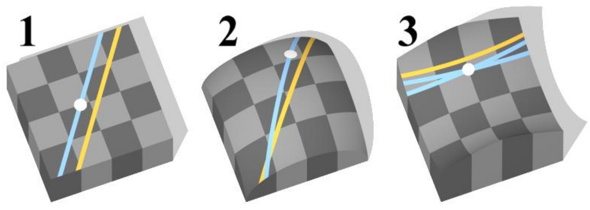
5: The parallel postulate: Given a line and a point off that line, there is exactly one line passing through the point, which does not intersect the first line.

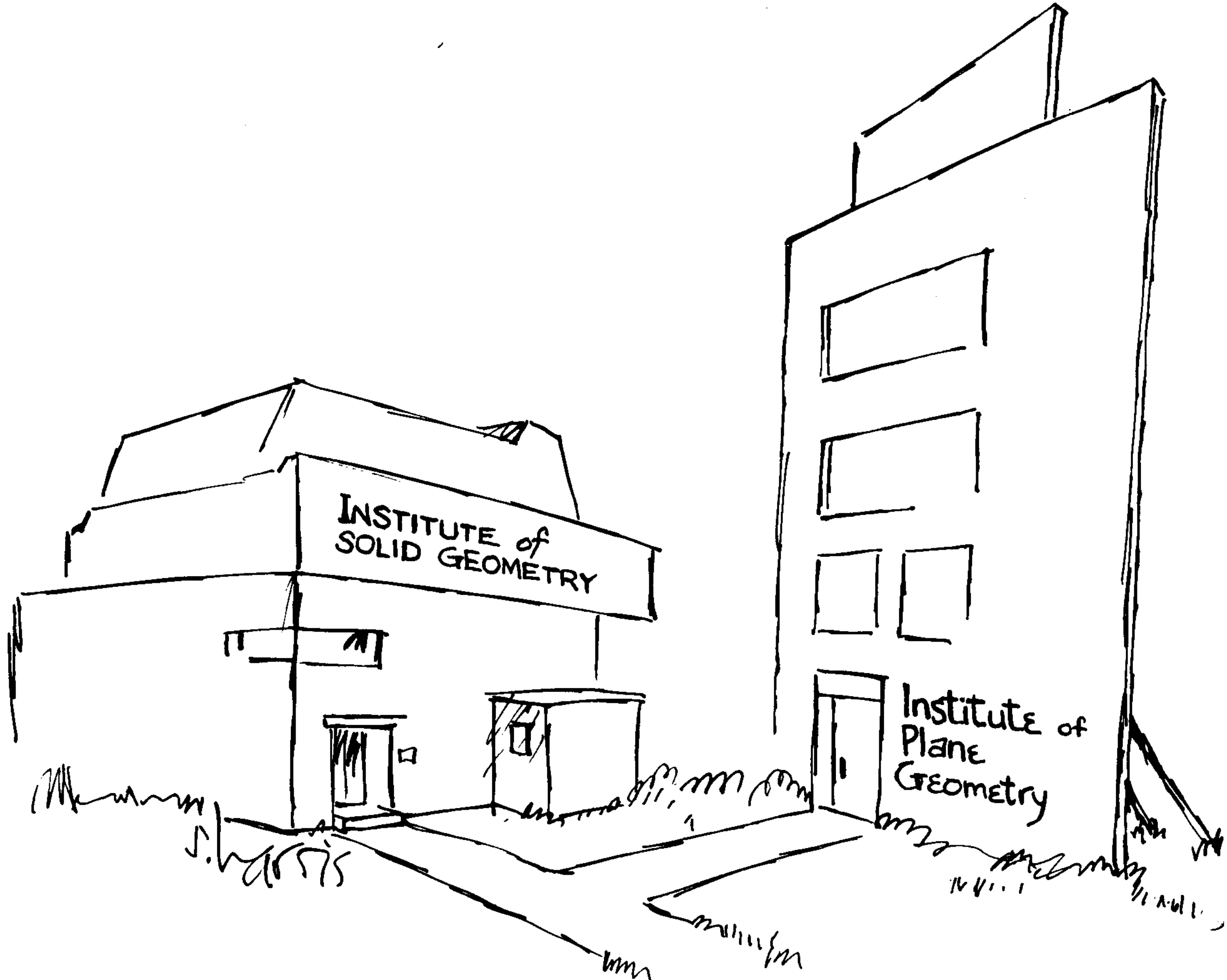


The first 28 propositions of Euclid's Elements were proven without using the parallel postulate!

Theorem [Beltrami, 1868]: The parallel postulate is independent of the other axioms of Euclidean geometry.

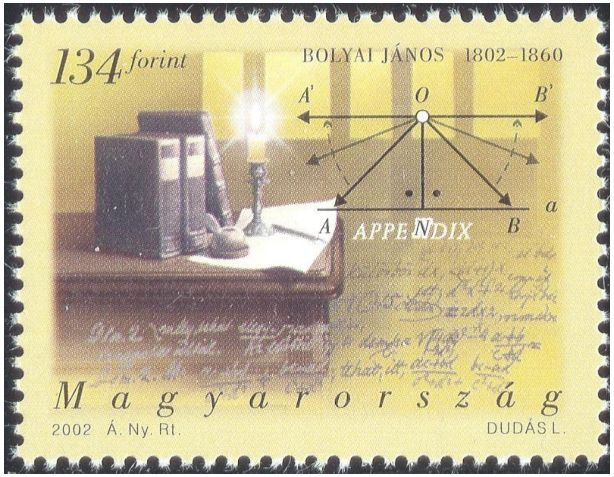
The parallel postulate can be modified to yield non-Euclidean geometries!

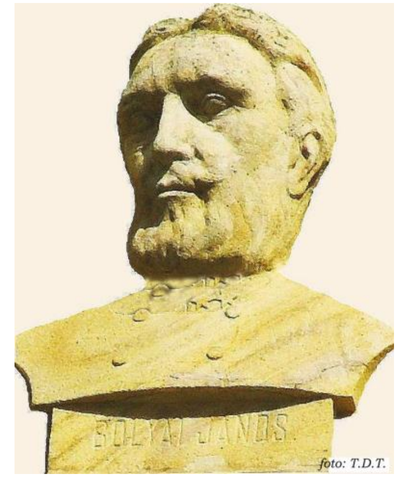



INSTITUTE of
SOLID GEOMETRY
Institute of
Plane
Geometry

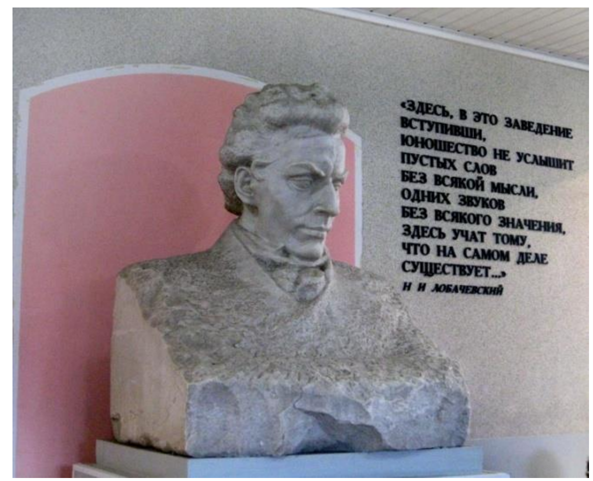
Founders of Non-Euclidean Geometry

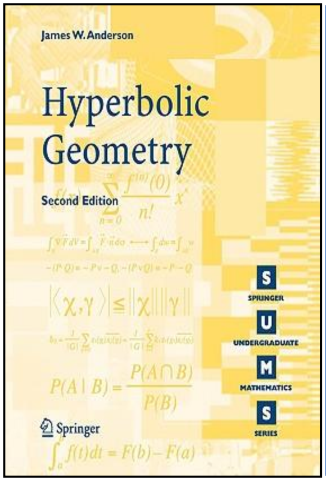
János Bolyai (1802-1860)





Nikolai Ivanovich Lobachevsky (1792-1856)

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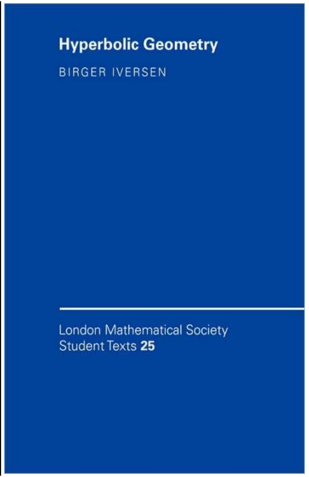
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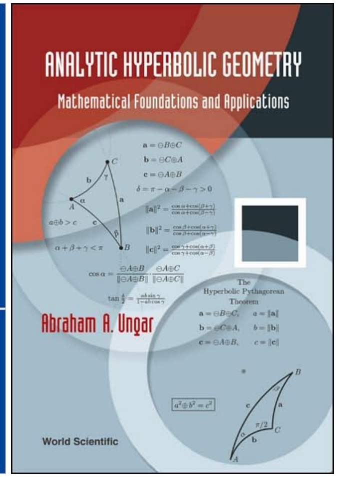
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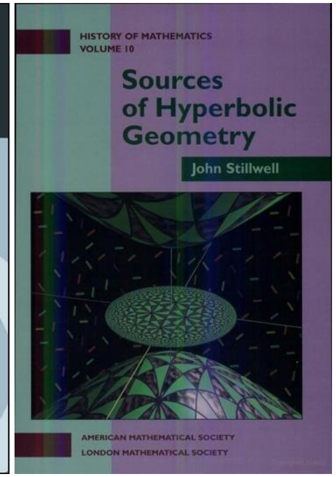
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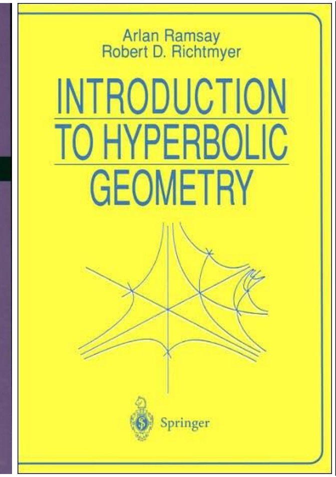
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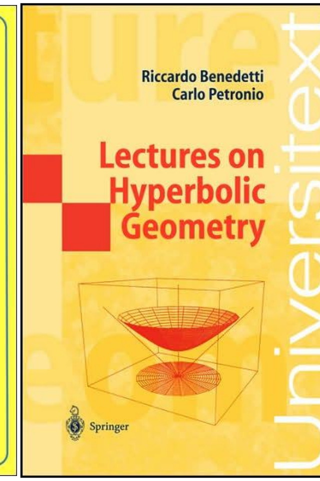
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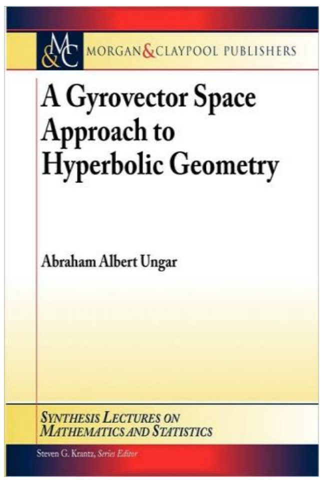
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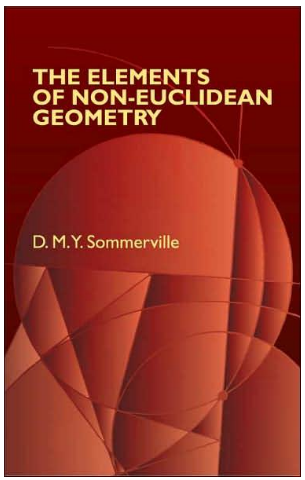
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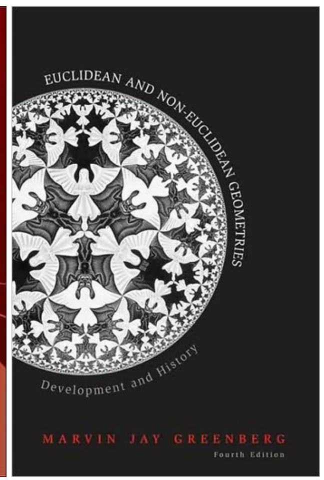
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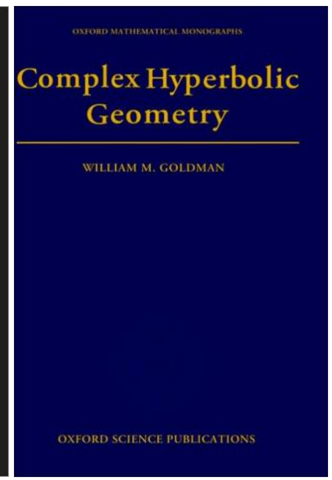
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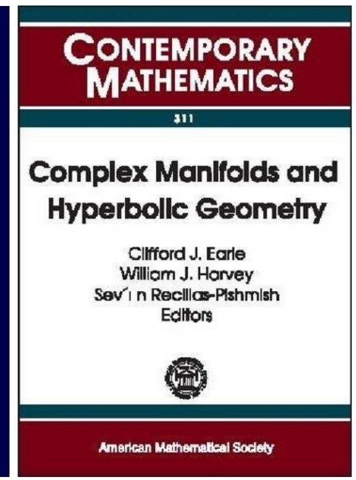
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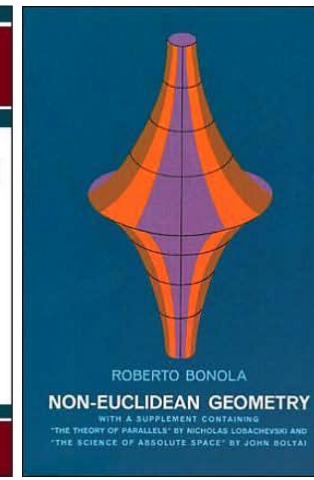
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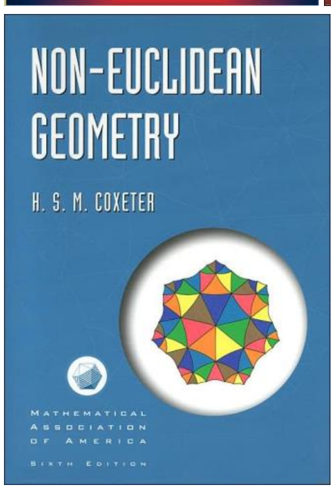
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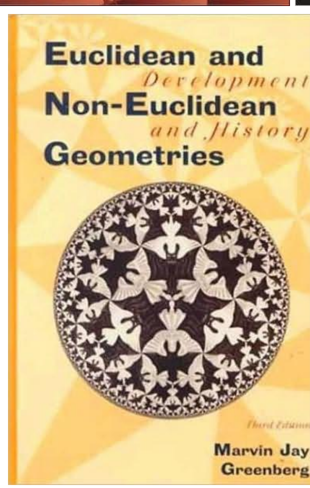
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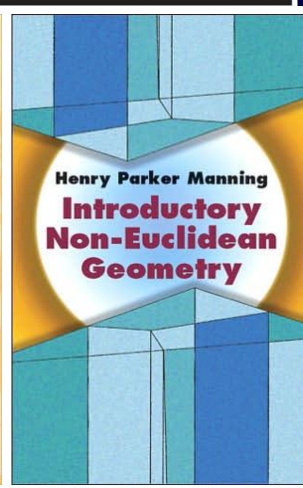
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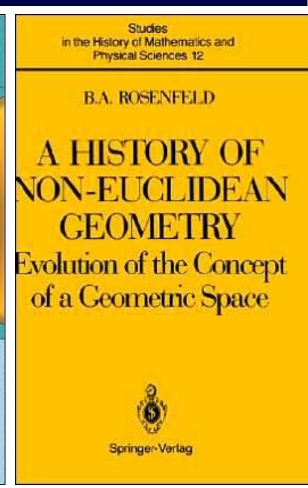
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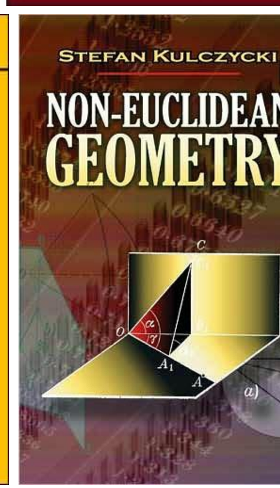
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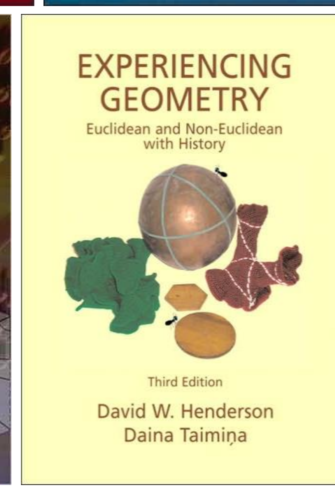
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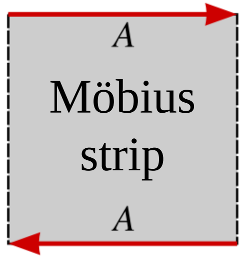
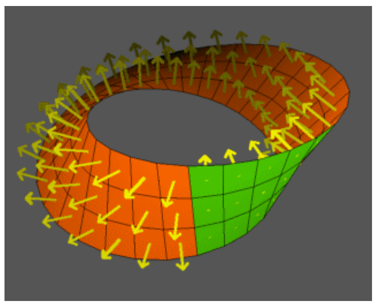
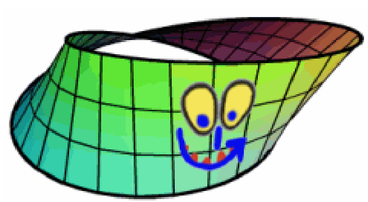
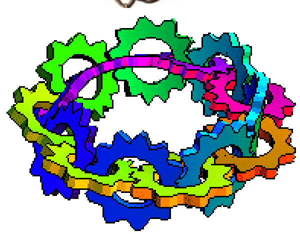
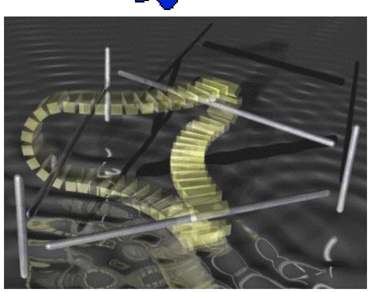
Non-Euclidean Non-Orientable Surfaces



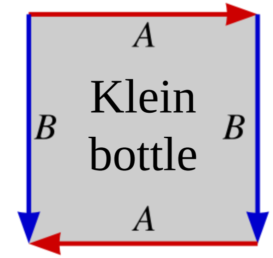


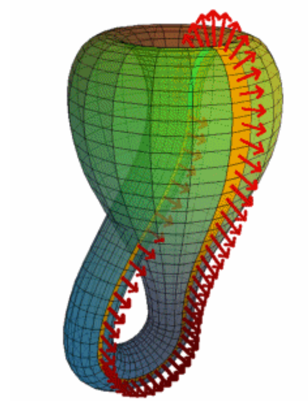


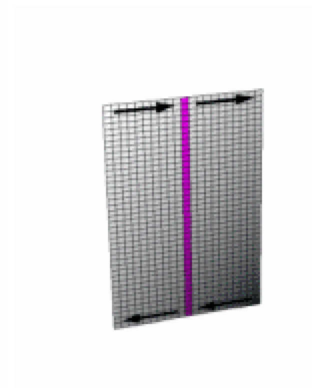


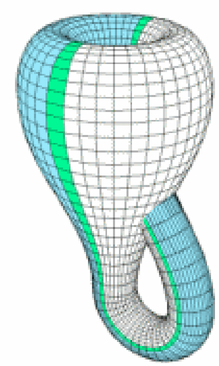


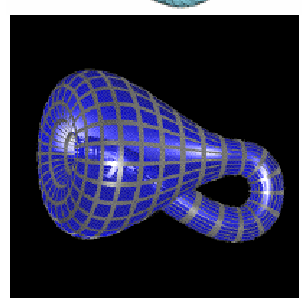
one side,
one boundary!



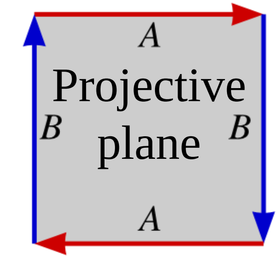


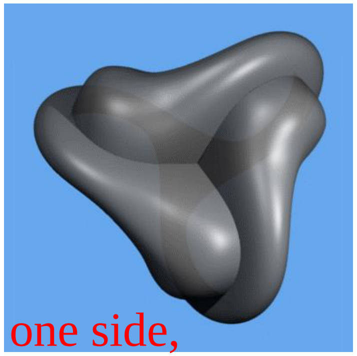




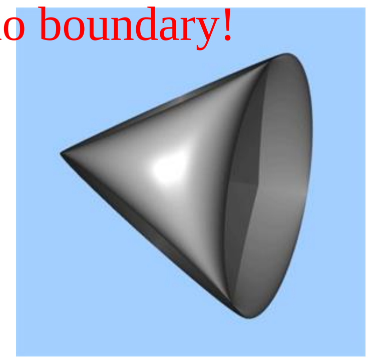


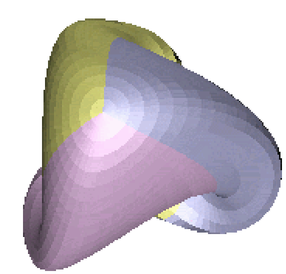
one side,
no boundary!





one side,
no boundary!

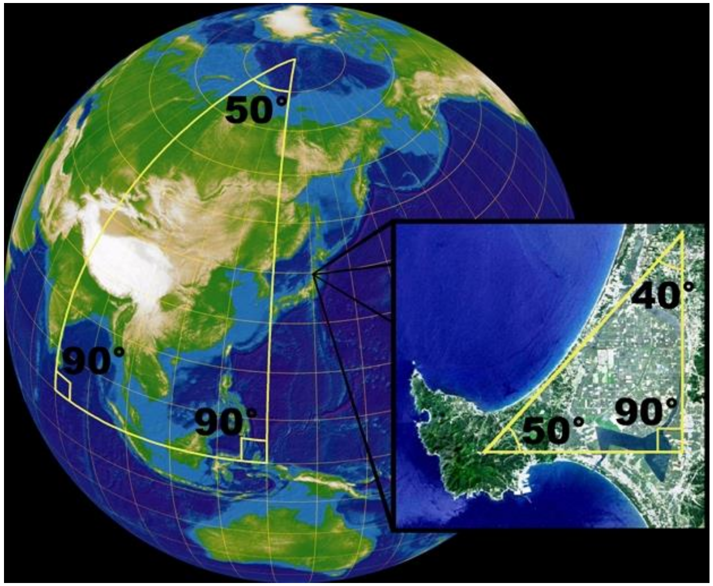


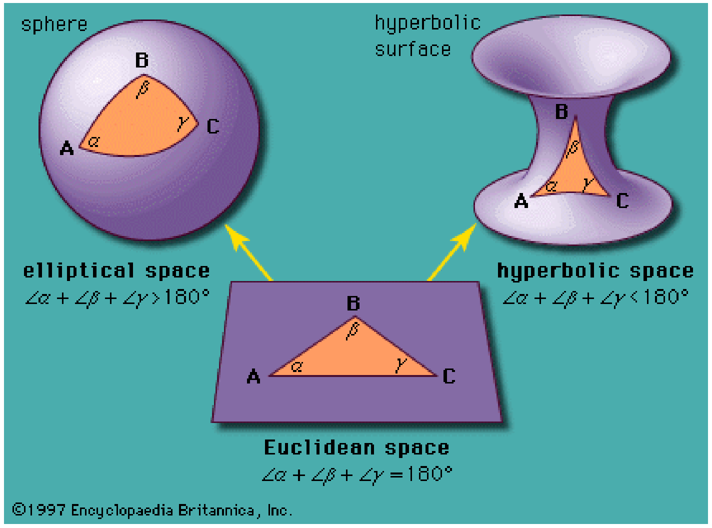


Non-Euclidean Geometries

Spherical / Elliptic geometry: Given a line and a point off that line, there are no lines passing through that point that do not intersect the first line.

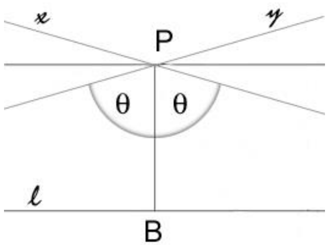
- Lines are geodesics - “great circles”
- Sum of triangle angles is > 180°
- Not all triangles have same angle sum
- Figures can not scale up indefinitely
- Area does not scale as the square
- Volume does not scale as the cube
- The Pythagorean theorem fails
- Self-consistent, and complete



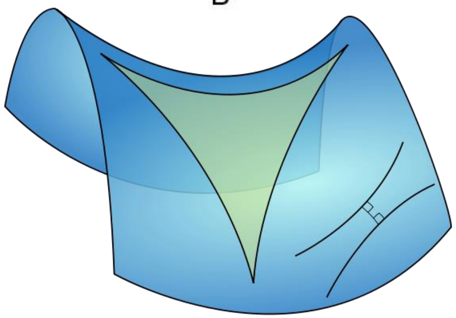


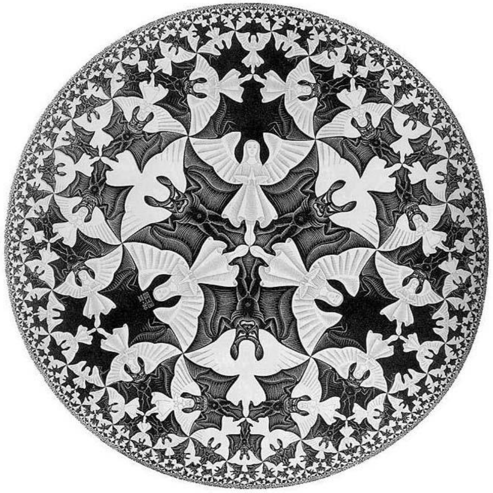
Non-Euclidean Geometries

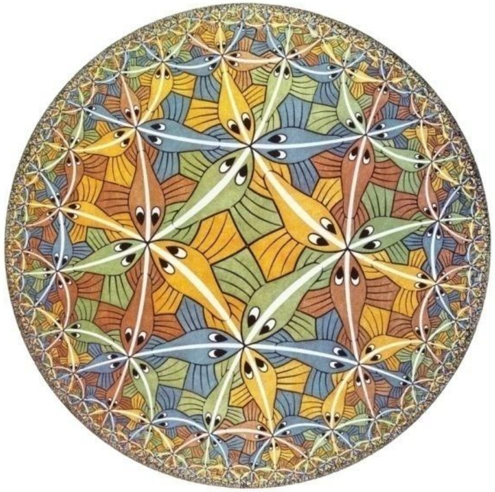
Hyperbolic geometry: Given a line and a point off that line, there are an infinity of lines passing through that point that do not intersect the first line.

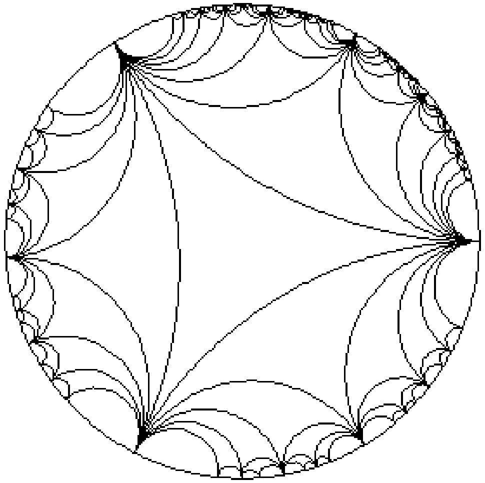


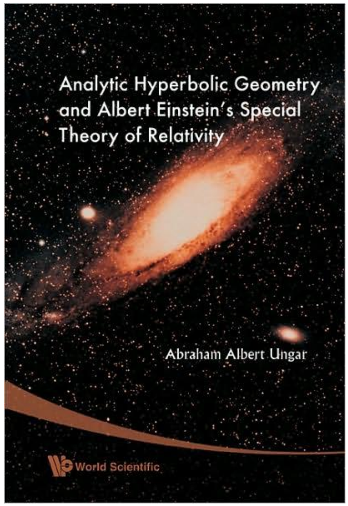
- Sum of triangle angles is less than 180^o
- Different triangles have different angle sum
- Triangles with same angles have same area
- There are no similar triangles
- Used in relativity theory



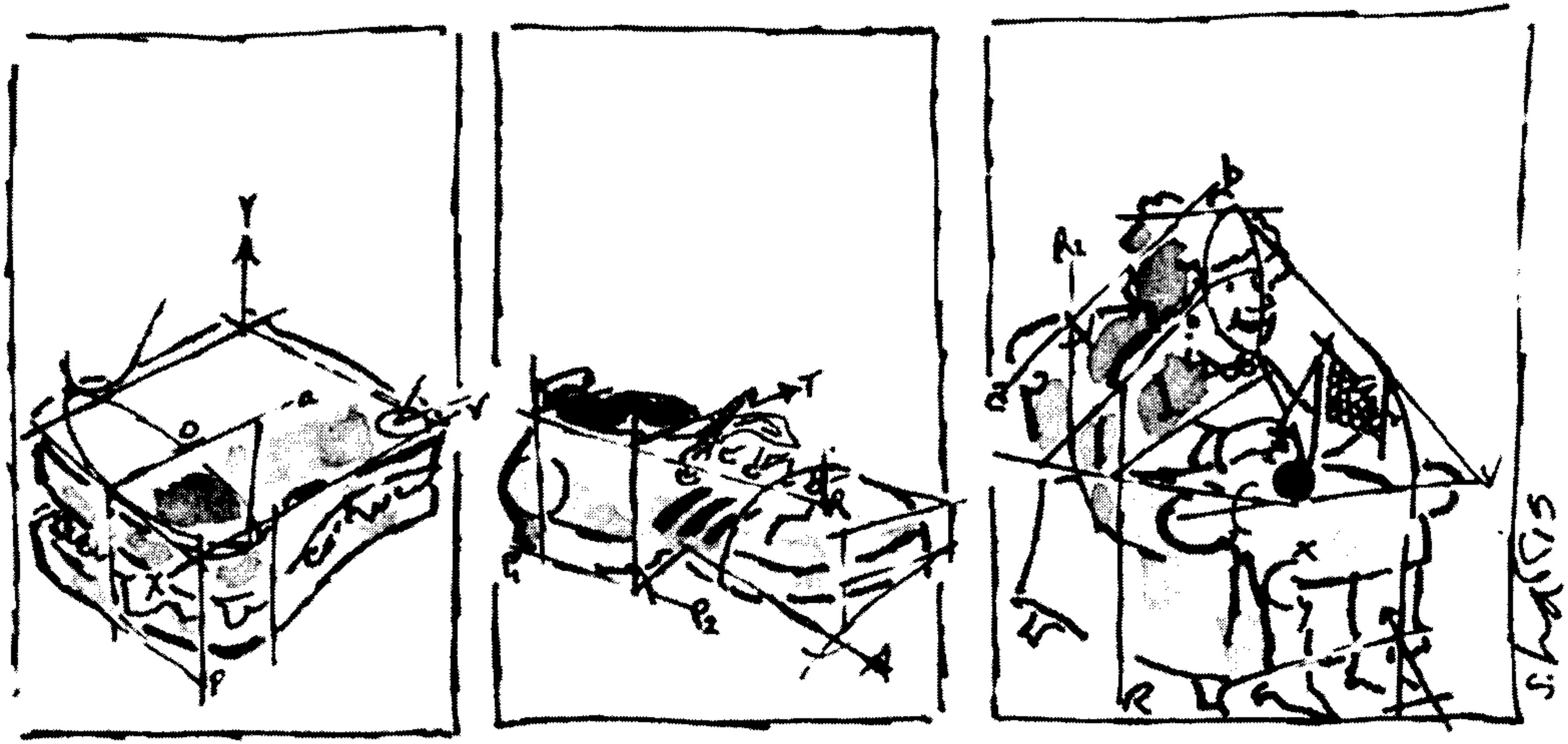






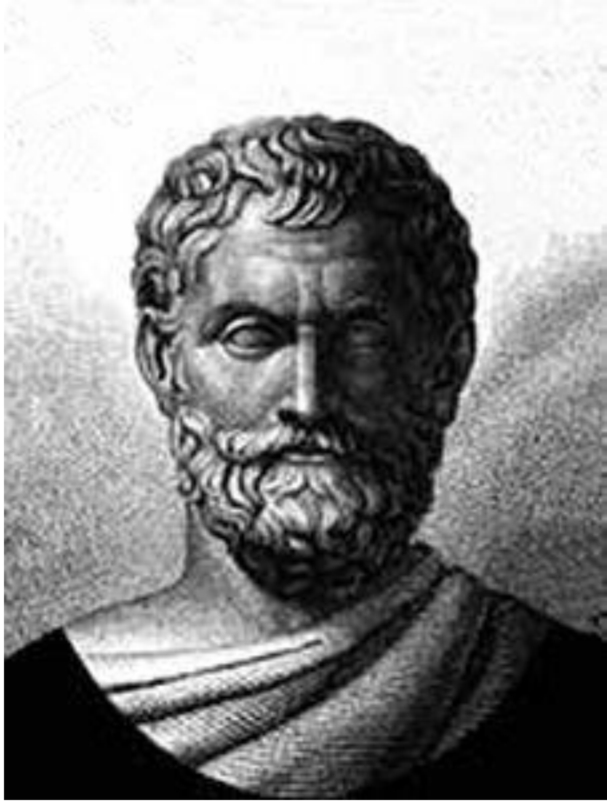


THE GEOMETRY OF EVERYDAY LIFE



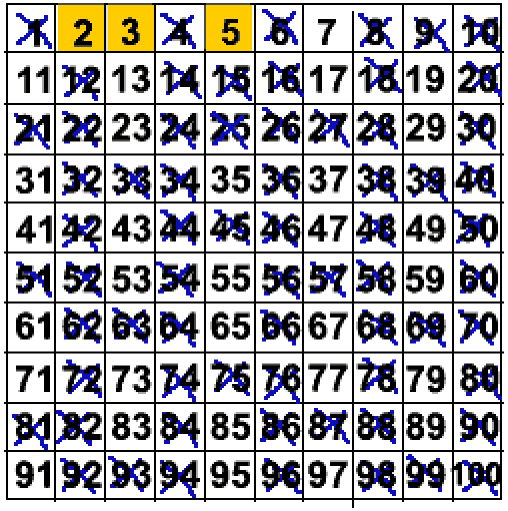
TUNA SANDWICH SNEAKER GRANDMA

Historical Perspectives



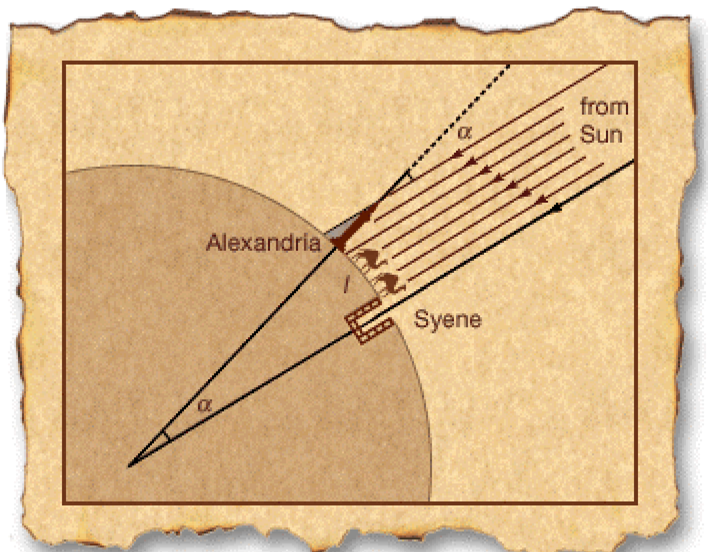
Eratosthenes (276BC-194BC)

- Chief librarian at Library of Alexandria
- Measured the Earth’s size (<1% error!)
- Calculated the Earth-Sun distance
- Invented latitude and longtitude
- Primes - “Sieve of Eratosthenes”
- Chronology of ancient history
- Wrote on astronomy, geography, history, mathematics, philosophy, and literature



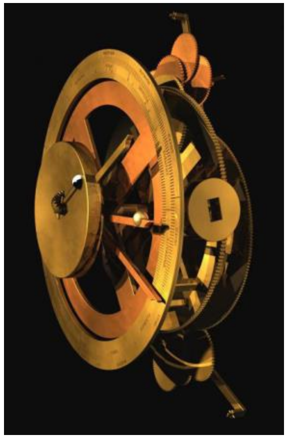
Prime numbers

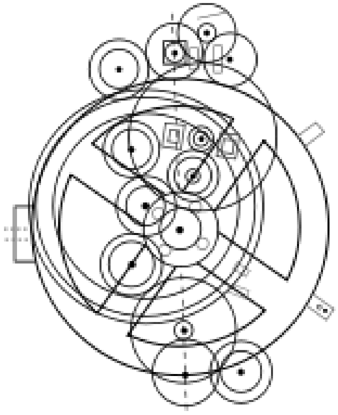
	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110
111	112	113	114	115	116	117	118	119	120

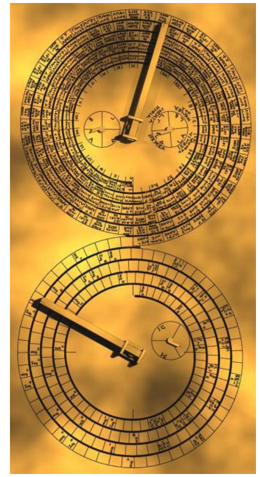


An Ancient Computer: The Antikythera

- Oldest known mechanical computer
- Built around 150-100 BCE !
- Calculates eclipses and astronomical positions of sun, moon, and planets
- Very sophisticated for its era
- Contains dozens of intricate gears
- Comparable to 1700's Swiss clocks
- Has an attached "instructions manual"
- Still the subject of ongoing research



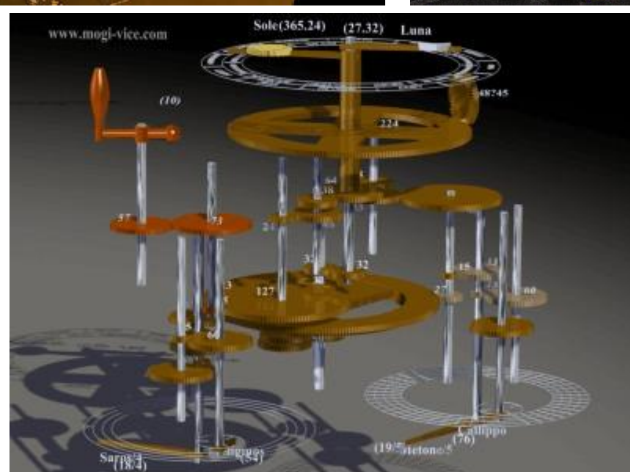









www.mogi-vice.com
Sole(365.24)
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Luna
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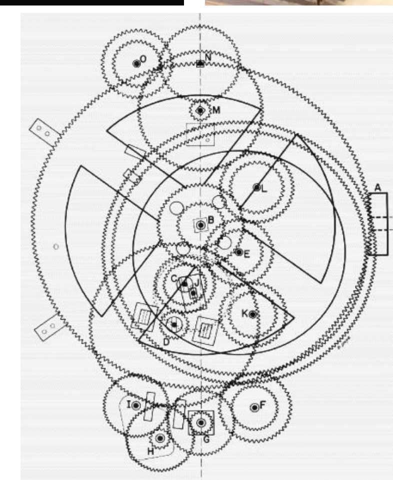
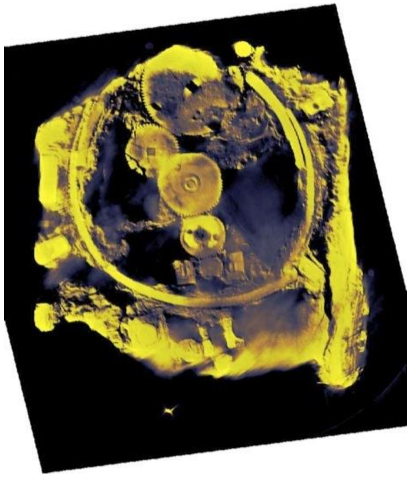
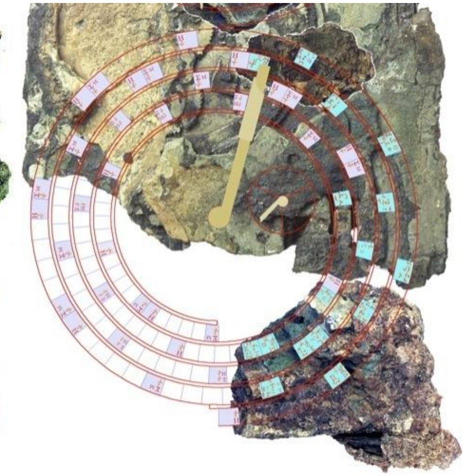
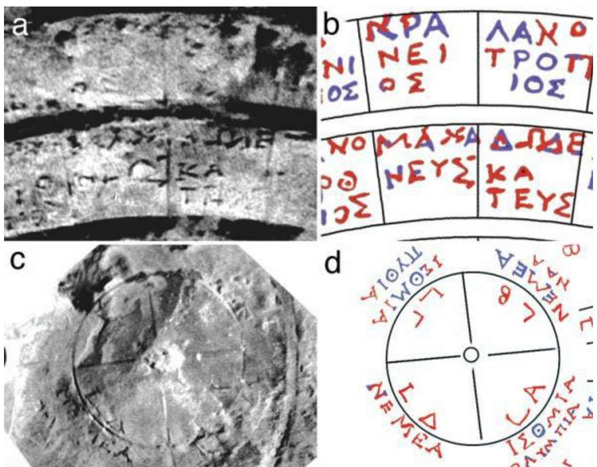
224
127
Calippo
(76)






© Antikythera Mechanism Research Project

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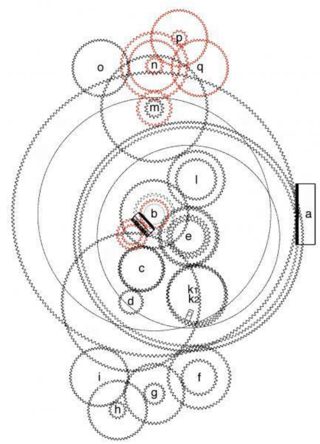

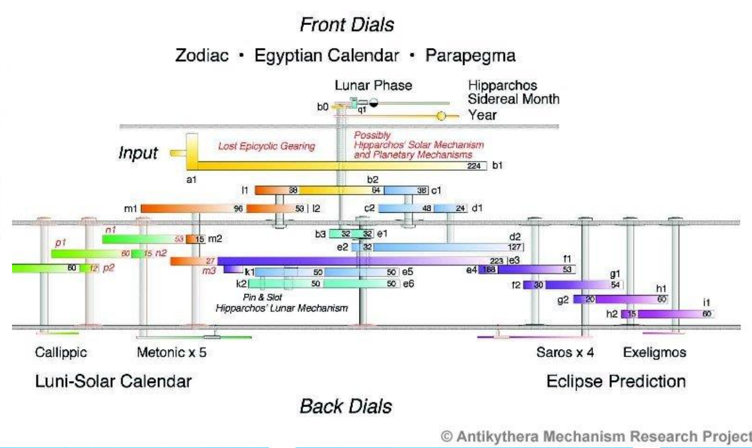
Front Dials
Zodiac · Egyptian Calendar · Parapegma
Lunar Phase
Hipparchos
Sidereal Month
Year
Input
Lost Epicyclic Gearing
Possibly
Hipparchos' Solar Mechanism
and Planetary Mechanisms
Pin & Slot
Hipparchos' Lunar Mechanism
Callippic
Metonic x 5
Saros x 4
Exeligmos
Luni-Solar Calendar
Eclipse Prediction
Back Dials
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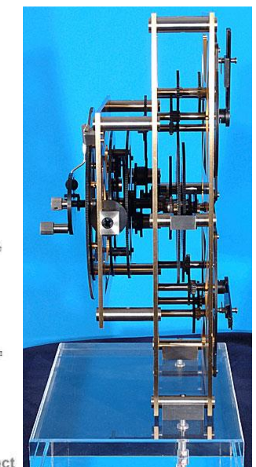

DECODING AN *Ancient Computer*

New explorations have revealed how the Antikythera mechanism modeled lunar motion and predicted eclipses, among other sophisticated tricks

By Tony Freeth

ANCIENT GREEKS knew how to calculate the recurring patterns of lunar eclipses thanks to observations made for centuries by the Babylonians. The Antikythera mechanism would have done those calculations for them—or perhaps for the wealthy Romans who could afford to own it. The depiction here is based on a theoretical reconstruction by the author and his collaborators.

KEY CONCEPTS

- The Antikythera mechanism is a unique mechanical calculator from second-century B.C. Greece. Its sophistication surprised archaeologists when it was discovered in 1901. But no one had anticipated its true power.
- Advanced imaging tools have finally enabled researchers to reconstruct how the device predicted lunar and solar eclipses and the motion of the moon in the sky.
- Inscriptions on the mechanism suggest that it might have been built in the Greek city of Syracuse (now in modern Sicily), perhaps in a tradition that originated with Archimedes.

—*The Editors*

If it had not been for two storms 2,000 years apart in the same area of the Mediterranean, the most important technological artifact from the ancient world could have been lost forever.

The first storm, in the middle of the 1st century B.C., sank a Roman merchant vessel laden with Greek treasures. The second storm, in A.D. 1900, drove a party of sponge divers to shelter off the tiny island of Antikythera, between Crete and the mainland of Greece. When the storm subsided, the divers tried their luck for sponges in the local waters and chanced on the wreck. Months later the divers returned, with backing from the Greek government. Over nine months they recovered a hoard of beautiful ancient Greek objects—rare bronzes, stunning glassware, amphorae, pottery and jewelry—in one of the first major underwater archaeological excavations in history.

One item attracted little attention at first: an undistinguished, heavily calcified lump the size of a phone book. Some months later it fell apart, revealing the remains of corroded bronze gearwheels—all sandwiched together and with teeth just one and a half millimeters long—along with plates covered in scientific scales and Greek inscriptions. The discovery was a shock: until then, the ancients were thought to have made gears only for crude mechanical tasks.

Three of the main fragments of the Antikythera mechanism, as the device has come to be known, are now on display at the Greek National Archaeological Museum in Athens. They look small and fragile, surrounded by imposing bronze statues and other artistic glories of ancient Greece. But their subtle power is even more shocking than anyone had imagined at first.

I first heard about the mechanism in 2000. I was a filmmaker, and astronomer Mike Edmunds of Cardiff University in Wales contacted me because he thought the mechanism would make a great subject for a TV documentary. I learned that over many decades researchers studying the mechanism had made considerable progress, suggesting that it calculated astronomical data, but they still had not been able to fully grasp how it worked. As a former mathematician, I became intensely interested in understanding the mechanism myself.

Edmunds and I gathered an international collaboration that eventually included historians, astronomers and two teams of imaging experts. In the past few years our group has reconstructed how nearly all the surviving parts worked and what functions they performed. The mechanism calculated the dates of lunar and solar eclipses, modeled the moon's subtle apparent motions through the sky to the best of the available knowledge, and kept track of the dates of events of social significance, such as the Olympic Games. Nothing of comparable technological sophistication is known anywhere in the world for at least a millennium afterward. Had this unique specimen not survived, historians would have thought that it could not have existed at that time.

Early Pioneers

German philologist Albert Rehm was the first person to understand, around 1905, that the Antikythera mechanism was an astronomical calculator. Half a century later, when science historian Derek J. de Solla Price, then at the Institute for Advanced Study in Princeton, N.J., described the device in a *Scientific American* article, it still had revealed few of its secrets.

The device, Price suggested, was operated by turning a crank on its side, and it displayed its output by moving pointers on dials located on its front and back. By turning the crank, the user could set the machine on a certain date as indicated on a 365-day calendar dial in the front. (The dial could be rotated to adjust for an extra day every four years, as in today's leap years.) At the same time, the crank powered all the other gears in the mechanism to yield the information corresponding to the set date.

A second front dial, concentric with the calendar, was marked out with 360 degrees and with the 12 signs representing the constellations of the zodiac [*see box on pages 80 and 81*]. These are the constellations crossed by the sun in its apparent motion with respect to the "fixed" stars—"motion" that in fact results from Earth's orbiting the sun—along the path called the ecliptic. Price surmised that the front of the mechanism probably had a pointer showing where along the ecliptic the sun would be at the desired date.

In the surviving fragments, Price identified the remains of a dozen gears that had been part of the mechanism's innards. He also estimated their tooth counts—which is all one can do given that nearly all the gears are damaged and incomplete. Later, in a landmark 1974 study, Price described 27 gears in the main fragment and provided improved tooth counts based on the first x-rays of the mechanism, by Greek radiologist Charalambos Karakalos.

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[THE PLACES]

The Greek and Roman worlds, circa 145 B.C.

Where Was It From?

The Antikythera mechanism was built around the middle of the 2nd century B.C., a time when Rome was expanding at the expense of the Greek-dominated Hellenistic kingdoms (*green*). Divers recovered its corroded remnants (*including fragment at left*) in A.D. 1901 from a shipwreck near the island of Antikythera. The ship sank around 65 B.C. while carrying Greek artistic treasures, perhaps from Pergamon to Rome. Rhodes had one of the major traditions of Greek astronomy, but the latest evidence points to a Corinthian origin. Syracuse, which had been a Corinthian colony in Sicily, is a possibility: the great Greek inventor Archimedes had lived there and may have left behind a technological tradition.

Tooth counts indicate what the mechanism calculated. For example, turning the crank to give a full turn to a primary 64-tooth gear represented the passage of a year, as shown by a pointer on the calendar dial. That primary gear was also paired to two 38-tooth secondary gears, each of which consequently turned by 64/38 times for every year. Similarly, the motion relayed from gear to gear throughout the mechanism; at each step, the ratio of the numbers of gear teeth represents a different fraction. The motion eventually transmitted to the pointers, which thus turned at rates corresponding to different astronomical cycles. Price discovered that the ratios of one of these gear trains embodied an ancient Babylonian cycle of the moon.

Price, like Rehm before him, suggested that the mechanism also contained epicyclic gearing—gears spinning on bearings that are themselves attached to other gears, like the cups on a Mad Hatter teacup ride. Epicyclic gears extend the range of formulas gears can calculate beyond multiplications of fractions to additions and subtractions. No other example of epicyclic gearing is known to have existed in Western technology for another 1,500 years.

Several other researchers studied the mechanism, most notably Michael Wright, a curator at the Science Museum in London, in collaboration with computer scientist Allan Bromley of the University of Sydney. They took the first three-dimensional x-rays of the mechanism and showed that Price's model of the mechanism had to be wrong. Bromley died in 2002, but Wright persisted and made significant advances. For example, he found evidence that the back dials, which at first look like concentric rings, are in fact spirals and discovered an epicyclic mechanism at the front that calculated the phase of the moon.

Wright also adopted one of Price's insights, namely that the dial on the upper back might be a lunar calendar, based on the 19-year, 235-lunar-month cycle called the Metonic cycle. This calendar is named after fifth-century B.C. astronomer Meton of Athens—although it had been discovered earlier by the Babylonians—and is still used today to determine the Jewish festival of Rosh Hashanah and the Christian festival of Easter. Later, we would discover that the pointer was extensible, so that a pin on its end could follow a groove around each successive turn of the spiral.

BladeRunner in Athens

As our group began its efforts, we were hampered by a frustrating lack of data. We had no access to the previous x-ray studies, and we did not even have a good set of still photographs. Two images in a science magazine—x-rays of a goldfish and an enhanced photograph of a Babylonian clay tablet—suggested to me new ways to get better data.

We asked Hewlett-Packard in California to perform state-of-the-art photographic imaging and X-Tek Systems in the U.K. to do three-dimensional x-ray imaging. After four years of careful diplomacy, John Seiradakis of the Aristotle University of Thessaloniki and Xenophon Moussas of the University of Athens obtained the required permissions, and we arranged for the imaging teams to bring their tools to Athens, a necessary step because the Antikythera mechanism is too fragile to travel.

Meanwhile we had a totally unexpected call from Mary Zafeiropoulou at the museum. She had been to the basement storage and found boxes of bits labeled "Antikythera." Might we be interested? Of course we were interested. We now had a total of 82 fragments, up from about 20.

The HP team, led by Tom Malzbender, assembled a mysterious-looking dome about five feet across and covered in electronic flashbulbs that provided lighting from a range of different angles. The team exploited a technique from the computer gaming industry, called polynomial texture mapping, to enhance surface details. Inscriptions Price had found difficult to read were now clearly legible, and fine details could be enhanced on the computer screen by controlling the reflectance of the surface and the angle of the lighting. The inscriptions are essentially an instruction manual written on the outer plates.

A month later local police had to clear the streets in central Athens so that a truck carrying the BladeRunner, X-Tek's eight-ton x-ray machine, could gain access to the museum. The BladeRunner performs computed tomography similar to a hospital's CT scan, but with finer detail. X-Tek's Roger Hadland and his group had specially modified it with enough x-ray power to penetrate the fragments of the Antikythera mechanism. The resulting 3-D reconstruction was wonderful: whereas Price could see only a puzzle of overlapping gears, we could now isolate layers inside the fragment and see all the fine details of the gear teeth.

Unexpectedly, the x-rays revealed more than 2,000 new text characters that had been hidden deep inside the fragments. (We have now identified and interpreted a total of 3,000 characters out of perhaps 15,000 that existed originally.) In Athens, Moussas and Yanis Bitsakis, also at the University of Athens, and Agamemnon Tselikas of the Center for History and Palaeography be-

Historians would have thought that SOMETHING SO COMPLEX *could not have existed at the time.*

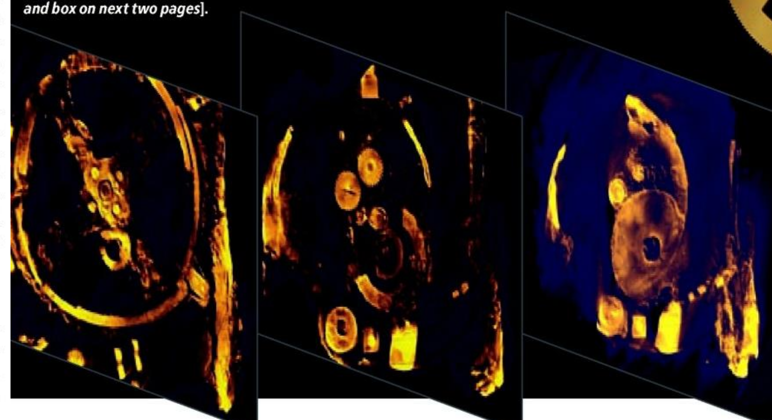
[THE AUTHOR]

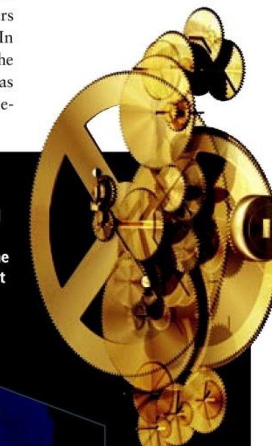
Tony Freeth's academic background is in mathematics and mathematical logic (in which he holds a Ph.D.). His award-winning career as a filmmaker culminated in a series of documentaries about increasing crop yields in sub-Saharan Africa, featuring the late Nobel Peace Prize Laureate Norman Borlaug. Since 2000 Freeth has returned to an academic focus with research on the Antikythera mechanism. He is managing director of the film and television production company Images First, and he is now developing a film on the mechanism.

[THE RECONSTRUCTION]

Anatomy of a Relic

Computed tomography—a 3-D mapping obtained from multiple x-ray shots—enabled the author and his colleagues to get inside views of the Antikythera mechanism's remnants. For example, a CT scan can be used to virtually slice up an object (*below, slices of main fragment*). The information helped the team see how the surviving gears connected and estimate their tooth counts, which determined what calculations they performed. The team could then reconstruct most of the device [*see model at right and box on next two pages*].





gan to discover inscriptions that had been invisible to human eyes for more than 2,000 years. One translated as "... spiral subdivisions 235...," confirming that the upper back dial was a spiral describing the Metonic calendar.

Babylon System

Back at home in London, I began to examine the CT scans as well. Certain fragments were clearly all part of a spiral dial in the lower back. An estimate of the total number of divisions in the dial's four-turn spiral suggested 220 to 225.

The prime number 223 was the obvious contender. The ancient Babylonians had discovered that if a lunar eclipse is observed—something that can happen only during a full moon—usually a similar lunar eclipse will take place 223 full moons later. Similarly, if the Babylonians saw a solar eclipse—which can take place only during a new moon—they could predict that 223 new moons later there would be a similar one (although they could not always see it: solar eclipses are visible only from specific locations, and ancient astronomers could not predict them reliably). Eclipses repeat this way because every 223 lunar months the sun, Earth and the moon return to approximately the same alignment with respect to one another, a periodicity known as the Saros cycle.

Between the scale divisions were blocks of symbols, nearly all containing Σ (*sigma*) or *H* (*eta*), or both. I soon realized that Σ stands for Σεληνη (*selene*), Greek for "moon," indicating a lunar eclipse; *H* stands for Ηλιοσ (*helios*), Greek for "sun," indicating a solar eclipse. The Babylonians also knew that within the 223-month period, eclipses can take place only in particular months, arranged in a predictable pattern and separated by gaps of five or six months; the distribution of symbols around the dial exactly matched that pattern.

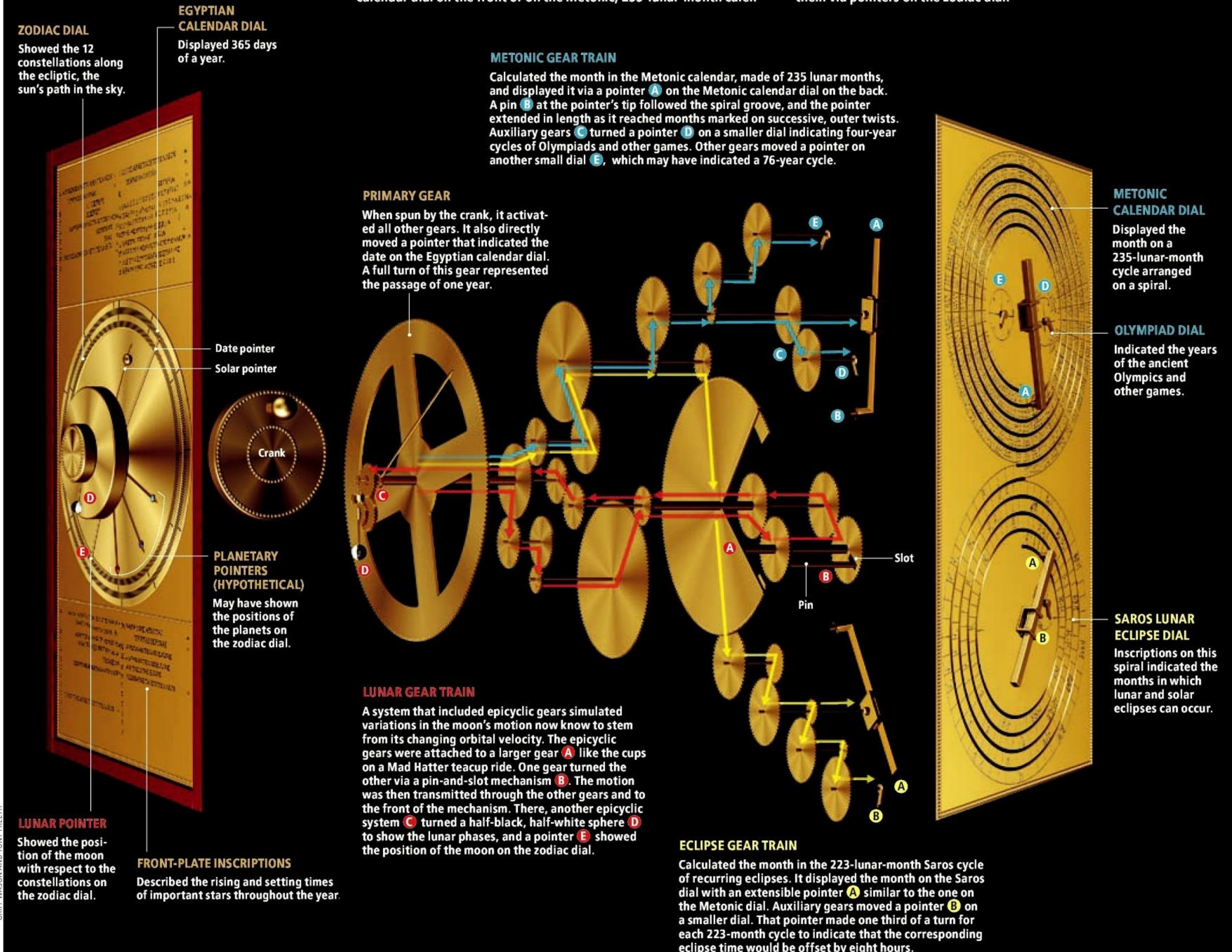
I now needed to follow the trail of clues into the heart of the mechanism to discover where this new insight would lead. The first step was to find a gear with 223 teeth to drive this new Saros dial. Karakalos had estimated that a large gear visible at the back of the main fragment had 222 teeth. But Wright had revised this estimate to 223, and Edmunds confirmed this. With plausible tooth counts for other gears and with the addition of a small, hypothetical gear, this 223-tooth gear could perform the required calculation.

But a huge problem still remained unsolved and proved to be the hardest part of the gearing to crack. In addition to calculating the Saros cy-

[INSIDE THE ANTIKYTHERA MECHANISM]

Astronomical Clockwork

This exploded view of the mechanism shows all but one of the 30 known gears, plus a few that have been hypothesized. Turning a crank on the side activated all the gears in the mechanism and moved pointers on the front and back dials: the arrows colored blue, red and yellow explain how the motion transmitted from one gear to the next. The user would choose a date on the Egyptian, 365-day calendar dial on the front or on the Metonic, 235-lunar-month calendar on the back and then read the astronomical predictions for that time—such as the position and phases of the moon—from the other dials. Alternatively, one could turn the crank to set a particular event on an astronomical dial and then see on what date it would occur. Other gears, now lost, may have calculated the positions of the sun and of some or all of the five planets known in antiquity and displayed them via pointers on the zodiac dial.



GRIFF WASON AND TONY FREETH

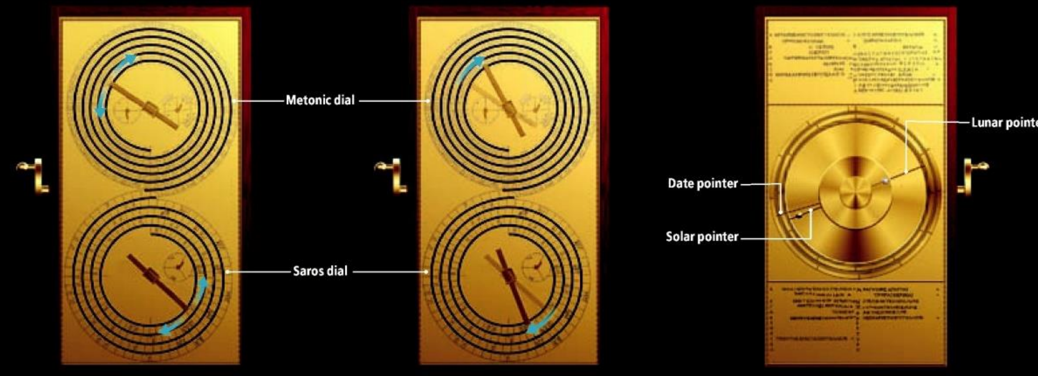
cle, the large 223-tooth gear also carried the epicyclic system noticed by Price: a sandwich of two small gears attached to the larger gear in teacup-ride fashion. Each epicyclic gear also connected to another small gear. Confusingly, all four small gears appeared to have the same tooth count—50—which seemed nonsensical because the output would then be the same as the input.

After months of frustration, I remembered that Wright had observed that one of the two epicyclic gears has a pin on its face that engages with a slot on the other. His key idea was that the two gears turned on slightly different axes, separated by about a millimeter. As a consequence, the angle turned by one gear alternated between being slightly wider and being slightly narrower than the angle turned by the other gear. Thus, if one gear turned at a constant rate, the other gear's rate kept varying between slightly faster and slightly slower.

[A USER'S MANUAL]

How to Predict an Eclipse

Operating the Antikythera mechanism may have required only a small amount of practice and astronomical knowledge. After an initial calibration by an expert, the mechanism could provide fairly accurate predictions of events several decades in the past or future. The inscriptions on the Saros dial, coming at intervals of five or six months, corresponded to months when Earth, the sun and the moon come to a near alignment (and so represented potential solar and lunar eclipses) in a 223-lunar-month cycle. Once the month of an eclipse was known, the actual day could be calculated on the front dials using the fact that solar eclipses always happen during new moons and lunar eclipses during full moons.



RESET DATE

Begin by turning the crank to set the current month and year on the Metonic calendar. The lower pointer will turn to the corresponding month on the Saros (*eclipse*) dial.

FIND ECLIPSE MONTH

Turn the crank to move time forward until the pointer on the Saros dial points to an eclipse inscription. The inscription will indicate month and time of the day (but not the day) of an eclipse and whether it will be solar or lunar.

CALCULATE DAY

Adjust the crank until the lunar and solar pointers are aligned (*for a solar eclipse*) or at 180 degrees (*for a lunar eclipse*). The Egyptian calendar pointer will move correspondingly and indicate the day of the eclipse.

Ask for the Moon

Although Wright rejected his own observation, I realized that the varying rotation rate is precisely what is needed to calculate the moon's motion according to the most advanced astronomical theory of the second century B.C., the one often attributed to Hipparchos of Rhodes. Before Kepler (A.D. 1605), no one understood that orbits are elliptical and that the moon accelerates toward the perigee—its closest point to Earth—and slows down toward the apogee, the opposite point. But the ancients did know that the moon's motion against the zodiac appears to periodically slow down and speed up. In Hipparchos's model, the moon moved at a constant rate around a circle whose center itself moved around a circle at a constant rate—a fairly good approximation of the moon's apparent motion. These circles on circles, themselves called epicycles, dominated astronomical thinking for the next 1,800 years.

There was one further complication: the apogee and perigee are not fixed, because the ellipse of the moon's orbit rotates by a full turn about every nine years. The time it takes for the body to get back to the perigee is thus a bit longer than the time it takes it to come back to the same point in the zodiac. The difference was just 0.112579655 turns a year. With the input gear having 27 teeth, the rotation of the large gear was slightly too big; with 26 teeth, it was slightly too small. The right result seemed to be about halfway in between. So I tried the impossible idea that the input gear had $26\frac{1}{2}$ teeth. I pressed the key on my calculator, and it gave 0.112579655—exactly the right answer. It could not be a coincidence to nine places of decimals! But gears cannot have fractional numbers of teeth.

Then I realized that $26\frac{1}{2} \times 2 = 53$. In fact, Wright had estimated a crucial gear to have 53 teeth, and I now saw that that count made everything work out. The designer had mounted the pin and slot epicyclically to subtly slow down the period of its variation while keeping the basic rotation the same, a conception of pure genius. Thanks to Edmunds, we also realized that the epicyclic gearing system, which is in the back of the mechanism, moved a shaft that turned inside another, hollow shaft through the rest of the mechanism and to the front, so that the lunar motion could be represented on the zodiac dial and on the lunar phase display. All gear counts were now explained, with the exception of one small gear that remains a mystery to this day.

Further research has caused us to make some modifications to our model. One was about a small subsidiary dial that is positioned in the back, inside the Metonic dial, and is divided into four quadrants. The first clue came when I read the word "*NEMEA*" under one of the quadrants. Alexander Jones, a New York University historian, explained that it refers to the Nemean Games, one of the major athletic events in ancient Greece. Eventually we found, engraved round the four sectors of the dial, most of "*ISTHMIA*," for games at Corinth, "*PYTHIA*," for games at Delphi, "*NAA*," for minor games at Dodona, and "*OLYMPIA*," for the most important games of the Greek world, the Olympics. All games took place every two or four years. Previously we had considered the mechanism to be purely an instrument of mathematical astronomy, but the Olympiad dial—as we named it—gave it an entirely unexpected social function.

DATA BY X-TEK SYSTEMS, SOFTWARE BY VOLUME GRAPHICS, © 2005 ANTIKYTHERA MECHANISM RESEARCH PROJECT

GRIFF WASON AND TONY FREETH

Twenty-nine of the 30 surviving gears calculate cycles of the sun and the moon. But our studies of the inscriptions at the front of the mechanism have also yielded a trove of information on the risings and settings of significant stars and of the planets. Moreover, on the "primary" gearwheel at the front of the mechanism remnants of bearings stand witness to a lost epicyclic system that could well have modeled the back-and-forth motions of the planets along the ecliptic (as well as the anomalies in the sun's own motion). All these clues strongly support the inclusion of the sun and of at least some of the five planets known in ancient times—Mercury, Venus, Mars, Jupiter and Saturn.

Wright built a model of the mechanism with epicyclic systems for all five planets. But his ingenious layout does not agree with all the evidence. With its 40 extra gears, it may also be too complex to match the brilliant simplicity of the rest of the mechanism. The ultimate answer may still lie 50 meters down on the ocean floor.

Eureka?

The question of where the mechanism came from and who created it is still open. Most of the cargo in the wrecked ship came from the eastern Greek world, from places such as Pergamon, Kos and Rhodes. It was a natural guess that Hipparchos or another Rhodian astronomer built the mechanism. But text hidden between the 235 monthly scale divisions of the Metonic calendar contradicts this view. Some of the month names were used only in specific locations in the ancient Greek world and suggest a Corinthian origin. If the mechanism was from Corinth itself, it was almost certainly made before Corinth was completely devastated by the Romans in 146 B.C. Perhaps more likely is that it was made to be used in one of the Corinthian colonies in northwestern Greece or Sicily.

Sicily suggests a remarkable possibility. The island's city of Syracuse was home to Archimedes, the greatest scientist of antiquity. In the first century B.C. Roman statesman Cicero tells how in 212 Archimedes was killed at the siege of Syracuse and how the victorious Roman general, Marcellus, took away with him only one piece of plunder—an astronomical instrument made by Archimedes. Was that the Antikythera mechanism? We believe not, because it appears to have been made many decades after Archimedes died. But it could have been constructed in a tradition of instrument making that originated with the eureka man himself.

Many questions about the Antikythera mechanism remain unanswered—perhaps the greatest being why this powerful technology seems to have been so little exploited in its own era and in succeeding centuries.

In *Scientific American*, Price wrote:

> *It is a bit frightening to know that just before the fall of their great civilization the ancient Greeks had come so close to our age, not only in their thought, but also in their scientific technology.*

Our discoveries have shown that the Antikythera mechanism was even closer to our world than Price had conceived. ■

➡ MORE TO EXPLORE

An Ancient Greek Computer. Derek J. de Solla Price in *Scientific American*, Vol. 200, No. 6, pages 60–67; June 1959.

Gears from the Greeks: The Antikythera Mechanism—A Calendar Computer from ca. 80 B.C. Derek de Solla Price in *Transactions of the American Philosophical Society*, New Series, Vol. 64, No. 7, pages 1–70; 1974.

Decoding the Ancient Greek Astronomical Calculator Known as the Antikythera Mechanism. Tony Freeth et al. in *Nature*, Vol. 444, pages 587–591; November 30, 2006.

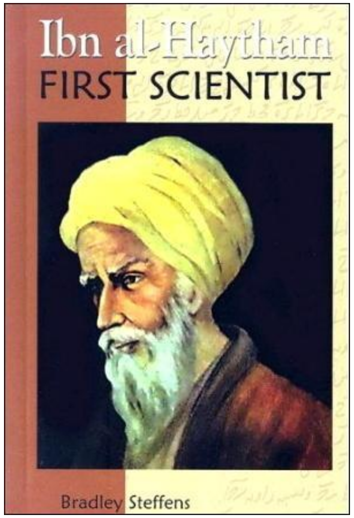
Calendars with Olympiad Display and Eclipse Prediction on the Antikythera Mechanism. Tony Freeth, Alexander Jones, John M. Steele and Yanis Bitsakis in *Nature*, Vol. 454, pages 614–617; July 31, 2008.

The Antikythera Mechanism Research Project: **www.antikythera-mechanism.gr**

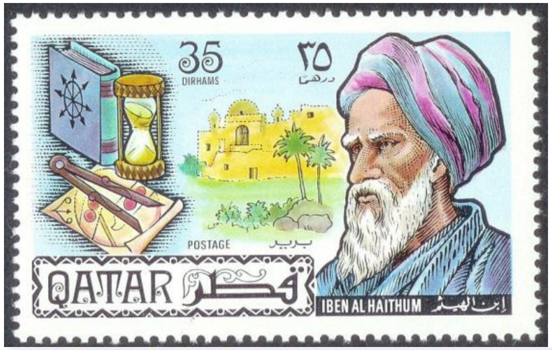
Historical Perspectives

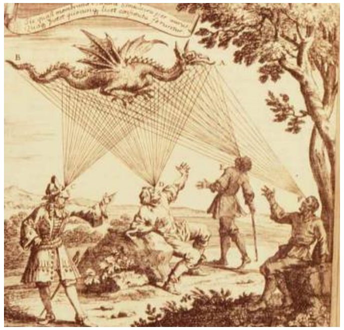
Abu Ali al-Hasan ibn al-Haytham (965-1039)

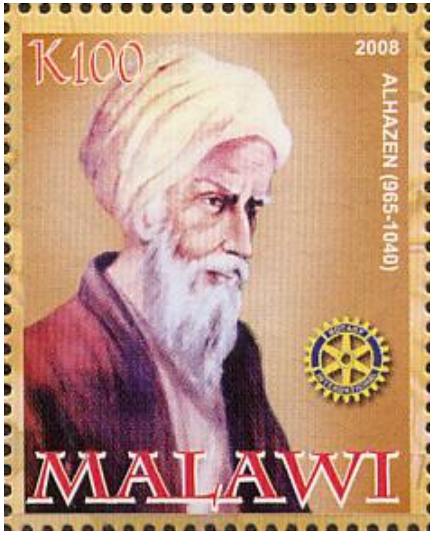
- AKA Alhazen or “The Physicist”
- Greatest scientist of the middle ages
- Contributed to mathematics, physics, optics, astronomy, anatomy, medicine, engineering, philosophy, psychology
- Pioneered the scientific method, modern optics and experimental physics
- Polymath: authored over 200 treatises, including influential “Book of Optics”
- Influenced Leonardo da Vinci, Bacon, Descartes, Kepler, Galileio and Newton

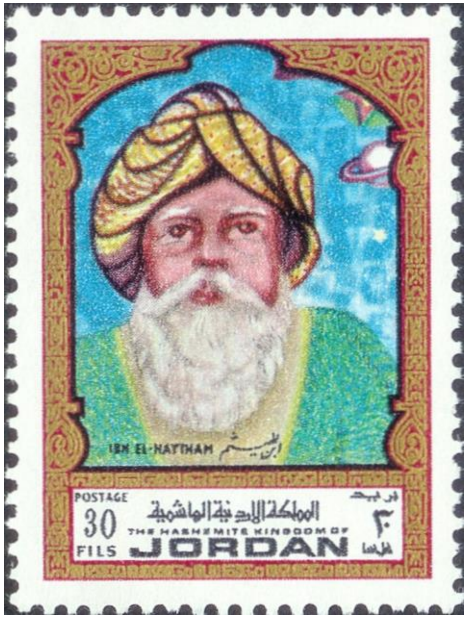


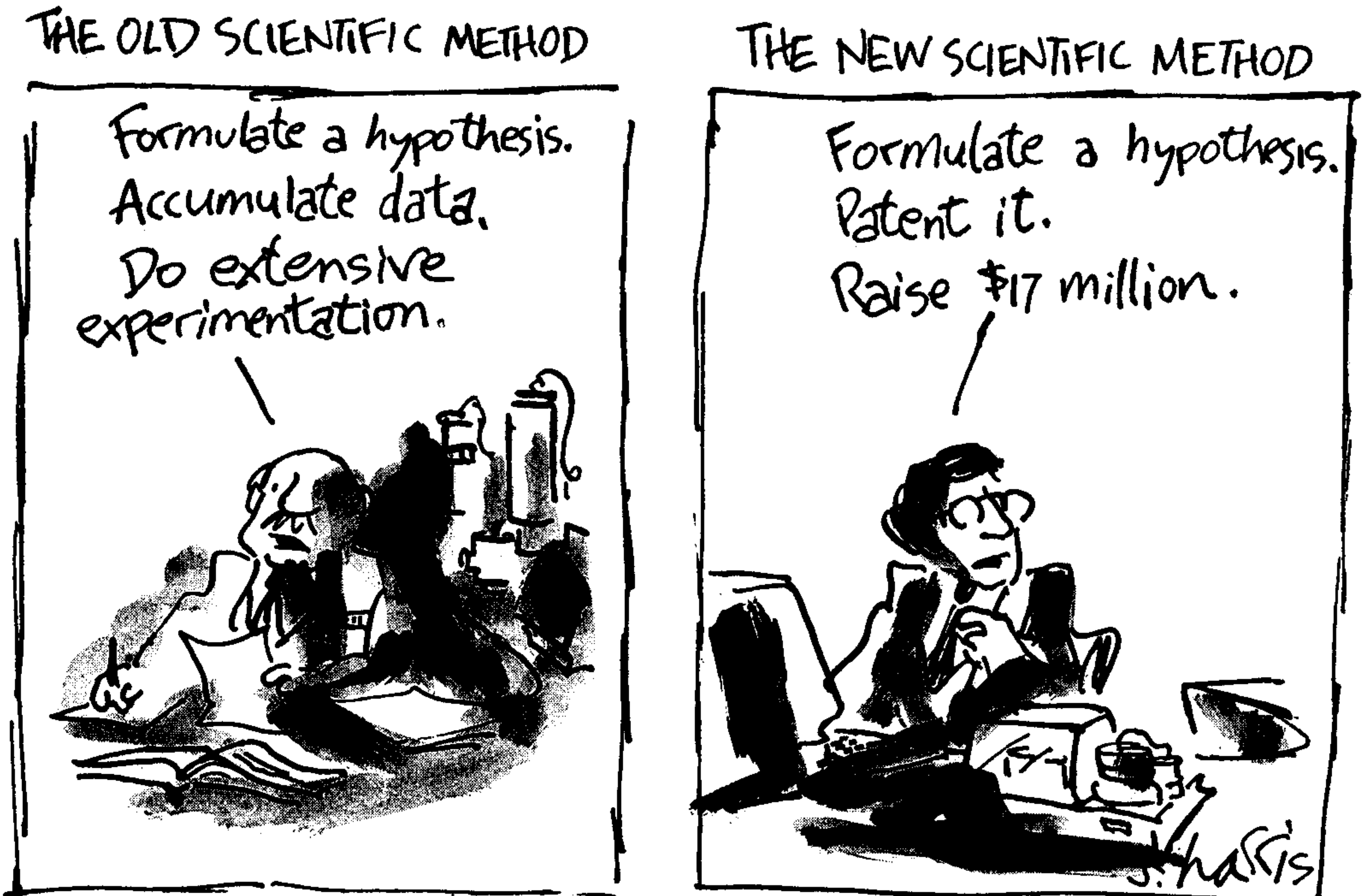

ALHAZEN FILII
ALHAYZEN OPTICAE
LIBER PRIMVS










THE OLD SCIENTIFIC METHOD
Formulate a hypothesis. Accumulate data. Do extensive experimentation.
THE NEW SCIENTIFIC METHOD
Formulate a hypothesis. Patent it. Raise $17 million.
S. harris

Historical Perspectives

Leonardo of Pisa (1170–1250)

- Better known as “Fibonacci”
- Considered the most talented mathematician of the middle ages
- Published (1202) “Liber Abaci” – “The Book of Calculation”
- Introduced Hindu-Arabic positional number system in Europe
- Popularized Fibonacci sequence

1 1 2 3 5 8 13 21 34 55 89

	0	1	2	3	4	5	6	7	8	9
European	0	1	2	3	4	5	6	7	8	9
Arabic-Indic	٠	١	٢	٣	٤	٥	٦	٧	٨	٩
Eastern Arabic-Indic (Persian and Urdu)	۰	۱	۲	۳	۴	۵	۶	۷	۸	۹
Devanagari (Hindi)	०	१	२	३	४	५	६	७	८	९
Tamil		௧	௨	௩	௪	௫	௬	௭	௮	௯

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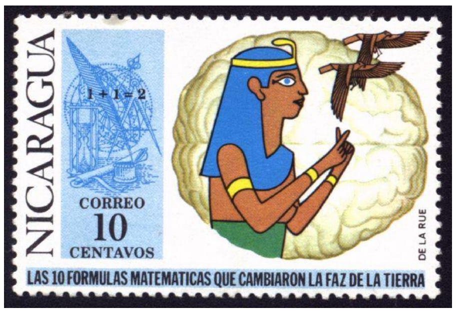
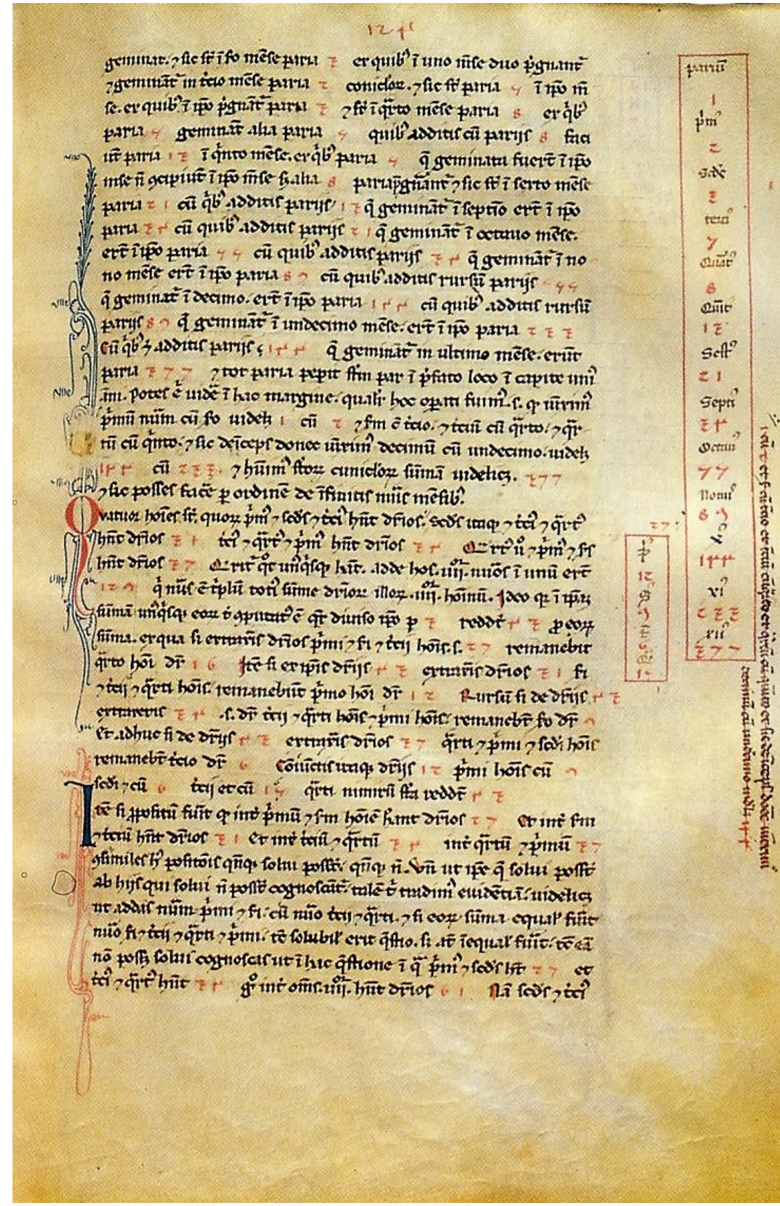
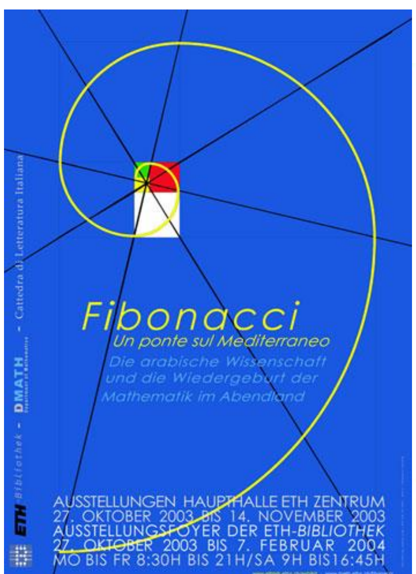
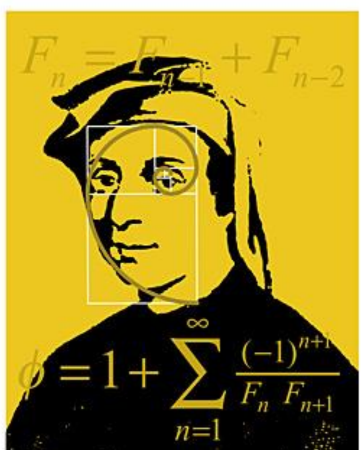








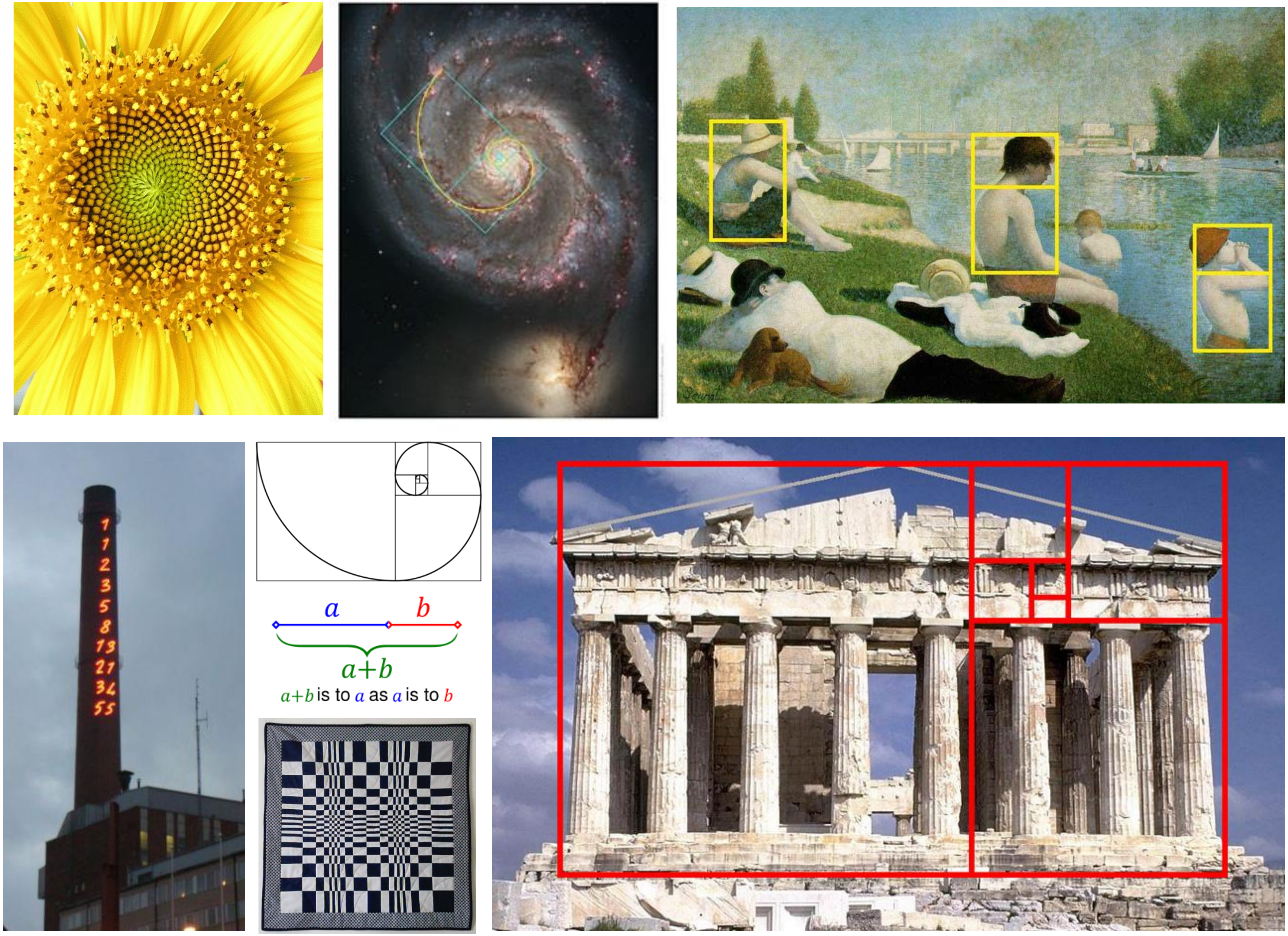
Leonardo Pisano Fibonacci

1170 - 1250

THE FIBONACCI ASSOCIATION

The Fibonacci Quarterly

Official Publication of The Fibonacci Association



1 1 2 3 5 8 13 21 34 55
a
b
a+b
a+b is to a as a is to b


Nicolai N. Vorobiev
Fibonacci Numbers
Birkhäuser
The Golden Ratio and Fibonacci Numbers
by Richard A. Dunlap
World Scientific
Applications of Fibonacci Numbers
Volume 4
edited by
G. E. Bergum, A. N. Philippou and A. F. Horadam
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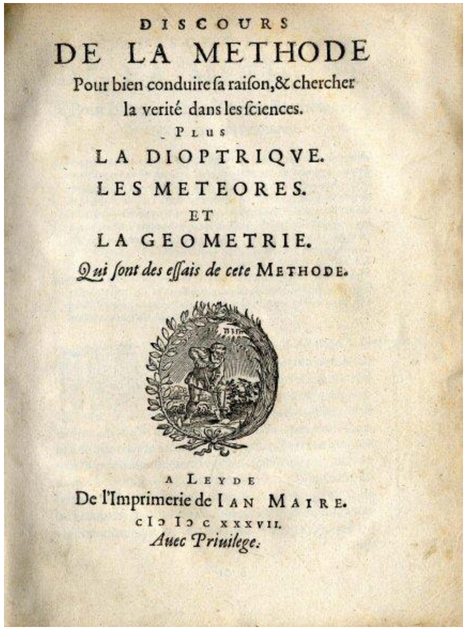
Nature's Secret Code Revealed
by Joy N. Hulme
Illustrations by Carol Schwartz

Historical Perspectives

René Descartes (1596-1650)

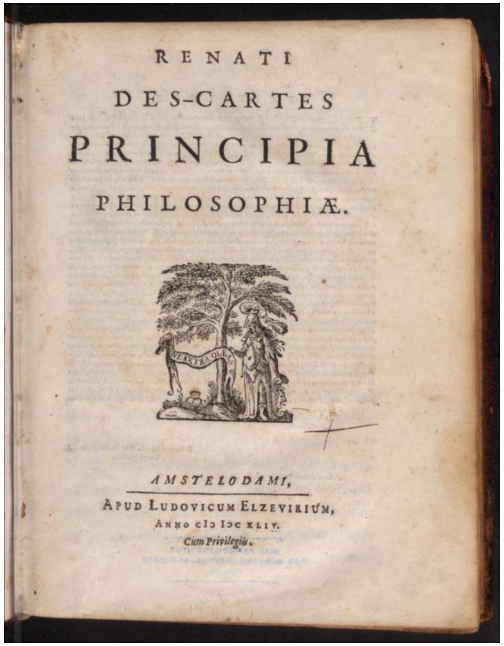
- Father of modern philosophy
- Invented Cartesian coordinates, analytic geometry, heuristics
- Characterized paradoxes & falacies
- Discovered momentum conservation
- Authored “Principia Philosophiae”
- Pioneered methodological skepticism “Cogito ergo sum” - “Je pense, donc je suis ”
- “Discours de la Méthode” (1637) - one of the most influential works in modern science
- Pioneered the scientific method & revolution



DISCOURS
DE LA METHODE
Pour bien conduire ſa raiſon, & chercher
la verité dans les ſciences.
PLUS
LA DIOPTRIQVE.
LES METEORES.
ET
LA GEOMETRIE.
Qui ſont des eſſais de cete METHODE.

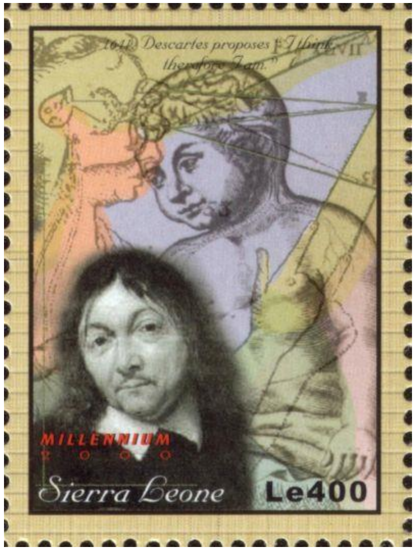
A LEYDE
De l'Imprimerie de IAN MAIRE.
CIƆ IƆ C XXXVII.
Auec Priuilege.

“For it is not enough to have a good mind: one must use it well.” - Descartes



RENATI
DES-CARTES
PRINCIPIA
PHILOSOPHIÆ.

AMSTELODAMI,
APUD LUDOVICUM ELZEVIRIUM,
ANNO CIↃ IↃC XLIV.
Cum Privilegio.



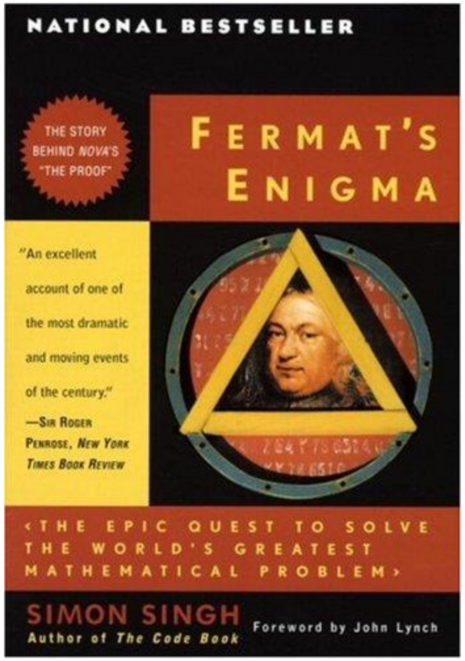
René Descartes 1596 - 1650

RENÉ DESCARTES EXPLAINS THE COORDINATE SYSTEM WHICH TIES TOGETHER ALGEBRA AND GEOMETRY

Historical Perspectives

Pierre de Fermat (1601-1665)

- Father of modern number theory
- Lawyer, Parlement of Toulouse
- Laid groundwork for calculus
- Contributions to optics, probability, and analytic geometry
- Fermat numbers, primes, perfect #'s
- Descartes' Law of refraction
- Reponsible for many open problems
- "Fermat's Last Theorem" (1637-1995)
- Recognized "principle of least action" and "principle of least time" in physics
- Influenced Newton and Leibniz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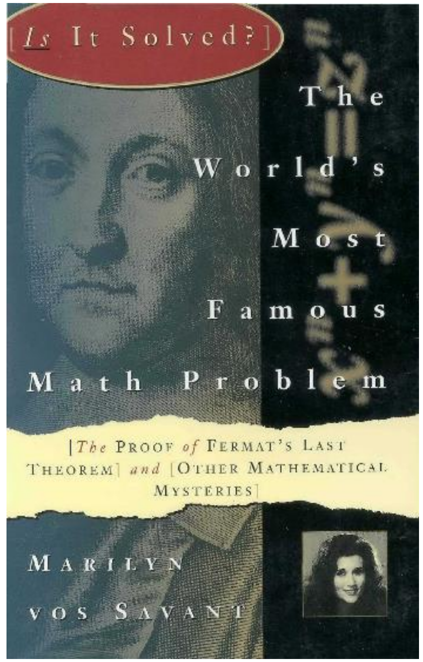
Foreword by John Lynch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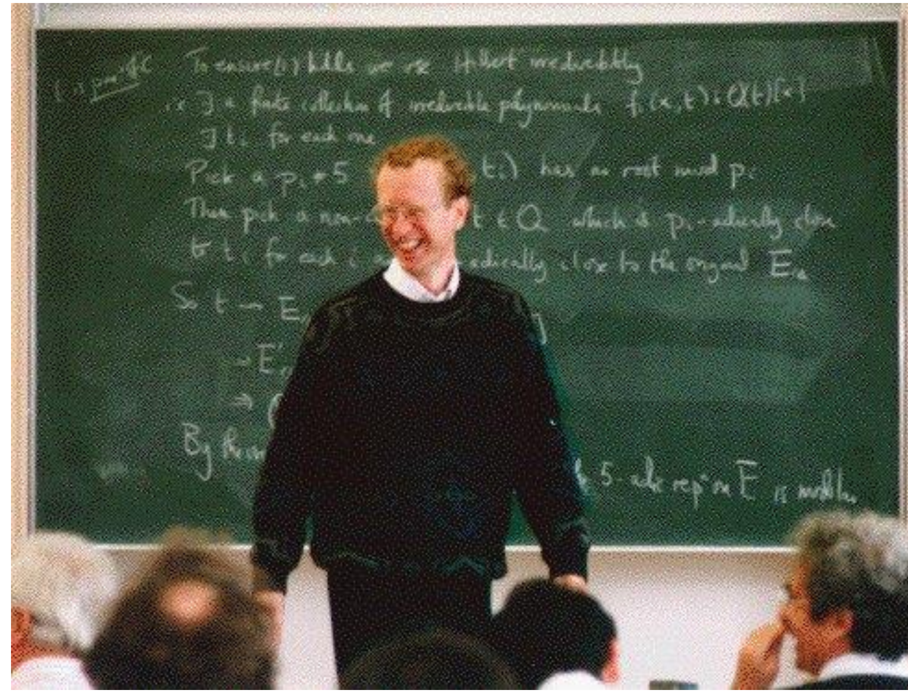
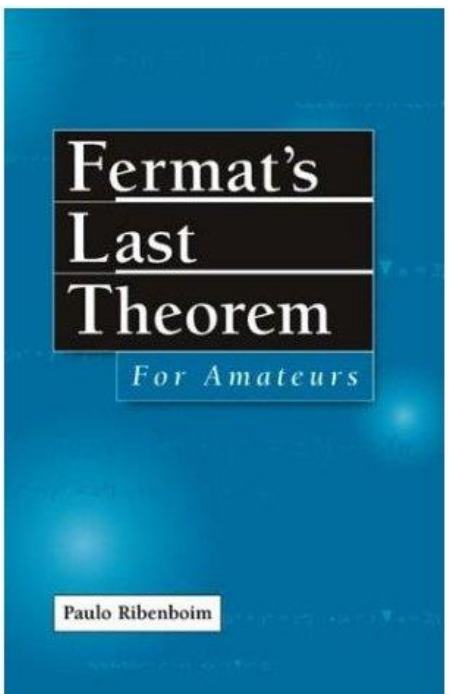
The World's Most Famous Math Problem
[The Proof of Fermat's Last Theorem] and [Other Mathematical Mysteries]
MARILYN VOS SAVANT

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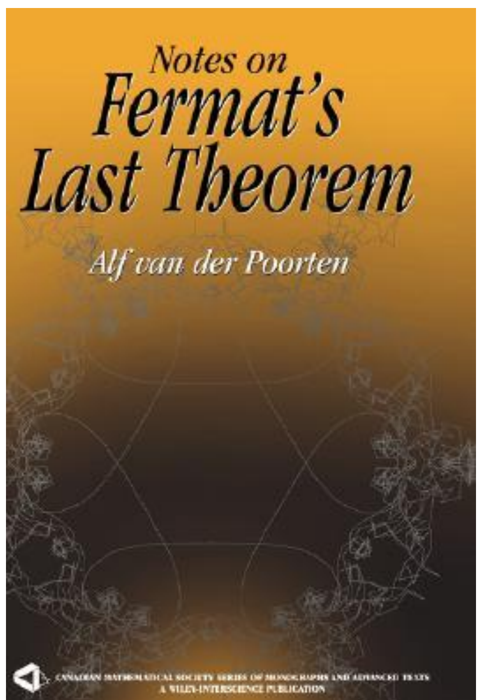
For Amateurs
Paulo Ribenboim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Alf van der Poorten
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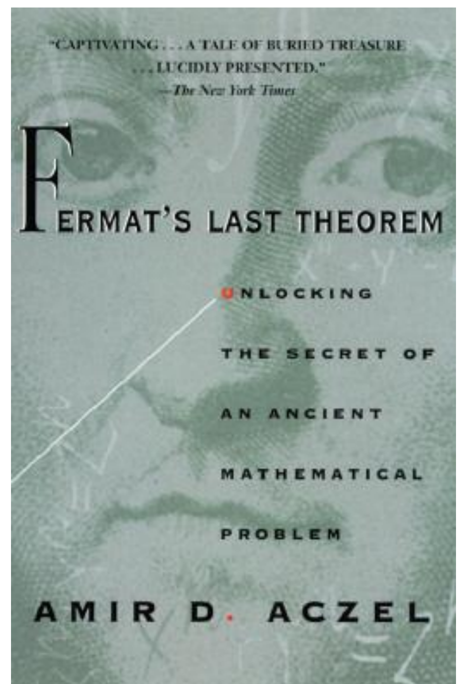
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—The New York Times
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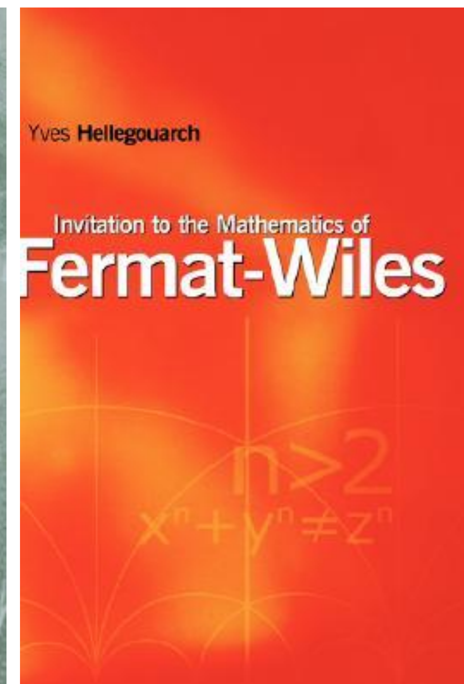
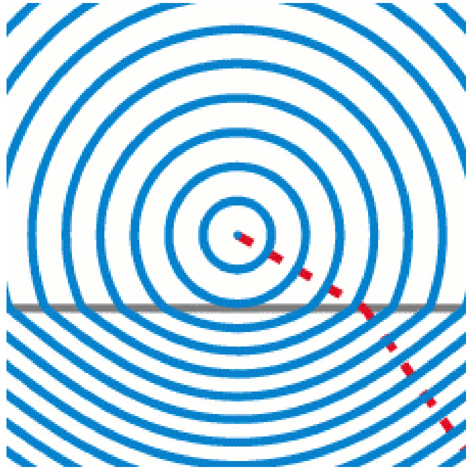
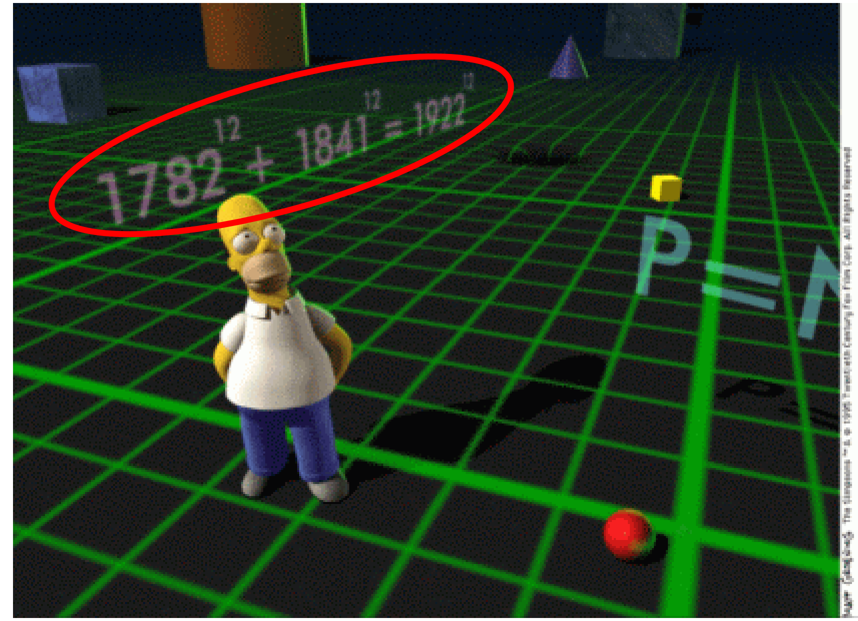
UNLOCKING THE SECRET OF AN ANCIENT MATHEMATICAL PROBLEM
AMIR D. ACZEL

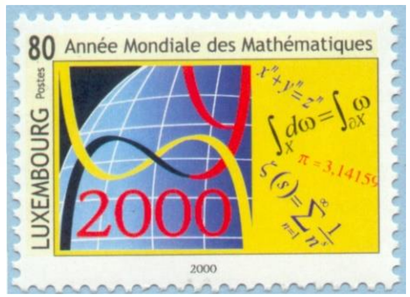

Yves Hellegouarch
Invitation to the Mathematics of
Fermat-Wiles
n>2
x^n+y^n≠z^n

Pierre de Fermat

1601 - 1665







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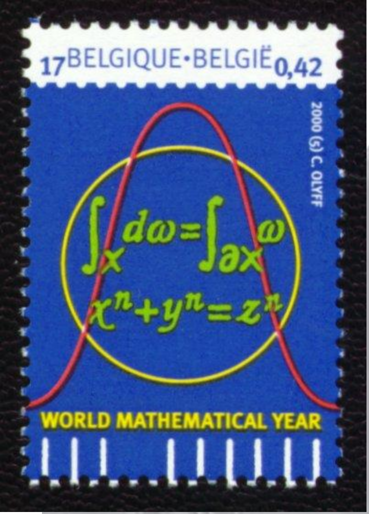
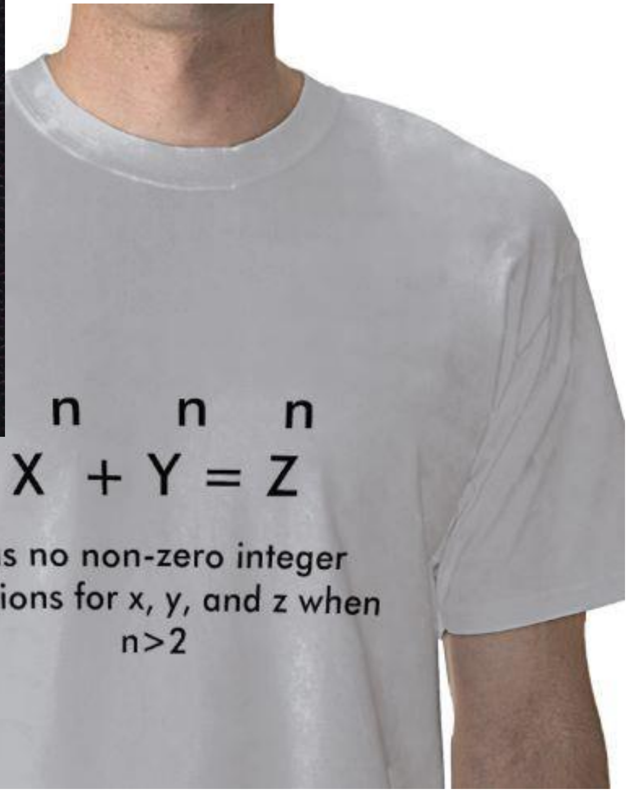

17 BELGIQUE·BELGIË 0,42
2000 (c) C. OLYFF
$\int_X d\omega = \int_{\partial X} \omega$
$x^n + y^n = z^n$
WORLD MATHEMATICAL YEAR


$X^n + Y^n = Z^n$
has no non-zero integer solutions for x, y, and z when n>2


FERMAT
39 km
97 / 10 / 08
D=254mm f/D=10
Moon "LIGHT"
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B/W QuickCam
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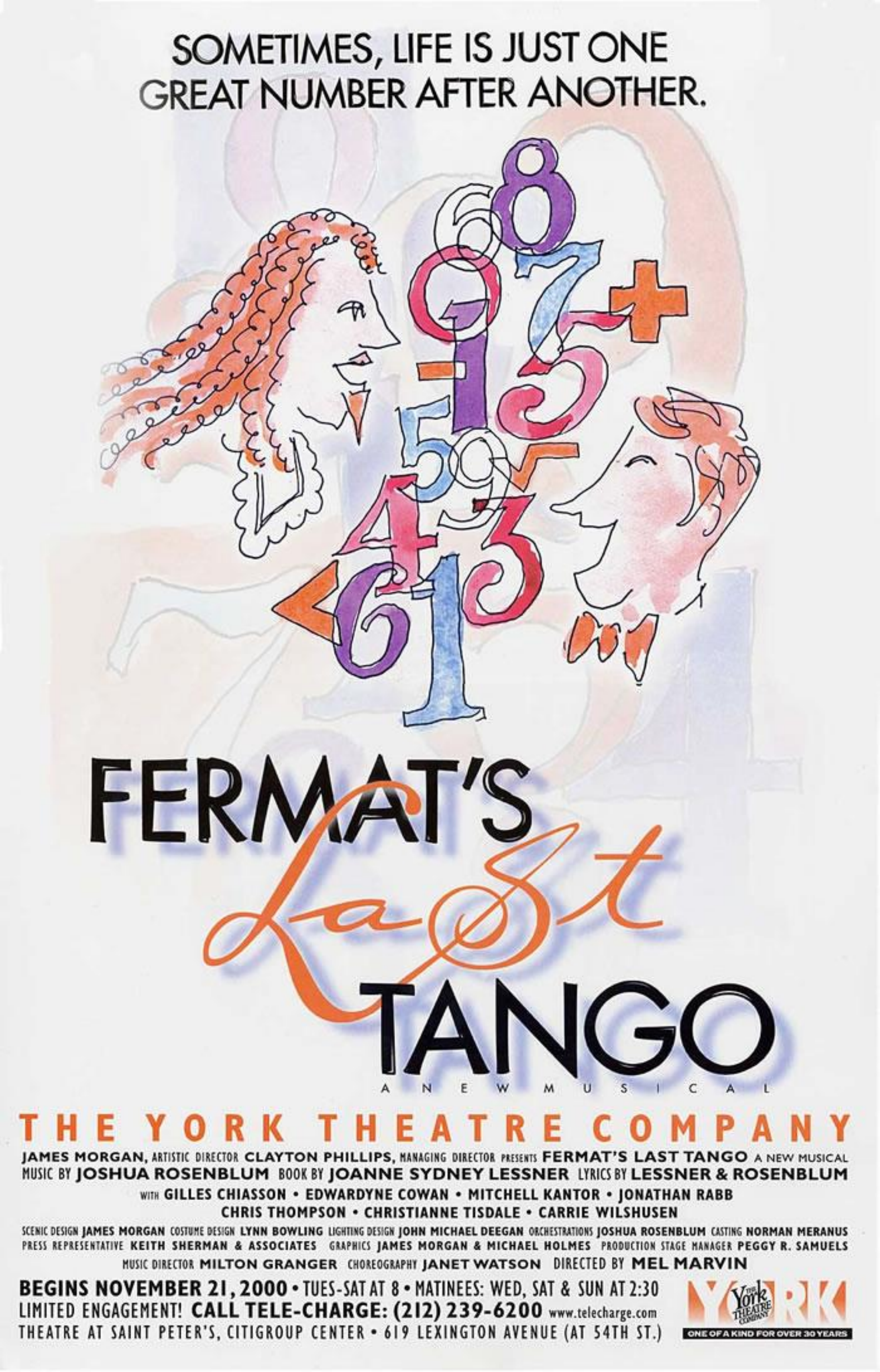
SOMETIMES, LIFE IS JUST ONE GREAT NUMBER AFTER ANOTHER.
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THE YORK THEATRE COMPANY

A Musical Fantasy inspired by Andrew Wiles and his encounters with Fermat's Last Theorem

"Rollicking! Whimsical! Catchy & Clever!" - The New York Times

FERMAT'S LAST TANGO

Followed by an Interview with Andrew Wiles

A CMI production

VHS

In 1993 Andrew Wiles stunned the world when he announced a solution to "Fermat's Last Theorem," the famous unsolved mathematics problem set forth by Pierre de Fermat in 1637. In the musical *Fermat's Last Tango*, the fictional character Daniel Keane earns overnight acclaim when he presents his findings. However, fanfare soon gives way to doubt when the reincarnated Fermat discovers a hole in Keane's proof. The singular pursuit by Keane to correct this flaw results in a love triangle involving himself, his wife, and mathematics—the story of which is brought to life by Fermat and his immortal friends from the "AfterMath," namely: Pythagoras, Euclid, Newton, and Gauss. The musical is both a cheerful romp through history and a personal confrontation with destiny. It provides a testament to the extraordinary excitement of mathematics and its unparalleled beauty.

The Composer Joshua Rosenblum enjoyed mathematics while studying music at Yale along with the author, his wife Joanne Sydney Lessner. They both take an active role in the New York music community. This recording was captured by David Stern and his Emmy Award-winning crew during a performance at the York Theatre Company in New York City.

STARRING

Carl Friedrich Gauss / Reporter	GILLES CHIASSON
Anna Keane	EDWARDYNE COWAN
Pythagoras / Reporter	MITCHELL KANTOR
Pierre de Fermat	JONATHAN RABB
Daniel Keane	CHRIS THOMPSON
Euclid / Reporter	CHRISTIANNE TISDALE
Sir Isaac Newton / Reporter	CARRIE WILSHUSEN

Approximate Running Time: 100 minutes
Color/Not Rated/VHS/NTSC
Produced by The Clay Mathematics Institute, Cambridge, MA
Arthur Jaffe, *Producer*
David Stern, *Director*

Illustrated Guide Enclosed

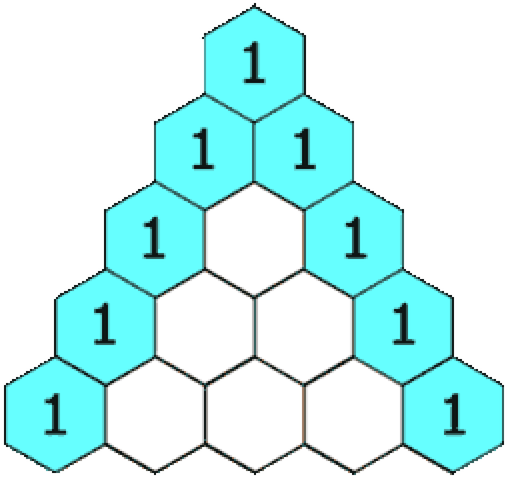
The Clay Mathematics Institute
1770 Massachusetts Avenue #331
Cambridge, MA 02140
Email: fermat@claymath.org
Website: www.claymath.org

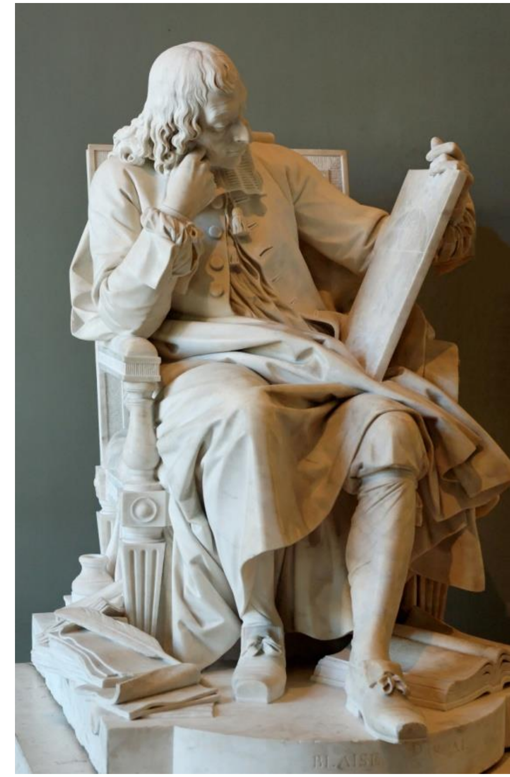
FERMAT'S *Last* TANGO

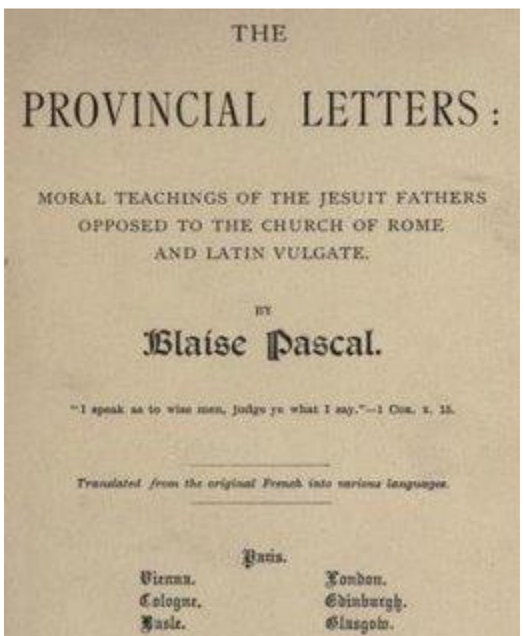
Historical Perspectives

Blaise Pascal (1623-1662)

- Mathematician, physicist, philosopher
- Studied fluids, pressure, vacuum
- Helped pioneer projective geometry, probability, and the scientific method
- Influenced modern economics
- "Pascal's triangle", "Pascal's law"
- Invented hydraulic press and syringe
- Constructed a mechanical calculator
- Used humor, wit, and satire in writings
- Influenced Voltaire and Rousseau
- Inagurated the world's first bus line
- SI unit of pressure - "pascal"






THE

PROVINCIAL LETTERS:

MORAL TEACHINGS OF THE JESUIT FATHERS
OPPOSED TO THE CHURCH OF ROME
AND LATIN VULGATE.

BY

Blaise Pascal.

"I speak as to wise men, judge ye what I say."—1 Cor. x. 15.

Translated from the original French into various languages.

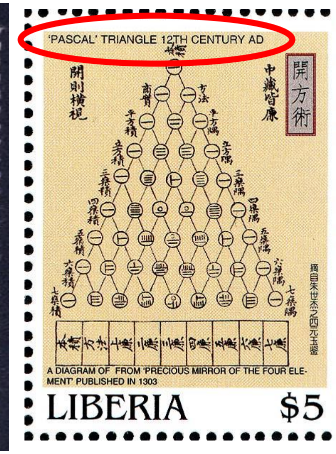
Paris.

Vienna. London.
Cologne. Edinburgh.
Basle. Glasgow.

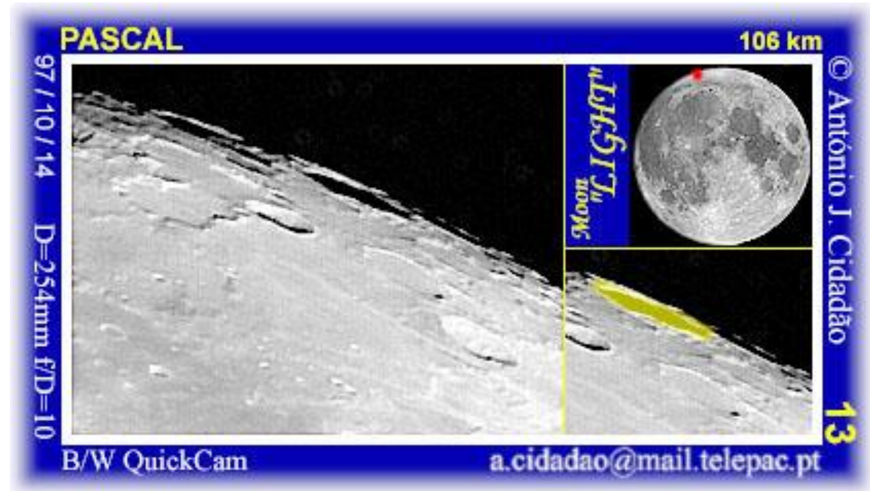

0,50
PASCAL
1623-1662
PENSÉES
REPUBLIQUE FRANÇAISE
POSTES

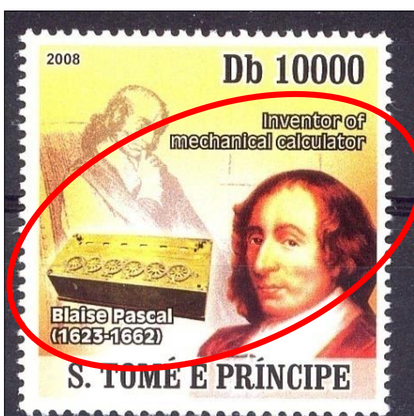

BLAISE PASCAL
1623-MONACO-1973
0,50

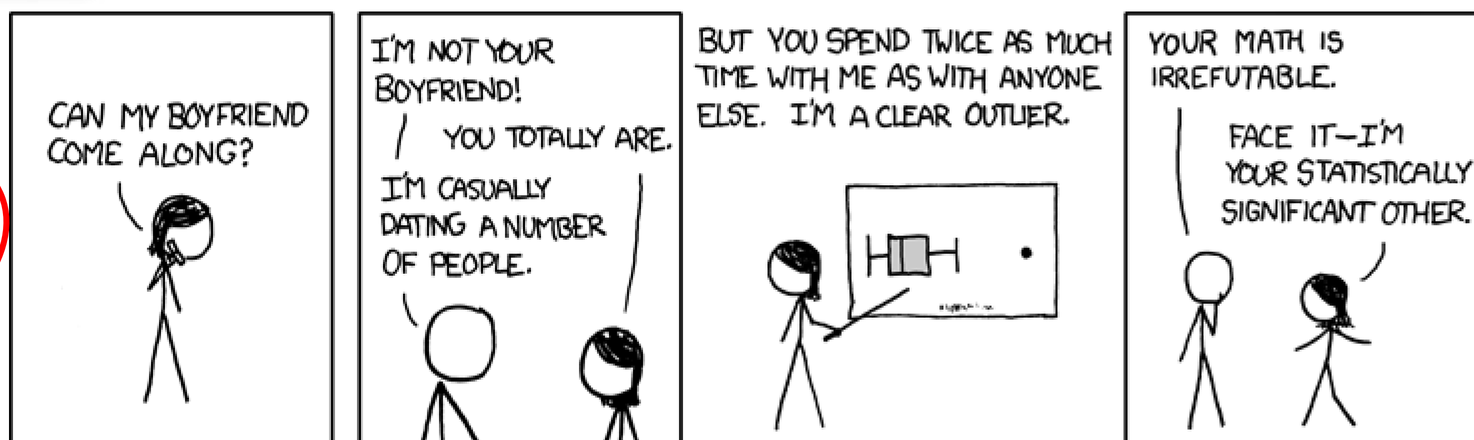

1623 PASCAL 1662
POSTES 1f20+2f80
FRANCE


'PASCAL' TRIANGLE 12TH CENTURY AD
開方術
A DIAGRAM OF FROM 'PRECIOUS MIRROR OF THE FOUR ELEMENT' PUBLISHED IN 1303
LIBERIA
$5

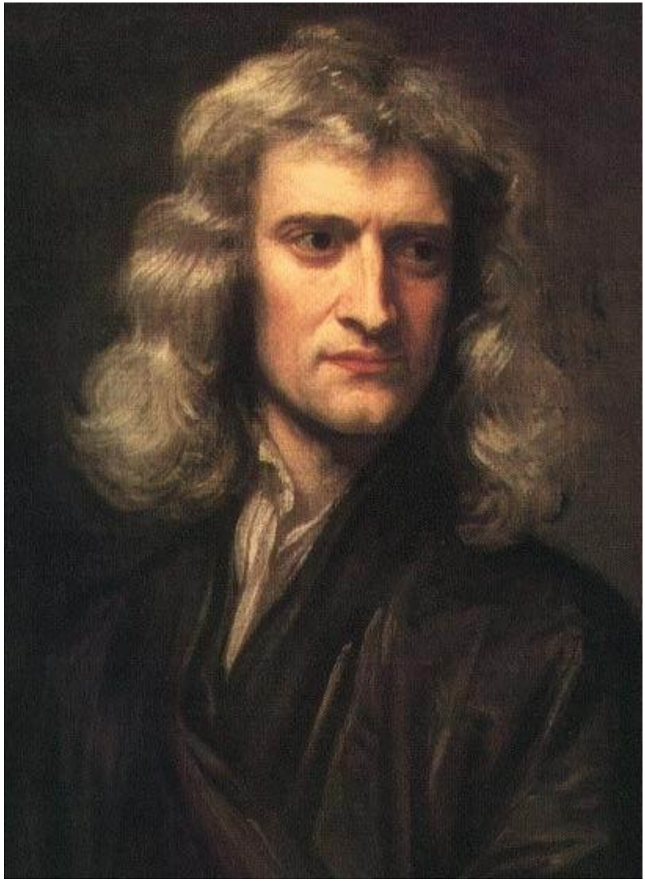

The heart has its reasons which reason cannot know
Blaise Pascal


PASCAL
106 km
97 / 10 / 14
D=254mm f/D=10
Moon "LIGHT"
© António J. Cidadão
13
B/W QuickCam
a.cidadao@mail.telepac.pt


2008
Db 10000
Inventor of mechanical calculator
Blaise Pascal (1623-1662)
S. TOMÉ E PRÍNCIPE

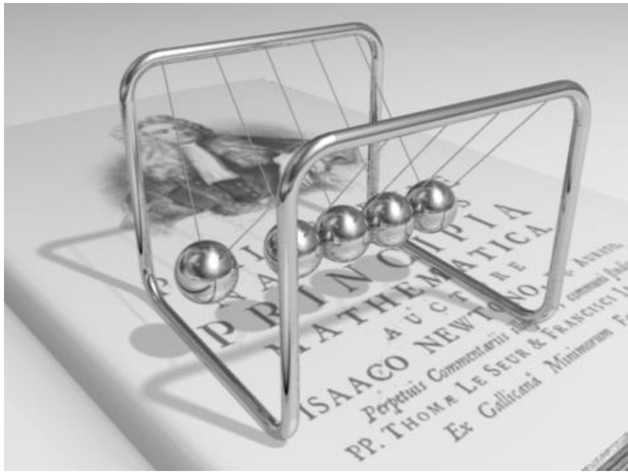

CAN MY BOYFRIEND COME ALONG?
I'M NOT YOUR BOYFRIEND!
YOU TOTALLY ARE.
I'M CASUALLY DATING A NUMBER OF PEOPLE.
BUT YOU SPEND TWICE AS MUCH TIME WITH ME AS WITH ANYONE ELSE. I'M A CLEAR OUTLIER.
YOUR MATH IS IRREFUTABLE.
FACE IT—I'M YOUR STATISTICALLY SIGNIFICANT OTHER.

Historical Perspectives



Sir Isaac Newton (1643-1727)

- Mathematician, physicist, astronomer, philosopher, alchemist, theologian
- One of history's most influential people
- "Principia Mathematica" (1687)
- Invented calculus, theory of gravitation
- Founded "Newtonian mechanics"
- Discovered laws of motion, inertia
- "Newtonian fluid", "Newtonian Universe"
- Advanced the Scientific Revolution
- Developed practical reflecting telescope, theory of color, "Newton's method"
- SI unit of force: newton



PHILOSOPHIÆ NATURALIS PRINCIPIA MATHEMATICA.

Autore JS. NEWTONO, Trin. Coll. Cantab. Soc. Matheseos Professore *Lucasiano*, & Societatis Regalis Sodali.

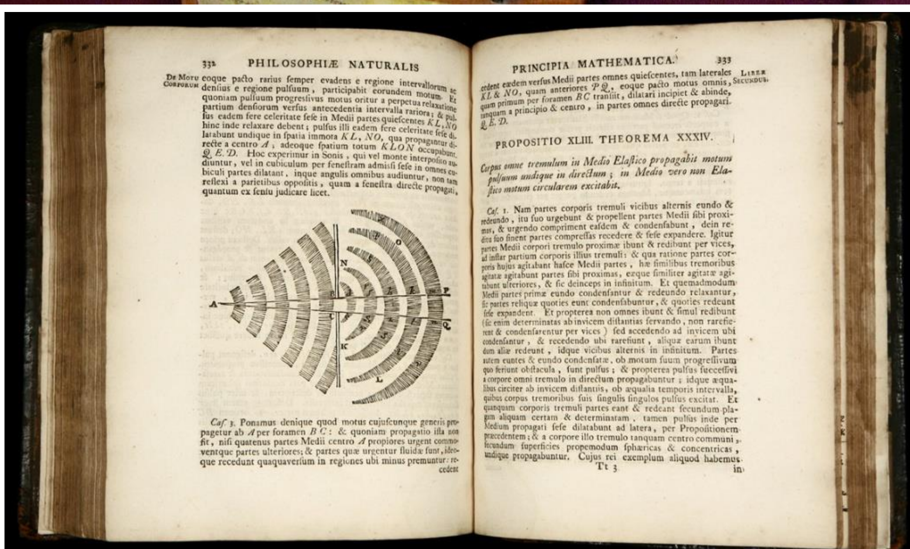
Isaaco Equite Aurato,

et ~~Societatis~~ Regiae Societatis Praeside

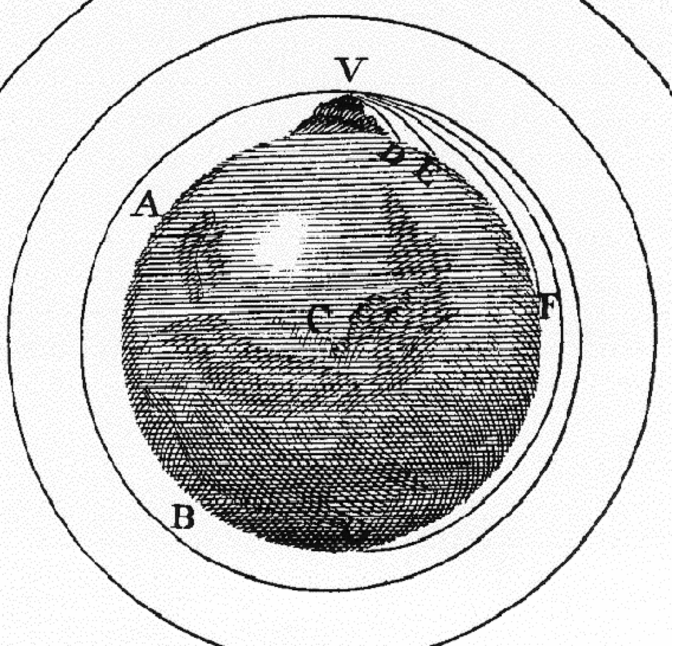
IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

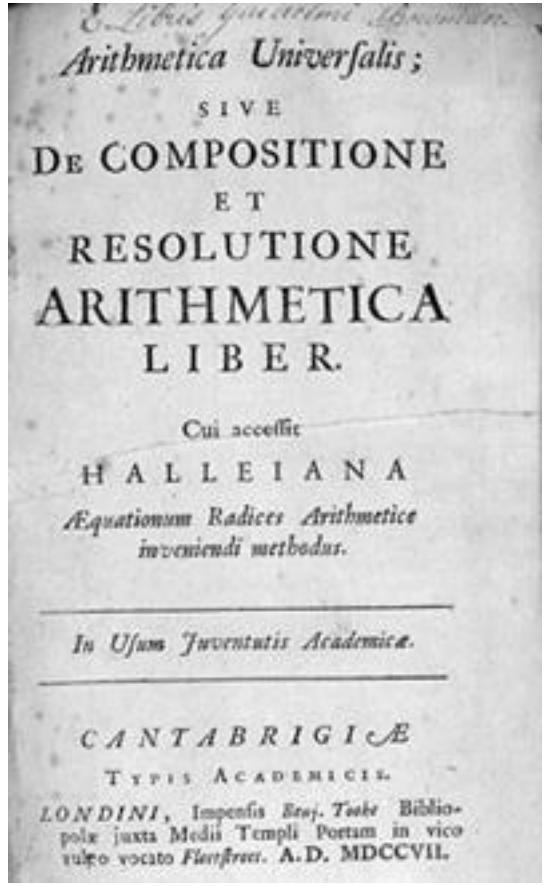
LONDINI,

Jussu *Societatis Regiæ* ac Typis *Josephi Streater*. Prostat apud plures Bibliopolas. *Anno* MDCLXXXVII.


PHILOSOPHIÆ NATURALIS
PRINCIPIA MATHEMATICA.
PROPOSITIO XLIII. THEOREMA XXXIV.


NEWTON




E Libris Guielmi Brownlow

Arithmetica Universalis;

SIVE

DE COMPOSITIONE

ET

RESOLUTIONE

ARITHMETICA

LIBER.

Cui accessit

HALLEIANA

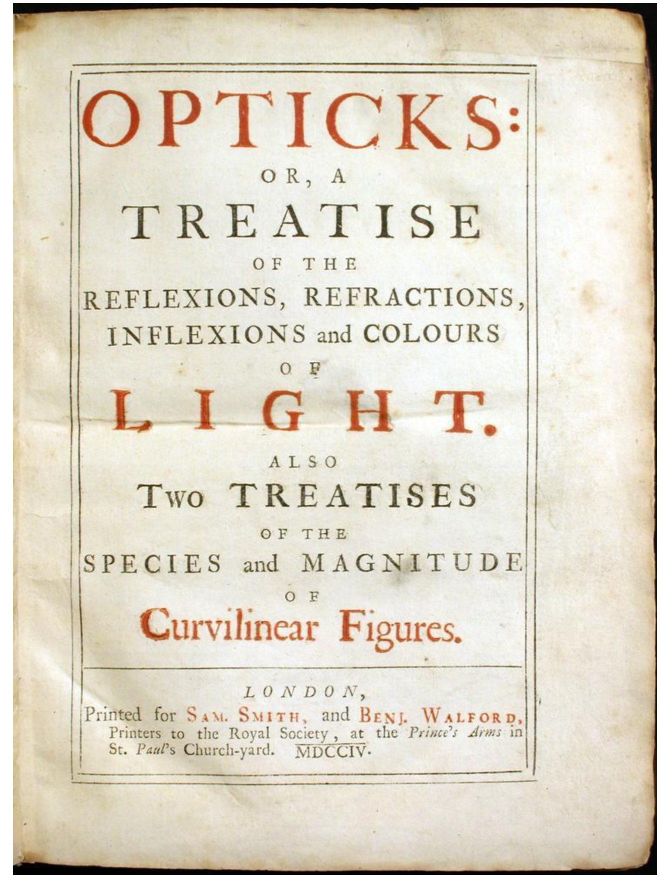
Æquationum Radices Arithmetice inveniendi methodus.

In Usum Juventutis Academicæ.

CANTABRIGIÆ

Typis Academicis.

LONDINI, Impensis Benj. Tooke Bibliopolæ juxta Medii Templi Portam in vico vulgo vocato Fleetstreet. A.D. MDCCVII.


OPTICKS:

OR, A

TREATISE

OF THE

REFLEXIONS, REFRACTIONS, INFLEXIONS and COLOURS

OF

LIGHT.

ALSO

Two TREATISES

OF THE

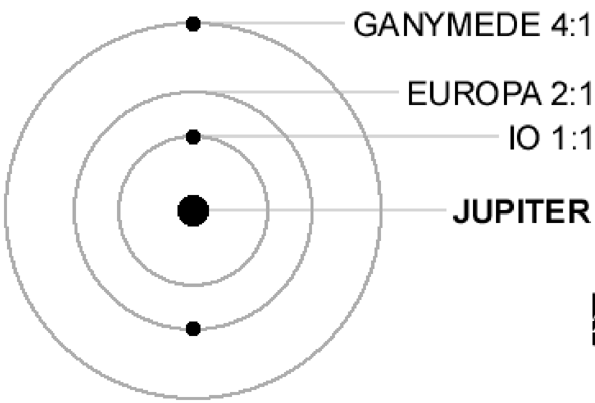
SPECIES and MAGNITUDE

OF

Curvilinear Figures.

LONDON,

Printed for Sam. Smith, and Benj. Walford, Printers to the Royal Society, at the Prince's Arms in St. Paul's Church-yard. MDCCIV.



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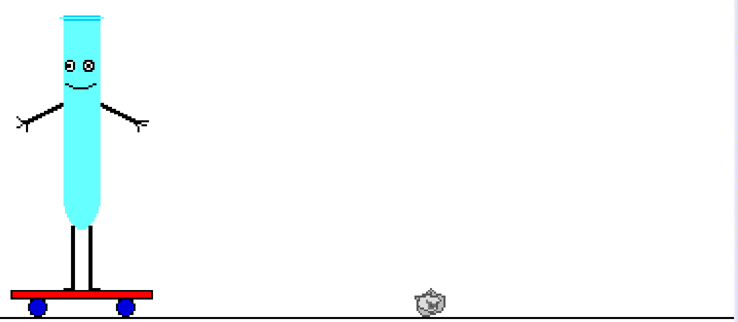
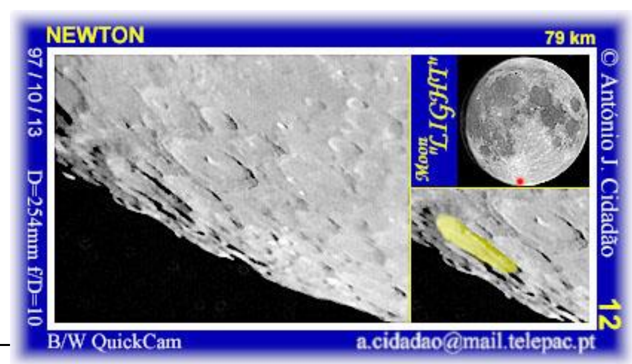
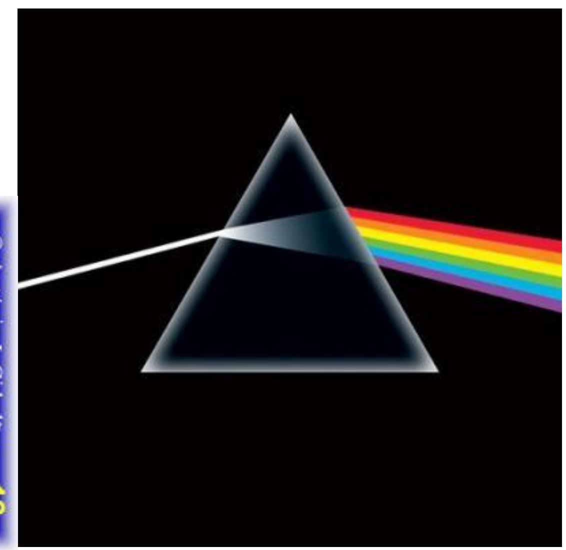
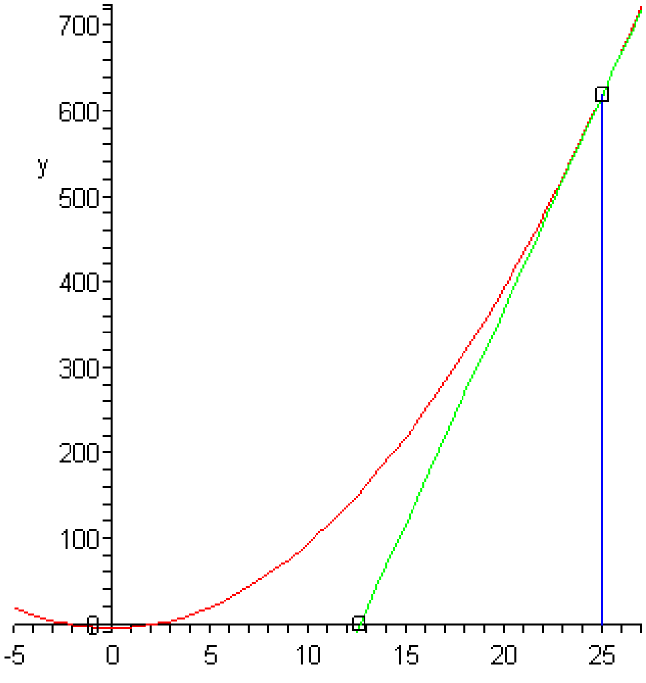


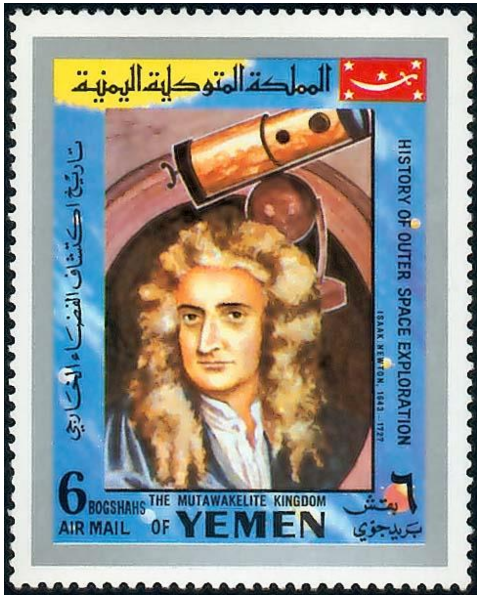




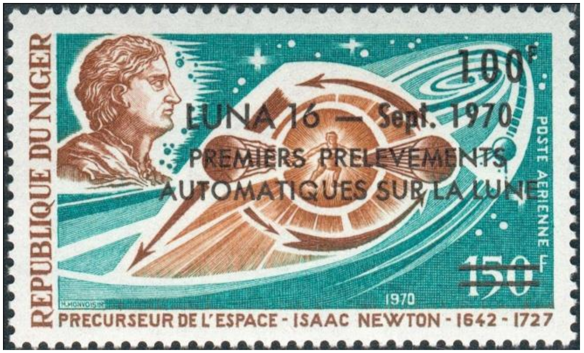

700
600
500
400
300
200
100
0
y
-5
0
5
10
15
20
25

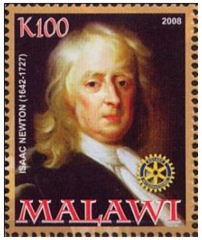

JOHANNES KEPLER'S UPHILL BATTLE
...SO, YOU SEE, THE ORBIT OF A PLANET IS ELLIPTICAL.
WHAT'S AN ORBIT?
WHAT'S A PLANET?
WHAT'S 'ELLIPTICAL'?
J. harris


ONE POUND
£1
Sir Isaac Newton
1642 · 1727

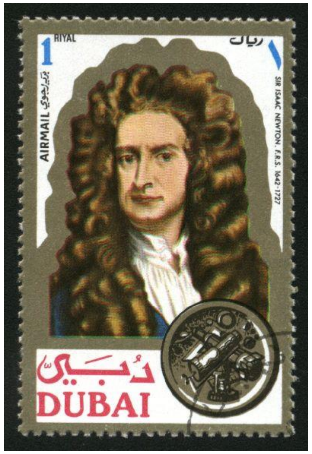

المملكة المتوكلية اليمنية
HISTORY OF OUTER SPACE EXPLORATION
ISAAC NEWTON, 1643 - 1727
6 BOGSHAHS
AIR MAIL
THE MUTAWAKELITE KINGDOM OF YEMEN
بريد جوي


REDONDA
20¢
SIR ISAAC NEWTON
CRANE COURT, HOME OF THE ROYAL SOCIETY


REPUBLIQUE DU NIGER
100F
LUNA 16 — Sept. 1970
PREMIERS PRELEVEMENTS
AUTOMATIQUES SUR LA LUNE
POSTE AERIENNE
~~150~~
1970
PRECURSEUR DE L'ESPACE - ISAAC NEWTON - 1642 - 1727


K100
2008
ISAAC NEWTON (1642-1727)
MALAWI

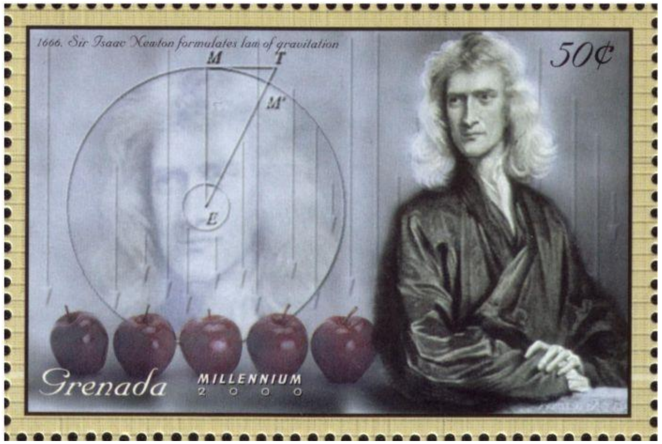

REPUBLIQUE POPULAIRE DU CONGO
140F
POSTE AERIENNE 1977
ISAAC NEWTON 1642.1727


1 RIYAL
AIRMAIL
SIR ISAAC NEWTON, F.R.S. 1642-1727
دبي
DUBAI


поща БЪЛГАРИЯ
BULGARIA
1 00
ИСАК НЮТОН
1643
1727
ГРУЕВ 1993

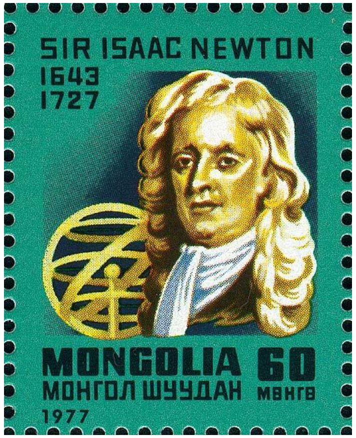

IZAAK NEWTON
1642-1727
POLSKA 1 ZŁ 55
STCZ-CHLUDZINSKI PWPW B.KOWALSKA-SC


ISAAC NEWTON 1643-1727
$\Delta(mv)=F\Delta t$
DEUTSCHE BUNDESPOST
100
1993
VIỆT NAM 1985
BƯU CHÍNH
I-XẮC NIU-TƠN
1642-1727
2 đ
REPUBLIQUE FRANÇAISE
18F
NEWTON
1642-1727
POSTES
M.LALAU
P.MUNIER
1642-1727 ISAAC NEWTON
(a+b)n
SAN MARINO
40
I.P.Z.S.-1982
A. TITONEL
5 К
Почта СССР 1987
1643
1727
Исаак НЬЮТОН
1687
„Математические начала натуральной философии"-
вершина творчества
И.Ньютона.
Впервые была создана
единая система
земной и небесной
механики,
которая легла в основу
классической физики.
Isaac Newton 1643-1727
3Ft
MAGYAR POSTA
PRINCIPIA MATHEMATICA
REPUBLIQUE POPULAIRE DU BENIN
150F
POSTE AERIENNE
1977
250e ANNIVERSAIRE
DE LA MORT D'ISAAC NEWTON
1642-1727
L'Histoire de L'Espace
SIR ISAAC NEWTON
(1642-1727)
inventa le télescope
à réflexion
utilisant une
lentille et
un miroir
paraboique
BURUNDI 1500 F
18P
PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA
Sir ISAAC NEWTON (1642-1727)
22P
MOTION OF BODIES IN ELLIPSES
Sir ISAAC NEWTON (1642-1727)
31P
OPTICKS
TREATISE OF THE REFLEXIONS REFRACTIONS INFLECTIONS and COLOURS OF LIGHT
Sir ISAAC NEWTON (1642-1727)
34P
THE SYSTEM OF THE WORLD
Sir ISAAC NEWTON (1642-1727)
1987


1666. Sir Isaac Newton formulates law of gravitation
50¢
Grenada
MILLENNIUM
2000

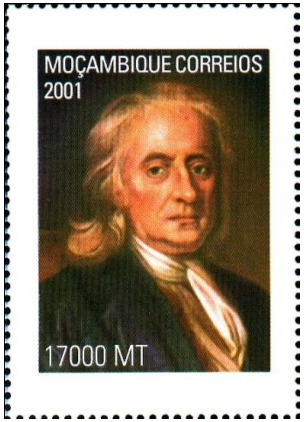

REPUBLIQUE TOGOLAISE
La comète de Halley
Edmond HALLEY 1656-1742
1000F
Isaac NEWTON 1642-1727
Poste Aérienne 1986


POSTES LAO 1984


SIR ISAAC NEWTON
1643
1727
MONGOLIA 60
МОНГОЛ ШУУДАН мөнгө
1977


Isaac Newton
URUGUAY
$ 7.50
CORREOS
(1642 - 1727)
BARREIRO 96
M.A.BIA


MALDIVES
LIGHT SPECTRUM
Rf1.50
NEWTON


MOÇAMBIQUE CORREIOS
2001
17000 MT

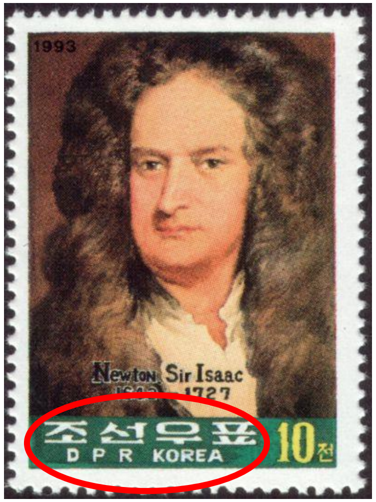

HALLEY ET NEWTON
HALLEY'S COMET
1985 - OFFICIAL - 1986
1607
1682
1759
POSTE AERIENNE
REPUBLIQUE DE GUINEE 300F

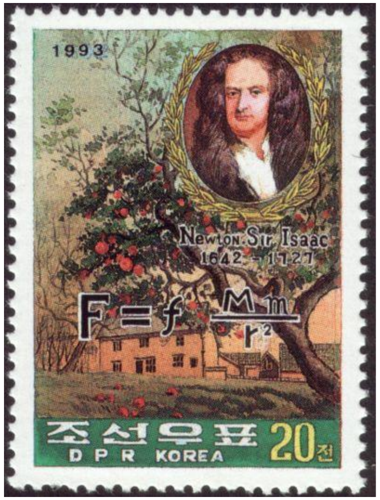

HALLEY'S COMET
1985 - OFFICIAL - 1986
HALLEY ET NEWTON OBSERVANT LA COMETE
POSTES
300f
REPUBLIQUE CENTRAFRICAINE
IMPRESSOR S.A. (SWITZERLAND) • W.SPINNER • 1985

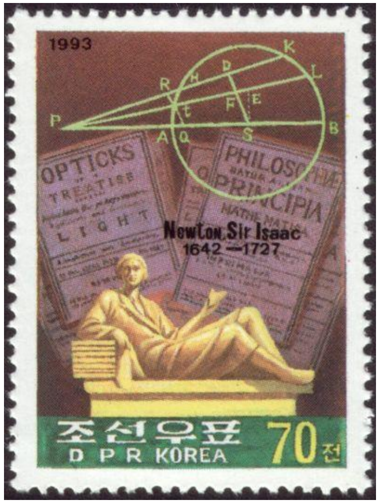

POSTES 2006
650F
RÉPUBLIQUE DU MALI

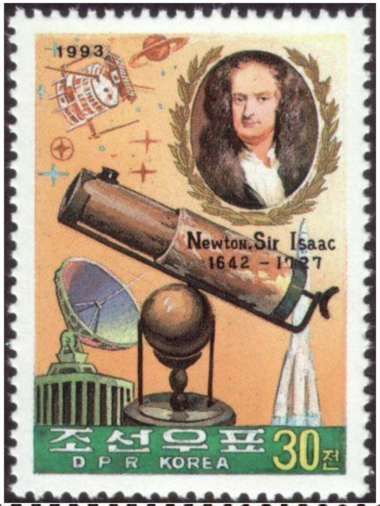

USA EXPLORER VII
13.10.1959
DISCOVERIES OF UNIVERSE
ISAAC NEWTON
1642 - 1727
ENGLAND
10B
YEMEN ARAB REPUBLIC
AIR MAIL
الجمهورية العربية اليمنية
Newton builds first reflecting telescope
MILLENNIUM
2000
Grenada
50¢
RÉPUBLIQUE DE GUINÉE
300 F
POSTES
Sir Isaac Newton
1642-1727
Sonde Voyager
PUVILLAND
NEVIS
30¢
MILLENNIUM
Isaac Newton publishes Opticks, in which he describes nature of light and his invention of the reflecting telescope.
LESOTHO
5s
REFLECTING TELESCOPE
Sir Isaac Newton
1642-1727
MONGOLIA
200₮
UGANDA
35/
OPTICKS
THEORY OF COLOR AND LIGHT
SIR ISAAC NEWTON
1642-1727
GREAT SCIENTIFIC ACHIEVEMENTS
300-летие опубликования И.Ньютоном „Математических начал натуральной философии"
5 К
Почта СССР 1987
Исаак НЬЮТОН
1643
1727
1687
GHANA
C200
HALLEY'S COMET 1985-6
CORREO DEL PARAGUAY
GRAVITACION UNIVERSAL
OPTICA
ISAAC NEWTON
25 DICIEMBRE 1642
CALCULO INFINITESIMAL Y DIFERENCIAL
BINOMIO
TANGENTES
LUNA
TIERRA
₲ 0.10
GRENADA
50¢
NEWTON
Law of Gravity
REPUBLIQUE DU CONGO
POSTES 2000
150F
ISAAC NEWTON (1642-1727)
CORREO DEL PARAGUAY
₲ 0.30

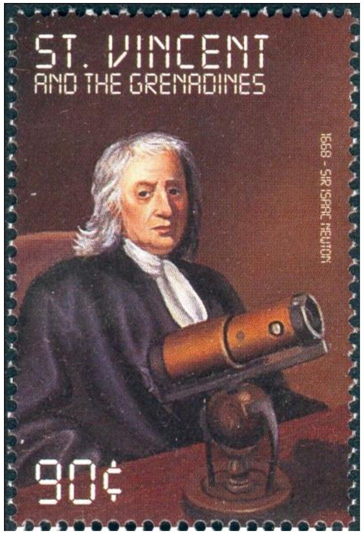

1993
Newton,Sir Isaac
1642 - 1727
$(a+b)^n = \sum_{k=0}^{n} C_n^k a^{n-k} b^k$
조선우표
D P R KOREA
50전


1993
Newton Sir Isaac
1727
조선우표
D P R KOREA
10전

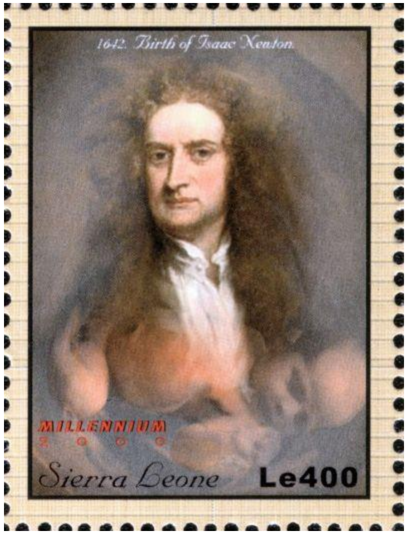

1993
Newton,Sir Isaac
1642 - 1727
$F = f\frac{Mm}{r^2}$
조선우표
D P R KOREA
20전

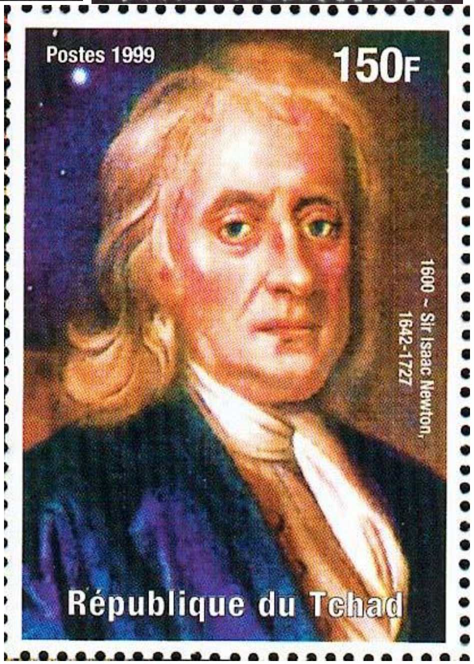

1993
OPTICKS
PHILOSOPHIAE
PRINCIPIA
Newton,Sir Isaac
1642 —1727
조선우표
D P R KOREA
70전


1993
Newton,Sir Isaac
1642 - 1727
조선우표
D P R KOREA
30전

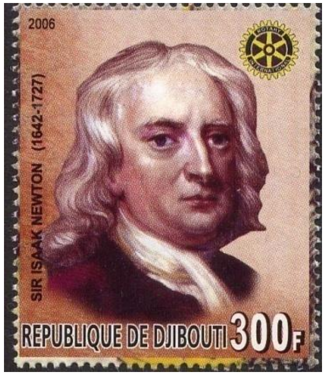

ST. VINCENT
AND THE GRENADINES
1668 - SIR ISAAC NEWTON
90¢


EXPLOITATION DES RESSOURCES DE L'ESPACE
SIR ISAAC NEWTON — SATELLITE TDF 1
REPUBLIQUE DU TCHAD
1500F


1642. Birth of Isaac Newton
MILLENNIUM
Sierra Leone
Le400


Postes 1999
150F
1600 ~ Sir Isaac Newton,
1642-1727
République du Tchad

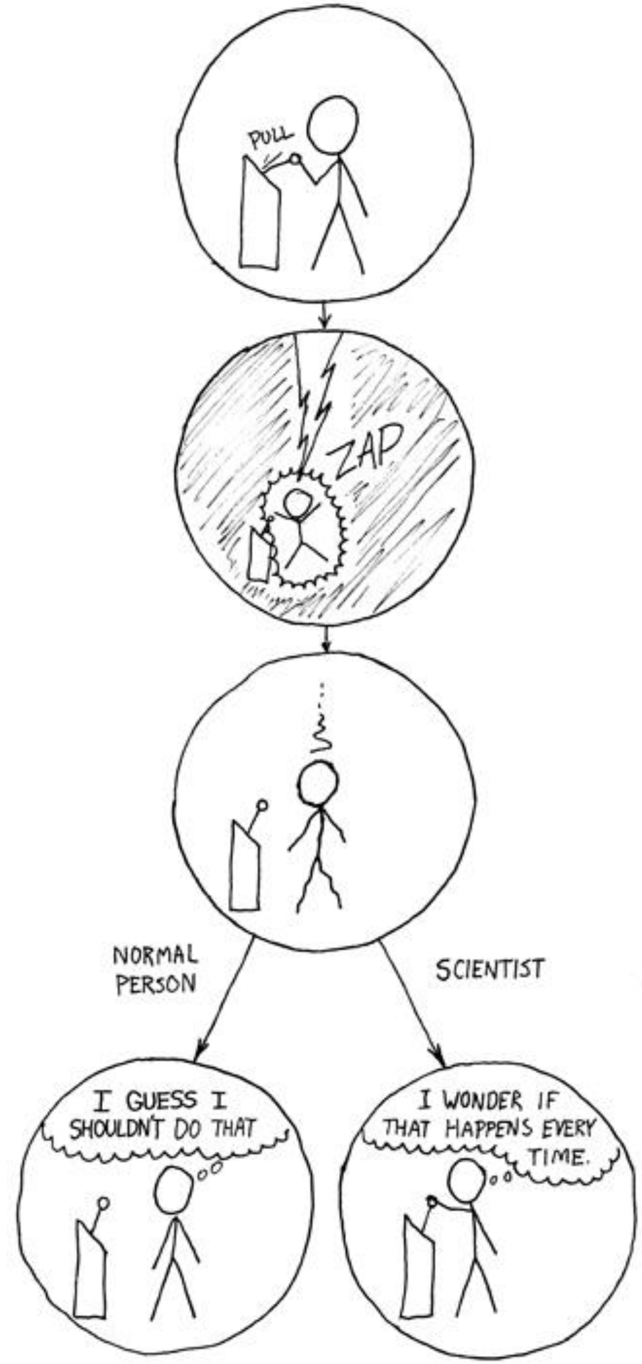

ISAAC NEWTON,
MATHEMATICIAN
& ASTRONOMER
$2\frac{1}{2}$P
ASCENSION


2006
SIR ISAAK NEWTON (1642-1727)
REPUBLIQUE DE DJIBOUTI
300F


Isaac Newton (1642-1726)
Telescopio de Newton 1688
CORREOS 1994
C$1.50
NICARAGUA


ISAAC NEWTON.1643.1727
400F
REPUBLIQUE DU MALI

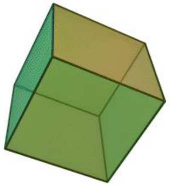

THE UNKNOWN SCIENTIST
(WHO DID SOME VERY IMPORTANT GROUNDWORK)

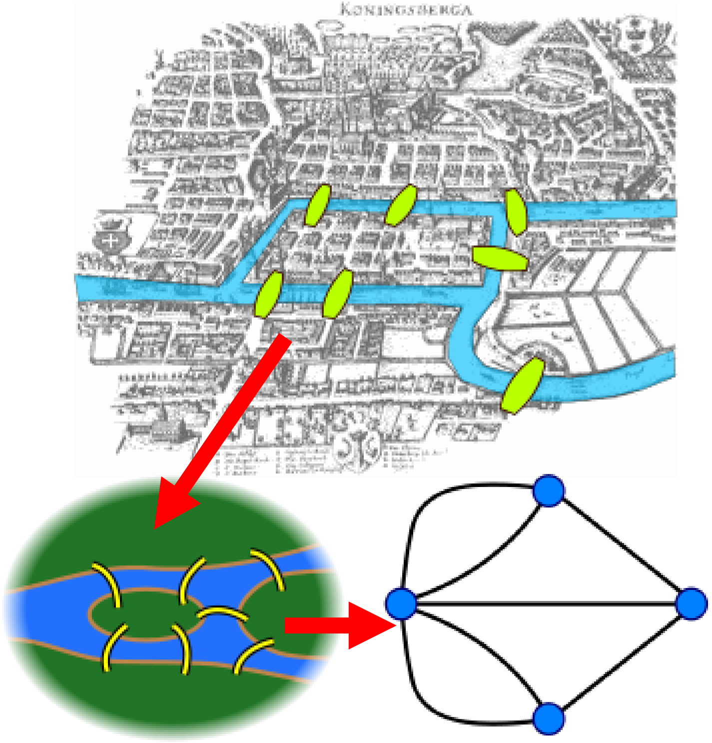

PULL
ZAP
NORMAL PERSON
SCIENTIST
I GUESS I SHOULDN'T DO THAT
I WONDER IF THAT HAPPENS EVERY TIME.

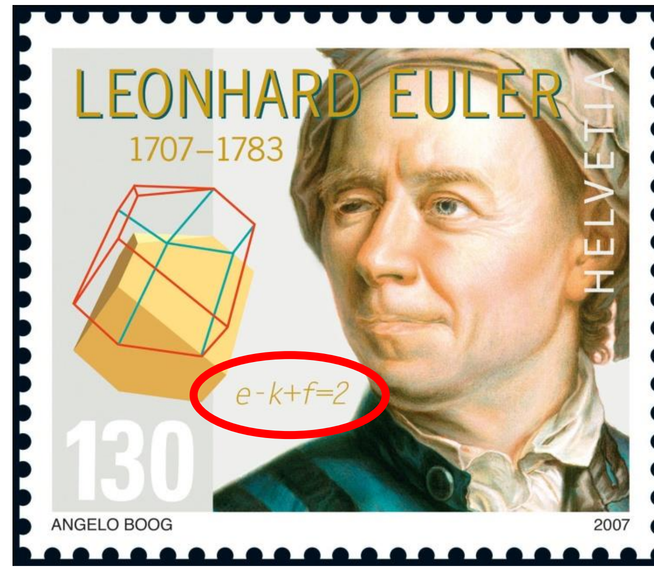
Historical Perspectives

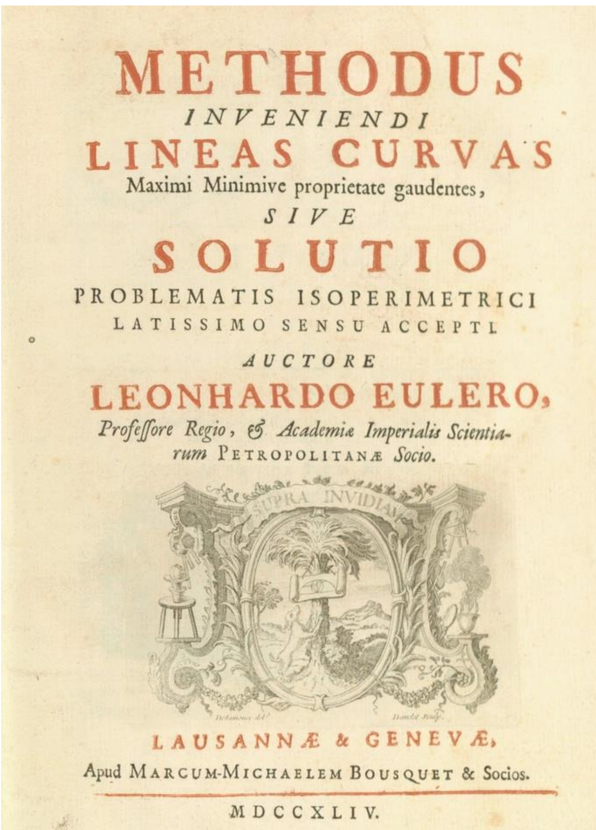
Leonhard Euler (1707–1783)

- Invented graph theory
- "Bridges of Königsberg", Prussia
- Eulerian tour
- Euler's formula: $V + F = E + 2$
- Euler's number: e
- Euler's identity: $e^{i\pi} + 1 = 0$
- Major contributions to analysis, algebra, calculus, number theory, topology, optics, fluid dynamics, mechanics, astronomy, education








METHODUS
INVENIENDI
LINEAS CURVAS
Maximi Minimive proprietate gaudentes,
SIVE
SOLUTIO
PROBLEMATIS ISOPERIMETRICI
LATISSIMO SENSU ACCEPTI.
AUCTORE
LEONHARDO EULERO,
Professore Regio, & Academiæ Imperialis Scientiarum Petropolitanæ Socio.

LAUSANNÆ & GENEVÆ,
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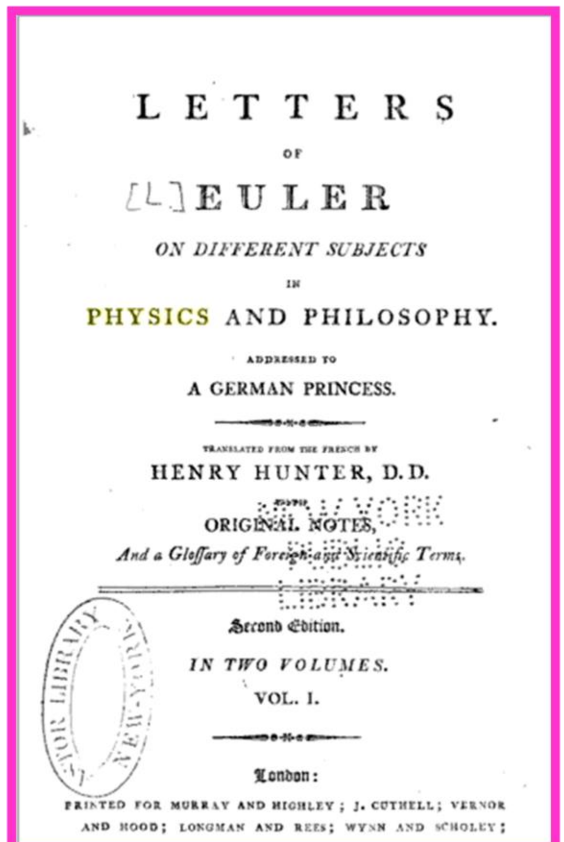
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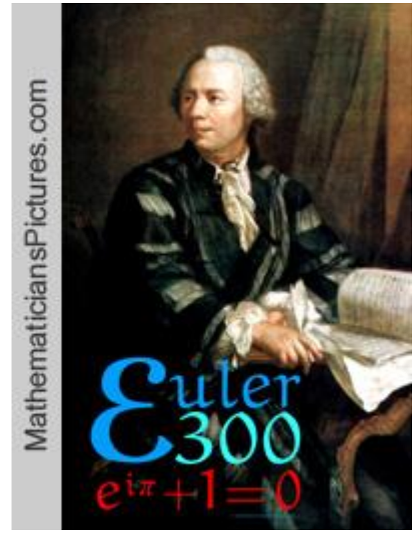

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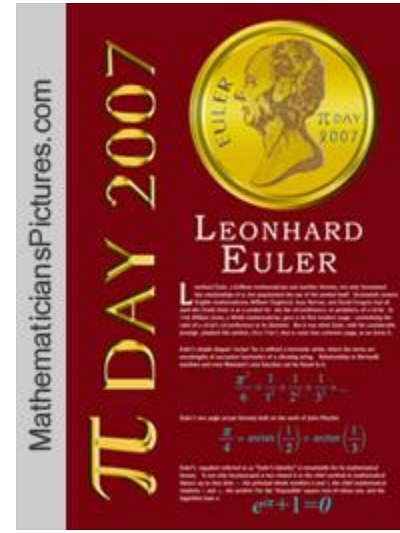

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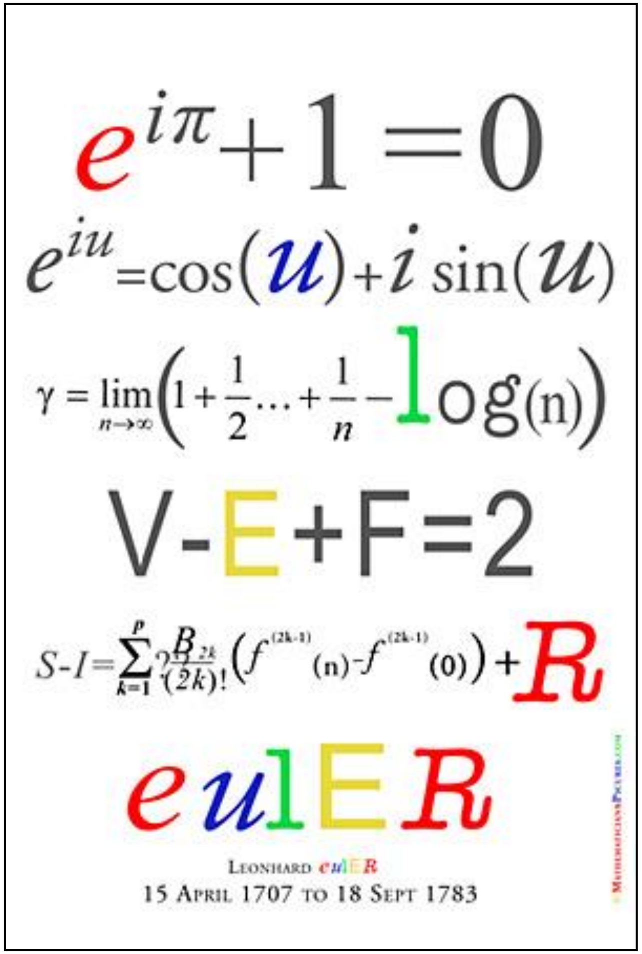

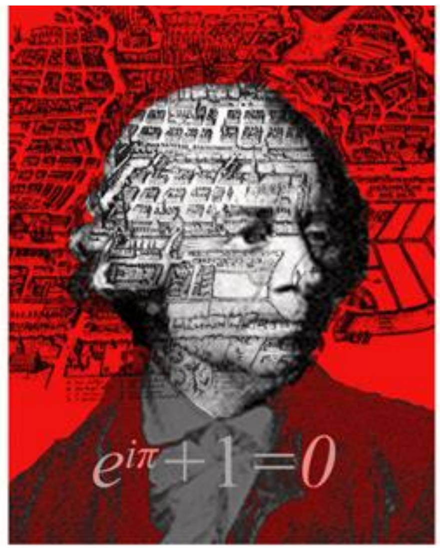

Leonhard Euler
1707 - 1783


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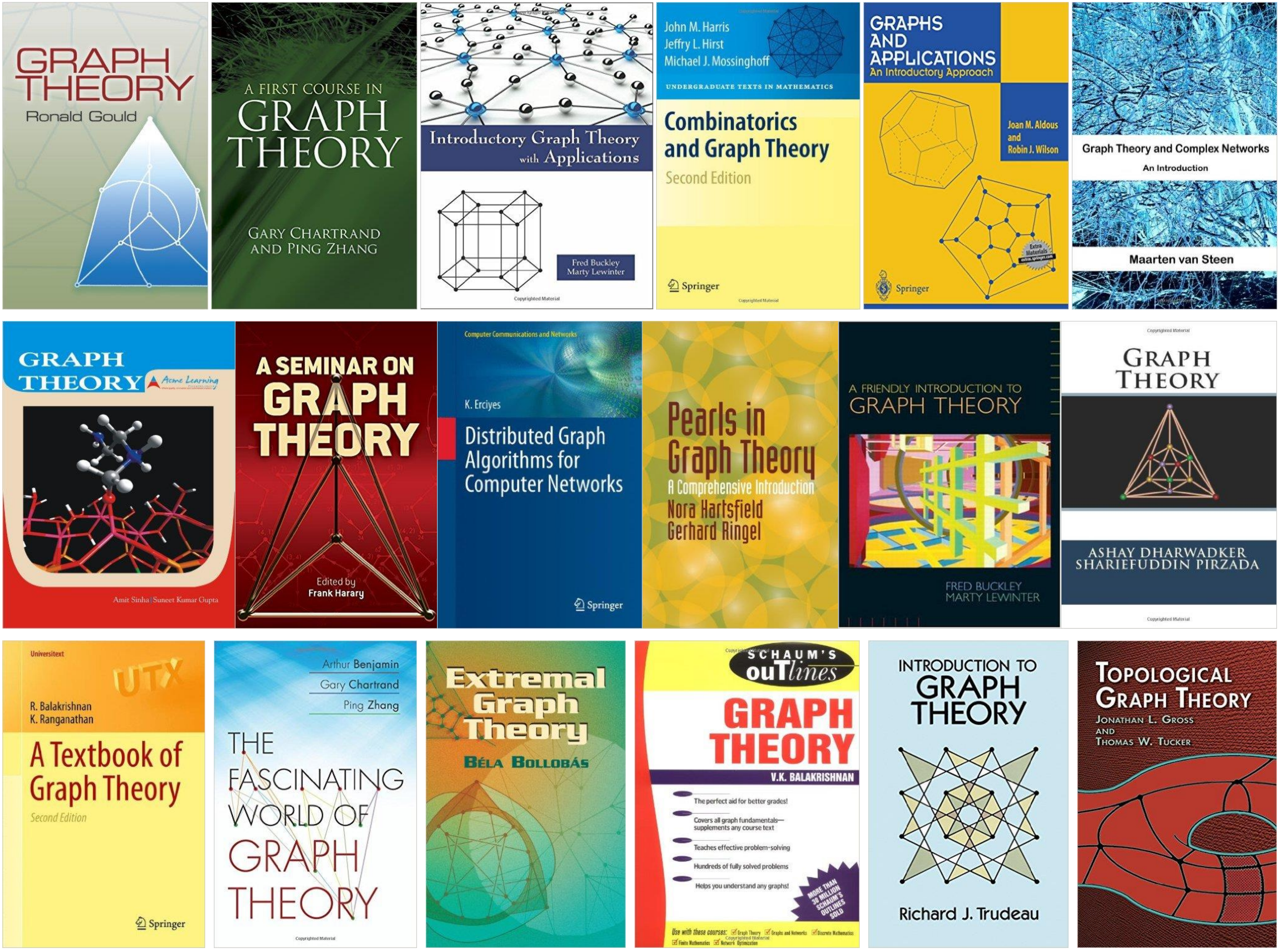
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SEVENTH CRACOW CONFERENCE ON GRAPH THEORY "RYTRO '14"

September 14-19, 2014
Rytro, Poland

Related events:

Cycles and Colourings

5th Polish Combinatorial Conference

17th Workshop on Hereditary Graph Properties

The meeting is next in the series of former Cracow Conferences on Graph Theory organized in Niedzica (1990), Zgorzelisko (1994), Kazimierz Dolny (1997), Czorsztyn (2002), Ustroń (2006) and Zgorzelisko (2010).

Selected papers presented at the conference will be published in a Special Issue of Discrete Mathematics dedicated to the 7th Cracow Conference on Graph Theory. Already six Special Issues of DM were devoted to our conferences (volumes: 121, 164, 236, 307/11-12, 309/22, 312/14).

Invited speakers:

Ralph Faudree, University of Memphis, USA

Linear Forests on Hamiltonian Cycles

András Gyárfás, Hungarian Academy of Sciences, Budapest, Hungary

Vertex covers by monochromatic pieces - results and problems

Wilfried Imrich, Montanuniversität Leoben, Austria

Graph Products and Symmetry Breaking in Graphs

Ken-ichi Kawarabayashi, National Institute of Informatics, Tokyo, Japan

Coloring graphs with some forbidden or restricted configurations

Jan Kratochvil, Charles University, Prague, Czech Republic

Extending Partial Geometric Representations of Graphs

Dieter Rautenbach, Universität Ulm, Germany

INTERNATIONAL CONFERENCE ON GRAPH THEORY AND ITS APPLICATIONS

December 16-19, 2015
Amrita School of Engineering, Coimbatore, India

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- Accomodation and Local Information
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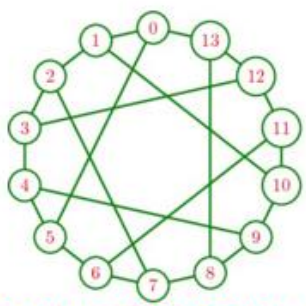
About The Conference

This will be a Four-day Conference in Graph Theory, Graph Algorithms and its applications. It will be focusing on the subareas in graph theory that has applications in Optimization, Computing Techniques, VLSI Design and Testing, Image Processing, and Network Communications. The goal of this conference is to bring top researchers in these areas to Amrita to foster collaboration and to expose students to important problems in the growing field. The conference is expected to stimulate joint work among researchers from India and abroad and attract research students and postdoctoral fellows who work in graph theory.The Conference will cover a broad range of topics in Graph Theory. The topics include, but are not limited to:

- Graph Theory
- Algebraic Graph Theory
- Algorithms and Computing Techniques
- Graph Optimization
- VLSI Design and Testing
- Image Processing
- Networks
- Communications and Control Theory



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VENUE :Amrita School of Engineering, Coimbatore, India

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- Modern Trends in Algebraic Graph Theory
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- Accommodations
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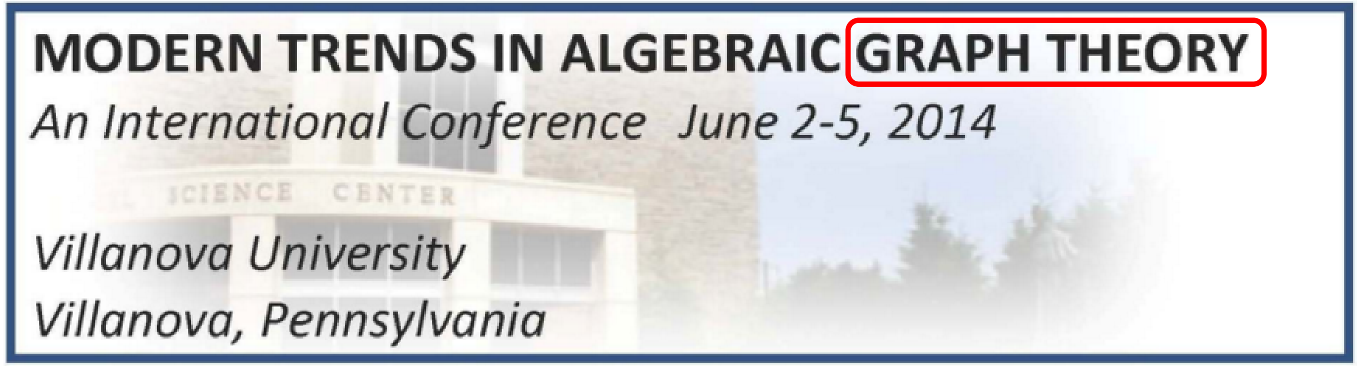
- Information for International Participants
- Conference Photos
- Slides of all Talks



Modern Trends in Algebraic Graph Theory - AFTERMATH

First, i wish to express my deepest gratitude to those who helped to make MTAGT a reality..

Generous financial support was provided by the National Science Foundation, Villanova (VU) College of Arts and Sciences, VU Office of Research and Graduate Programs, VU Office of Reasearch and Sponsored Projects, VU Office of the Vice President of Academic Affairs, and VU Office of the President.

Staffing support was provided by Marie O'Brien, Lorraine McGraw, Doug Norton, Najib Nadi, Taylor Berrang, Carrie Caswell, Carolyn Romano, Joseph Reiter, and Pat Woldar.

An indispensable role was played by the Office of Conference Services. In particular, I wish to mention Ron Diment and Stefanie Austinat. I also wish to thank Elisa Wiley and Clete Rickert for web support.

Last but not least, I wish to thank those who attended MTAGT. When all is said and done, the success of a conference depends integrally on the qualifications of its participants.

We had a wonderfully strong and diverse group. More than half of the 110 participants traveled to Villanova from 20 different nations. Over 20% of the participants were female, and roughly 25% were graduate students/recent PhDs. We are most proud of these demographics.

The conference presentations were truly inspired. I am most pleased to now report their online availability:

<video recordings of plenary talks>

<Slides of all talks>

Mathematics alone does not make a successful mathematics conference. It is a desirable (if not imperative) to promote healthy multicultural relations, and unobstructed lines of communication between participants. As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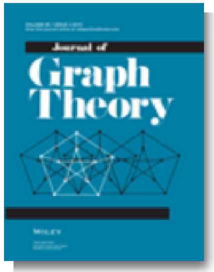

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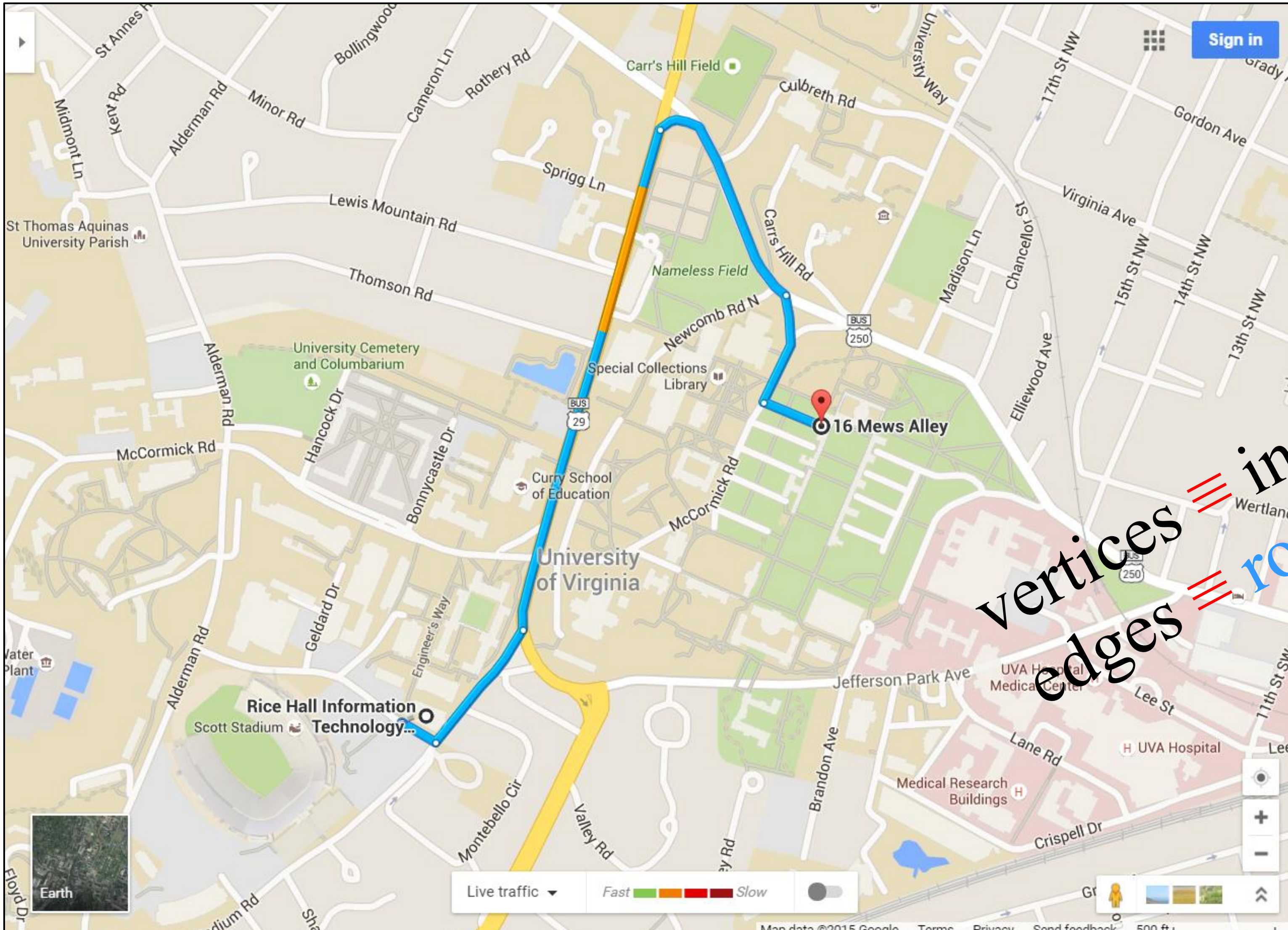
- Geographical information / GPS systems



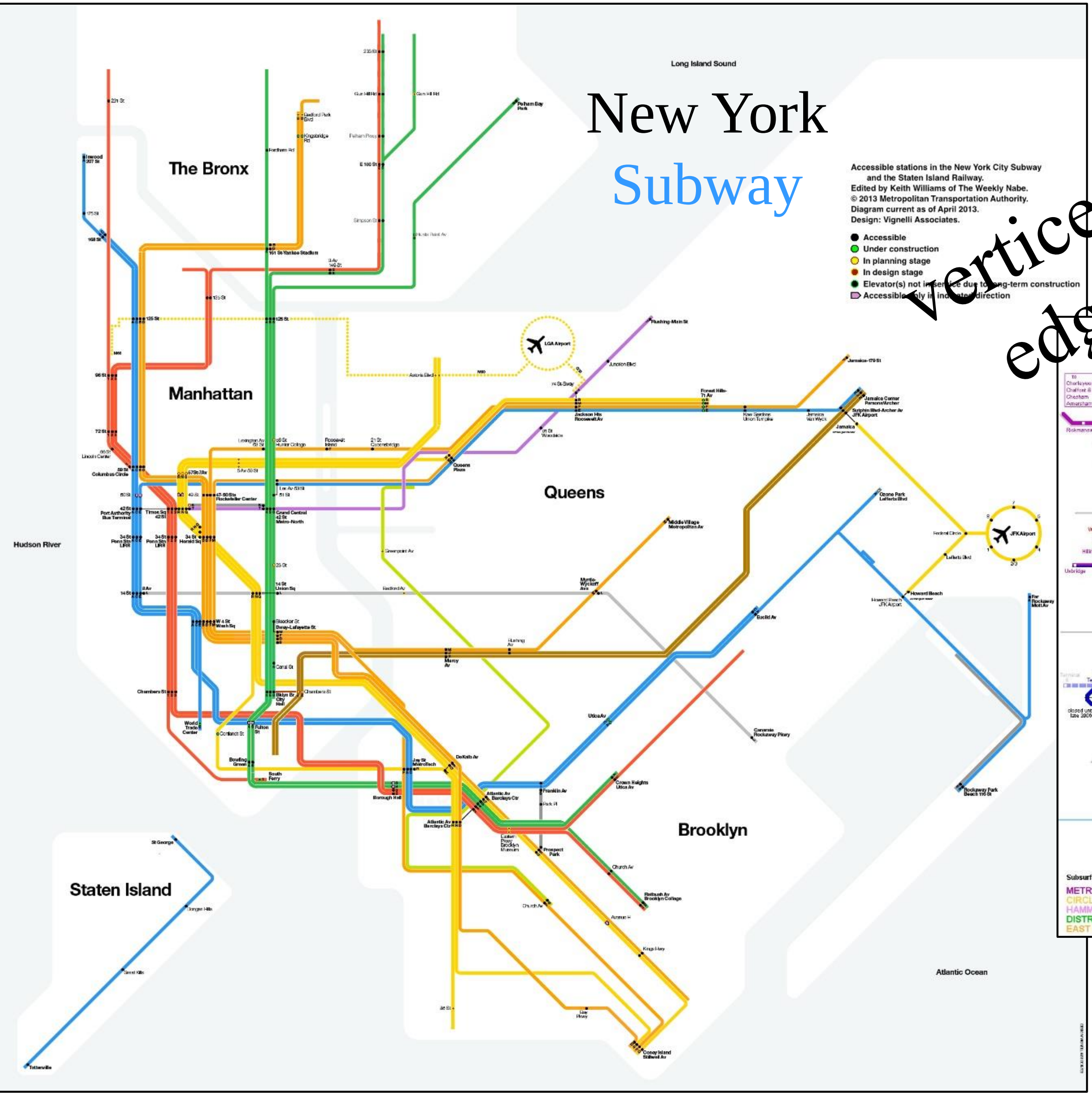
vertices ≡ intersections

edges ≡ roads / streets

Leonhard Euler
1707–1783

Applications of Graphs

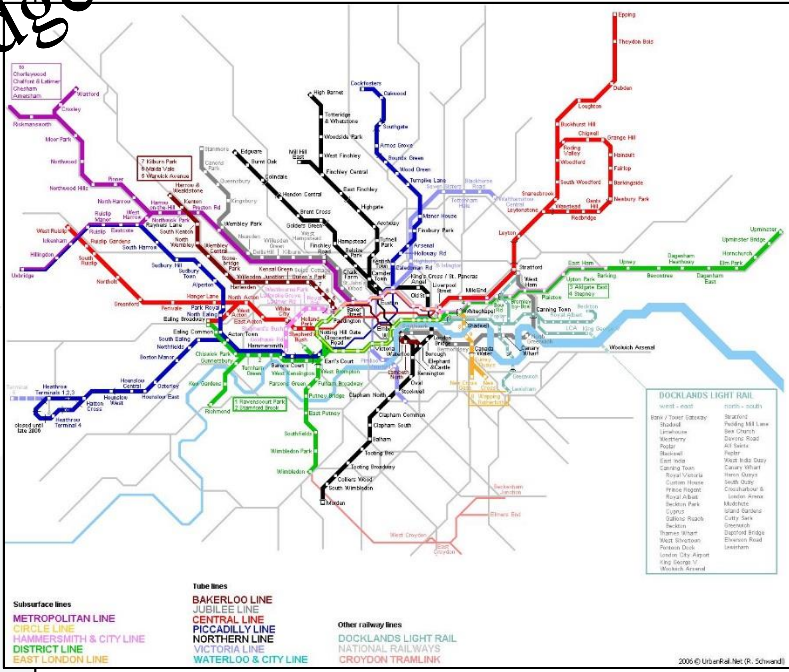
- Subway maps



New York
Subway

vertices ≡ stations
edges ≡ tracks

Leonhard Euler
1707–1783

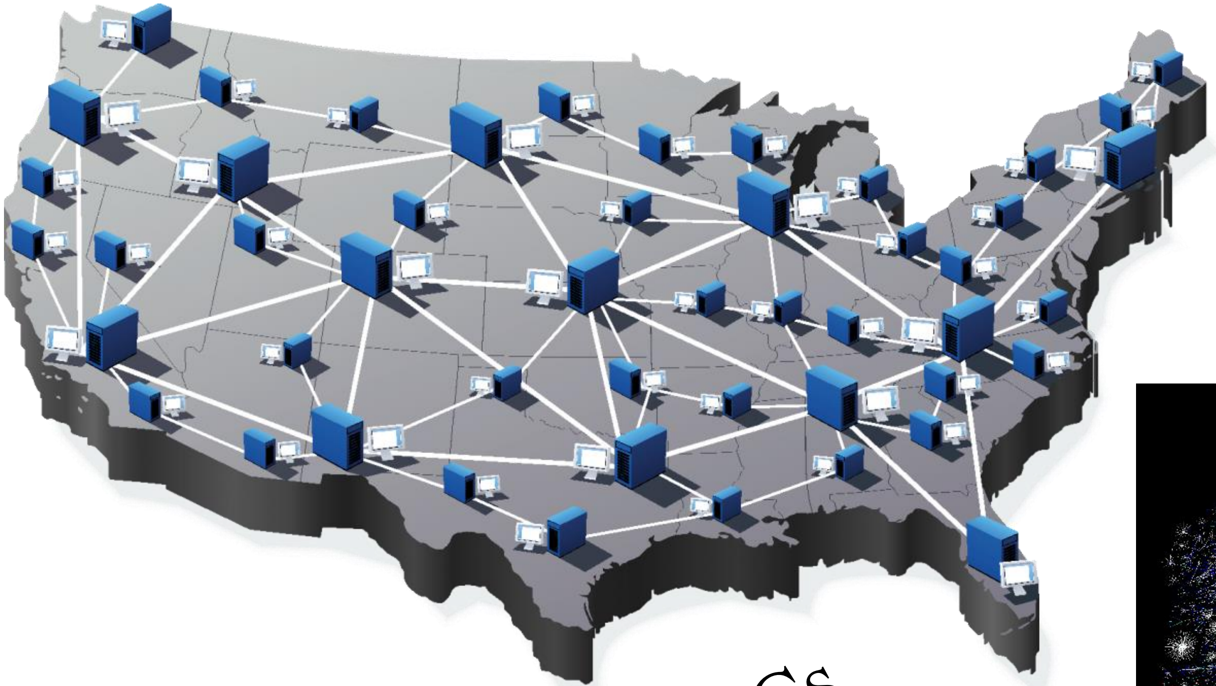


London underground

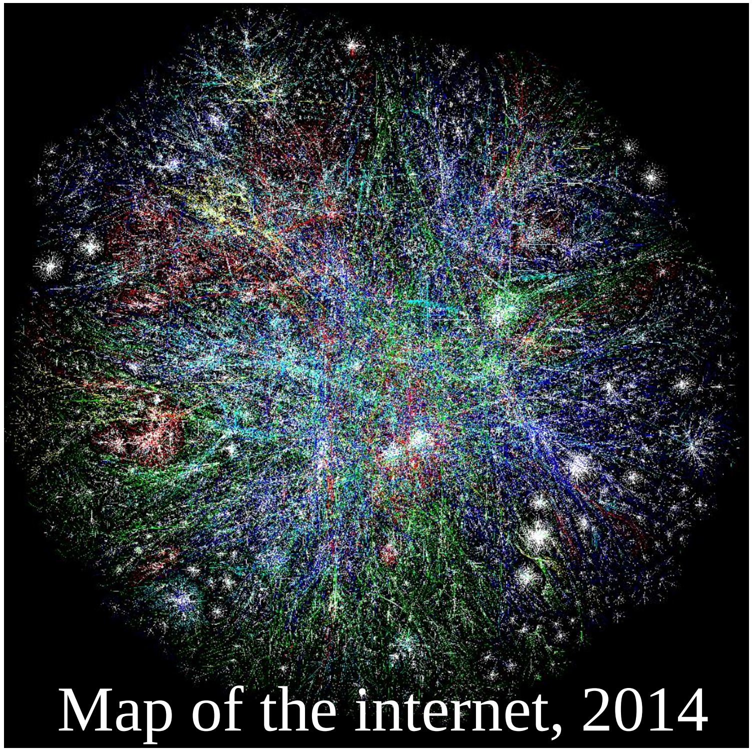
Applications of Graphs

Leonhard Euler
1707–1783

- Computer networks



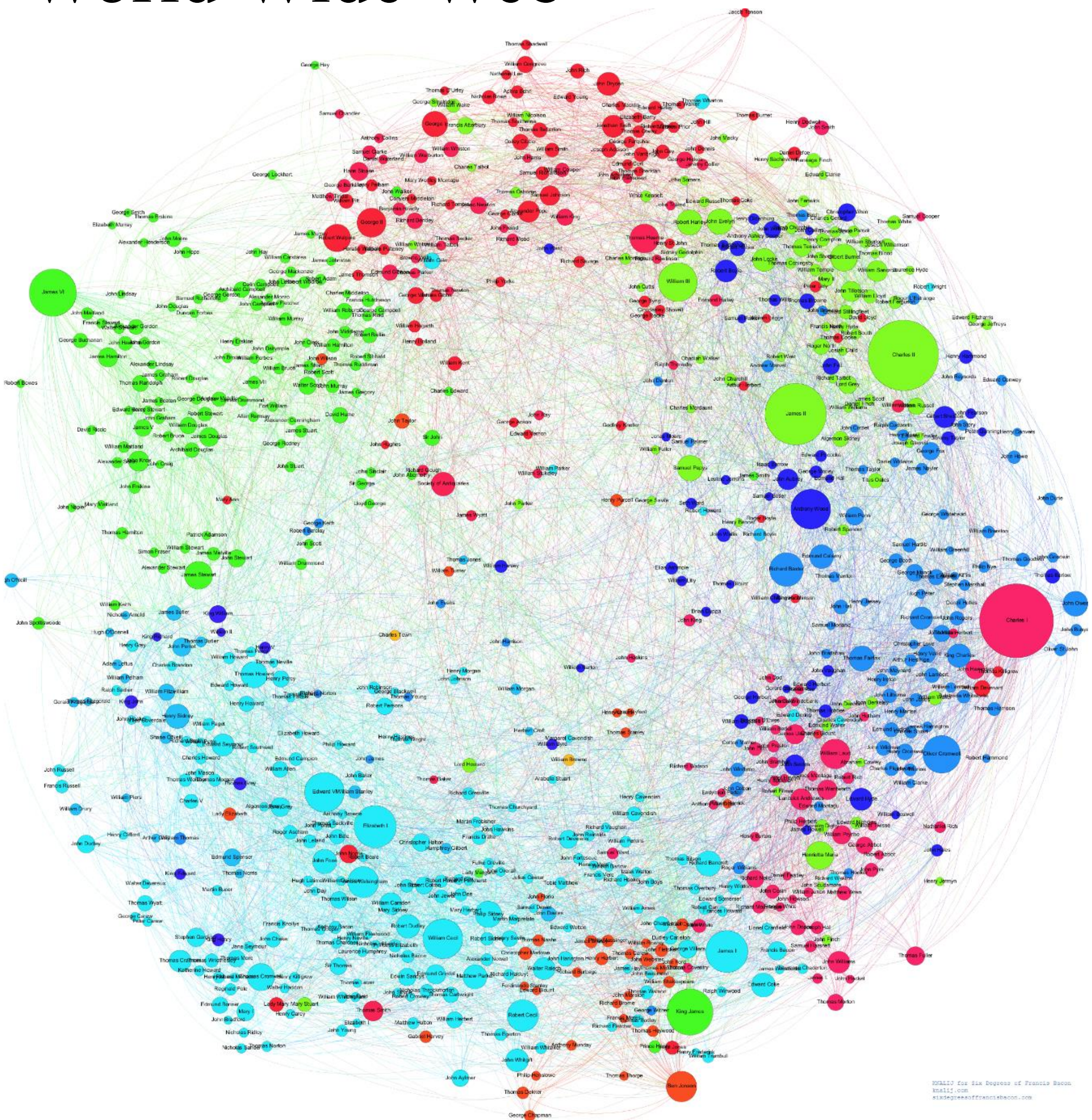
vertices ≡ routers / PCs
edges ≡ fiber / links



Map of the internet, 2014

Applications of Graphs

- World Wide Web



vertices ≡ pages
edges ≡ URLs

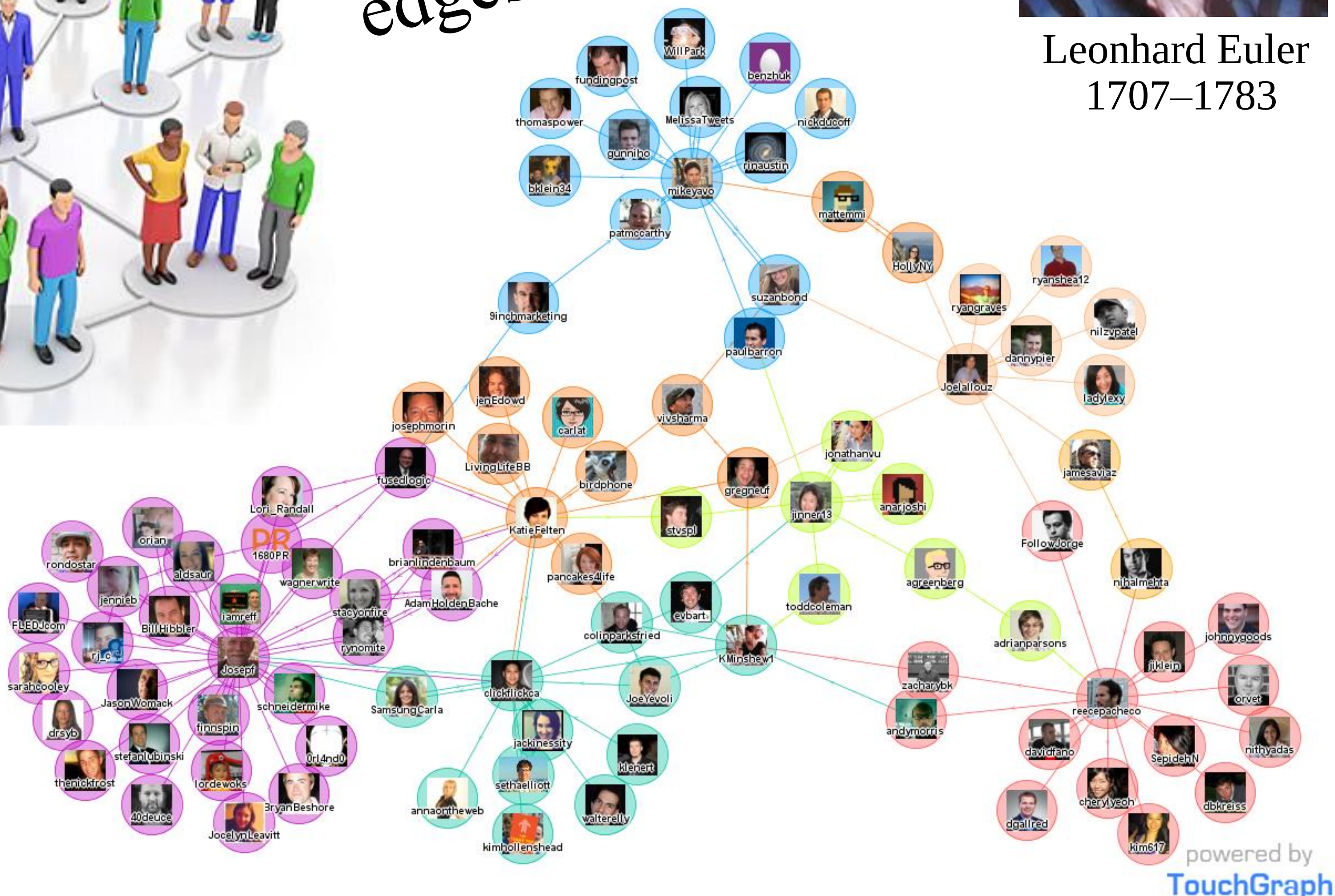
Leonhard Euler
1707–1783

Applications of Graphs

- Social networks

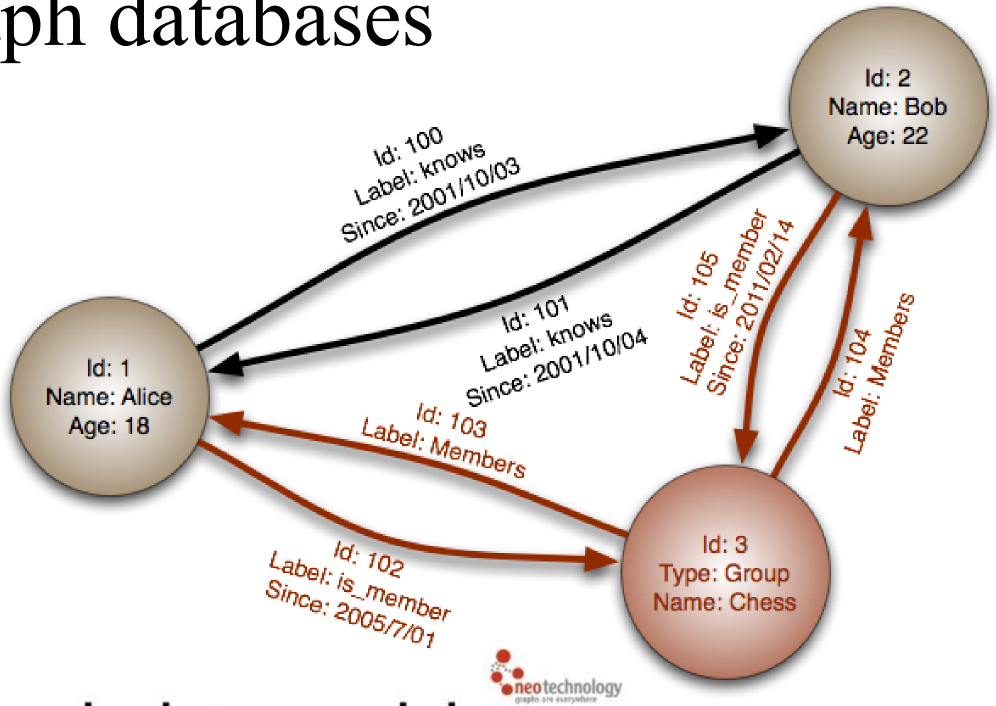
vertices ≡ people
edges ≡ "friends"

Leonhard Euler
1707–1783



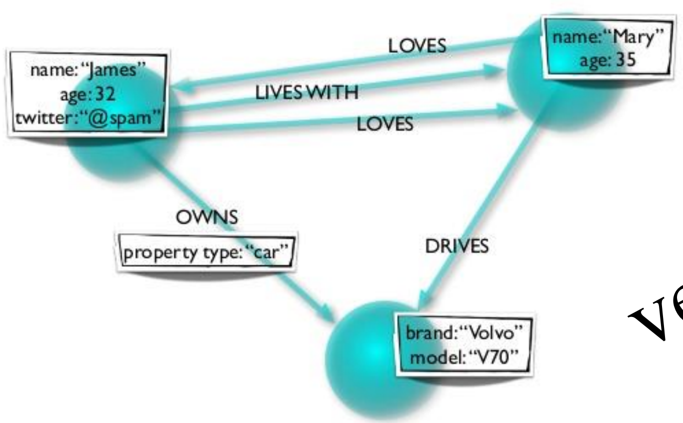
Applications of Graphs

- Graph databases

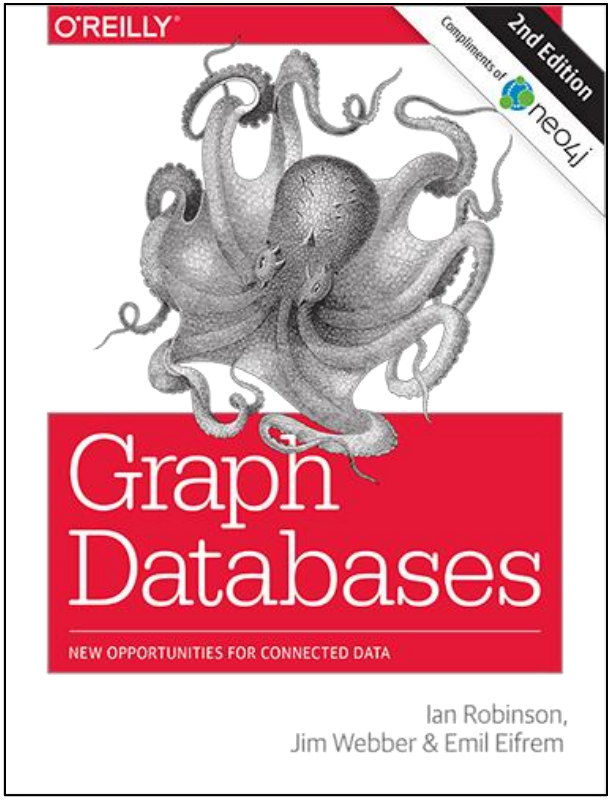


Leonhard Euler
1707–1783

Graph data model



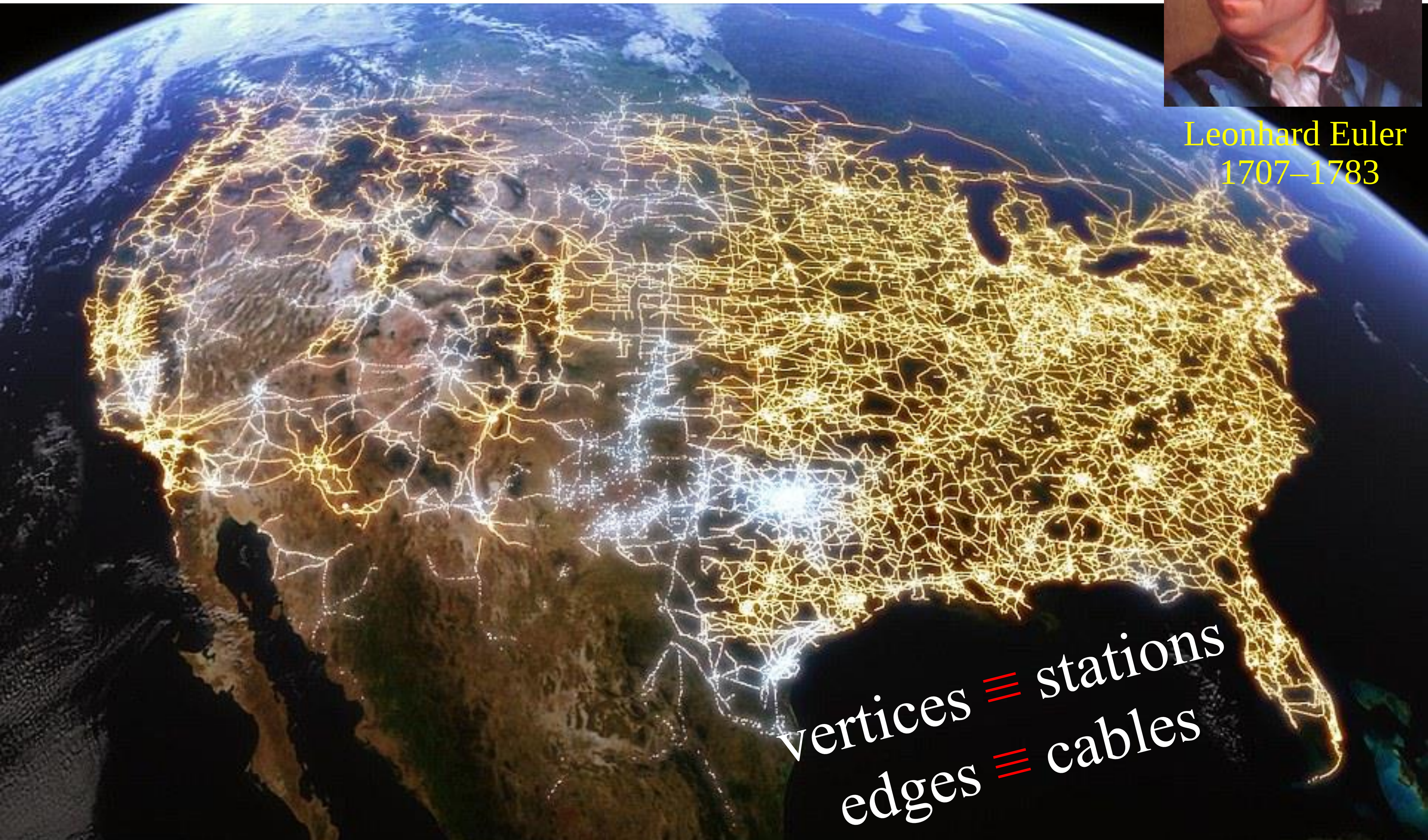
vertices ≡ records
edges ≡ relations



Applications of Graphs

- Electrical grids

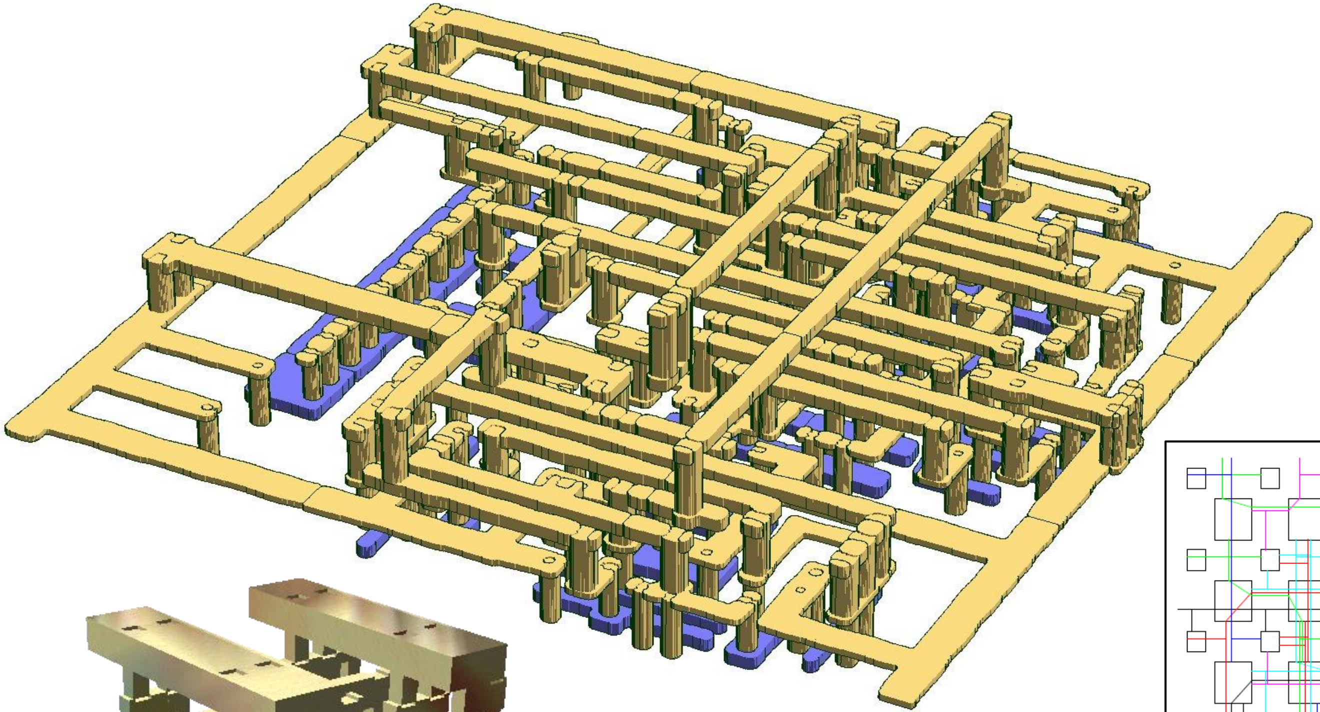
Leonhard Euler
1707–1783

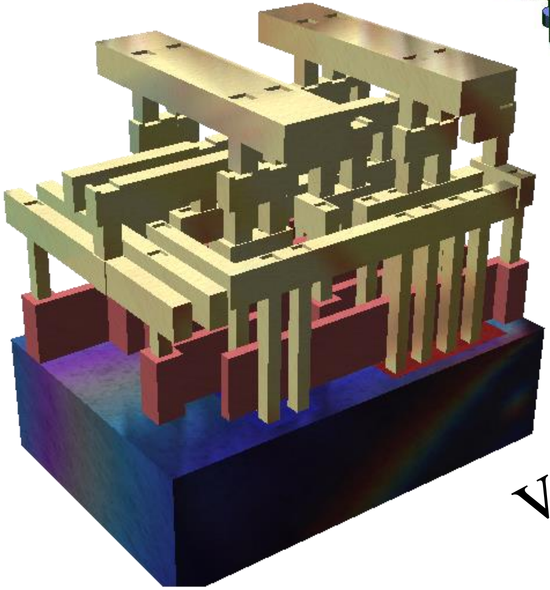


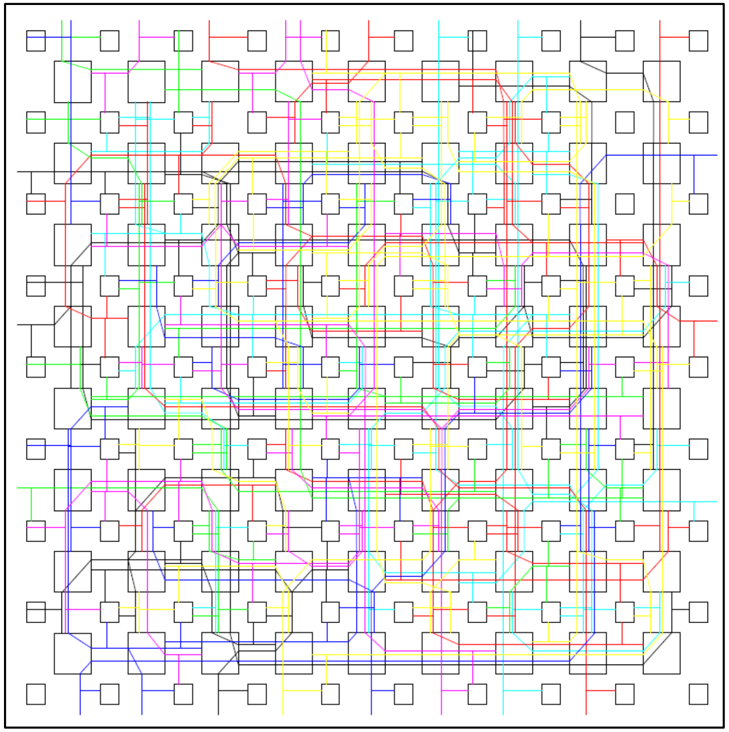
Applications of Graphs

- Integrated circuit design (VLSI chips)

Leonhard Euler
1707–1783





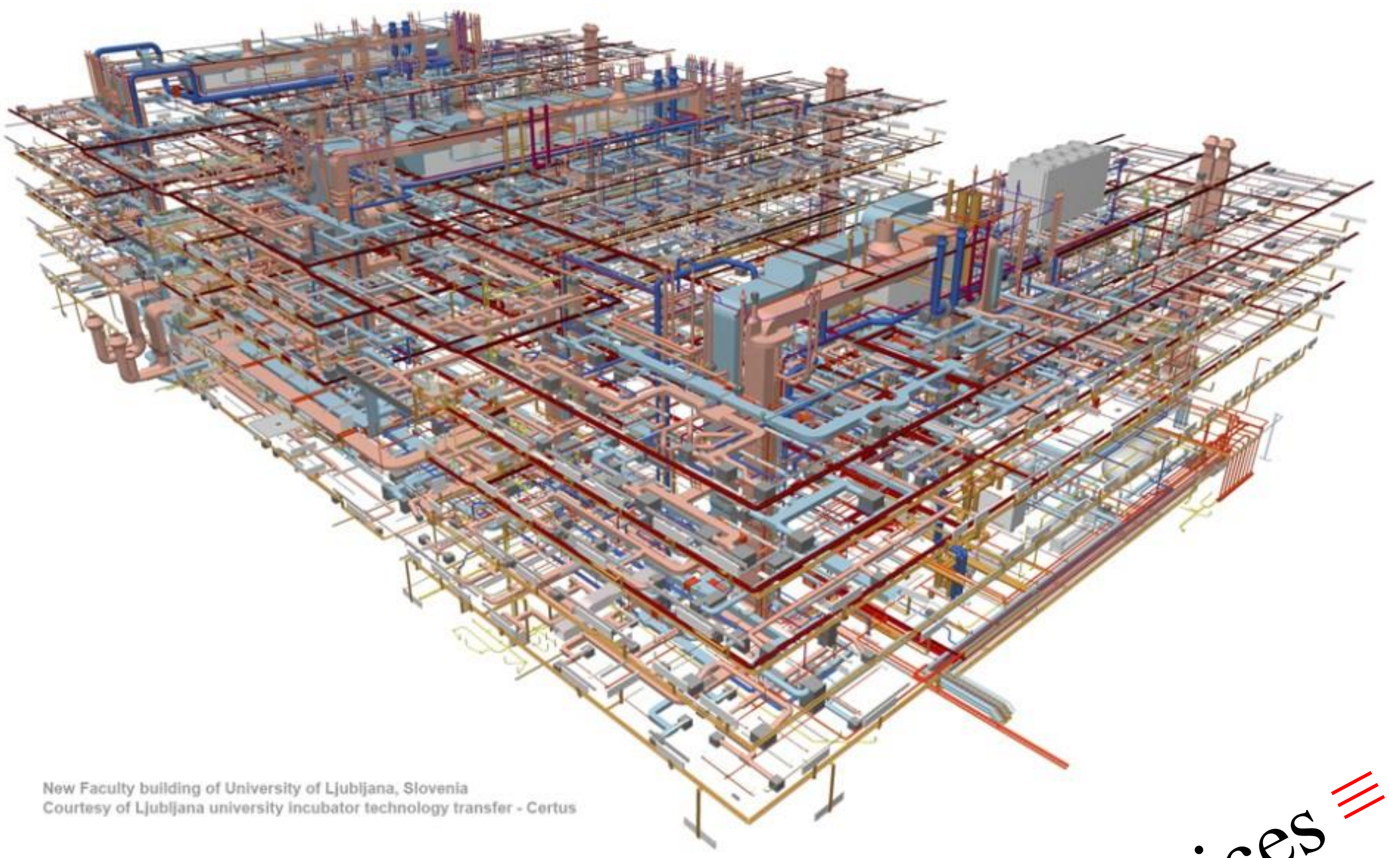


vertices ≡ transistors
edges ≡ wires

Applications of Graphs

Leonhard Euler
1707–1783

- CAD / building HVAC design

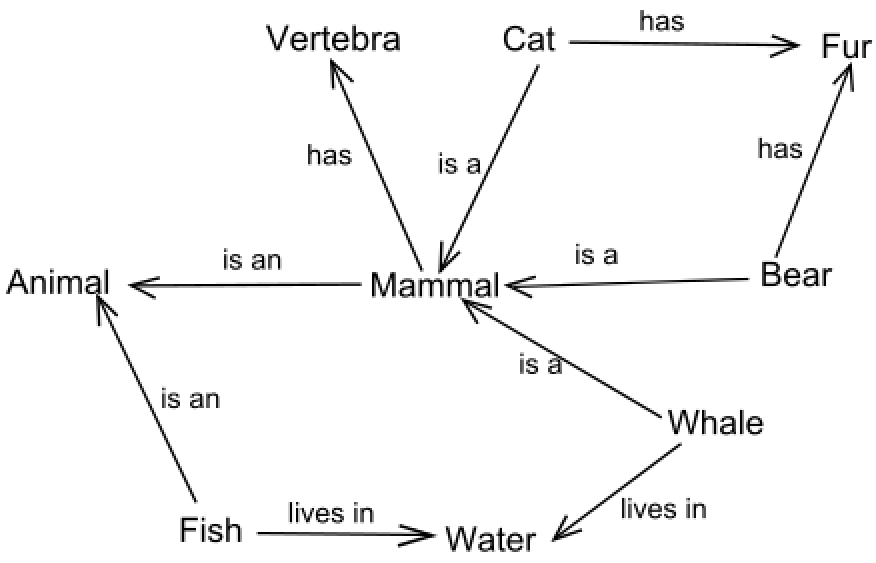


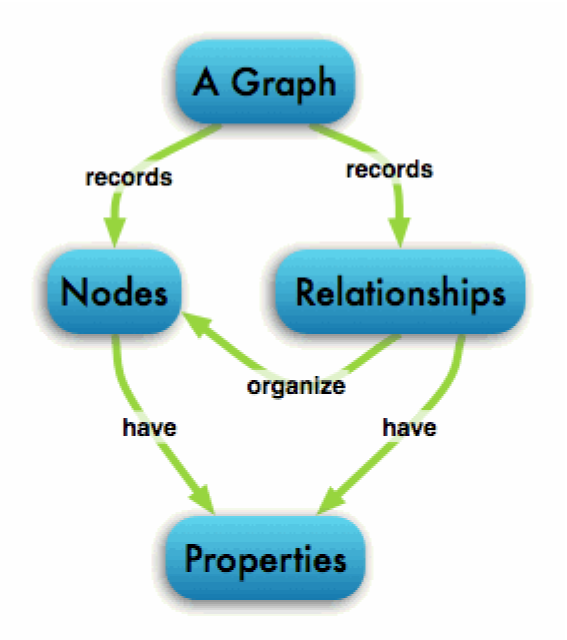
vertices ≡ connectors
edges ≡ ducts

Applications of Graphs

Leonhard Euler
1707–1783

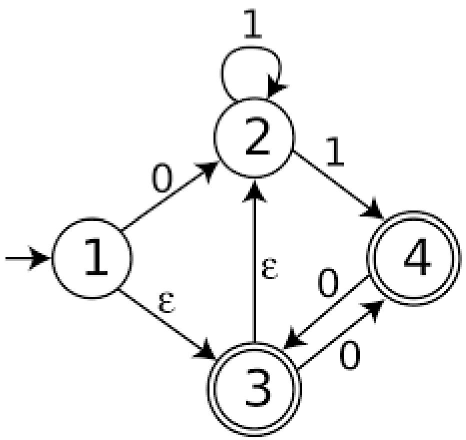
- Semantic nets





- Finite automata

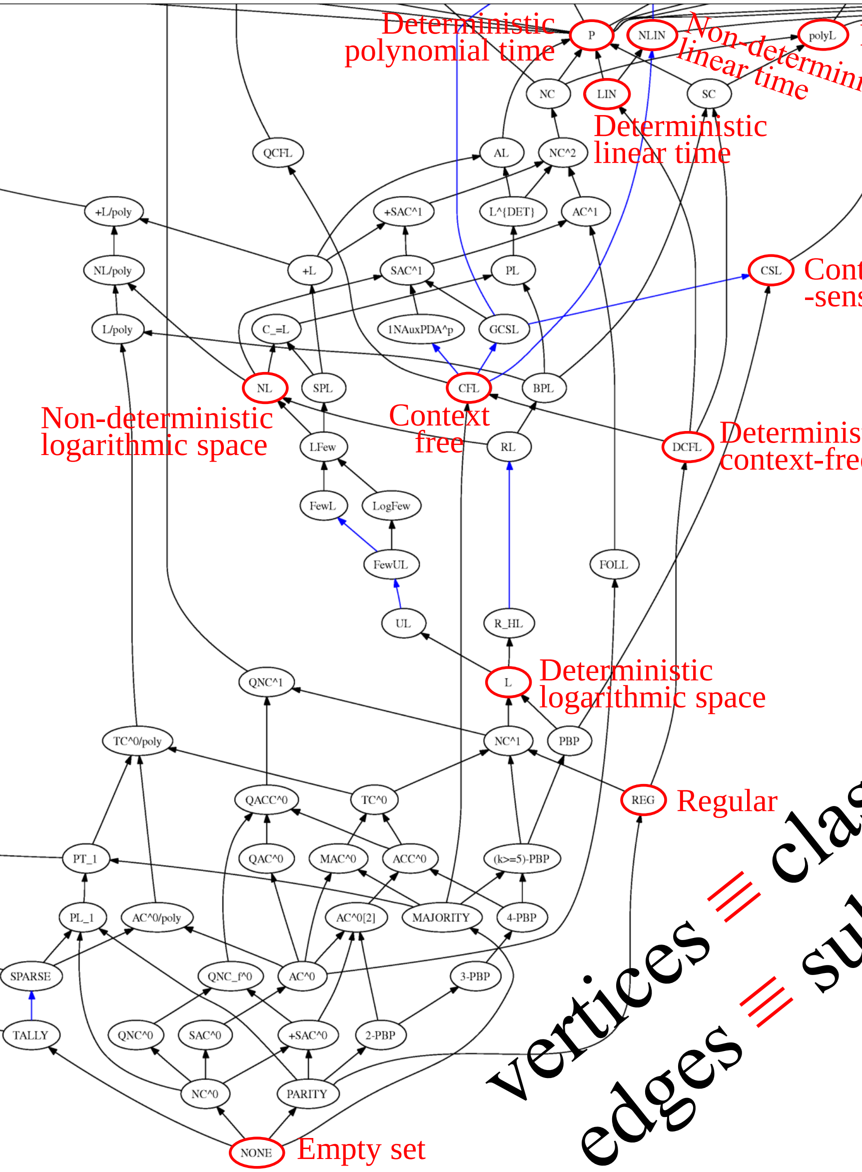
vertices ≡ objects
edges ≡ relations



vertices ≡ states
edges ≡ transitions

Applications of Graphs

- Time / space complexity classes



vertices ≡ classes

edges ≡ subsets

Leonhard Euler
1707–1783

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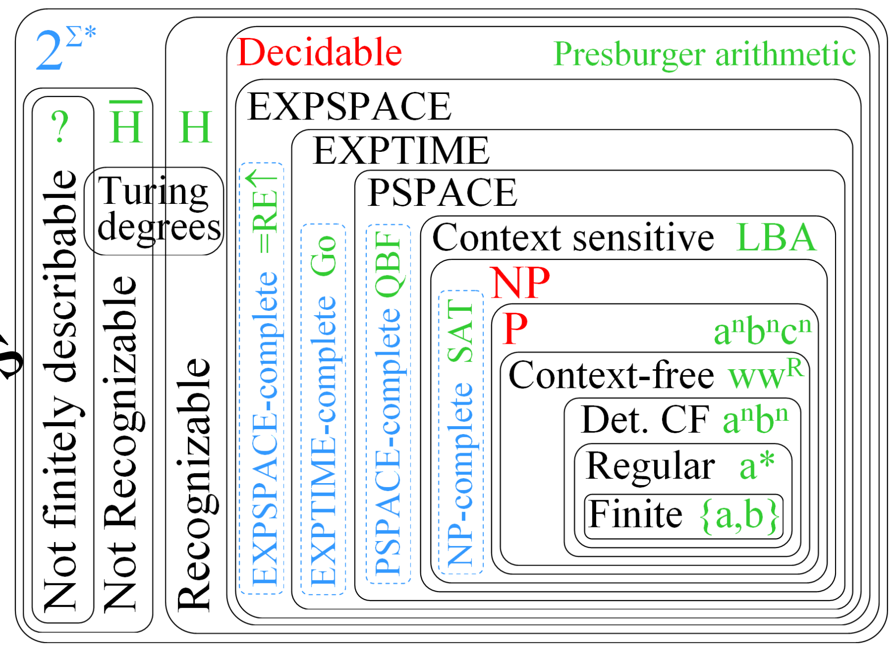
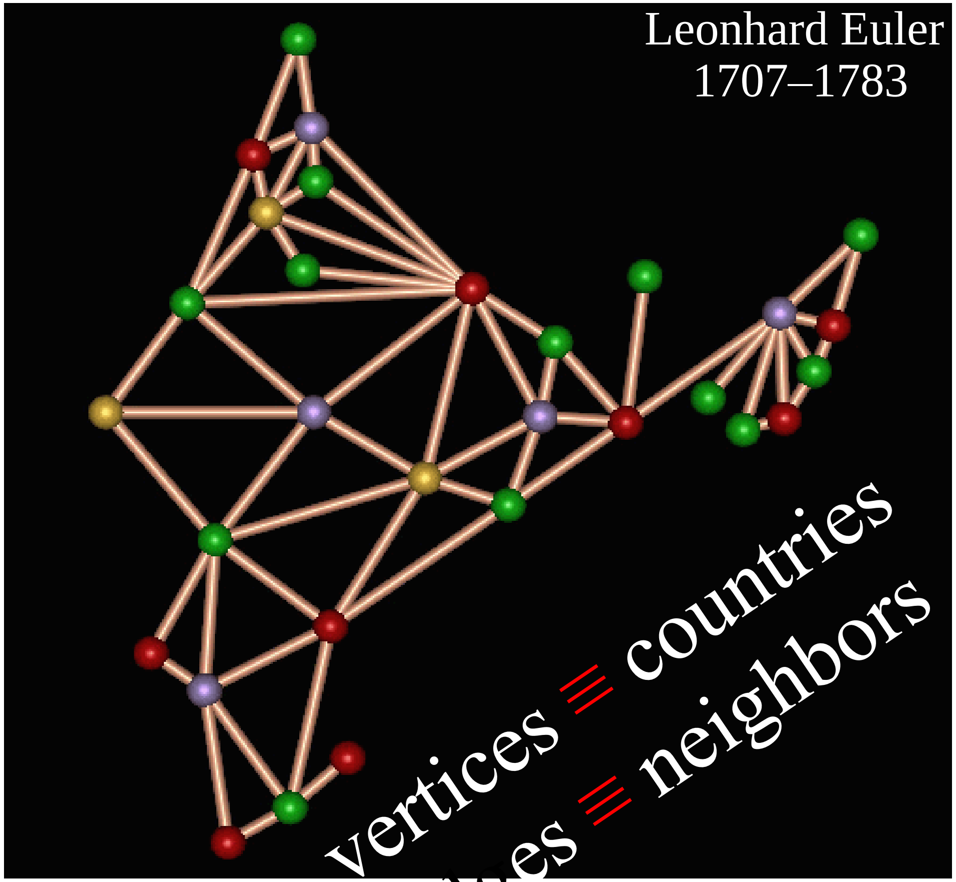


Applications of Graphs

- Map coloring

Leonhard Euler
1707–1783



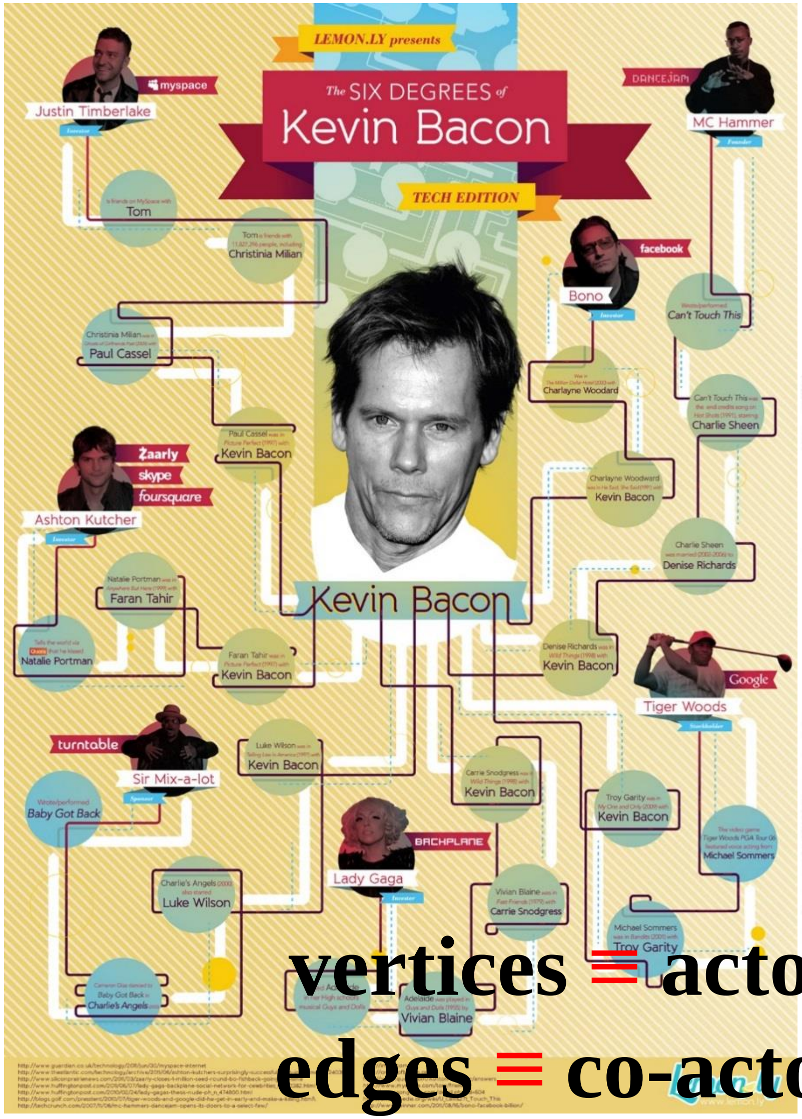
vertices ≡ countries
edges ≡ neighbors

Applications of Graphs

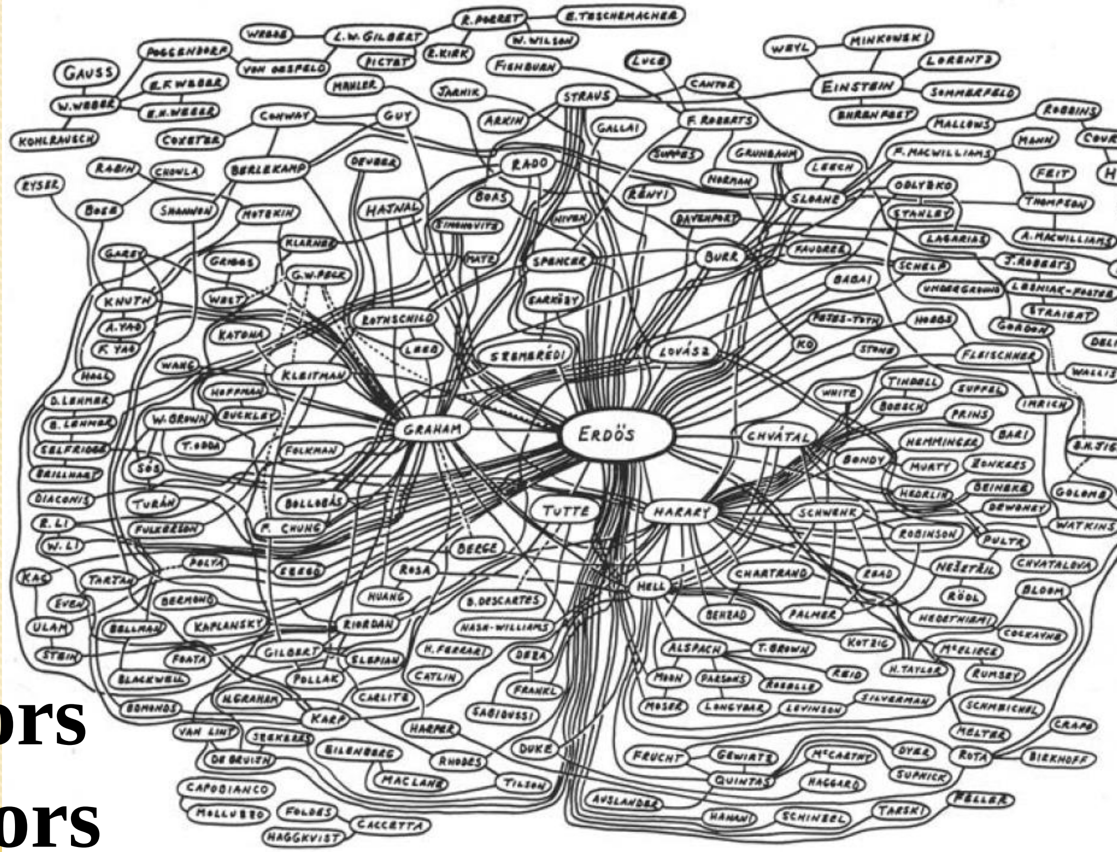
- Erdős numbers - "6 degrees" of separation

Leonhard Euler
1707–1783

vertices ≡ authors
edges ≡ co-authors



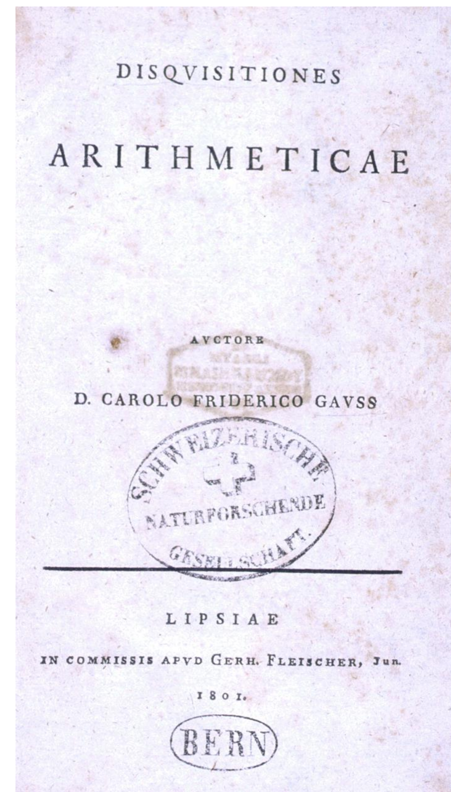
vertices ≡ actors
edges ≡ co-actors



Historical Perspectives

Carl Friedrich Gauss (1777–1855)

- "Prince of Mathematics"
- Founded modern number theory
- Authored "Disquisitiones Arithmeticae"
- Fundamental Theorem of Algebra
- Major contributions to astronomy, optics electromagnetism, statistics, geometry
- Gaussian distribution, Gaussian elimination Gaussian noise, Gaussian integers & primes Gauss' Law, Gauss' constant, "degaussing"
- SI unit of magnetic field strength: gauss
- Students: Dedekind, Riemann, Bessel



DISQVISITIONES

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D. CAROLO FRIDERICO GAVSS

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1801.

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1777–1855 Carl Friedr. Gauß
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CARL FRIEDRICH GAUSS
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TERRES AUSTRALES ET ANTARCTIQUES FRANÇAISES
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1901~1903
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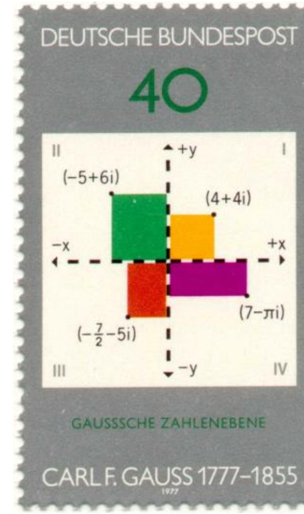
C. HALEY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CARL F. GAUSS 1777–1855


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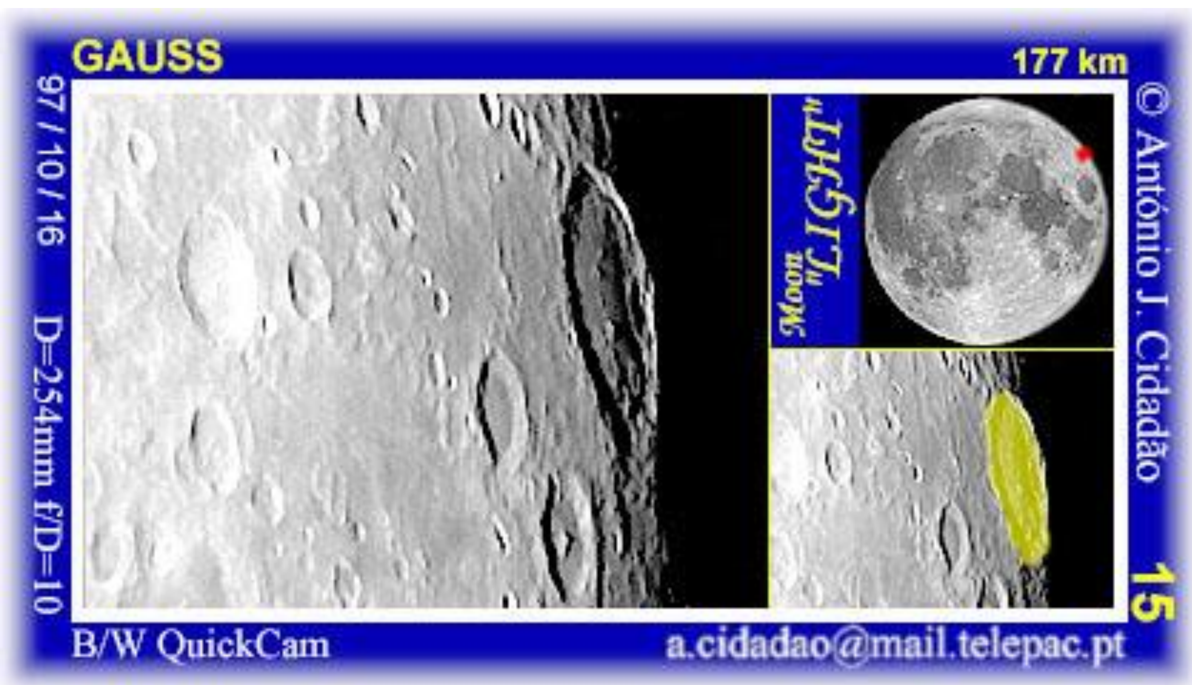
GAUSS
177 km
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D=254mm f/D=10
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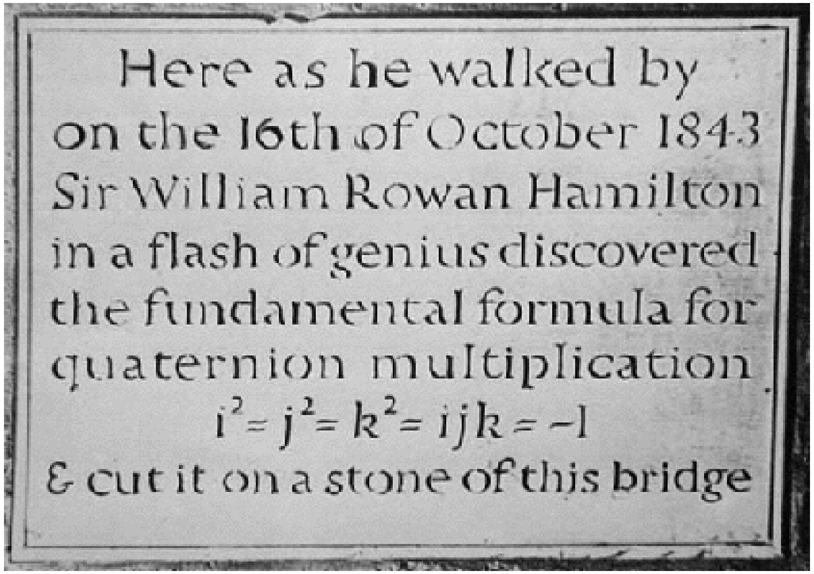
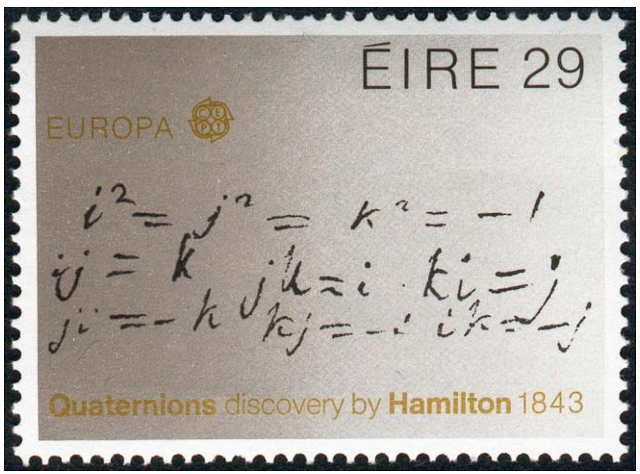
Gottinga
Karl Friedrich Gauss (1777-1855)

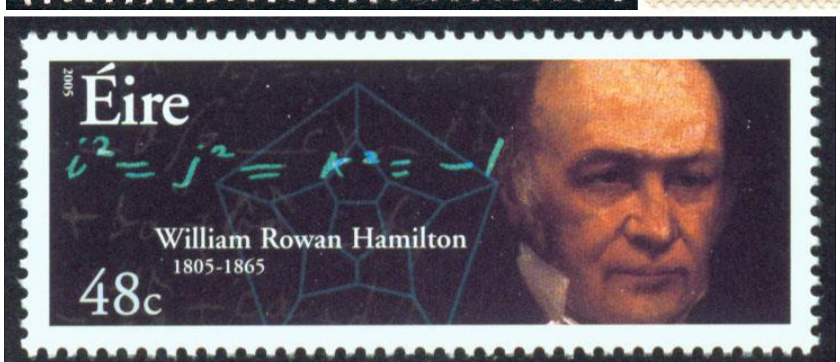
Historical Perspectives

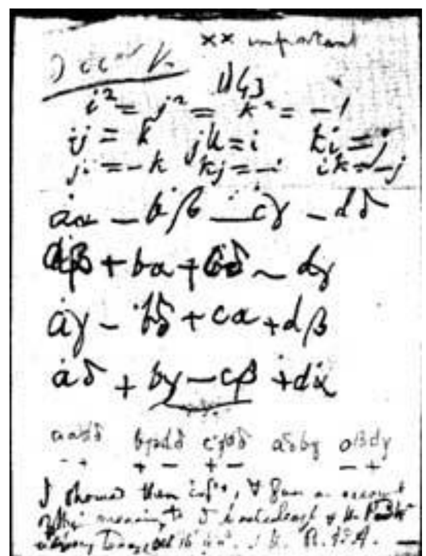
William R. Hamilton (1805-1865)

- Mathematician, physicist, and astronomer
- Contributed to algebra, mechanics, optics
- Formulated Hamiltonian mechanics
- Discovered quaternions, conical refraction, Hamilton function, Hamilton principle, Hamiltonian group
- Invented "Icosian Calculus", dot & cross products, Hamiltonian paths
- Influenced computer graphics, mechanics, electromagnetism, relativity, quantum theory, vector algebra







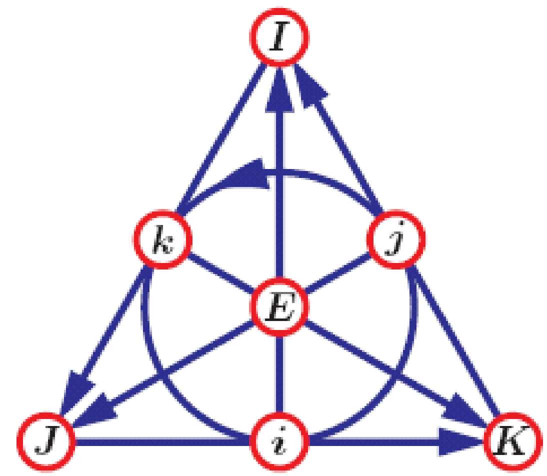


	1	−1	i	−i	j	−j	k	−k
1	1	−1	i	−i	j	−j	k	−k
−1	−1	1	−i	i	−j	j	−k	k
i	i	−i	−1	1	k	−k	−j	j
−i	−i	i	1	−1	−k	k	j	−j
j	j	−j	−k	k	−1	1	i	−i
−j	−j	j	k	−k	1	−1	−i	i
k	k	−k	j	−j	−i	i	−1	1
−k	−k	k	−j	j	i	−i	1	−1

Octonions: Generalization of Quaternions

- Non-associative! (e.g., (ij)K=-E ≠ E=i(jK))
- Discovered by John Graves (1843), friend of Hamilton
- Useful in general relativity, quantum logic, string theory

×	*i*	*j*	*k*	*E*	*I*	*J*	*K*
i	−1	*k*	−*j*	*I*	−*E*	−*K*	*J*
j	−*k*	−1	*i*	*J*	*K*	−*E*	−*I*
k	*j*	−*i*	−1	*K*	−*J*	*I*	−*E*
E	−*I*	−*J*	−*K*	−1	*i*	*j*	*k*
I	*E*	−*K*	*J*	−*i*	−1	−*k*	*j*
J	*K*	*E*	−*I*	−*j*	*k*	−1	−*i*
K	−*J*	*I*	*E*	−*k*	−*j*	*i*	−1



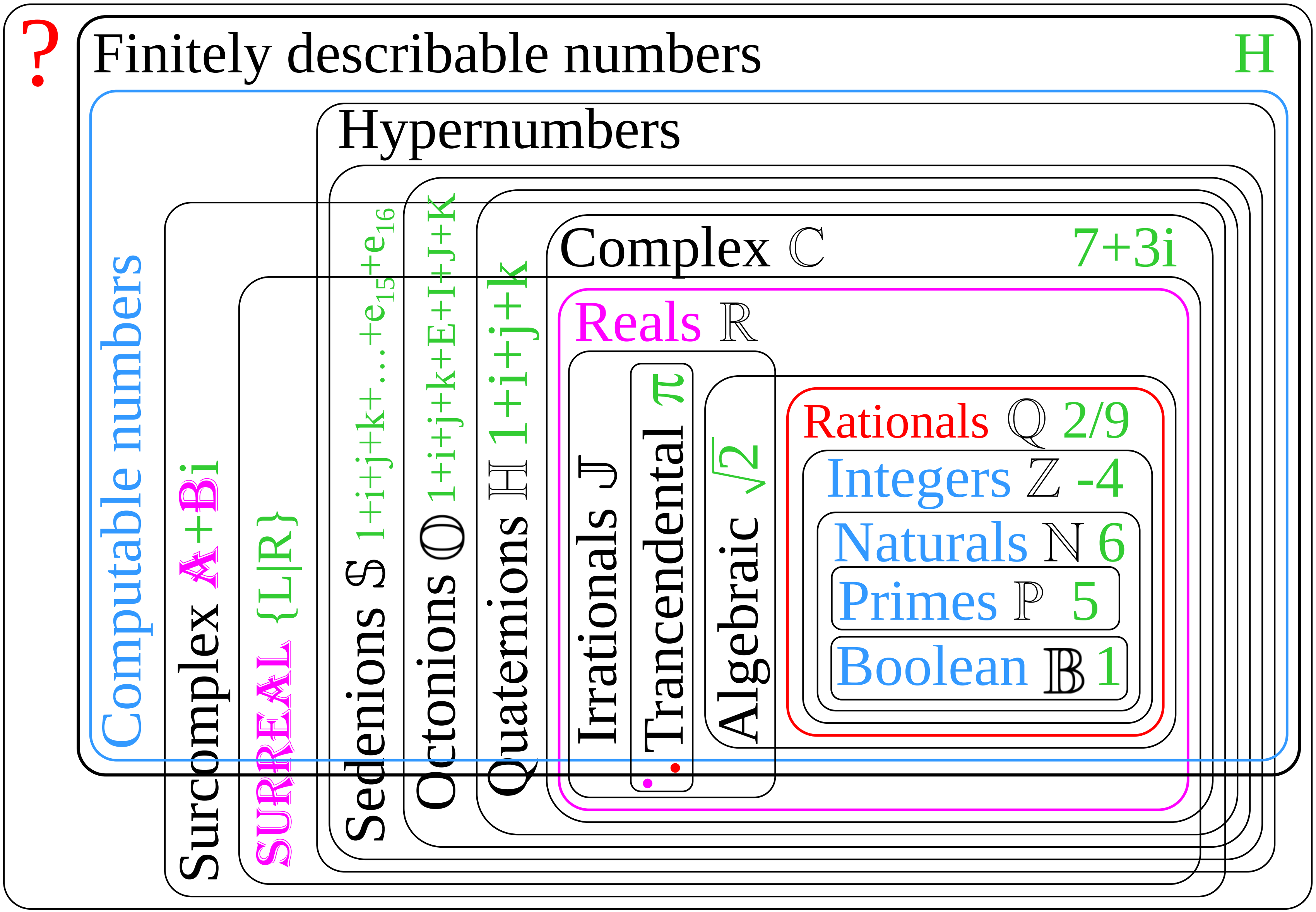
Mnemonic diagram for unit octonions products

Sedenions: Generalization of Octonions

- Non-alternative! (i.e., x(xy)=(xx)y doesn't hold)

×	1	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}	e_{11}	e_{12}	e_{13}	e_{14}	e_{15}
1	1	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	e_9	e_{10}	e_{11}	e_{12}	e_{13}	e_{14}	e_{15}
e_1	e_1	-1	e_3	$-e_2$	e_5	$-e_4$	$-e_7$	e_6	e_9	$-e_8$	$-e_{11}$	e_{10}	$-e_{13}$	e_{12}	e_{15}	$-e_{14}$
e_2	e_2	$-e_3$	-1	e_1	e_6	e_7	$-e_4$	$-e_5$	e_{10}	e_{11}	$-e_8$	$-e_9$	$-e_{14}$	$-e_{15}$	e_{12}	e_{13}
e_3	e_3	e_2	$-e_1$	-1	e_7	$-e_6$	e_5	$-e_4$	e_{11}	$-e_{10}$	e_9	$-e_8$	$-e_{15}$	e_{14}	$-e_{13}$	e_{12}
e_4	e_4	$-e_5$	$-e_6$	$-e_7$	-1	e_1	e_2	e_3	e_{12}	e_{13}	e_{14}	e_{15}	$-e_8$	$-e_9$	$-e_{10}$	$-e_{11}$
e_5	e_5	e_4	$-e_7$	e_6	$-e_1$	-1	$-e_3$	e_2	e_{13}	$-e_{12}$	e_{15}	$-e_{14}$	e_9	$-e_8$	e_{11}	$-e_{10}$
e_6	e_6	e_7	e_4	$-e_5$	$-e_2$	e_3	-1	$-e_1$	e_{14}	$-e_{15}$	$-e_{12}$	e_{13}	e_{10}	$-e_{11}$	$-e_8$	e_9
e_7	e_7	$-e_6$	e_5	e_4	$-e_3$	$-e_2$	e_1	-1	e_{15}	e_{14}	$-e_{13}$	$-e_{12}$	e_{11}	e_{10}	$-e_9$	$-e_8$
e_8	e_8	$-e_9$	$-e_{10}$	$-e_{11}$	$-e_{12}$	$-e_{13}$	$-e_{14}$	$-e_{15}$	-1	e_1	e_2	e_3	e_4	e_5	e_6	e_7
e_9	e_9	e_8	$-e_{11}$	e_{10}	$-e_{13}$	e_{12}	e_{15}	$-e_{14}$	$-e_1$	-1	$-e_3$	e_2	$-e_5$	e_4	e_7	$-e_6$
e_{10}	e_{10}	e_{11}	e_8	$-e_9$	$-e_{14}$	$-e_{15}$	e_{12}	e_{13}	$-e_2$	e_3	-1	$-e_1$	$-e_6$	$-e_7$	e_4	e_5
e_{11}	e_{11}	$-e_{10}$	e_9	e_8	$-e_{15}$	e_{14}	$-e_{13}$	e_{12}	$-e_3$	$-e_2$	e_1	-1	$-e_7$	e_6	$-e_5$	e_4
e_{12}	e_{12}	e_{13}	e_{14}	e_{15}	e_8	$-e_9$	$-e_{10}$	$-e_{11}$	$-e_4$	e_5	e_6	e_7	-1	$-e_1$	$-e_2$	$-e_3$
e_{13}	e_{13}	$-e_{12}$	e_{15}	$-e_{14}$	e_9	e_8	e_{11}	$-e_{10}$	$-e_5$	$-e_4$	e_7	$-e_6$	e_1	-1	e_3	$-e_2$
e_{14}	e_{14}	$-e_{15}$	$-e_{12}$	e_{13}	e_{10}	$-e_{11}$	e_8	e_9	$-e_6$	$-e_7$	$-e_4$	e_5	e_2	$-e_3$	-1	e_1
e_{15}	e_{15}	e_{14}	$-e_{13}$	$-e_{12}$	e_{11}	e_{10}	$-e_9$	e_8	$-e_7$	e_6	$-e_5$	$-e_4$	e_3	e_2	$-e_1$	-1

Generalized Numbers



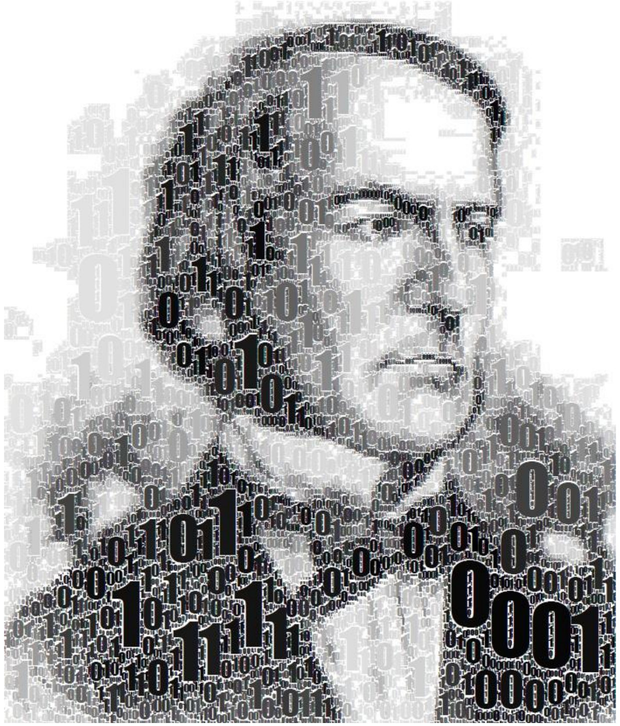
Theorem: some real numbers are not finitely describable!

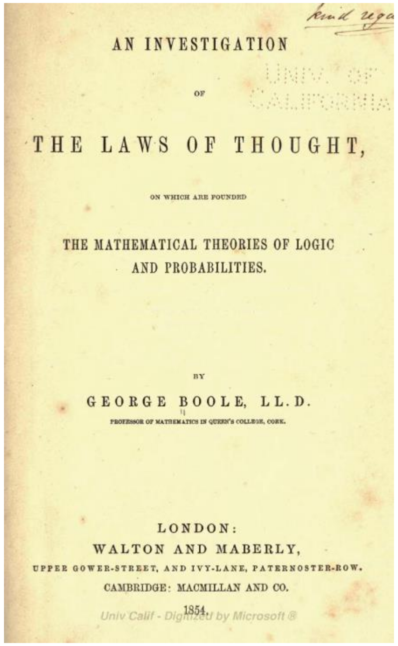
Theorem: some finitely describable real numbers are not computable!

Historical Perspectives

George Boole (1815-1864)

- Mathematician and philosopher
- Invented symbolic / Boolean logic
- Invented Boolean algebra, i.e. “calculus of reasoning”
- A founder of computer science
- “An Investigation into the Laws of Thought”
- Influenced De Morgan, Schröder, Shannon
- All modern computers, electronics, phones, data transmission, rely on Boolean principles





AN INVESTIGATION

OF

THE LAWS OF THOUGHT,

ON WHICH ARE FOUNDED

THE MATHEMATICAL THEORIES OF LOGIC AND PROBABILITIES.

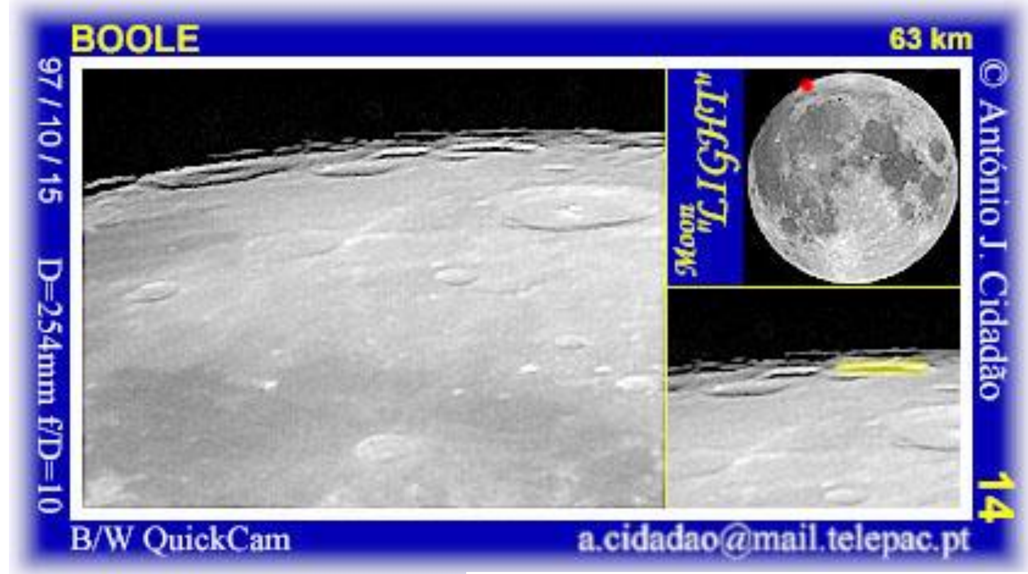
BY

GEORGE BOOLE, LL.D.

PROFESSOR OF MATHEMATICS IN QUEEN'S COLLEGE, CORK.

LONDON:
WALTON AND MABERLY,
UPPER GOWER-STREET, AND IVY-LANE, PATERNOSTER-ROW.
CAMBRIDGE: MACMILLAN AND CO.
1854.


GEORGE BOOLE
LL.D. D.C.L. F.R.S.
1815 — 1864
GEORGE BOOLE, FATHER OF MODERN ALGEBRA, AUTHOR OF THE LAWS OF THOUGHT AND FIRST PROFESSOR OF MATHEMATICS AT UNIVERSITY COLLEGE, CORK, WAS BORN IN LINCOLN AND ESTABLISHED AN ACADEMY IN THIS HOUSE C. 1840.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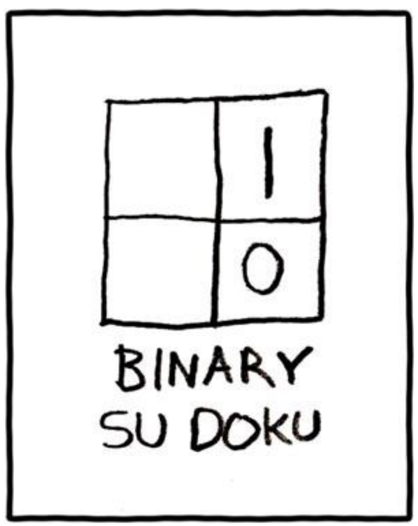
РЕПУБЛИКА МАКЕДОНИЈА
САМИТ ЗА ИНФОРМАТИЧКО ОПШТЕСТВО
ПОШТА
2004 СКЕНПОИНТ
САМИТ ЗА ИНФОРМАТИЧКО ОПШТЕСТВО


LOGIC LANE


All cats have four legs.
I have four legs.
Therefore, I am a cat.
S. Harris


GEORGE BOOLE
DIED DEC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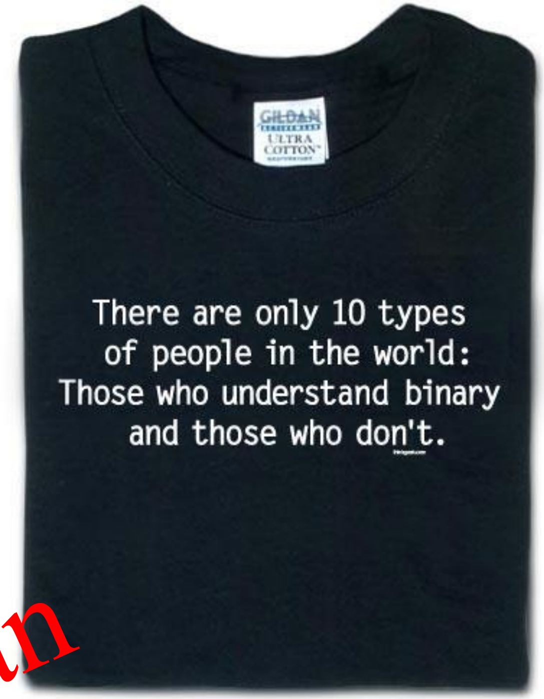
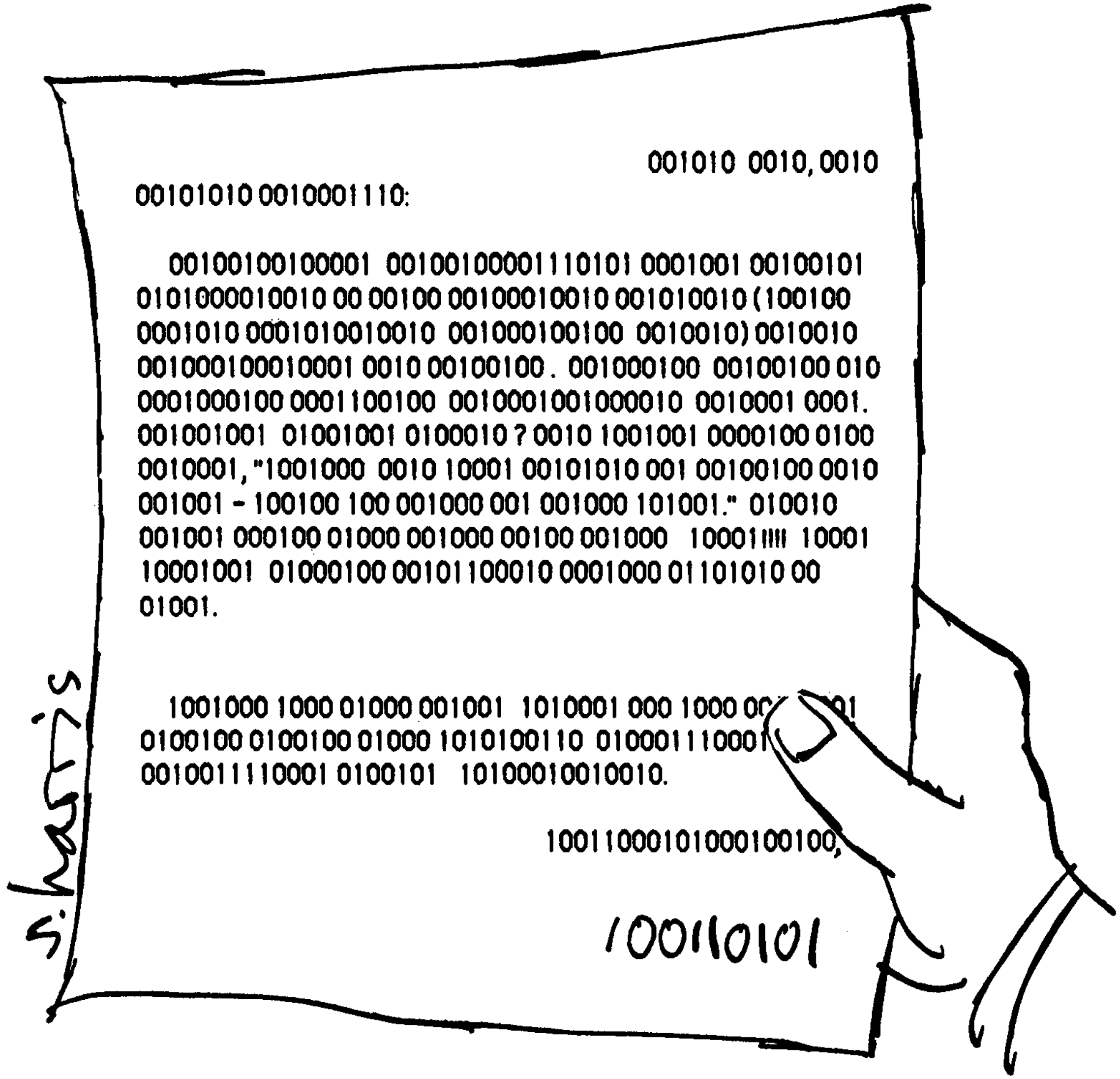
Boolean humor





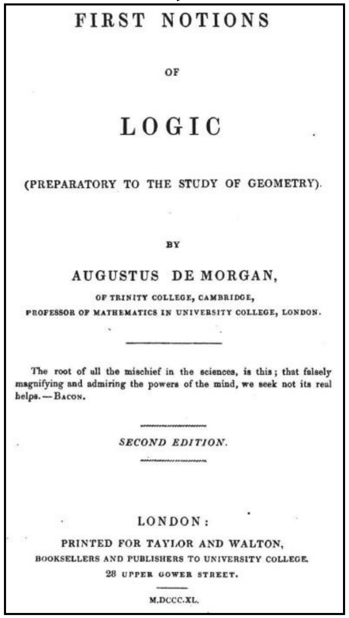
BINARY LETTER FROM GRANDMA

Mozart writing the digital version of his symphony No. 38
in D major.

Historical Perspectives

Augustus De Morgan (1806-1871)

- Mathematician and logician
- Developed logic & mathematical induction
- De Morgan's Laws in logic & set theory
- Invented relational algebra
- Corresponded extensively with Hamilton
- Influenced Russell, Whitehead, and Tarski
- Studied paradoxes



FIRST NOTIONS

OF

LOGIC

(PREPARATORY TO THE STUDY OF GEOMETRY).

BY

AUGUSTUS DE MORGAN,

OF TRINITY COLLEGE, CAMBRIDGE,

PROFESSOR OF MATHEMATICS IN UNIVERSITY COLLEGE, LONDON.

The root of all the mischief in the sciences, is this; that falsely magnifying and admiring the powers of the mind, we seek not its real helps. — Bacon.

SECOND EDITION.

LONDON:

PRINTED FOR TAYLOR AND WALTON,

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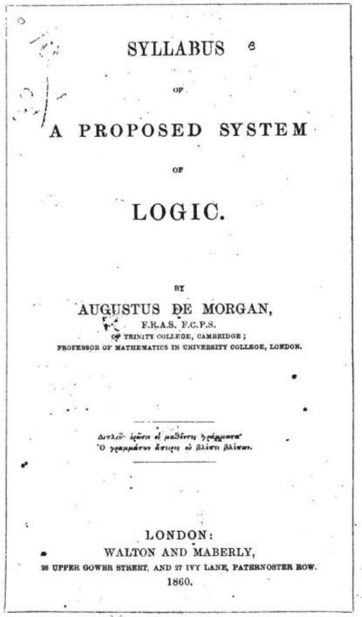
28 UPPER GOWER STREET.

M.DCCC.XL.



SYLLABUS

OF

A PROPOSED SYSTEM

OF

LOGIC.

BY

AUGUSTUS DE MORGAN,

F.R.A.S. F.C.P.S.

OF TRINITY COLLEGE, CAMBRIDGE;

PROFESSOR OF MATHEMATICS IN UNIVERSITY COLLEGE, LONDON.

LONDON:

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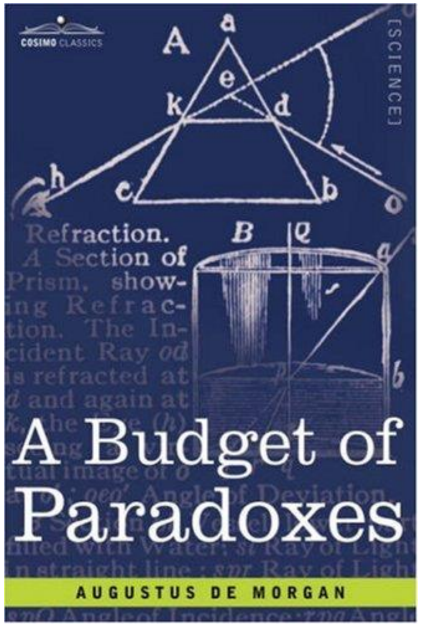
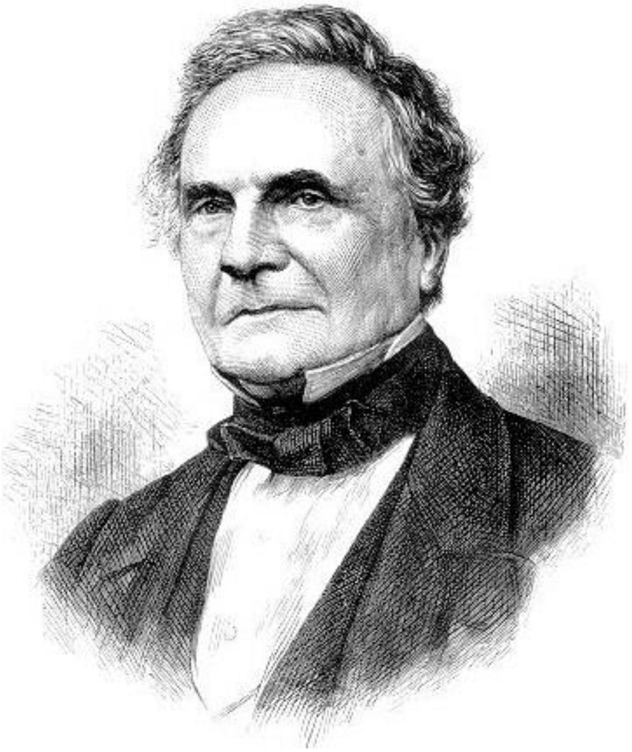
28 UPPER GOWER STREET, AND 27 IVY LANE, PATERNOSTER ROW.

1860.

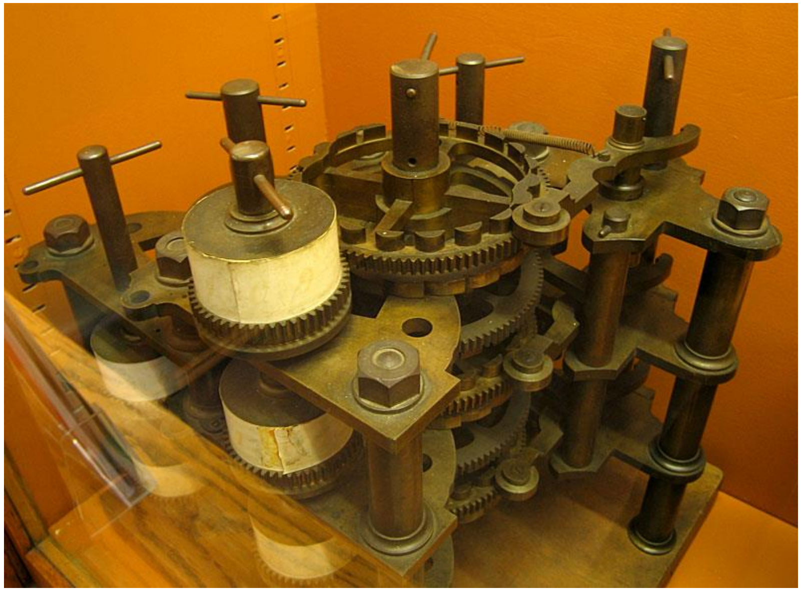


Historical Perspectives



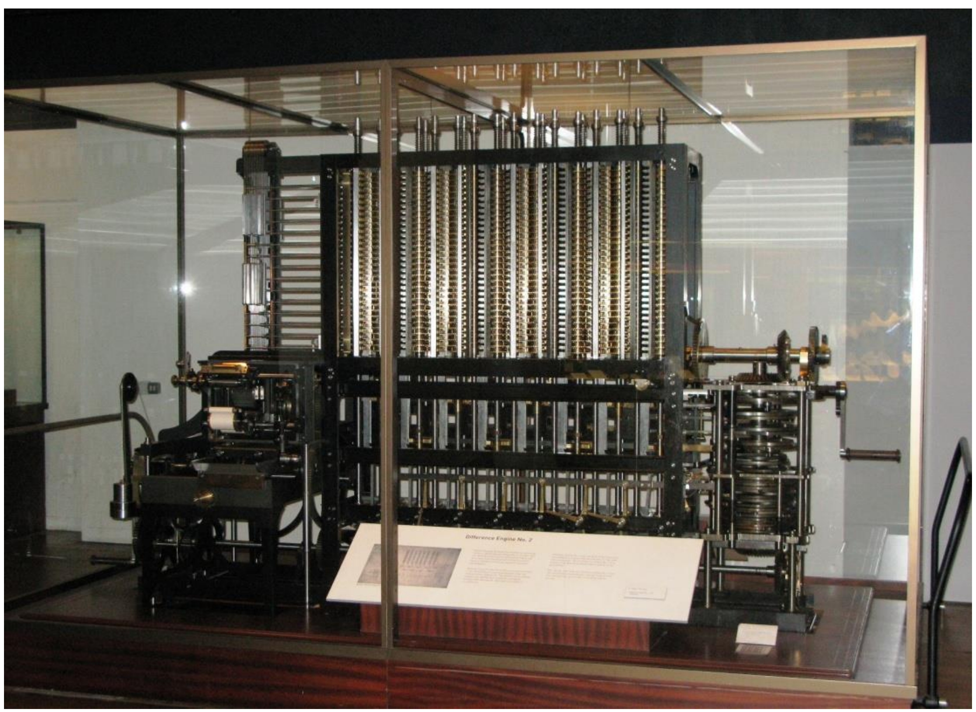
Charles Babbage (1791-1871)

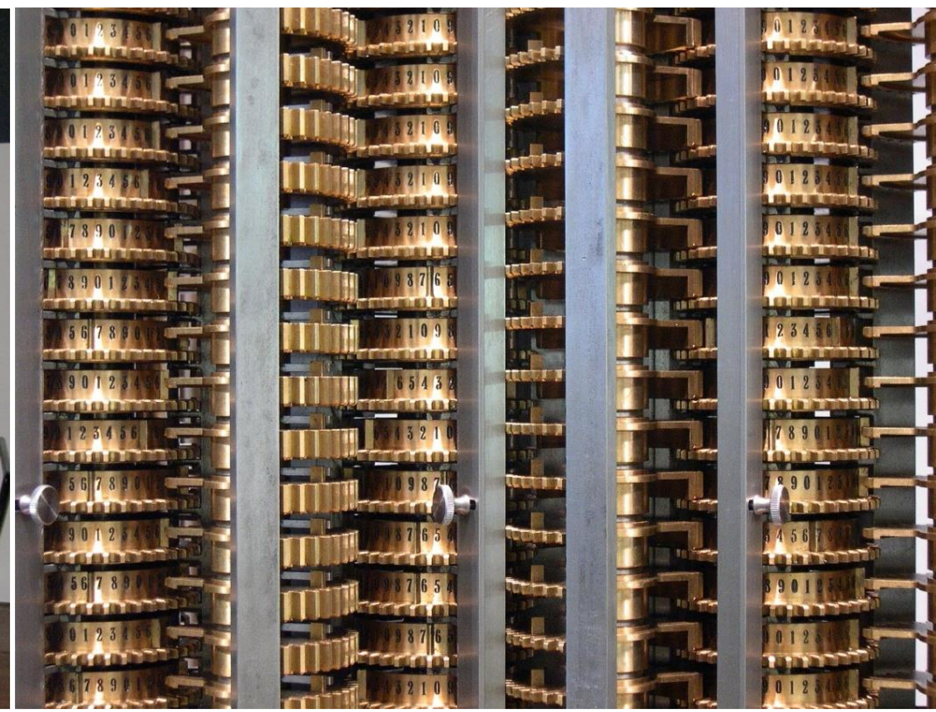
- Mathematician, philosopher, inventor mechanical engineer, and economist
- The father of computing
- Built world's first mechanical computer
  - the "difference engine" (1822)
- Originated the programmable computer
  - the "analytical engine" (1837)
- Worked in cryptography
- Developed Babbage's principle of division of labor



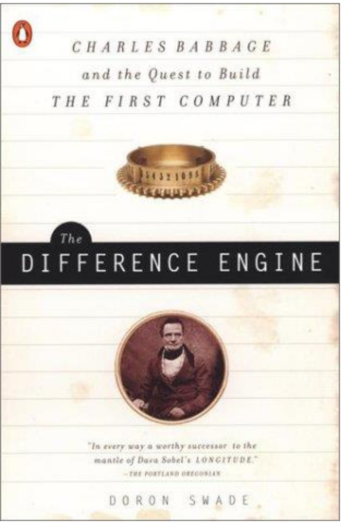
Babbage's Difference Engine

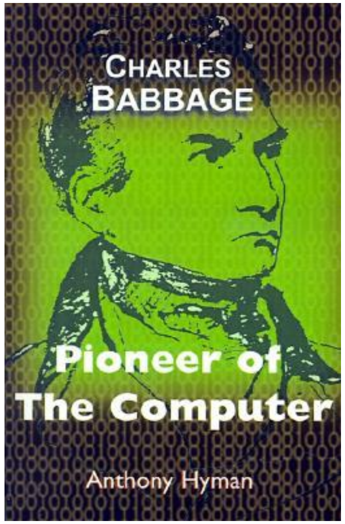
- World's first mechanical computer
- Designed in 1822, redesigned in 1847-1849
- 25,000 parts, 15 tons, 8ft tall, 31 digits of precision
- Tabulated polynomial functions, used Newton's method
- Approximated logarithmic and polynomial functions
- Used decimal number system and hand-crank

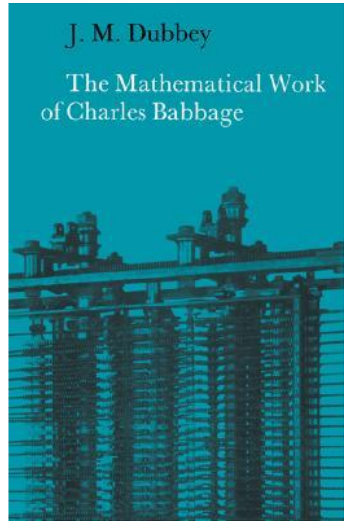


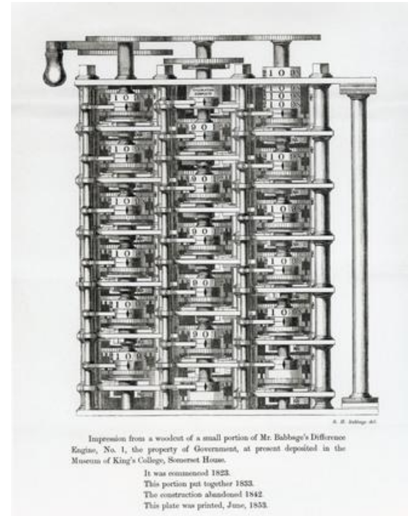


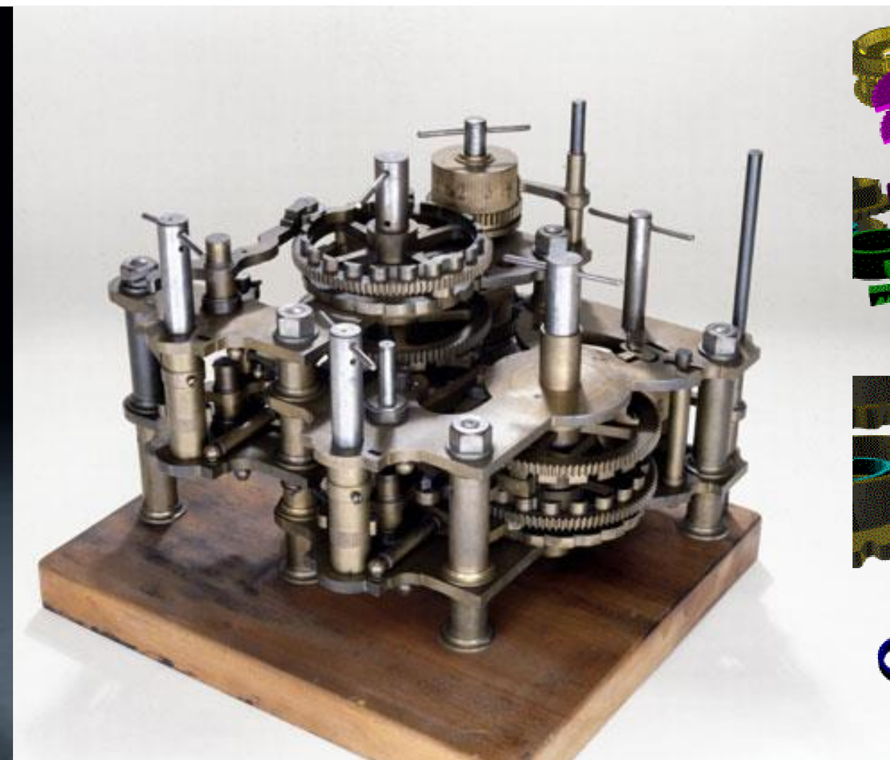
Babbage's Difference Engine

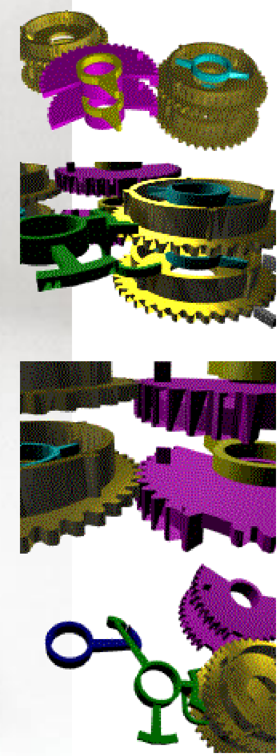




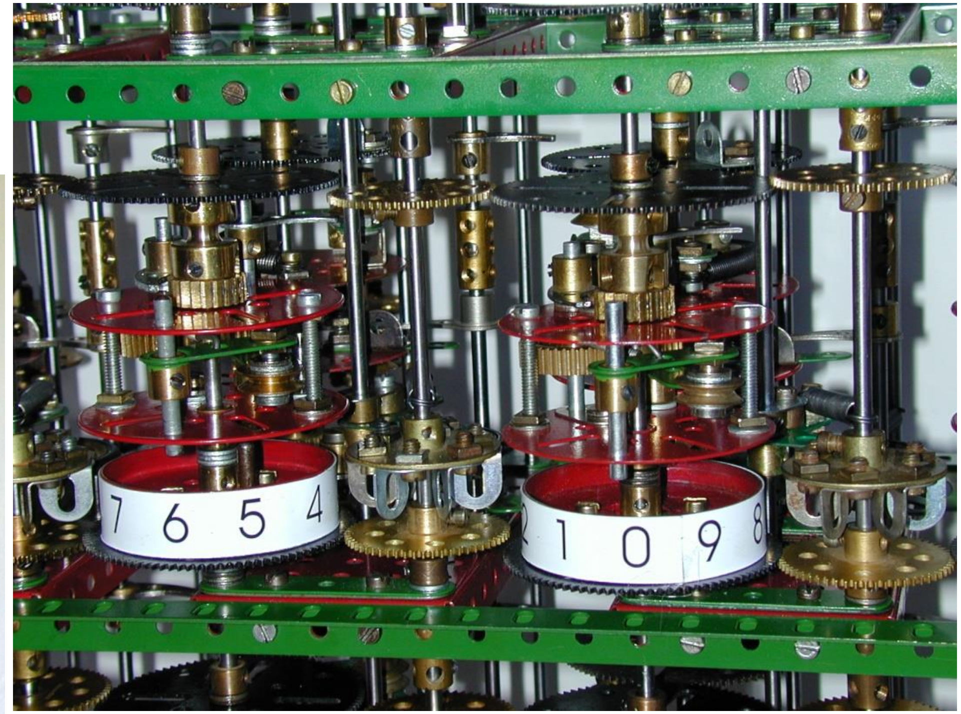


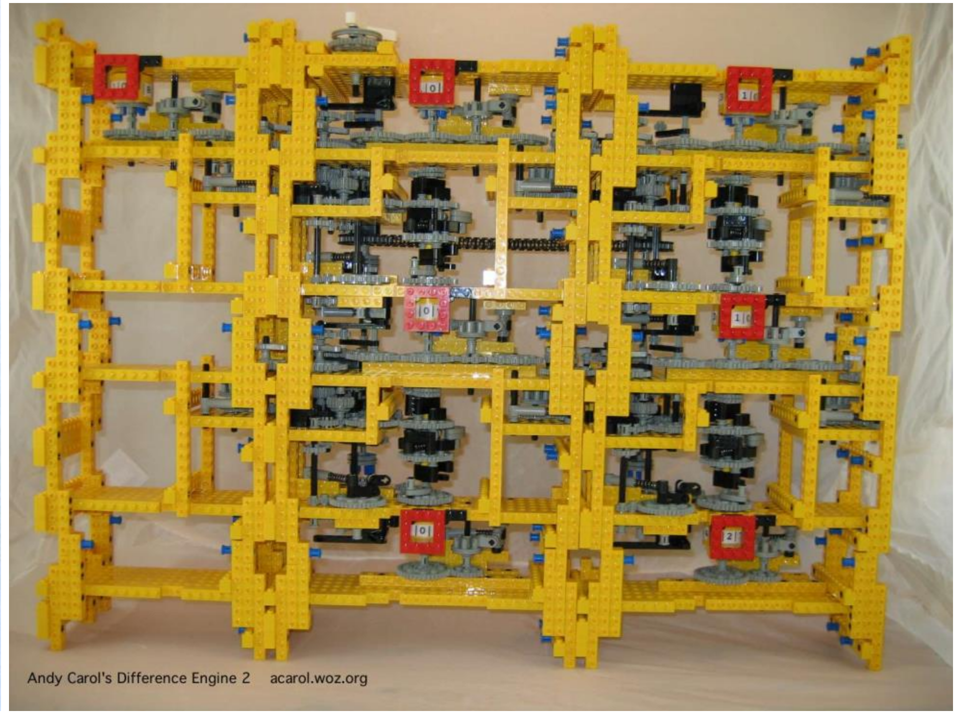






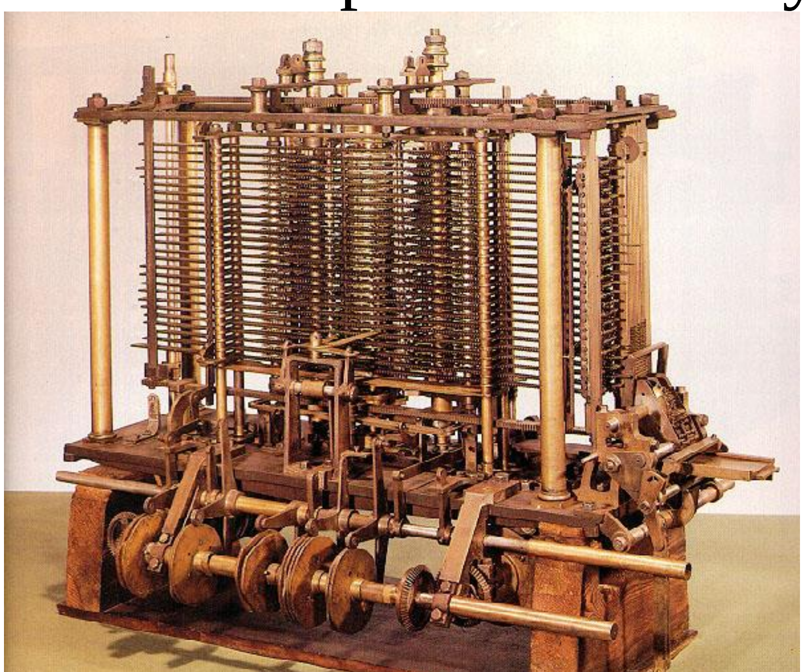
Babbage's difference engine built from Mechano and Lego

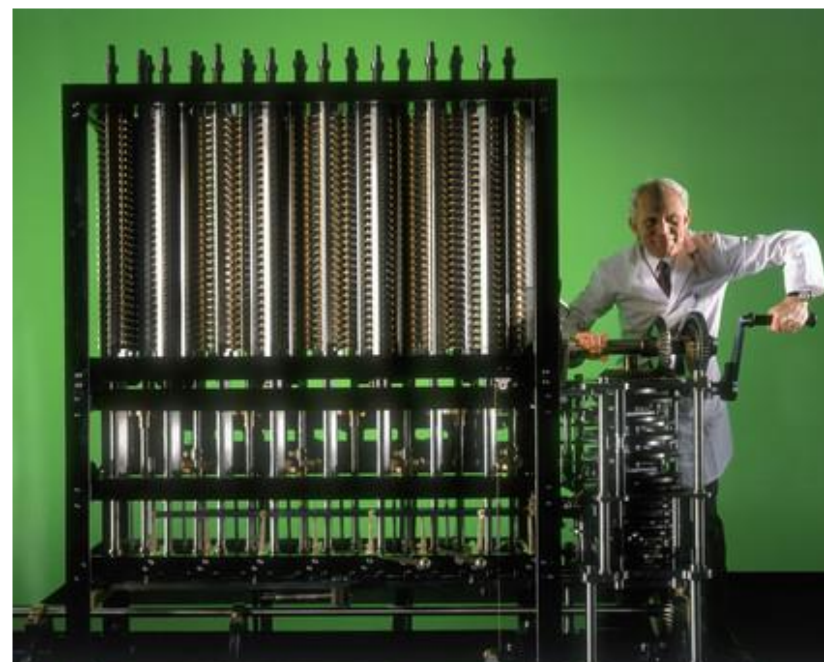




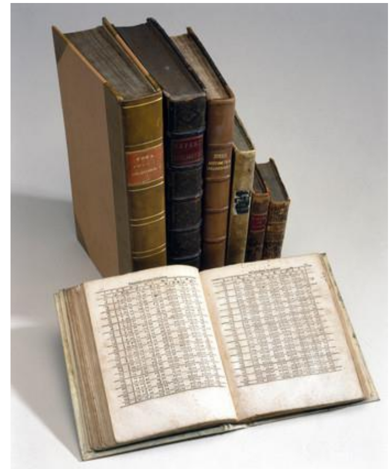
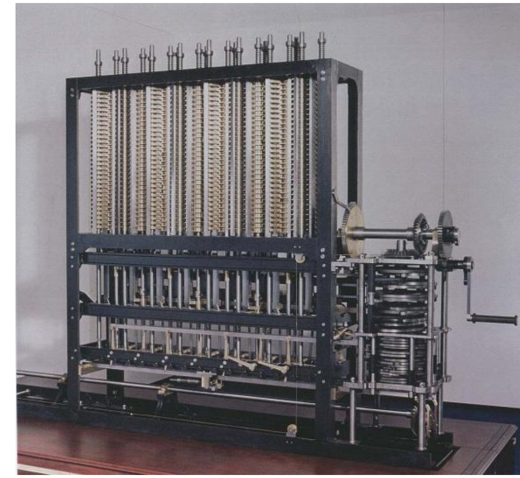
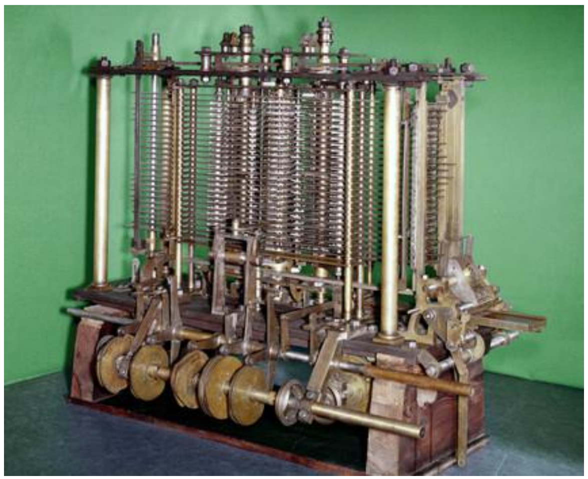
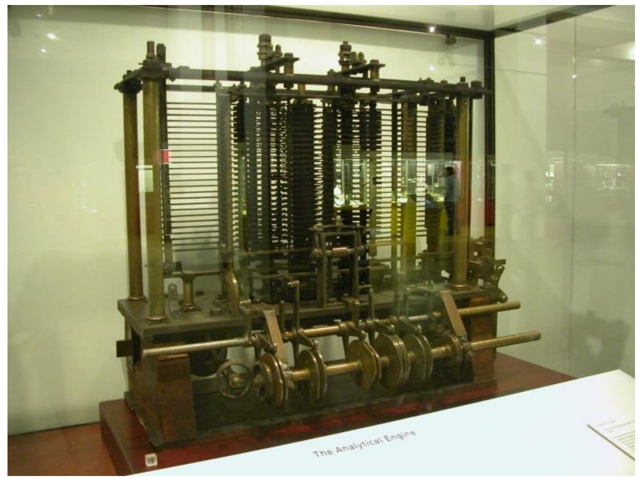
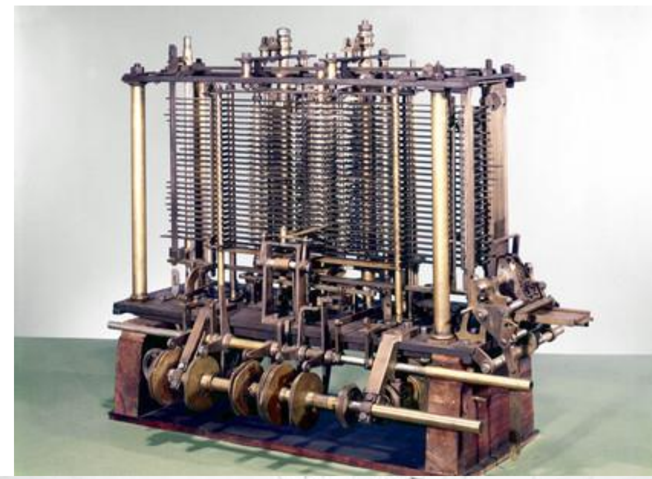
Babbage's Analytical Engine

- World's first general-purpose computer
- Designed in 1837, redesigned throughout Babbage's life
- Turing-complete, memory: 1000x50 digits (21 kB)
- Fully programmable "CPU", used punched cards
- Featured ALU, "microcode", loops, and printer!
- Could multiply two 20-digit numbers in 3 min
- Few components built by Babbage; constructed in 1991











The Analytical Engine




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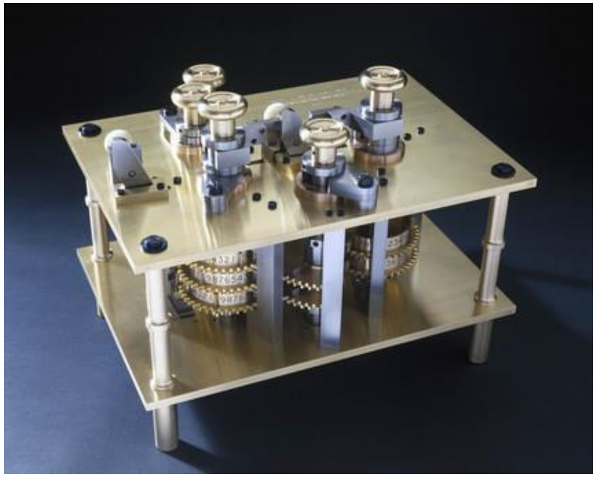
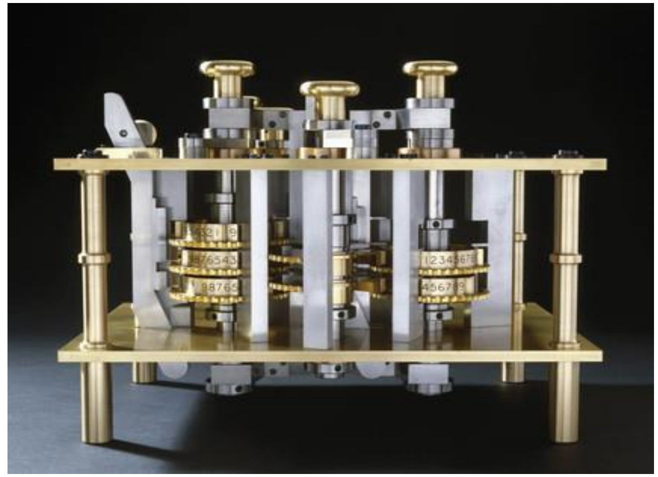


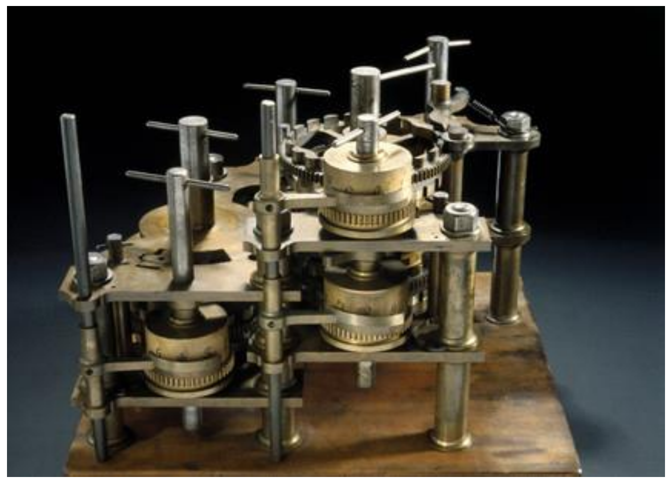





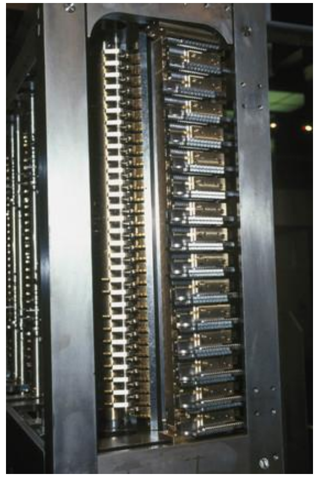

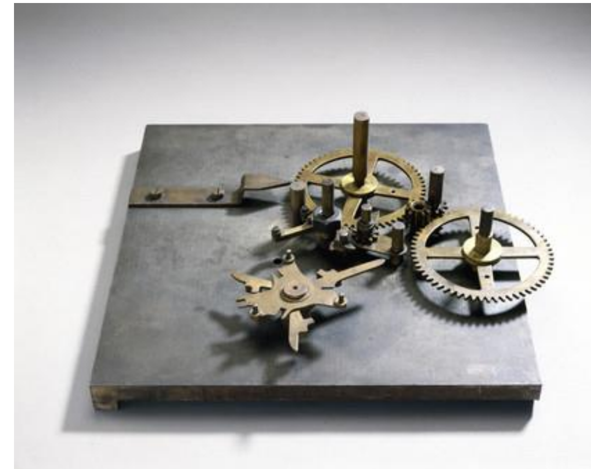
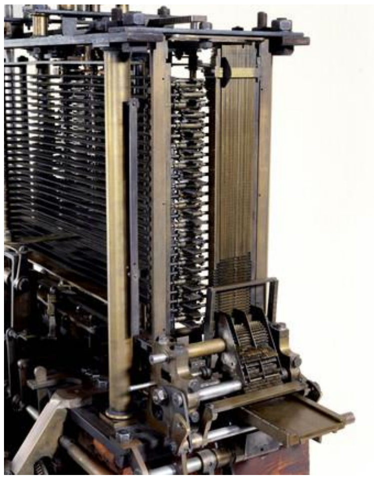


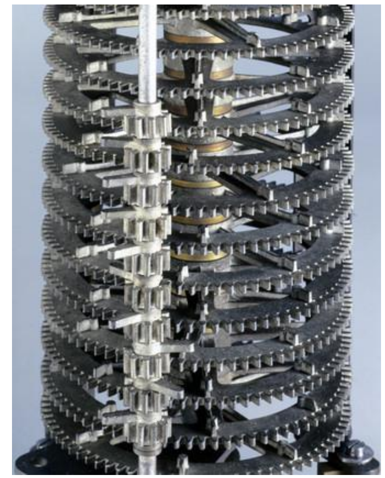



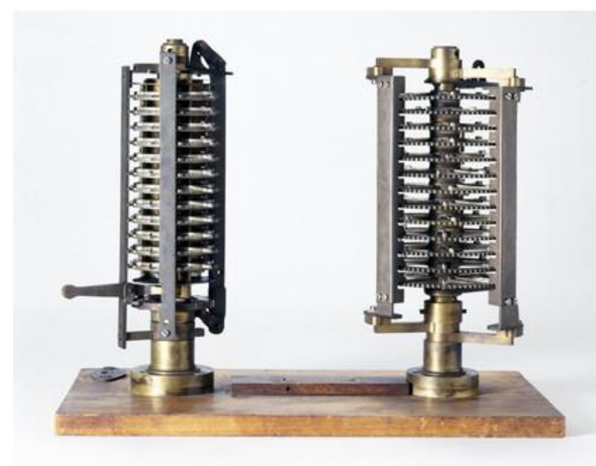

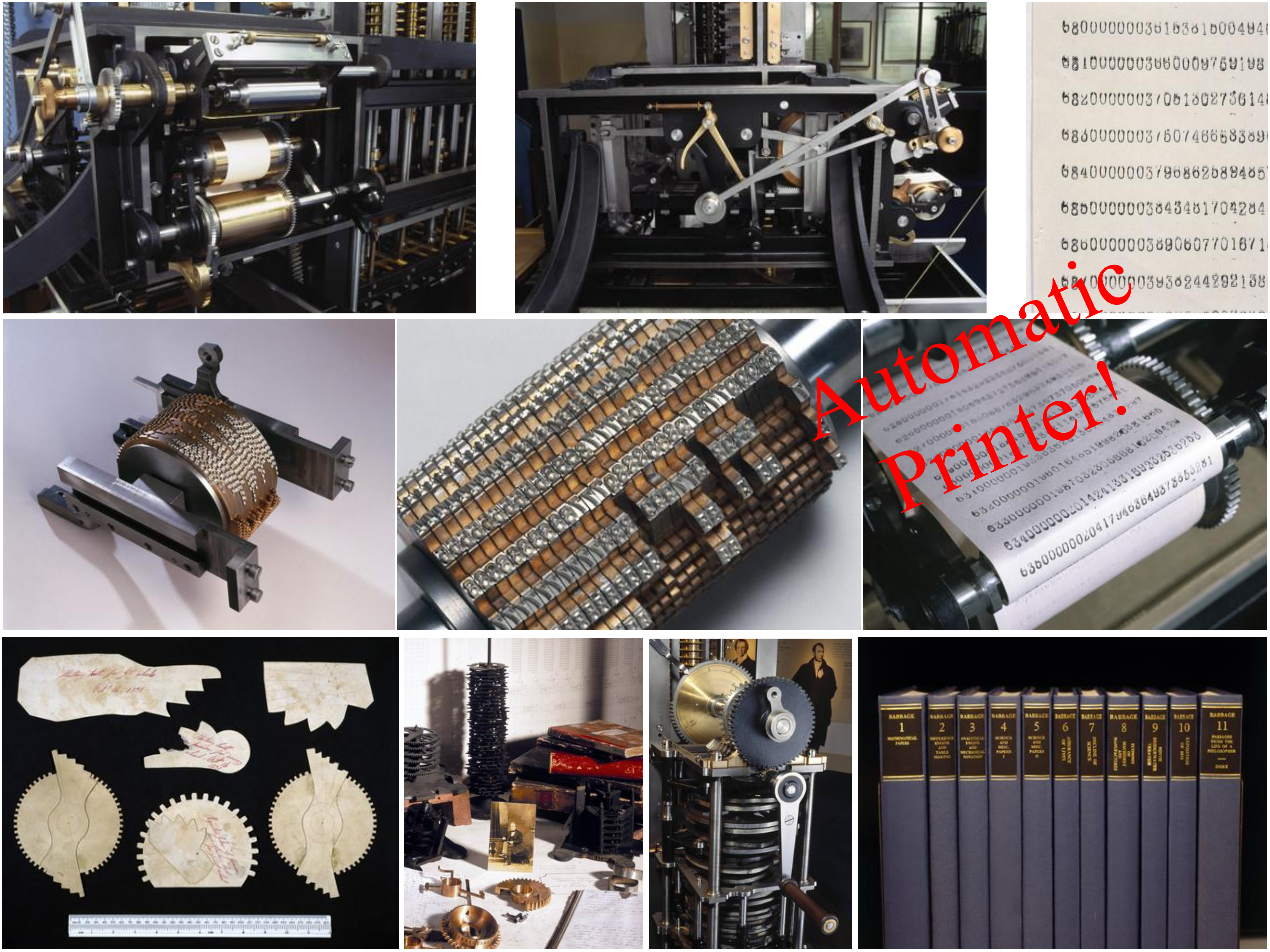
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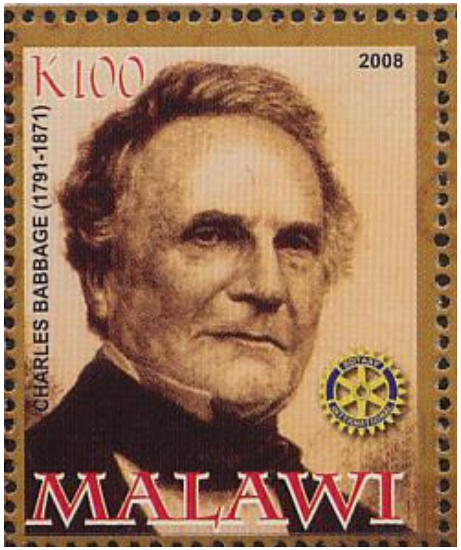
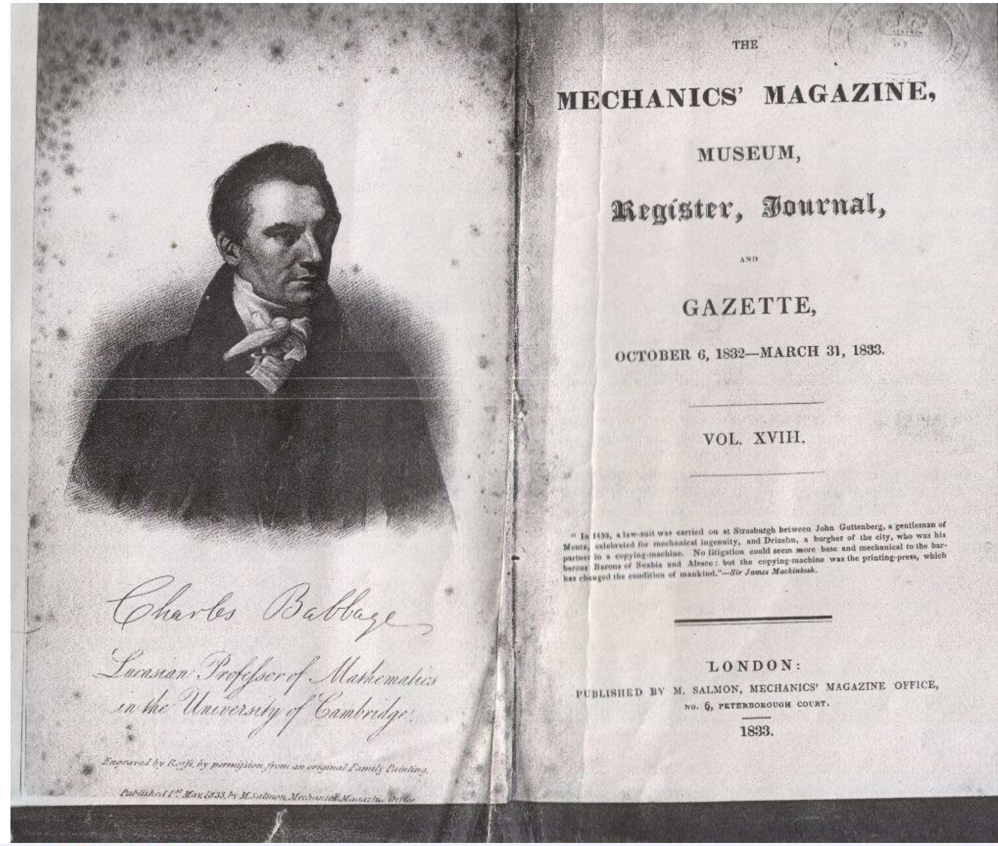




THE

MECHANICS' MAGAZINE,

MUSEUM,

Register, Journal,

AND

GAZETTE,

OCTOBER 6, 1832—MARCH 31, 1833.

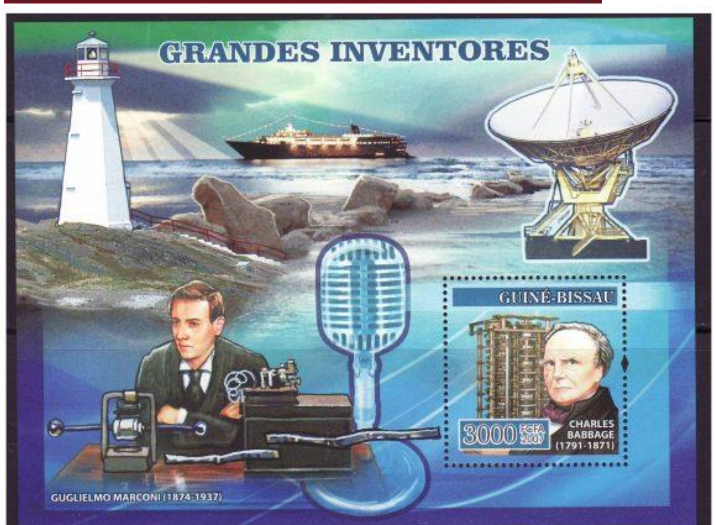
VOL. XVIII.

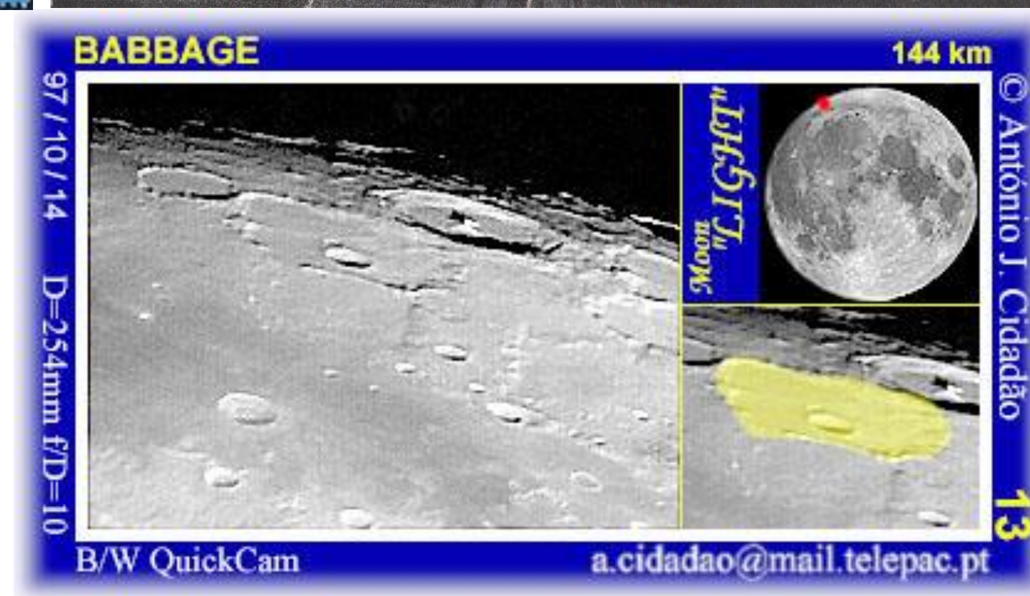
"In 1435, a law-suit was carried on at Strasburgh between John Guttenberg, a gentleman of Mentz, celebrated for mechanical ingenuity, and Drizehn, a burgher of the city, who was his partner in a copying-machine. No litigation could seem more base and mechanical to the barbarous Barons of Suabia and Alsace: but the copying-machine was the printing-press, which has changed the condition of mankind."—*Sir James Mackintosh.*

LONDON:

PUBLISHED BY M. SALMON, MECHANICS' MAGAZINE OFFICE, No. 6, PETERBOROUGH COURT.

1833.





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WELCOME TO THE CHARLES BABBAGE INSTITUTE

The Charles Babbage Institute (CBI) is an archives and research center dedicated to preserving the history of information technology and promoting and conducting research in the field.

Primary support for CBI is provided by the University of Minnesota, through the Institute of Technology and the University Libraries. Additional support is provided by corporate donors and individuals through the Friends of CBI.

SPOTLIGHT

- May 20th MHHC: IBM's Blue Gene
- New *CBI Newsletter* (Spring 2009, Vol. 31:1)
- McDonald Named 2009-2010 Tomash Fellow
- 2009 Norberg Travel Award Recipients

THE CBI ARCHIVES

The CBI Archives collects, preserves and provides access to rich archival collections and rare publications documenting the history of technology. Detailed archival finding aids are available. Researchers can also access digitized images (Burroughs Corporation Image Database) and one of the world's largest collections of research grade oral history interviews (CBI Oral History Database) through the CBI Web site. More »

THE CBI RESEARCH PROGRAM

CBI's historical research program identifies areas in which to collect archival materials; fosters new understanding of developments in the history of computing, software, and networking; supports the work of scholars outside the Institute (Tomash Fellowship and Norberg Travel Grant); and works collaboratively with individuals and organizations throughout the world. More »

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Finding aids are online guides to the collections in the Charles Babbage Institute.

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Ask a CBI archivist your questions about collections and services through instant message during regular business hours.

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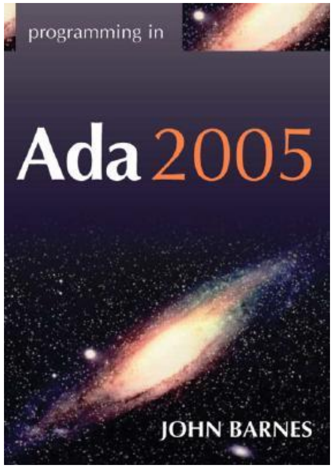
Historical Perspectives

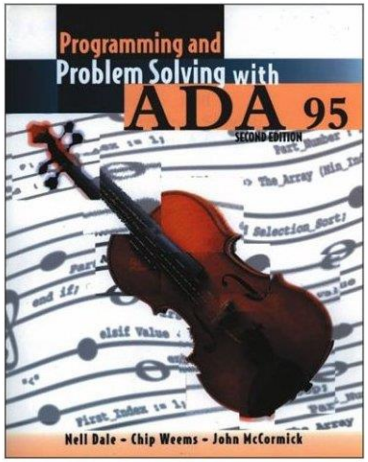
Countess Ada Lovelace (1815-1852)

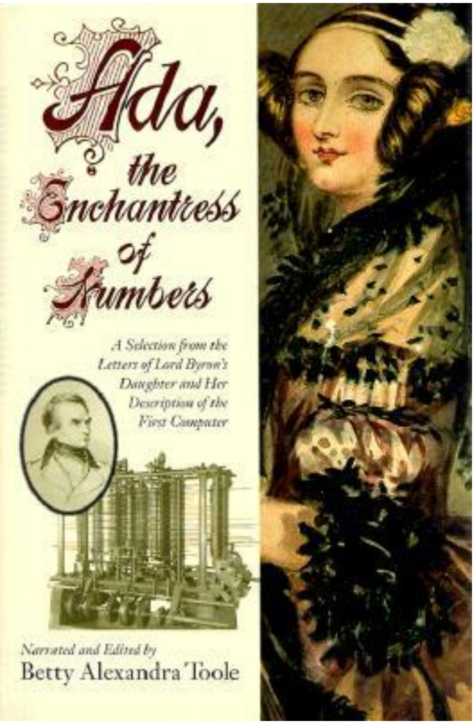
- Daughter of Lord Byron
- Tutored in math and logic by De Morgan
- Wrote the "manual" for Babbage's analytical engine, as well as programs for it
- World's first computer programmer!
- Foresaw the vast potential of computers
- Babbage: "The Enchantress of Numbers"
- DoD's Ada language "MIL-STD-1815"

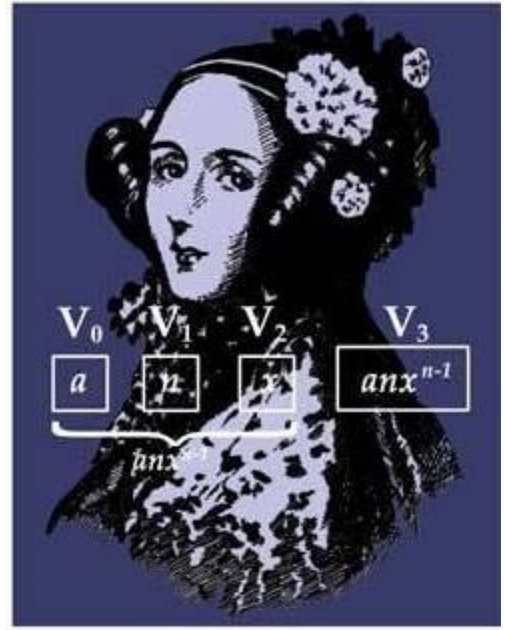
Ada

The International Language for Software Engineering

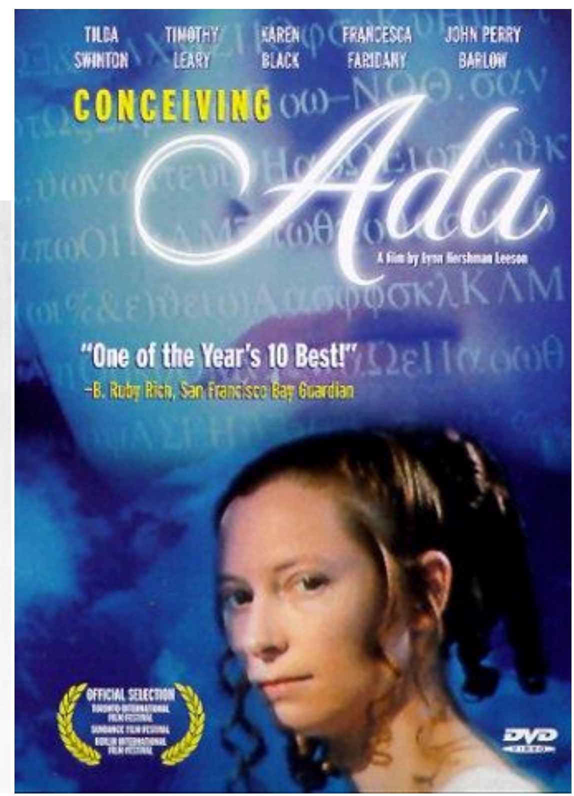








Ada Byron, Lady Lovelace
1815 - 1852

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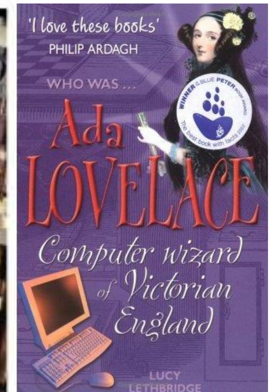
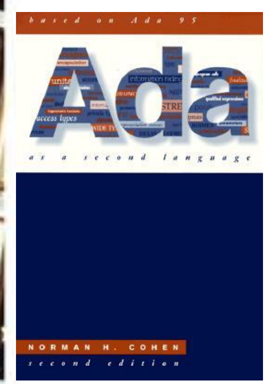
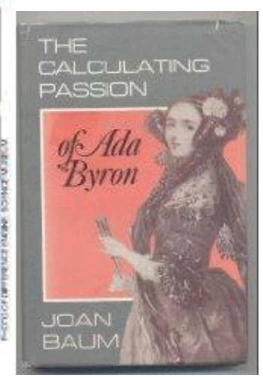
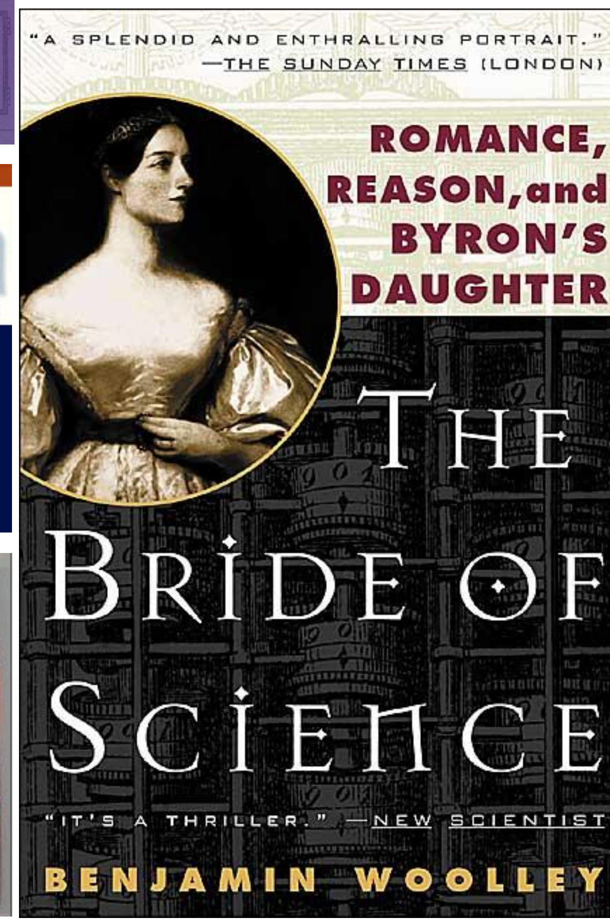
Ada Lovelace Day
24 March 2009


'I love these books'
PHILIP ARDAGH
WHO WAS ...
Ada LOVELACE
Computer wizard of Victorian England
LUCY LETHBRIDGE


based on Ada 95
Ada
as a second language
NORMAN H. COHEN
second edition


THE CALCULATING PASSION
of Ada Byron
JOAN BAUM


"A SPLENDID AND ENTHRALLING PORTRAIT." —THE SUNDAY TIMES (LONDON)
ROMANCE, REASON, and BYRON'S DAUGHTER
THE BRIDE OF SCIENCE
"IT'S A THRILLER." —NEW SCIENTIST
BENJAMIN WOOLLEY

Lovelace Medal

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- About the medal
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- Past winners

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Lovelace Medal

The Lovelace Medal is presented to individuals who have made a contribution which is of major significance in the advancement of Information Systems or which adds significantly to the understanding of Information Systems.

About the medal

Lovelace Medal 2009

2009 winner
The winner of the 2009 Lovelace Medal is Professor Yorick Wilks.

Previous Lectures

Video: A tribute to Karen Spärck Jones
The 2008 BCS Lovelace Medal lecture was a very special event dedicated to the memory of Karen Spärck Jones who was presented the award just weeks before she died last year. The lecture was delivered by Dr Ann Copestake and is now available to watch online.

2007 Lovelace Lecture - Sir Tim Berners-Lee
The Web is a technical and social creation, dependent on both technical protocols and social conventions. The origins and potential futures of this large scale, emergent phenomena were discussed by Sir Tim Berners-Lee in this year's BCS Lovelace Lecture - now available to watch via this website.

Previous winners

Previous winners of the Lovelace Medal have included:

2008 - Dr Tony Storey
2007 - Karen Sparck-Jones
2006 - Sir Tim Berners-Lee
2005 - Dr Nicholas McKeown

Ada Lovelace notes on “Sketch of the Analytical Engine Invented by Charles Babbage”, by L. F. Menabrea, 1843

Her notes (three times longer than the paper itself!) contain the world’s first computer program (for calculating Bernoulli numbers):

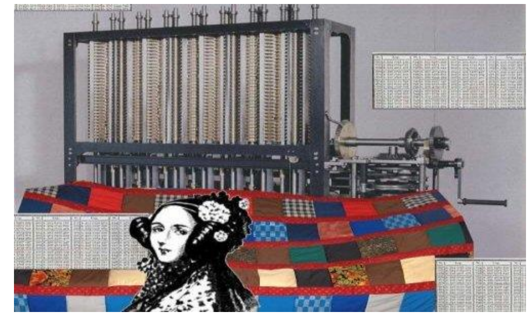
Number of Operations	Nature of Operations	Variables for Data						Working Variables									Variables for Results	
		$^1V_0$	$^1V_1$	$^1V_2$	$^1V_3$	$^1V_4$	$^1V_5$	$^0V_6$	$^0V_7$	$^0V_8$	$^0V_9$	$^0V_{10}$	$^0V_{11}$	$^0V_{12}$	$^0V_{13}$	$^0V_{14}$	$^0V_{15}$	$^0V_{16}$
		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		$\boxed{m}$	$\boxed{n}$	$\boxed{d}$	$\boxed{m'}$	$\boxed{n'}$	$\boxed{d'}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{}$	$\boxed{\frac{dn'-d'n}{mn'-m'n}=x}$	$\boxed{\frac{d'm-dm}{mn'-m'n}=y}$
1	×	m	....	....	....	n'	....	mn'										
2	×	....	n	....	m'	....	....	....	$m'n$									
3	×	....	....	d	....	....	....	....	....	dn'								
4	×	....	0	....	....	....	d'	....	....	....	$d'n$							
5	×	0	....	....	....	....	0	....	....	....	....	$d'm$						
6	×	....	....	0	0	....	....	....	....	....	....	.....	dm'					
7	−	....	....	....	....	....	....	0	0	....	....	.....	.....	$(mn'-m'n)$				
8	−	....	....	....	....	....	....	....	....	0	0	.....	.....	....	$(dn'-d'n)$			
9	−	....	....	....	....	....	....	....	....	....	....	0	0	....	....	$(d'm-dm')$		
10	÷	....	....	....	....	....	....	....	....	....	....	.....	.....	$(mn'-m'n)$	0	....	$\frac{dn'-d'n}{mn'-m'n}=x$	
11	÷	....	....	....	....	....	....	....	....	....	....	.....	.....	0	....	0	....	$\frac{d'm-dm'}{mn'-m'n}=y$

World's first computer program (for calculating Bernoulli numbers), by Ada Lovelace, 1843:

Number of Operation	Nature of Operation	Variables acted upon	Variables receiving results	Indication of change in the value on any Variable	Statement of Results	Data			Working Variables										Result Variables			
						${}^{1}V_{1}$ ○ 0 0 1 $\boxed{1}$	${}^{1}V_{2}$ ○ 0 0 2 $\boxed{2}$	${}^{1}V_{3}$ ○ 0 0 4 $\boxed{n}$	${}^{0}V_{4}$ ○ 0 0 0	${}^{0}V_{5}$ ○ 0 0 0	${}^{0}V_{6}$ ○ 0 0 0	${}^{0}V_{7}$ ○ 0 0 0	${}^{0}V_{8}$ ○ 0 0 0	${}^{0}V_{9}$ ○ 0 0 0	${}^{0}V_{10}$ ○ 0 0 0	${}^{0}V_{11}$ ○ 0 0 0	${}^{0}V_{12}$ ○ 0 0 0	${}^{0}V_{13}\cdots$ ○ 0 0 0	${}^{1}V_{21}$ ○ B in a dec. fract. $\boxed{B_1}$	${}^{1}V_{22}$ ○ B in a dec. fract. $\boxed{B_3}$	${}^{1}V_{23}$ ○ B in a dec. fract. $\boxed{B_5}$	${}^{0}V_{24}\cdots$ ○ 0 0 0 $\boxed{B_7}$
1	×	${}^{1}V_{2} \times {}^{1}V_{3}$	${}^{1}V_{4}, {}^{1}V_{5}, {}^{1}V_{6}$	$\left\{\begin{matrix} {}^{1}V_{2} = {}^{1}V_{2} \\ {}^{1}V_{3} = {}^{1}V_{3} \end{matrix}\right\}$	$= 2n$ ……	……	2	n	$2n$	$2n$	$2n$											
2	−	${}^{1}V_{4} - {}^{1}V_{1}$	${}^{2}V_{4}$ ……	$\left\{\begin{matrix} {}^{1}V_{4} = {}^{2}V_{4} \\ {}^{1}V_{1} = {}^{1}V_{1} \end{matrix}\right\}$	$= 2n - 1$ ……	1	……	……	$2n-1$													
3	+	${}^{1}V_{5} + {}^{1}V_{1}$	${}^{2}V_{5}$ ……	$\left\{\begin{matrix} {}^{1}V_{5} = {}^{2}V_{5} \\ {}^{1}V_{1} = {}^{1}V_{1} \end{matrix}\right\}$	$= 2n + 1$ ……	1	……	……	……	$2n+1$												
4	÷	${}^{2}V_{5} \div {}^{2}V_{4}$	${}^{1}V_{11}$ ……	$\left\{\begin{matrix} {}^{2}V_{5} = {}^{0}V_{5} \\ {}^{2}V_{4} = {}^{0}V_{4} \end{matrix}\right\}$	$= \frac{2n-1}{2n+1}$ ……	……	……	……	0	0	……	……	……	……	……	$\frac{2n-1}{2n+1}$						
5	÷	${}^{1}V_{11} \div {}^{1}V_{2}$	${}^{2}V_{11}$ ……	$\left\{\begin{matrix} {}^{1}V_{11} = {}^{2}V_{11} \\ {}^{1}V_{2} = {}^{1}V_{2} \end{matrix}\right\}$	$= \frac{1}{2} \cdot \frac{2n-1}{2n+1}$ ……	……	2	……	……	……	……	……	……	……	……	$\frac{1}{2} \cdot \frac{2n-1}{2n+1}$						
6	−	${}^{0}V_{13} - {}^{2}V_{11}$	${}^{1}V_{13}$ ……	$\left\{\begin{matrix} {}^{2}V_{11} = {}^{0}V_{11} \\ {}^{0}V_{13} = {}^{1}V_{13} \end{matrix}\right\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$ ……	……	……	……	……	……	……	……	……	……	……	0	……	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$				
7	−	${}^{1}V_{3} - {}^{1}V_{1}$	${}^{1}V_{10}$ ……	$\left\{\begin{matrix} {}^{1}V_{3} = {}^{1}V_{3} \\ {}^{1}V_{1} = {}^{1}V_{1} \end{matrix}\right\}$	$= n - 1 (= 3)$ ……	1	……	n	……	……	……	……	……	……	$n-1$							
8	+	${}^{1}V_{2} + {}^{0}V_{7}$	${}^{1}V_{7}$ ……	$\left\{\begin{matrix} {}^{1}V_{2} = {}^{1}V_{2} \\ {}^{0}V_{7} = {}^{1}V_{7} \end{matrix}\right\}$	$= 2 + 0 = 2$ ……	……	2	……	……	……	……	2										
9	÷	${}^{1}V_{6} \div {}^{1}V_{7}$	${}^{3}V_{11}$ ……	$\left\{\begin{matrix} {}^{1}V_{6} = {}^{1}V_{6} \\ {}^{0}V_{11} = {}^{3}V_{11} \end{matrix}\right\}$	$= \frac{2n}{2} = A_1$ ……	……	……	……	……	……	$2n$	2	……	……	……	$\frac{2n}{2} = A_1$						
10	×	${}^{1}V_{21} \times {}^{3}V_{11}$	${}^{1}V_{12}$ ……	$\left\{\begin{matrix} {}^{1}V_{21} = {}^{1}V_{21} \\ {}^{3}V_{11} = {}^{3}V_{11} \end{matrix}\right\}$	$= B_1 \cdot \frac{2n}{2} = B_1 A_1$ ……	……	……	……	……	……	……	……	……	……	……	$\frac{2n}{2} = A_1$	$B_1 \cdot \frac{2n}{2} = B_1 A_1$	……	B_1			
11	+	${}^{1}V_{12} + {}^{1}V_{13}$	${}^{2}V_{13}$ ……	$\left\{\begin{matrix} {}^{1}V_{12} = {}^{0}V_{12} \\ {}^{1}V_{13} = {}^{2}V_{13} \end{matrix}\right\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}$ ……	……	……	……	……	……	……	……	……	……	……	……	0	$\left\{-\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}\right\}$				
12	−	${}^{1}V_{10} - {}^{1}V_{1}$	${}^{2}V_{10}$ ……	$\left\{\begin{matrix} {}^{1}V_{10} = {}^{2}V_{10} \\ {}^{1}V_{1} = {}^{1}V_{1} \end{matrix}\right\}$	$= n - 2 (= 2)$ ……	1	……	……	……	……	……	……	……	……	$n-2$							
13	−	${}^{1}V_{6} - {}^{1}V_{1}$	${}^{2}V_{6}$ ……	$\left\{\begin{matrix} {}^{1}V_{6} = {}^{2}V_{6} \\ {}^{1}V_{1} = {}^{1}V_{1} \end{matrix}\right\}$	$= 2n - 1$ ……	1	……	……	……	……	$2n-1$											
14	+	${}^{1}V_{1} + {}^{1}V_{7}$	${}^{2}V_{7}$ ……	$\left\{\begin{matrix} {}^{1}V_{1} = {}^{1}V_{1} \\ {}^{1}V_{7} = {}^{2}V_{7} \end{matrix}\right\}$	$= 2 + 1 = 3$ ……	1	……	……	……	……	……	3										
15	÷	${}^{2}V_{6} \div {}^{2}V_{7}$	${}^{1}V_{8}$ ……	$\left\{\begin{matrix} {}^{2}V_{6} = {}^{2}V_{6} \\ {}^{2}V_{7} = {}^{2}V_{7} \end{matrix}\right\}$	$= \frac{2n-1}{3}$ ……	……	……	……	……	……	$2n-1$	3	$\frac{2n-1}{3}$									
16	×	${}^{1}V_{8} \times {}^{3}V_{11}$	${}^{4}V_{11}$ ……	$\left\{\begin{matrix} {}^{1}V_{8} = {}^{0}V_{8} \\ {}^{3}V_{11} = {}^{4}V_{11} \end{matrix}\right\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3}$ ……	……	……	……	……	……	……	……	0	……	……	$\frac{2n}{2} \cdot \frac{2n-1}{3}$						
17	−	${}^{2}V_{6} - {}^{1}V_{1}$	${}^{3}V_{6}$ ……	$\left\{\begin{matrix} {}^{2}V_{6} = {}^{3}V_{6} \\ {}^{1}V_{1} = {}^{1}V_{1} \end{matrix}\right\}$	$= 2n - 2$ ……	1	……	……	……	……	$2n-2$											
18	+	${}^{1}V_{1} + {}^{2}V_{7}$	${}^{3}V_{7}$ ……	$\left\{\begin{matrix} {}^{2}V_{7} = {}^{3}V_{7} \\ {}^{1}V_{1} = {}^{1}V_{1} \end{matrix}\right\}$	$= 3 + 1 = 4$ ……	1	……	……	……	……	……	4										
19	÷	${}^{3}V_{6} \div {}^{3}V_{7}$	${}^{1}V_{9}$ ……	$\left\{\begin{matrix} {}^{3}V_{6} = {}^{3}V_{6} \\ {}^{3}V_{7} = {}^{3}V_{7} \end{matrix}\right\}$	$= \frac{2n-2}{4}$ ……	……	……	……	……	……	$2n-2$	4	……	$\frac{2n-2}{4}$	……							
20	×	${}^{1}V_{9} \times {}^{4}V_{11}$	${}^{5}V_{11}$ ……	$\left\{\begin{matrix} {}^{1}V_{9} = {}^{0}V_{9} \\ {}^{4}V_{11} = {}^{5}V_{11} \end{matrix}\right\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{4} = A_3$ ……	……	……	……	……	……	……	……	……	0		$\left\{\frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{4}\right\} = A_3$						
21	×	${}^{1}V_{22} \times {}^{5}V_{11}$	${}^{0}V_{12}$ ……	$\left\{\begin{matrix} {}^{1}V_{22} = {}^{1}V_{22} \\ {}^{0}V_{12} = {}^{2}V_{12} \end{matrix}\right\}$	$= B_3 \cdot \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{4} = B_3 A_3$ ……	……	……	……	……	……	……	……	……	……	……	0	$B_3 A_3$	……	……	B_3		
22	+	${}^{2}V_{12} + {}^{2}V_{13}$	${}^{3}V_{13}$ ……	$\left\{\begin{matrix} {}^{2}V_{12} = {}^{0}V_{12} \\ {}^{2}V_{13} = {}^{3}V_{13} \end{matrix}\right\}$	$= A_0 + B_1 A_1 + B_3 A_3$ ……	……	……	……	……	……	……	……	……	……	……	……	0	$\{A_0 + B_1 A_1 + B_3 A_3\}$				
23	−	${}^{2}V_{10} - {}^{1}V_{1}$	${}^{3}V_{10}$ ……	$\left\{\begin{matrix} {}^{2}V_{10} = {}^{3}V_{10} \\ {}^{1}V_{1} = {}^{1}V_{1} \end{matrix}\right\}$	$= n - 3 (= 1)$ ……	1	……	……	……	……	……	……	……	……	$n-3$							
Here follows a repetition of Operations thirteen to twenty-three																						
24	+	${}^{4}V_{13} + {}^{0}V_{24}$	${}^{1}V_{24}$ ……	$\left\{\begin{matrix} {}^{4}V_{13} = {}^{0}V_{13} \\ {}^{0}V_{24} = {}^{1}V_{24} \end{matrix}\right\}$	$= B_7$ ……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	……	B_7
25	+	${}^{1}V_{1} + {}^{1}V_{3}$	${}^{1}V_{3}$ ……	$\left\{\begin{matrix} {}^{1}V_{1} = {}^{1}V_{1} \\ {}^{1}V_{3} = {}^{1}V_{3} \\ {}^{5}V_{6} = {}^{0}V_{6} \\ {}^{5}V_{7} = {}^{0}V_{7} \end{matrix}\right.$	$= n + 1 = 4 + 1 = 5$ by a Variable-card. by a Variable-card.	1	……	$n+1$	……	……	0	0										

Quotes from the Ada Lovelace notes on
"Sketch of the Analytical Engine Invented by Charles Babbage", 1843

"We may say most aptly, that the Analytical Engine *weaves algebraical patterns* just as the Jacquard-loom weaves flowers and leaves."



"Again, it might act upon other things besides *number*, were objects found whose mutual fundamental relations could be expressed by those of the abstract science of operations, and which should be also susceptible of adaptations to the action of the operating notation and mechanism of the engine. Supposing, for instance, that the fundamental relations of pitched sounds in the science of harmony and of musical composition were susceptible of such expression and adaptations, the engine might compose elaborate and scientific pieces of music of any degree of complexity or extent."

Quotes from the Ada Lovelace notes on "Sketch of the Analytical Engine Invented by Charles Babbage", 1843

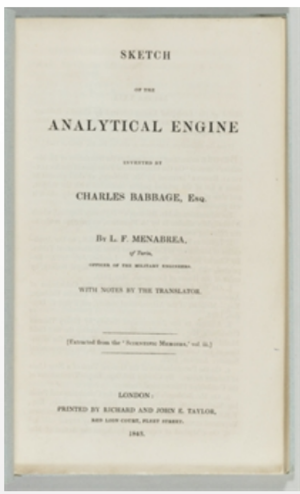
"Many persons who are not conversant with mathematical studies, imagine that because the business of the engine is to give its results in *numerical notation*, the *nature of its processes* must consequently be *arithmetical* and *numerical*, rather than *algebraical* and *analytical*. This is an error. The engine can arrange and combine its numerical quantities exactly as if they were *letters* or any other *general* symbols; and in fact it might bring out its results in algebraical *notation*, were provisions made accordingly."

"But it would be a mistake to suppose that because its *results* are given in the *notation* of a more restricted science, its *processes* are therefore restricted to those of that science. The object of the engine is in fact to give the *utmost practical efficiency* to the resources of *numerical interpretations* of the higher science of analysis, while it uses the processes and combinations of this latter."

LOT 21 / SALE 2013

EMAIL PRINT

[BABBAGE]. -- MENABREA, Luigi Federico (1809-1896). *Sketch of the Analytical Engine invented by Charles Babbage... with notes by the translator*. Offprint from: *Scientific Memoirs*. Translated by Augusta Ada King, Countess of Lovelace (1809-1896). Volume 3. London: Richard and John E. Taylor, 1843.



ENLARGE & ZOOM

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$170,500
Price includes buyer's premium

Estimate
$10,000 - $15,000

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Lot Description
[BABBAGE]. -- MENABREA, Luigi Federico (1809-1896). *Sketch of the Analytical Engine invented by Charles Babbage... with notes by the translator*. Offprint from: *Scientific Memoirs*. Translated by Augusta Ada King, Countess of Lovelace (1809-1896). Volume 3. London: Richard and John E. Taylor, 1843.

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LOT #22 BABBAGE, Charles. *Passages from the...*

LOT #23 BABBAGE, Charles. *The Ninth...*

LOT #24 [BALLISTICS]. *Une merveille du génie...*

LOT #25 [BALLISTICS]. BRITISH INFORMATION...

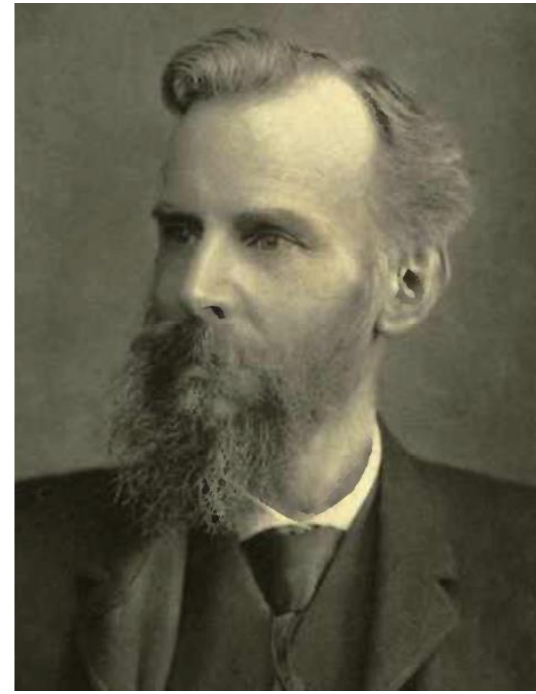
LOT #26 [BALLISTICS]. *The United States...*

LOT #27 BAYER, Johann (1572-1625)....

LOT #28 BEAUMONT, William (1785-1853)....

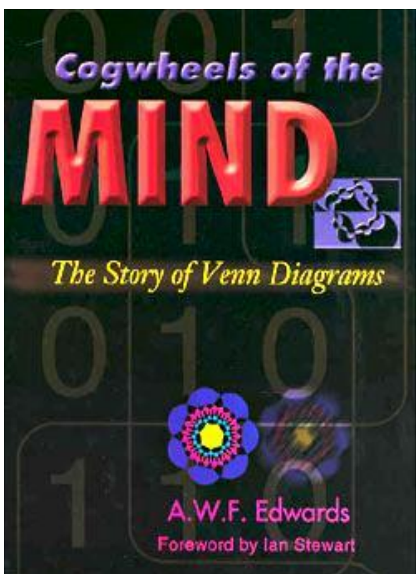
LOT #30

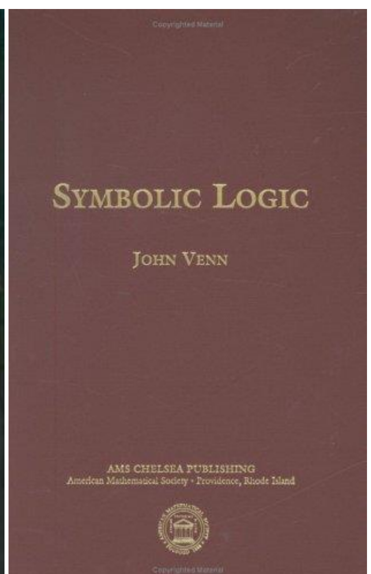
Historical Perspectives

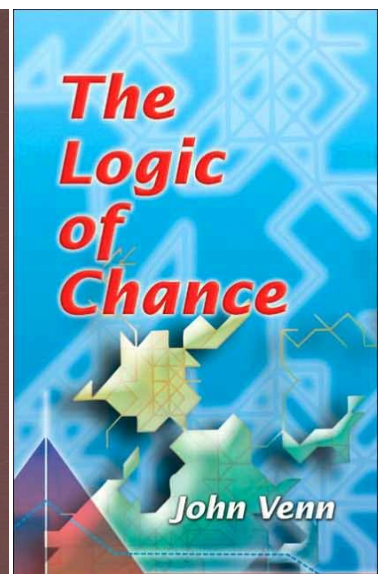


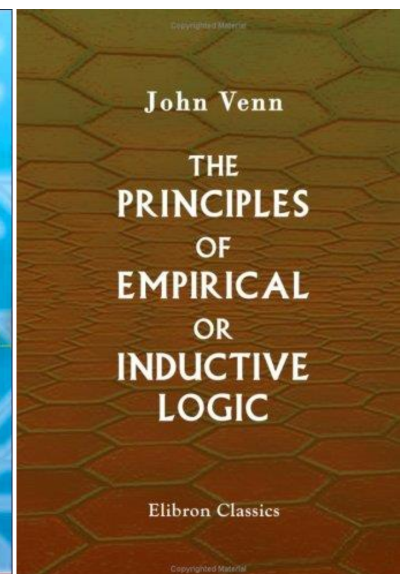
John Venn (1834-1923)

- Logician and philosopher
- Worked in logic, probability, set theory
- Introduced the "Venn diagram" (1880)
  - Very widely used, many applications
  - Ties together fundamental concepts from logic, geometry, combinatorics, knot theory

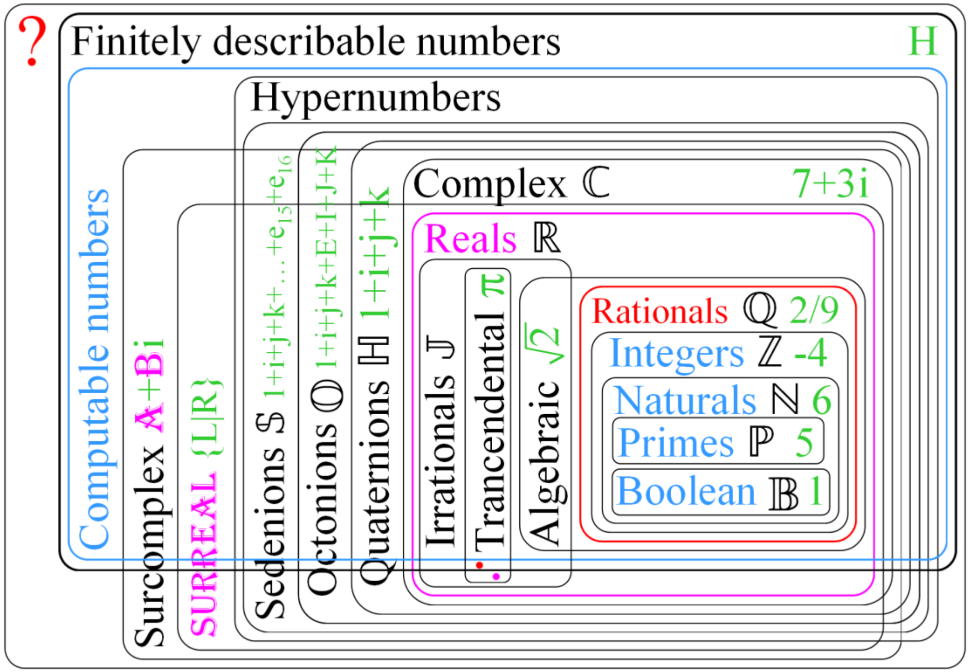




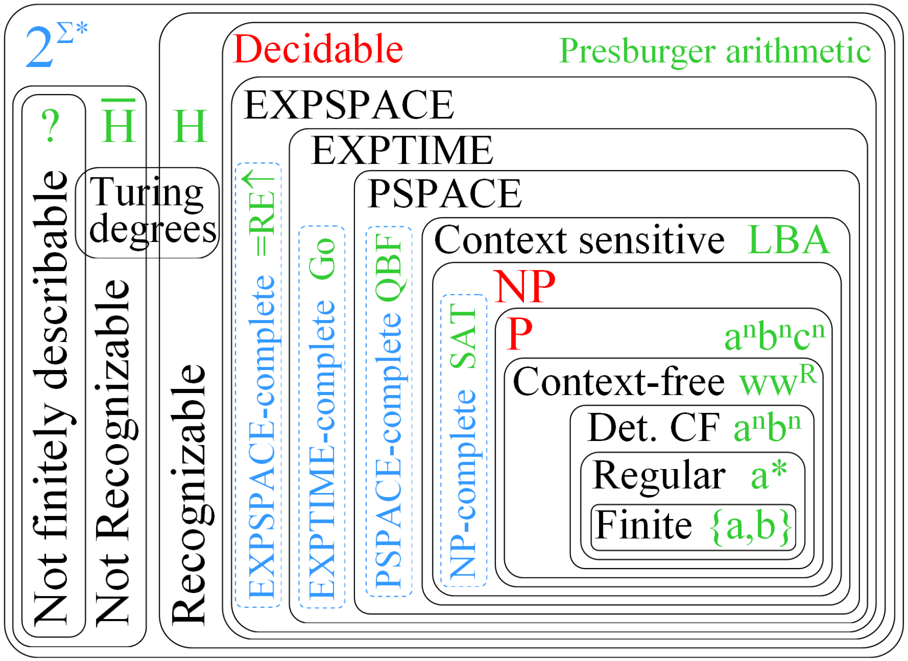


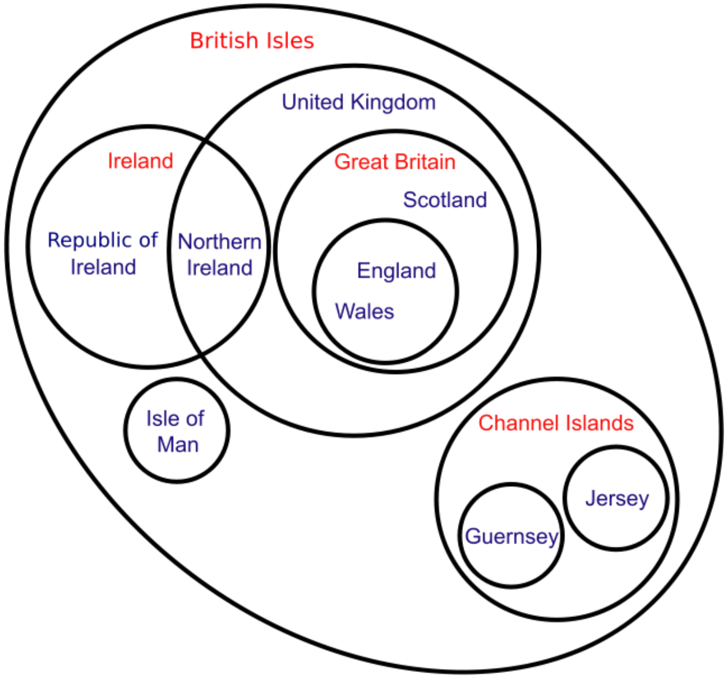


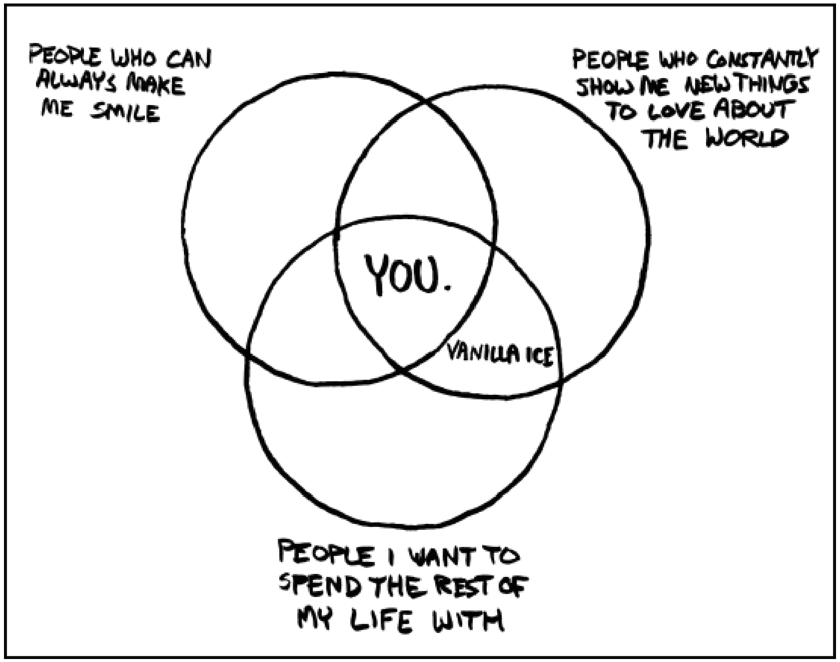
Generalized Numbers

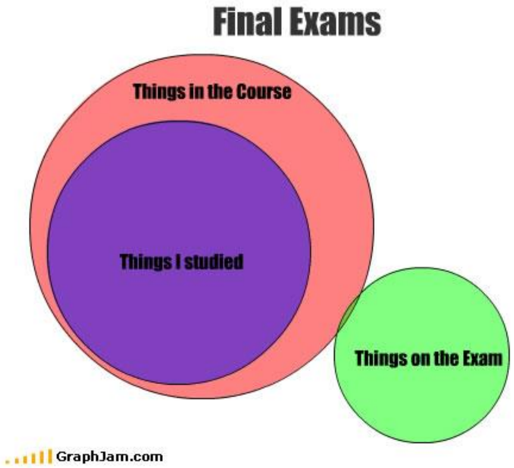


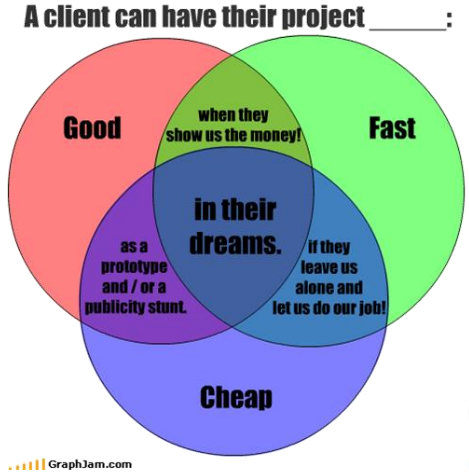
The Extended Chomsky Hierarchy

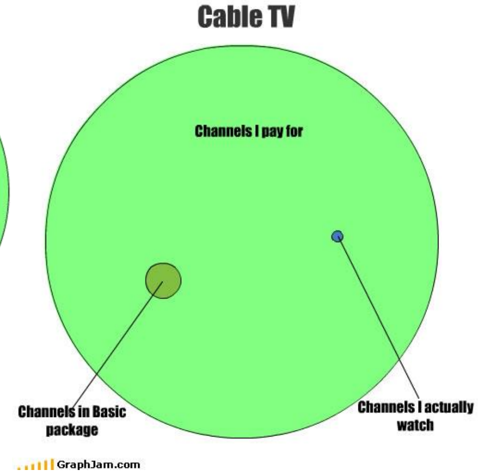


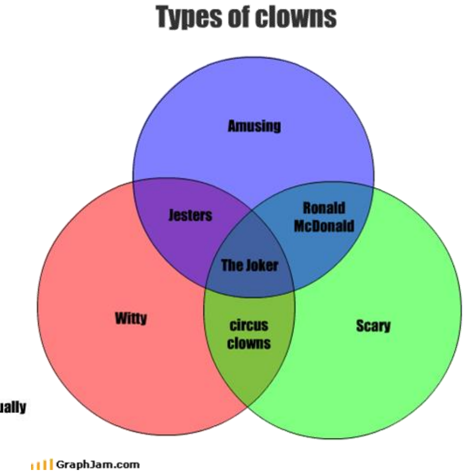


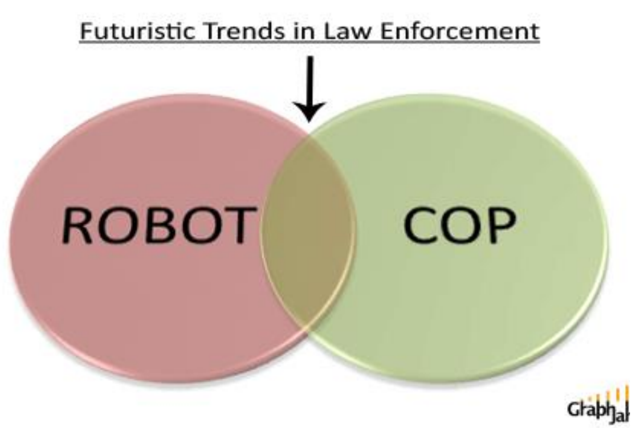


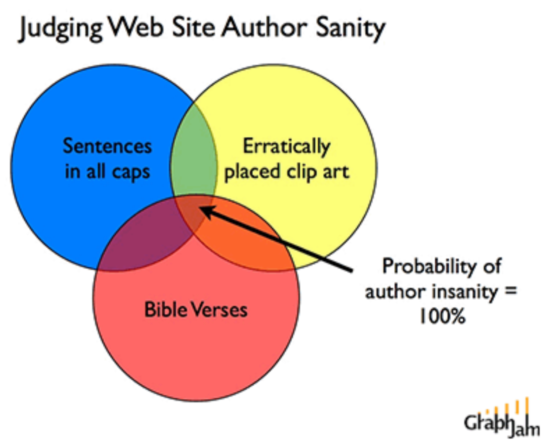

Final Exams
Things in the Course
Things I studied
Things on the Exam
GraphJam.com


A client can have their project ______:
Good
Fast
Cheap
when they show us the money!
in their dreams.
as a prototype and / or a publicity stunt.
if they leave us alone and let us do our job!
GraphJam.com

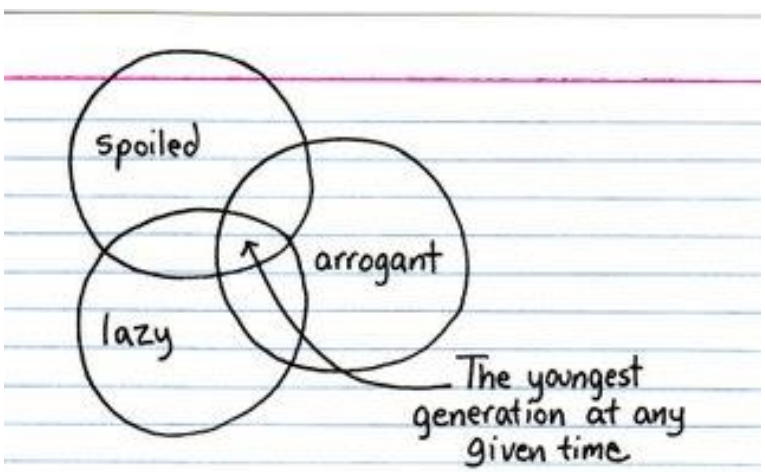

Cable TV
Channels I pay for
Channels in Basic package
Channels I actually watch
GraphJam.com

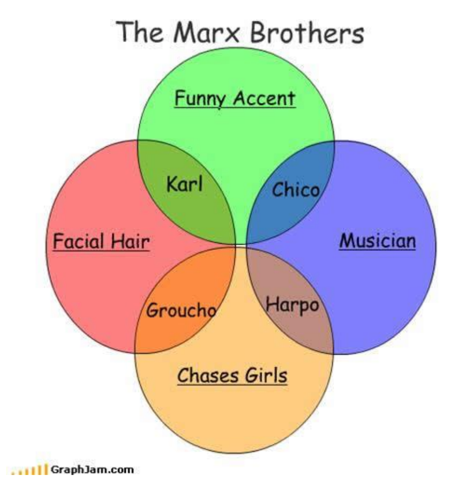

Types of clowns
Amusing
Jesters
Ronald McDonald
The Joker
Witty
circus clowns
Scary
GraphJam.com

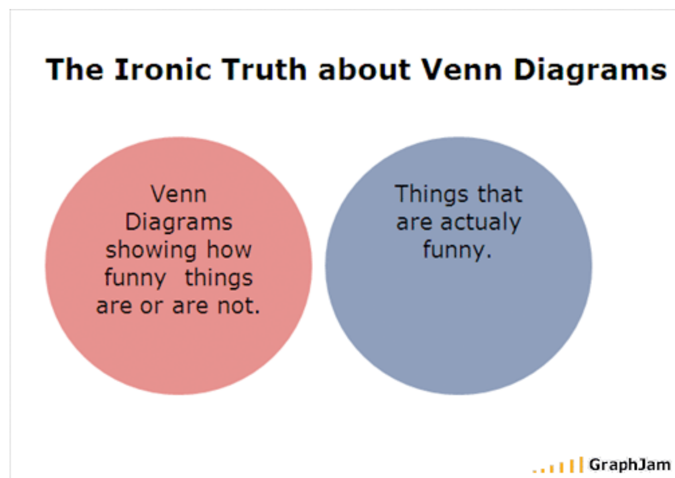

Futuristic Trends in Law Enforcement
ROBOT
COP
GraphJam

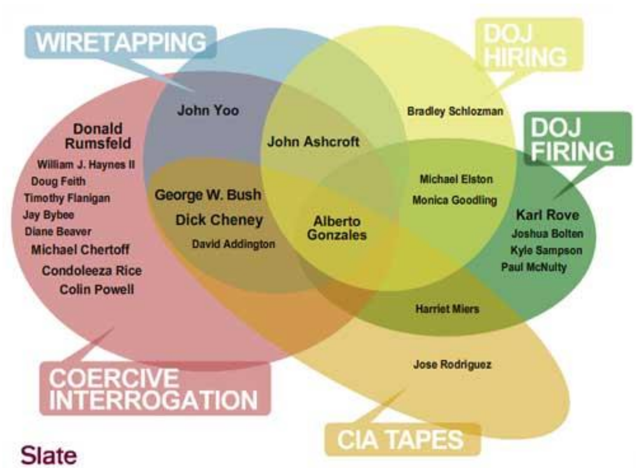

Judging Web Site Author Sanity
Sentences in all caps
Erratically placed clip art
Bible Verses
Probability of author insanity = 100%
GraphJam

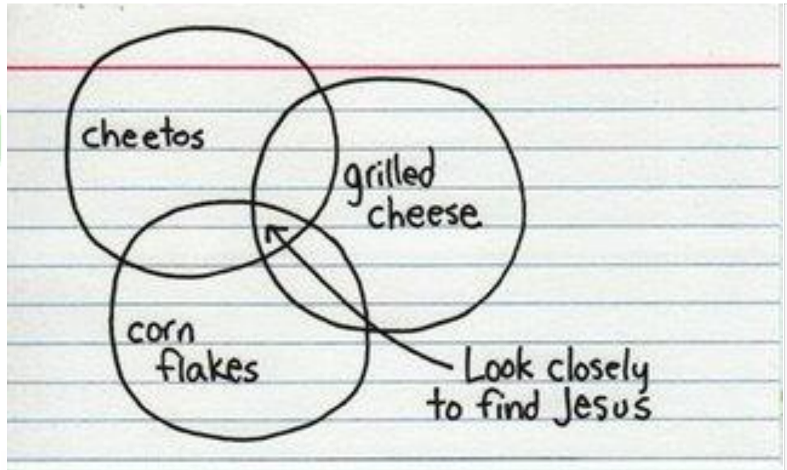

Clothing of Complainers
People Who Complain About Outsourced Jobs
People Who Wear Clothes Made In Asia
GraphJam.com

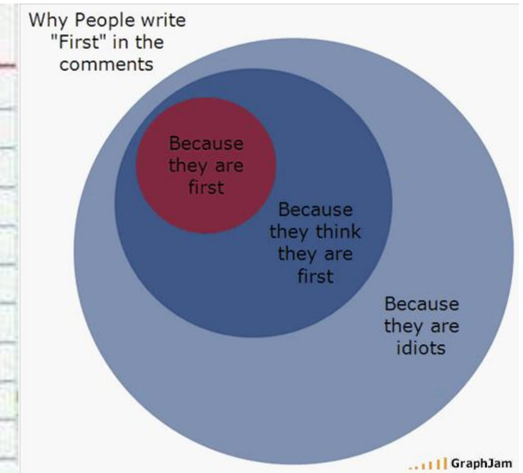

Spoiled
arrogant
lazy
The youngest generation at any given time


The Marx Brothers
Funny Accent
Karl
Chico
Facial Hair
Musician
Groucho
Harpo
Chases Girls
GraphJam.com

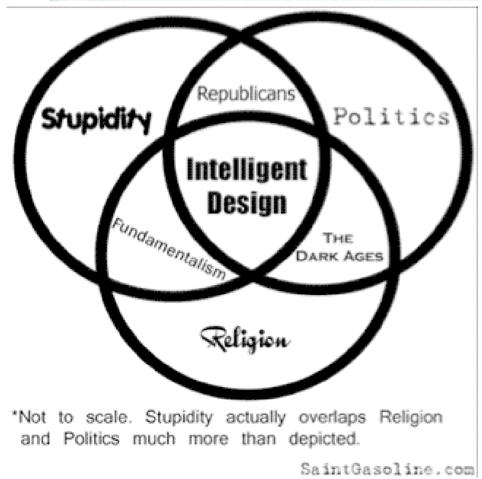

The Ironic Truth about Venn Diagrams
Venn Diagrams showing how funny things are or are not.
Things that are actualy funny.
GraphJam

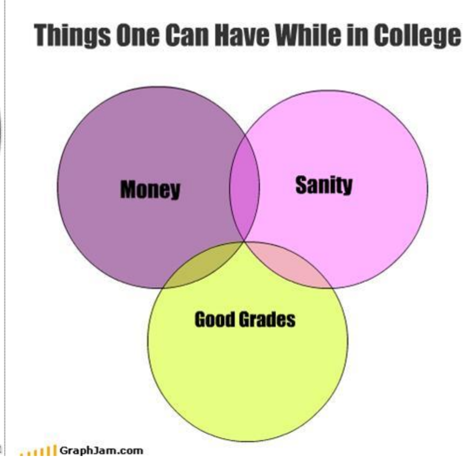

WIRETAPPING
DOJ HIRING
DOJ FIRING
COERCIVE INTERROGATION
CIA TAPES
Donald Rumsfeld
William J. Haynes II
Doug Feith
Timothy Flanigan
Jay Bybee
Diane Beaver
Michael Chertoff
Condoleeza Rice
Colin Powell
John Yoo
George W. Bush
Dick Cheney
David Addington
John Ashcroft
Alberto Gonzales
Bradley Schlozman
Michael Elston
Monica Goodling
Karl Rove
Joshua Bolten
Kyle Sampson
Paul McNulty
Harriet Miers
Jose Rodriguez
Slate

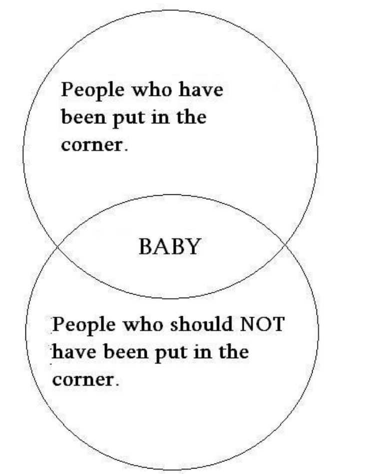

cheetos
grilled cheese
corn flakes
Look closely to find Jesus

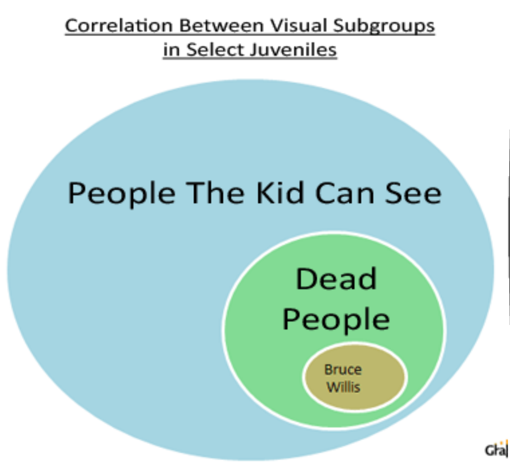

Why People write "First" in the comments
Because they are first
Because they think they are first
Because they are idiots
GraphJam

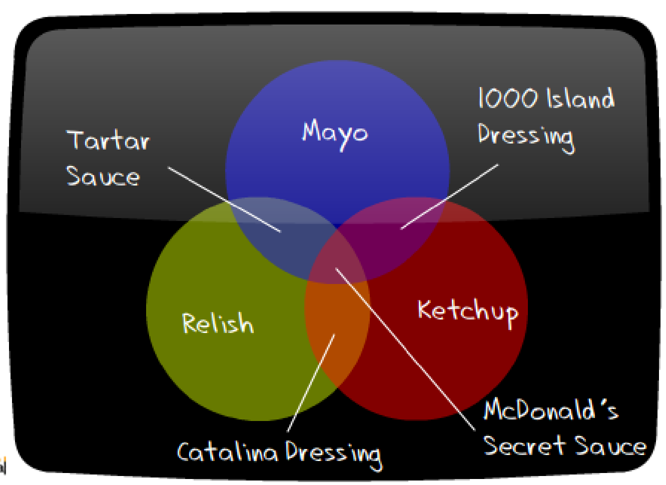

please, no more mascots
the real winner: the worldwide spandex industry
participation
excellence
hope
competition
unity
there should be at least one incredible wipeout where the person's body goes limp and equipment goes flying all over the place
any country can fake it for two weeks!


Stupidity
Republicans
Politics
Intelligent Design
Fundamentalism
The Dark Ages
Religion
*Not to scale. Stupidity actually overlaps Religion and Politics much more than depicted.
SaintGasoline.com

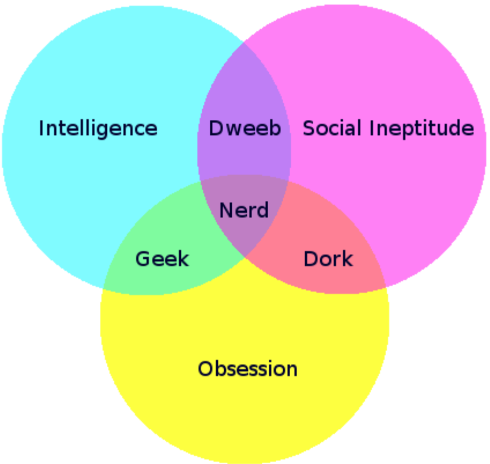

Things One Can Have While in College
Money
Sanity
Good Grades
GraphJam.com

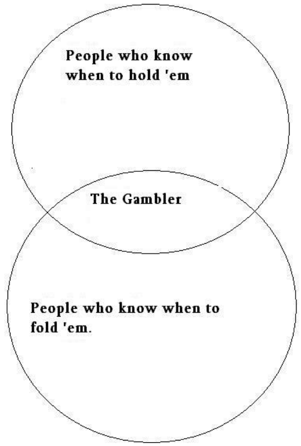

People who have been put in the corner.
BABY
People who should NOT have been put in the corner.

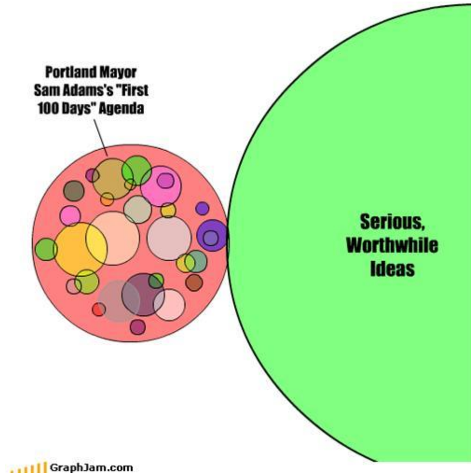

Correlation Between Visual Subgroups in Select Juveniles
People The Kid Can See
Dead People
Bruce Willis

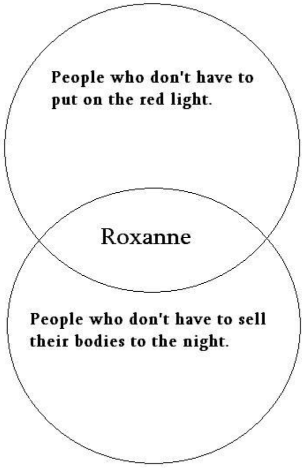

Mayo
Tartar Sauce
1000 Island Dressing
Relish
Ketchup
Catalina Dressing
McDonald's Secret Sauce


PONZI SCHEMES
SITUATIONS WHERE IT STINKS BEING THE BOTTOM
TWO PERSON HORSE COSTUMES

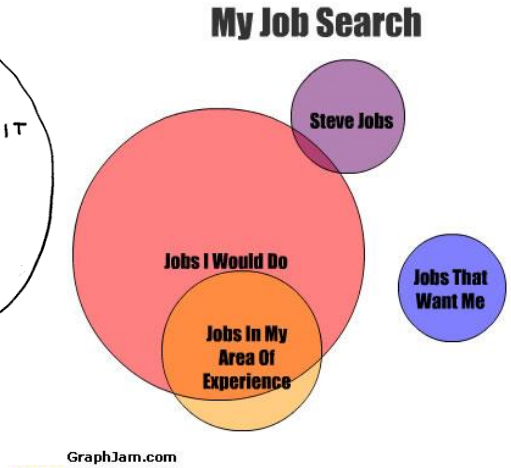

Intelligence
Dweeb
Social Ineptitude
Nerd
Geek
Dork
Obsession

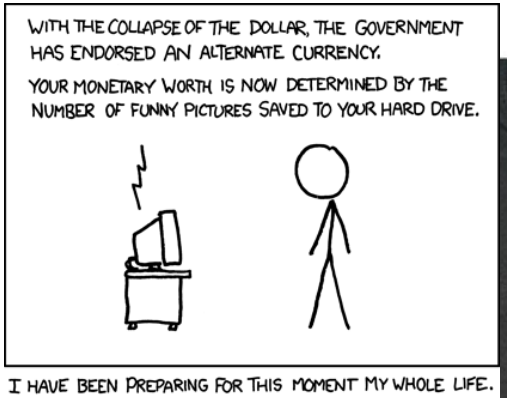

People who know when to hold 'em
The Gambler
People who know when to fold 'em.

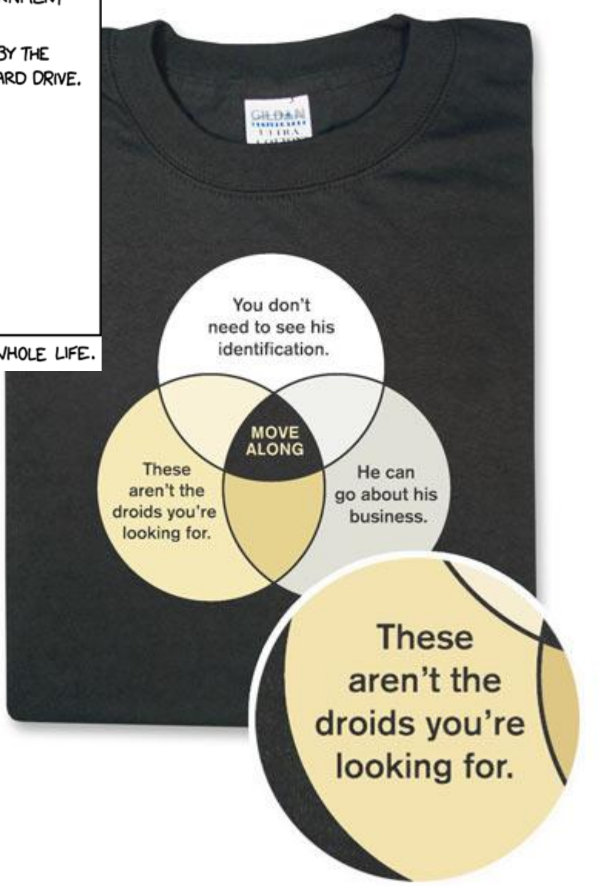

Portland Mayor Sam Adams's "First 100 Days" Agenda
Serious, Worthwhile Ideas
GraphJam.com

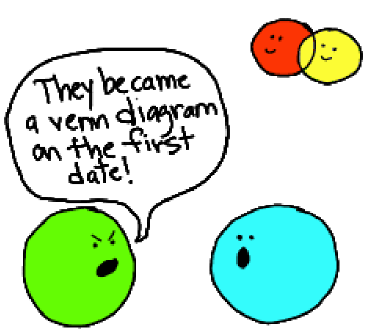

People who don't have to put on the red light.
Roxanne
People who don't have to sell their bodies to the night.

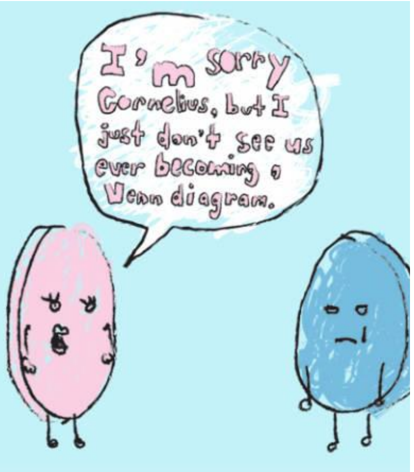

THOSE WHO GET IT
THOSE WHO GET IT AND DO NOT GET IT
THOSE WHO DO NOT GET IT
THOSE WHO ARE VERY CONFUSED
THOSE WHO GET IT BUT REALISE THERE IS NOTHING TO GET
THOSE WHO DO NOT GET IT AND REALISE THERE IS NOTHING TO GET
THOSE WHO REALISE THERE IS NOTHING TO GET

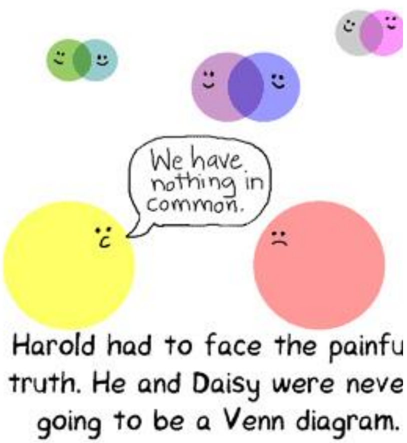

My Job Search
Steve Jobs
Jobs I Would Do
Jobs In My Area Of Experience
Jobs That Want Me
GraphJam.com


WITH THE COLLAPSE OF THE DOLLAR, THE GOVERNMENT HAS ENDORSED AN ALTERNATE CURRENCY.
YOUR MONETARY WORTH IS NOW DETERMINED BY THE NUMBER OF FUNNY PICTURES SAVED TO YOUR HARD DRIVE.
I HAVE BEEN PREPARING FOR THIS MOMENT MY WHOLE LIFE.


GILDAN
You don't need to see his identification.
MOVE ALONG
These aren't the droids you're looking for.
He can go about his business.
These aren't the droids you're looking for.


They became a venn diagram on the first date!

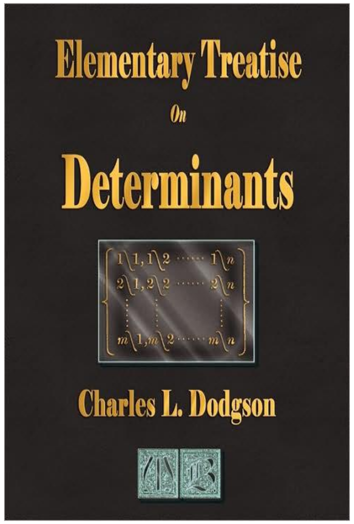

I'm sorry Cornelius, but I just don't see us ever becoming a Venn diagram.

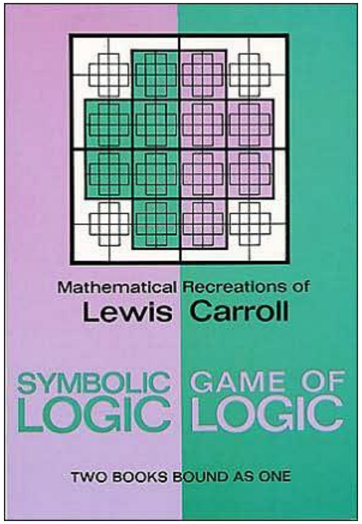

We have nothing in common.
Harold had to face the painfu
truth. He and Daisy were neve
going to be a Venn diagram.

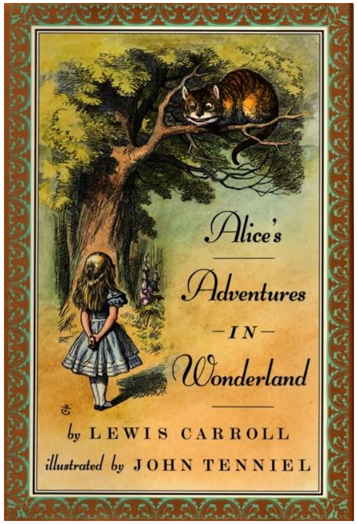
Historical Perspectives

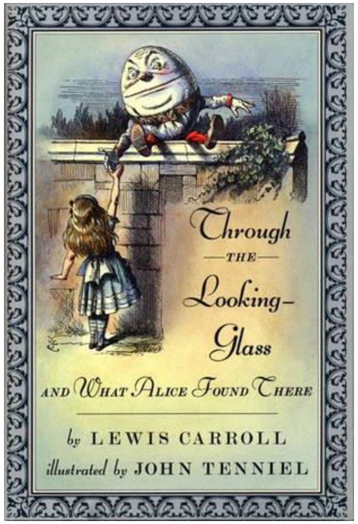
Charles Dodgson (1832-1898)

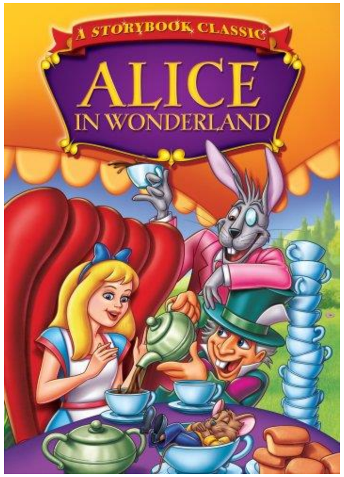
- AKA "Lewis Carroll"
- Mathematician, logician, author, photographer
- Wrote "Alice in Wonderland", "Jabberwocky", and "Through the Looking Glass"
- Popularized logic & syllogisms and made it fun!
- Invented "Scrabble" and "word ladder" games
- Profoundly influenced literature, art, and culture

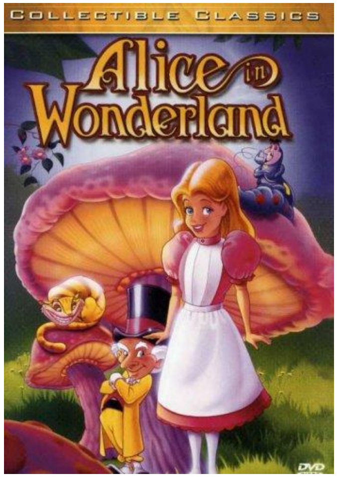









A STORYBOOK CLASSIC
ALICE
IN WONDERLAND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Alice in Wonderland
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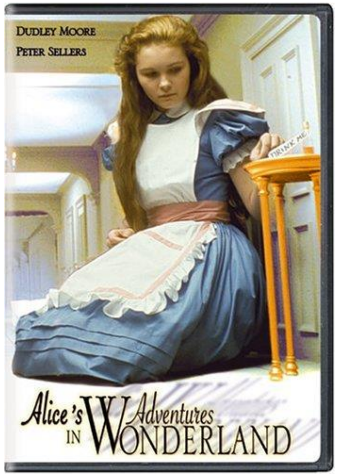
DUDLEY MOORE
PETER SELLERS
Alice's Adventures in WONDERLAND


Alice
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THE STUNNING ADAPTATION OF A FAMILY CLASSIC!
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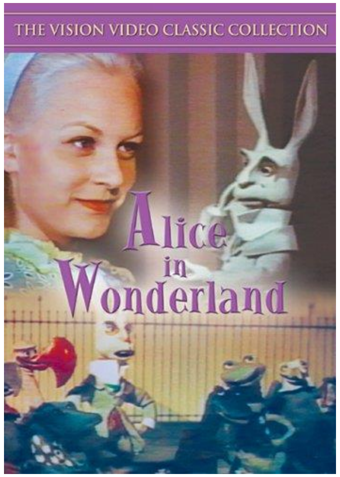
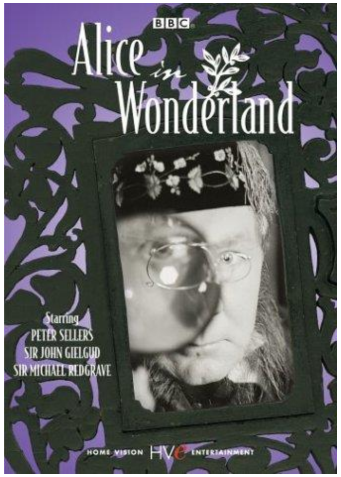

THE VISION VIDEO CLASSIC COLLECTION
Alice
in
Wonderland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Alice in Wonderland
Starring
PETER SELLERS
SIR JOHN GIELGUD
SIR MICHAEL REDGRAVE
HOME VISION
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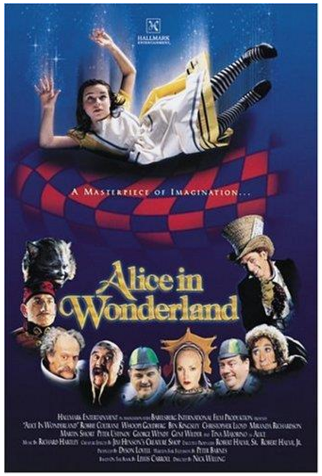
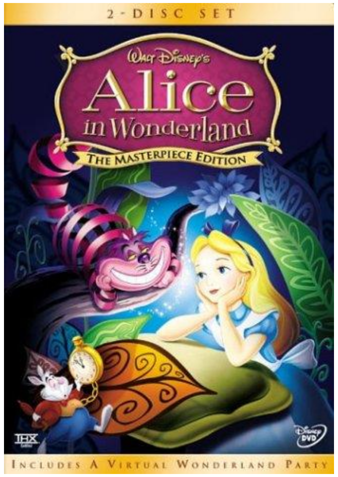
ENTERTAINMENT


HALLMARK
A MASTERPIECE OF IMAGINATION...
Alice in Wonderland


PETER SELLERS
DUDLEY MOORE
MICHAEL CRAWFORD
FIONA FULLERTON
ALICE'S ADVENTURES in WONDERLAND
JOURNEY DOWN THE RABBIT HOLE IN THIS TUNEFUL FAMILY CLASSIC!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Walt Disney's
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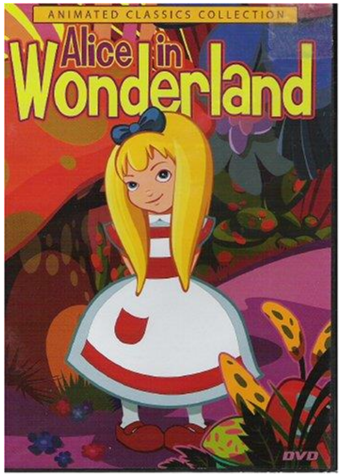
THE MASTERPIECE EDITION
THX
Disney DVD
INCLUDES A VIRTUAL WONDERLAND PARTY


ANIMATED CLASSICS COLLECTION
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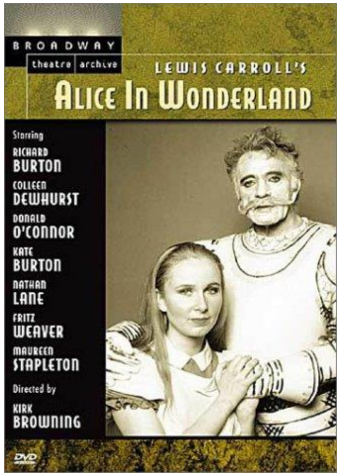
BROADWAY
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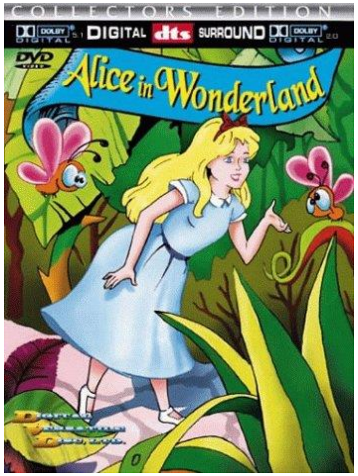
LEWIS CARROLL'S
ALICE IN WONDERLAND
Starring
RICHARD BURTON
COLLEEN DEWHURST
DONALD O'CONNOR
KATE BURTON
NATHAN LANE
FRITZ WEAVER
MAUREEN STAPLETON
Directed by
KIRK BROWNING
DVD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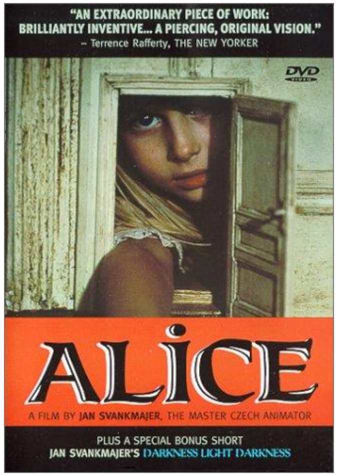
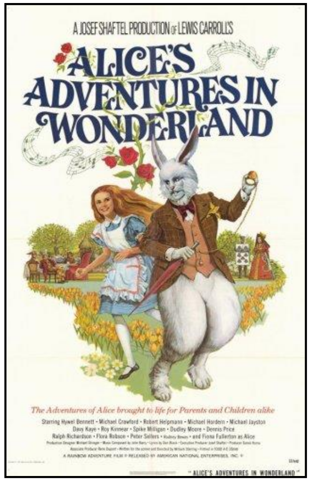
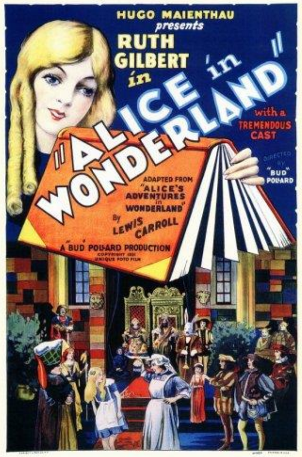
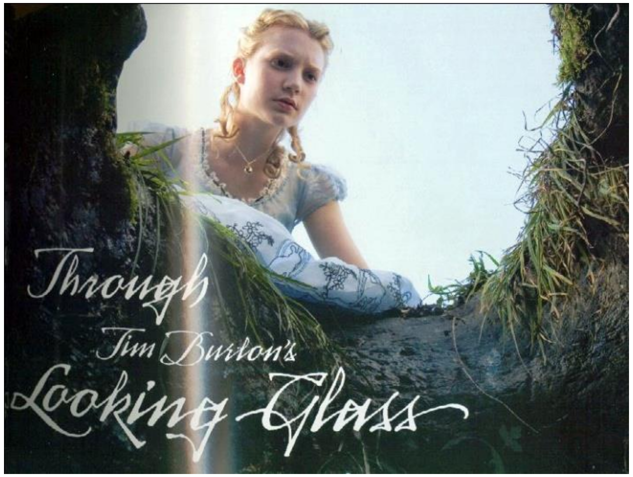

"AN EXTRAORDINARY PIECE OF WORK: BRILLIANTLY INVENTIVE... A PIERCING, ORIGINAL VISION."
– Terrence Rafferty, THE NEW YORKER
DVD VIDEO
ALICE
A FILM BY JAN SVANKMAJER, THE MASTER CZECH ANIMATOR
PLUS A SPECIAL BONUS SHORT
JAN SVANKMAJER'S DARKNESS LIGHT DARKNESS

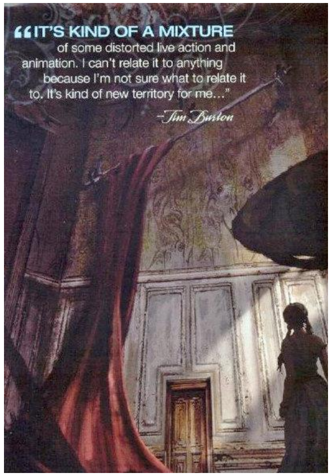

A JOSEF SHAFTEL PRODUCTION of LEWIS CARROLL'S
ALICE'S ADVENTURES IN WONDERLAND
The Adventures of Alice brought to life for Parents and Children alike
"ALICE'S ADVENTURES IN WONDERLAND"


HUGO MAIENTHAU
presents
RUTH GILBERT
in
"ALICE in WONDERLAND"
with a TREMENDOUS CAST
ADAPTED FROM "ALICE'S ADVENTURES IN WONDERLAND" By LEWIS CARROLL
A BUD POLLARD PRODUCTION


Through
Tim Burton's
Looking Glass






© Disney

"IT'S KIND OF A MIXTURE
of some distorted live action and
animation. I can't relate it to anything
because I'm not sure what to relate it
to. It's kind of new territory for me..."
–Tim Burton


Alice and the White Knight:
A Lesson in Logic, Semantics, and Pointers

`You are sad,' the Knight said in an anxious tone: `let me sing you a song to comfort you.'

`Is it very long?' Alice asked, for she had heard a good deal of poetry that day.

`It's long,' said the Knight, `but it's very, *very* beautiful. Everybody that hears me sing it -- either it brings the *tears* into their eyes, or else --'

logical disjunction!

`Or else what?' said Alice, for the Knight had made a sudden pause.

law of the excluded middle!

`Or else it doesn't, you know. The name of the song is called "***Haddocks' Eyes***".'

pointer to a pointer!

`Oh, that's the name of the song, is it?' Alice said, trying to feel interested.

`No, you don't understand,' the Knight said, looking a little vexed. `That's what the name is *called*. The name really *is* "***The Aged Aged Man***".'

pointer dereferencing: meta-pointer resolved!

`Then I ought to have said "That's what the *song* is called"?' Alice corrected herself.

separation of abstractions: variable vs. pointer!

`No, you oughtn't: that's quite another thing! The *song* is called "***Ways and Means***": but that's only what it's *called*, you know!'

call-by-name vs. call-by-value!

`Well, what *is* the song, then?' said Alice, who was by this time completely bewildered.

`I was coming to that,' the Knight said. `The song really *is* "***A-sitting On a Gate***": and the tune's my own invention.'

the name is called
"**Haddocks' Eyes**"

↓

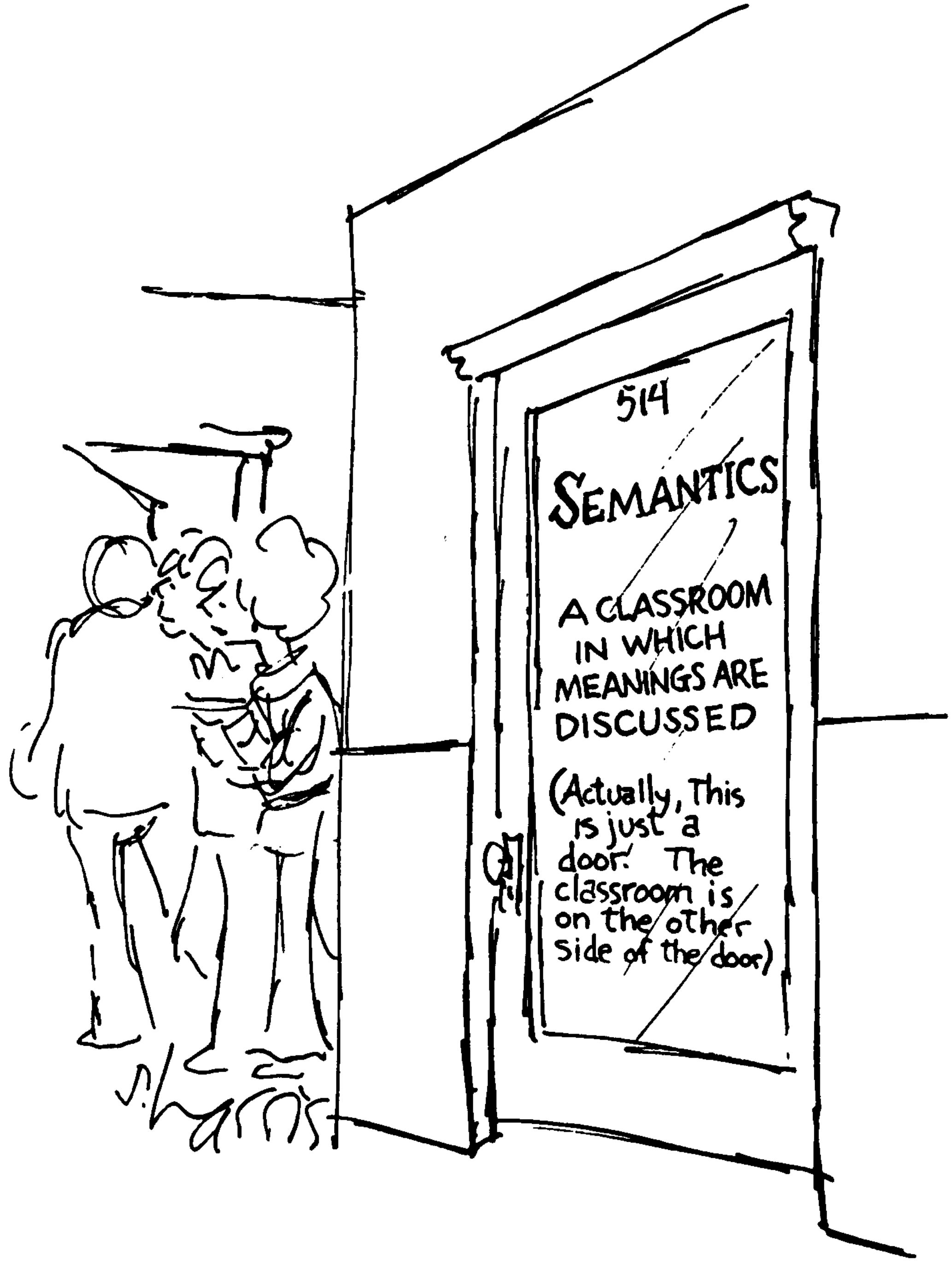
the name of the song is
"**The Aged Aged Man**"

↓

the song is
"**A-sitting On a Gate**"

↑

the song is called
"**Ways and Means**"


514
SEMANTICS
A CLASSROOM IN WHICH MEANINGS ARE DISCUSSED
(Actually, This is just a door. The classroom is on the other side of the door)
S. Harris

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Wolfram

Lewis Carroll Society of North America

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WELCOME

Welcome to The Lewis Carroll Society of North America (LCSNA) homepage. The LCSNA is a non-profit organization dedicated to furthering Carroll studies, increasing accessibility of research material, and maintaining public awareness of Carroll's contributions to society and culture. This website is one way we share information with Carroll enthusiasts around the World. If you are a Carrollian and would like to help in these endeavors, or if you simply enjoy Carroll and want to be among other people with a like interest, please consider joining the LCSNA.

For detailed information about C.L.Dodgson ("Lewis Carroll") and his creations, please access the Lewis Carroll Homepage.

Spring Meeting

The 2009 Spring meeting will be held in beautiful Sante Fe, New Mexico, on May 9. Please consult the **newly updated (as of April 24th)** meeting agenda for all of the details. See you there.

Find: Next Previous Highlight all Match case

Done

The Lewis Carroll Society

The Lewis Carroll Society

founded 1969 ~ registered charity no. 266239

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Events, People, Places
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Welcome to the Lewis Carroll Society Website

The Lewis Carroll Society was formed in 1969 with the aim of encouraging research into the life and works of Lewis Carroll (Charles Lutwidge Dodgson). The Society has members around the world, including many leading libraries and institutions, authors, researchers and many who simply enjoy Carroll's books and want to find out more about the man and his work.

Why not join the LCS - for your own interest and entertainment or to make a contribution to Carroll scholarship? Our subscription are remarkably low for a society of this nature. **Click Here for membership details**.

Events at Lyndhurst: from 15 May 2009

This wonderful season of Alice-related events has something for everyone! The village of Lyndhurst, in the beautiful New Forest, celebrates its Alice connections with walks, talks, tea-parties, musicals, and many other activities. Vist the **Alice Adventure** website for more details.

Events at Oxford: 4 July 2009

The city of Oxford plays host to the second Alice's Day this year, with a busy programme of events on 4 July. There are live performances, reading, drama workshops, exhibitions, talks and other activities for all the family.

The Lewis Carroll Society is hosting a series of lectures at the Natural History Museum from 10:15. Edward Wakeling talks about the real Alice and the original telling of her adventures, Anne Varty investigates the child-actresses who played Alice and were friends of Lewis Carroll and Mark Richards explores the connections between Carroll and Charles Darwin. All are welcome to attend - come and go as you please.


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An Educational Software that teaches students computer programming in a 3D environment
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Alice 3 wins Duke's Choice Award at JavaOne 2009!
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Alice is an innovative 3D programming environment that makes it easy to create an animation for telling a story, playing an interactive game, or a video to share on the web. Alice is a teaching tool for introductory computing. It uses 3D graphics and a drag-and-drop interface to facilitate a more engaging, less frustrating first programming experience.
Read more...
Teaching Materials
Alice is a teaching tool designed as a revolutionary approach to teaching and learning introductory programming concepts. The Alice team has developed instructional materials to support students and teachers in using this new approach. Resources include textbooks, lessons, sample syllabuses, test banks, and more. Other authors have generously joined our efforts, creating additional textbooks.
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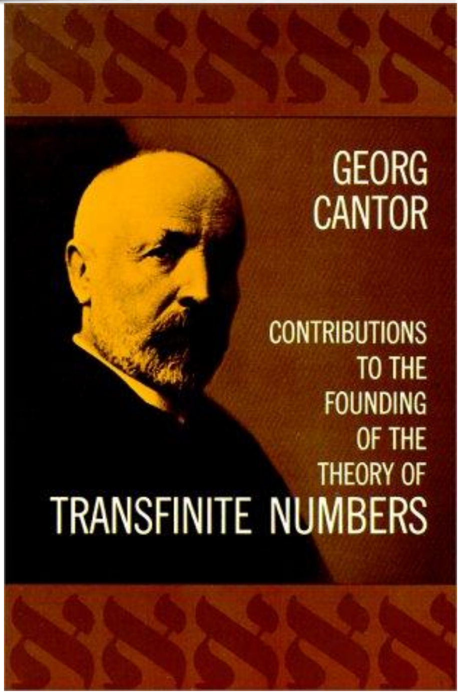
Done

Historical Perspectives

Georg Cantor (1845-1918)

- Created modern set theory
- Invented trans-finite arithmetic (highly controvertial at the time)
- Invented diagonalization argument
- First to use 1-to-1 correspondences with sets
- Proved some infinities “bigger” than others
- Showed an infinite hierarchy of infinities
- Formulated continuum hypothesis
- Cantor’s theorem, “Cantor set”, Cantor dust, Cantor cube, Cantor space, Cantor’s paradox
- Laid foundation for computer science theory
- Influenced Hilbert, Godel, Church, Turing




GEORG CANTOR
His Mathematics and Philosophy of the Infinite
Joseph Warren Dauben
David Foster Wallace
GEORG CANTOR
Der Jahrhundertmathematiker und die Entdeckung des Unendlichen
PIPER
MIDHAT J. GAZALÉ
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A Guide to Great Ideas
THEODORE G. FATICONI
ONE
TWO
THREE...
INFINITY
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AUTHOR OF CHAOS IN WONDERLAND
PLAYING WITH INFINITY
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N.Ya. Vilenkin
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in search of infinity
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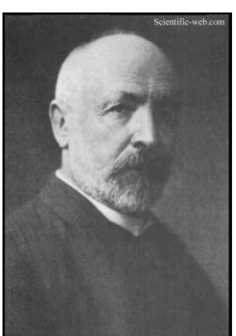
Mind-Boggling Puzzles
Raymond M. Smullyan

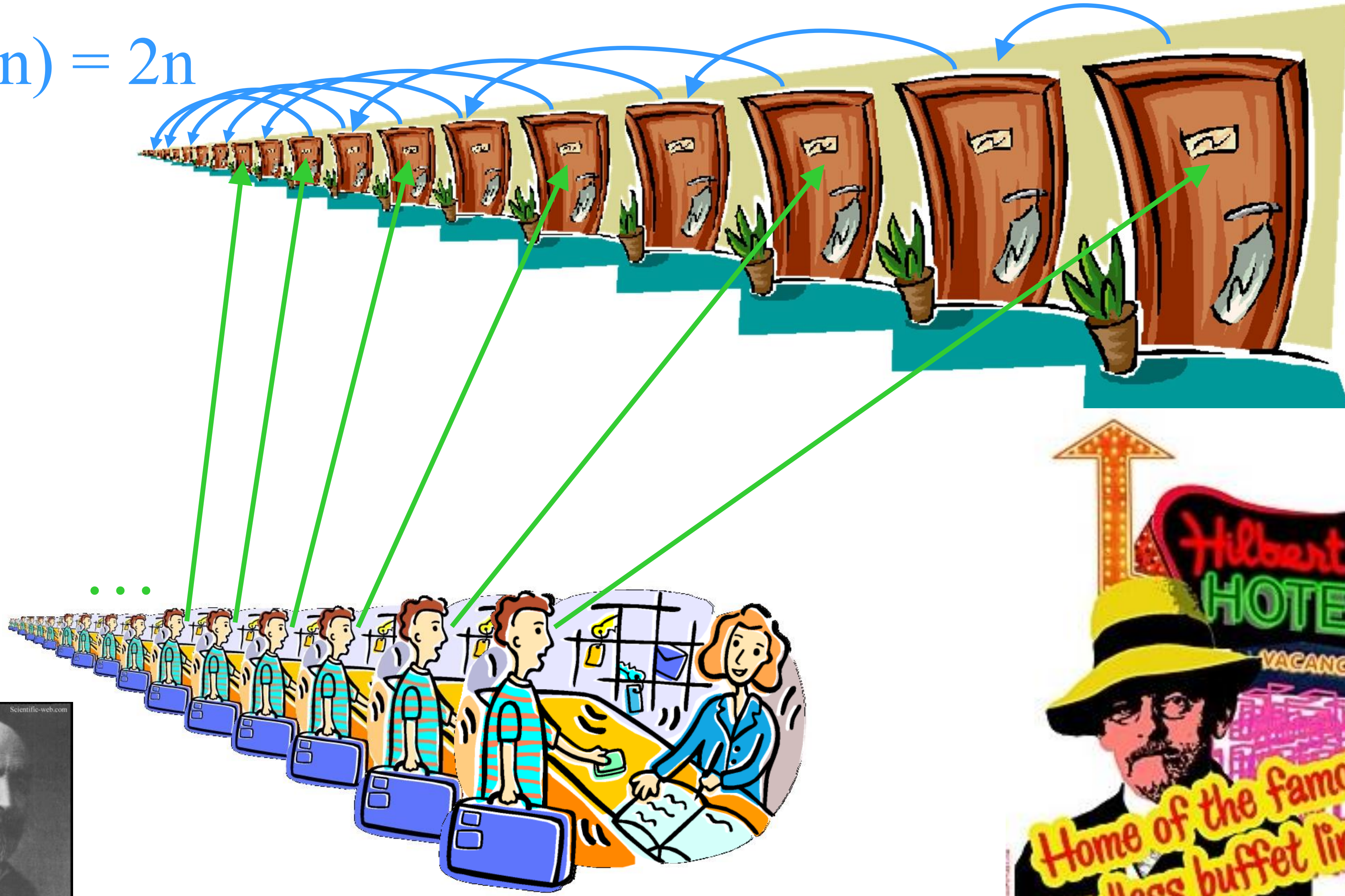
Problem: How can a new guest be accommodated in a full infinite hotel?

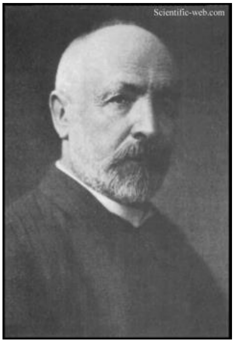
$f(n) = n+1$



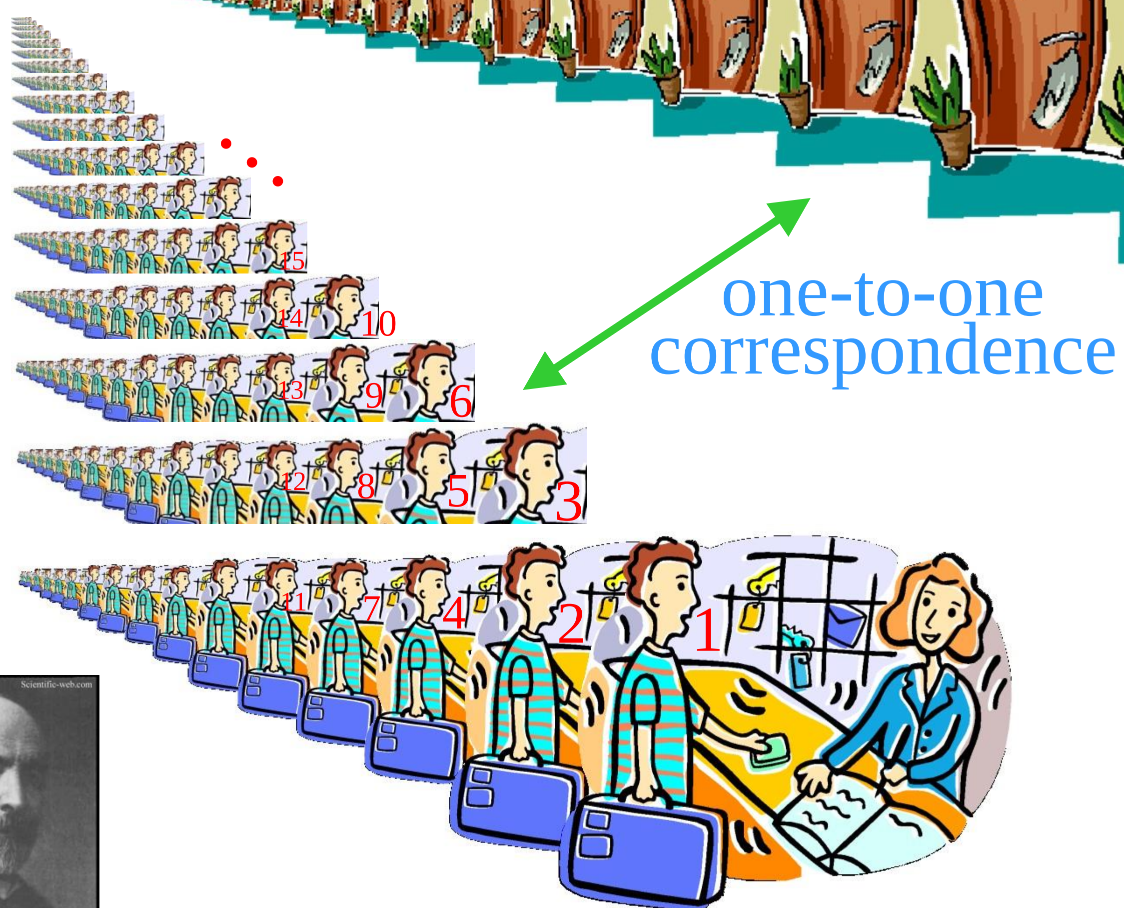
Problem: How can an infinity of new guests be accommodated in a full infinite hotel?

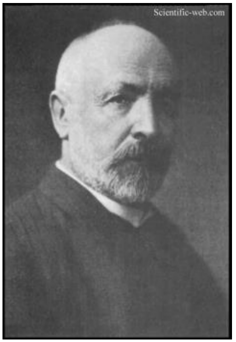
$f(n) = 2n$





Problem: How can an infinity of infinities of new guests be accommodated in a full infinite hotel?



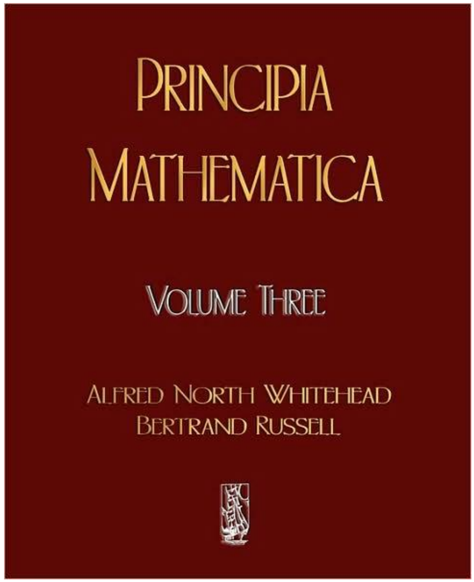


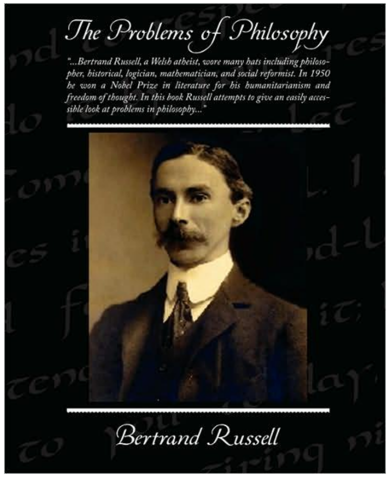

Celebrity Cruises X a true departure
WELCOME
TO
INFINITY
Infinity

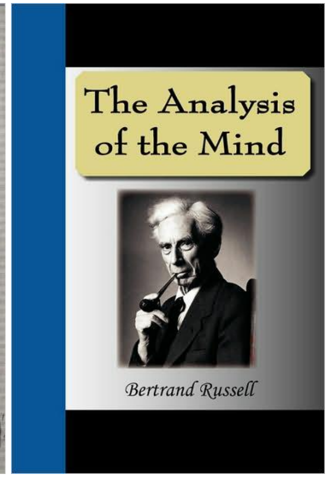
Historical Perspectives

Bertrand Russell (1872-1970)

- Philosopher, logician, mathematician, historian, social reformist, and pacifist
- Co-authored "Principia Mathematica" (1910)
- Axiomatized mathematics and set theory
- Co-founded analytic philosophy
- Originated Russell's Paradox
- Activist: humanitarianism, pacifism, education, free trade, nuclear disarmament, birth control gender & racial equality, gay rights
- Profoundly transformed math & philosophy, mentored Wittgenstein, influenced Godel
- Laid foundation for computer science theory
- Won Nobel Prize in literature (1950)




The Problems of Philosophy
"...Bertrand Russell, a Welsh atheist, wore many hats including philosopher, historical, logician, mathematician, and social reformist. In 1950 he won a Nobel Prize in literature for his humanitarianism and freedom of thought. In this book Russell attempts to give an easily accessible look at problems in philosophy..."
Bertrand Russell

Russell
An Inquiry into Meaning and Truth

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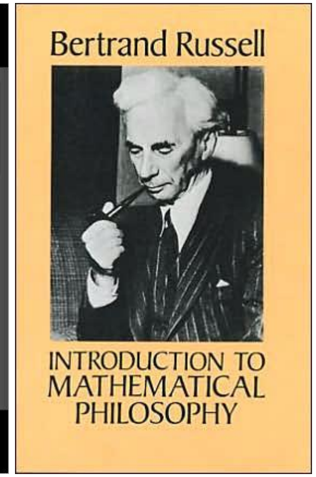
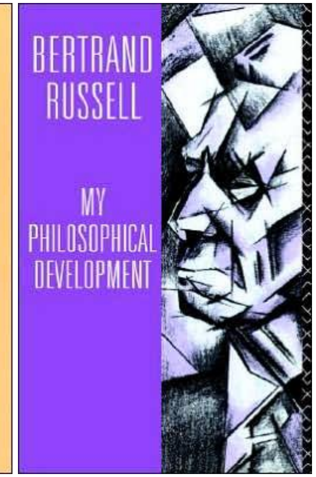
Bertrand Russell

Bertrand Russell
INTRODUCTION TO MATHEMATICAL PHILOSOPHY

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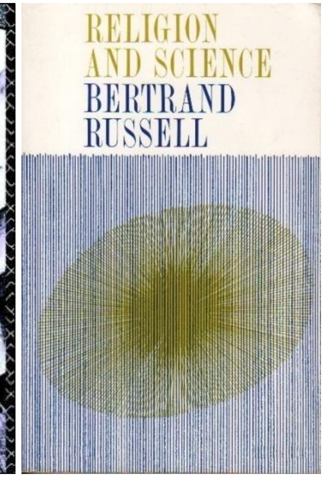
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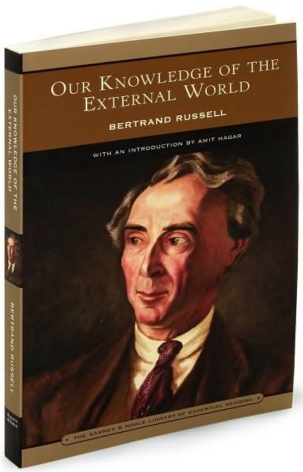
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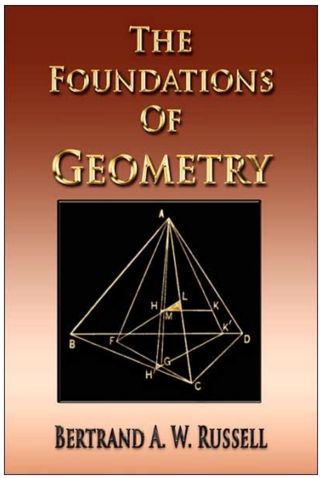
WITH AN INTRODUCTION BY AMIT HAGAR

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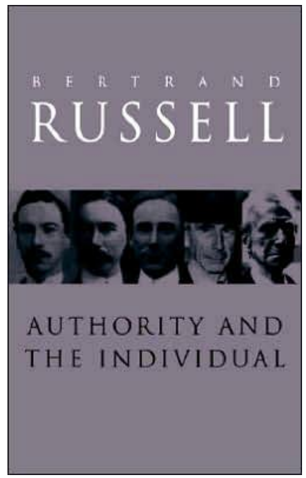
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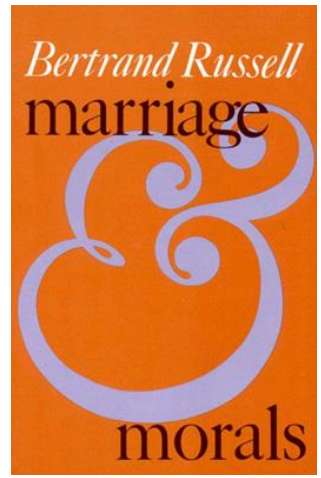
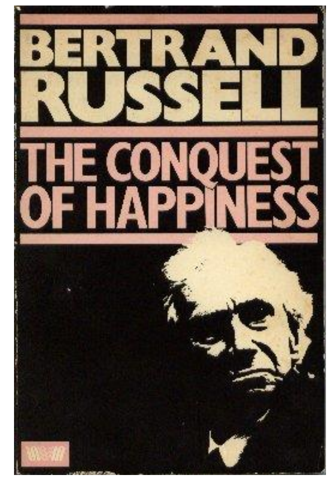

Bertrand Russell
marriage & morals

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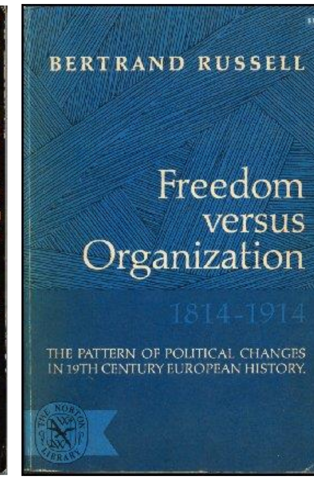
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1814-1914
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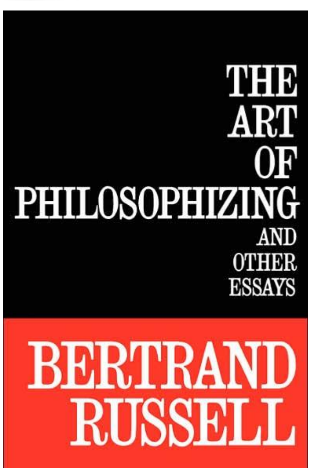
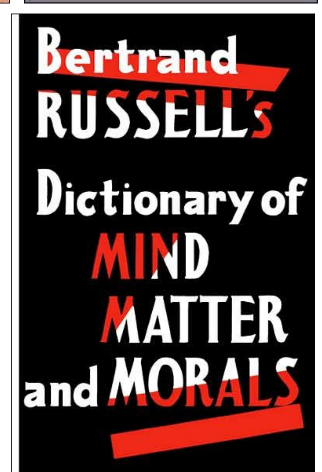

THE ART OF PHILOSOPHIZING AND OTHER ESSAYS
BERTRAND RUSSELL

The A B C Of Atoms
Bertrand Russell

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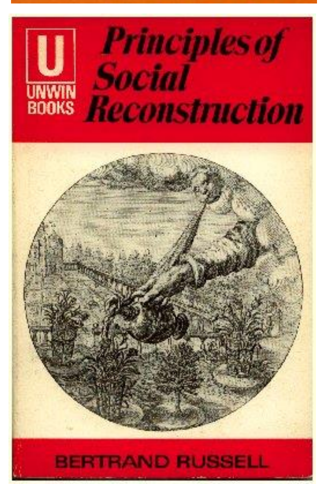
Dictionary of MIND MATTER and MORALS

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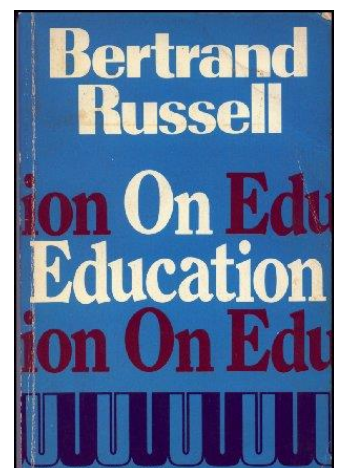
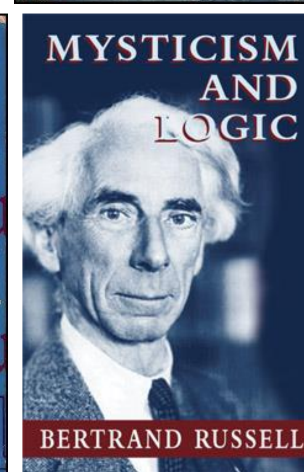
Principles of Social Reconstruction
BERTRAND RUSSELL

Bertrand Russell
On Education
UNWIN PAPERBACKS

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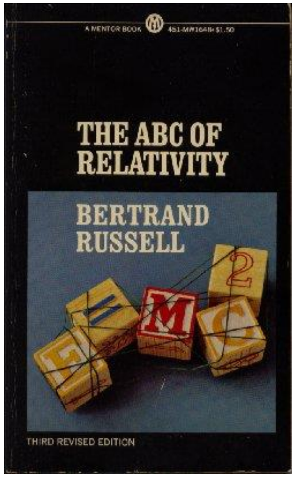
BERTRAND RUSSELL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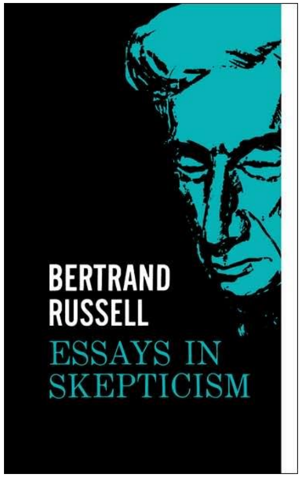
BERTRAND RUSSELL
THIRD REVISED EDITION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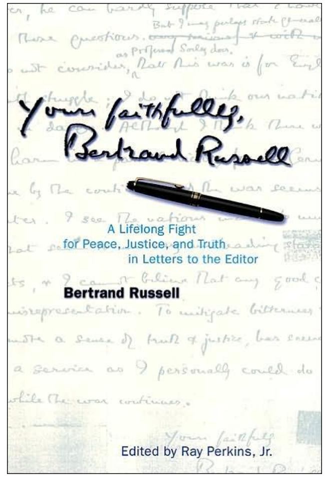
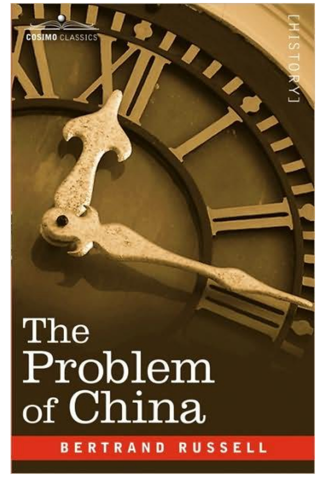

Yours faithfully,
Bertrand Russell
A Lifelong Fight
for Peace, Justice, and Truth
in Letters to the Editor
Bertrand Russell
Edited by Ray Perkins, Jr.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[HISTORY]
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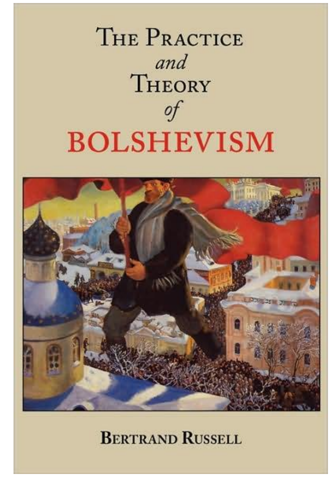
BERTRAND RUSSELL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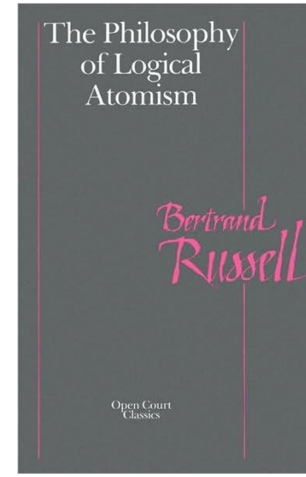
BOLSHEVISM
Bertrand Russell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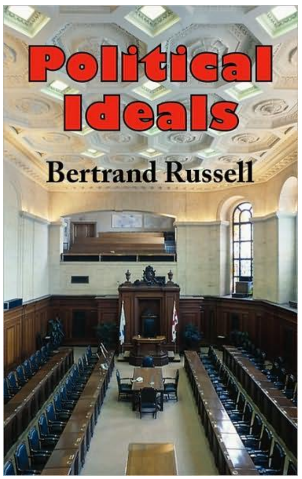
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Bertrand Russell


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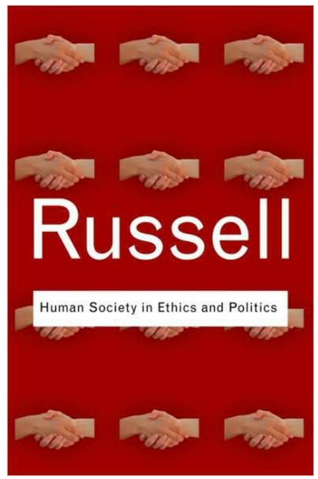
Bertrand Russell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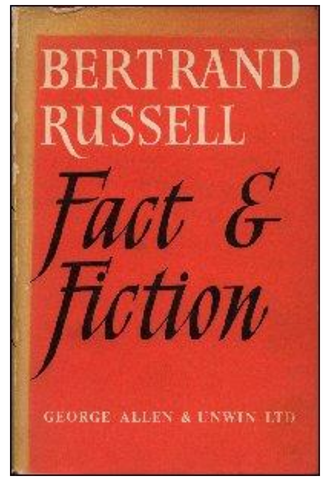
Human Society in Ethics and Politics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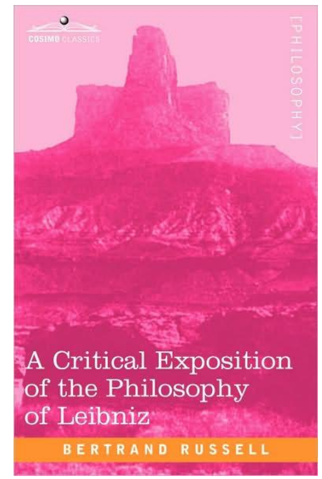
GEORGE ALLEN & UNWIN LTD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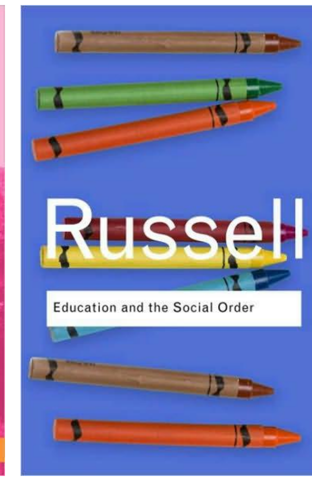
BERTRAND RUSSELL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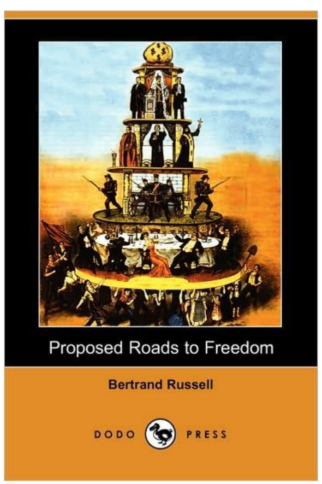
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Bertrand Russell
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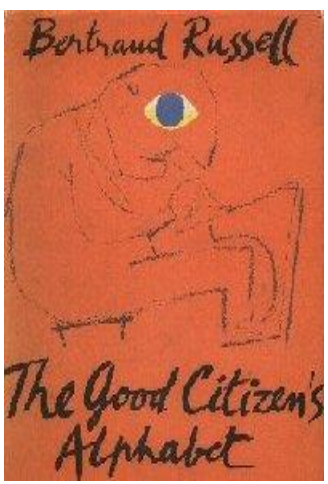
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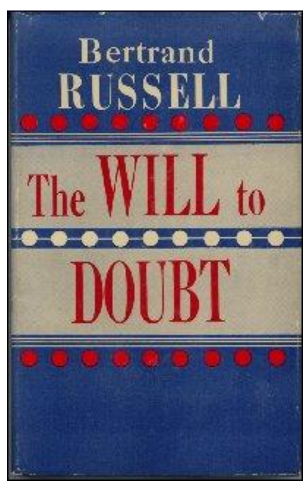
The Good Citizen's Alphabet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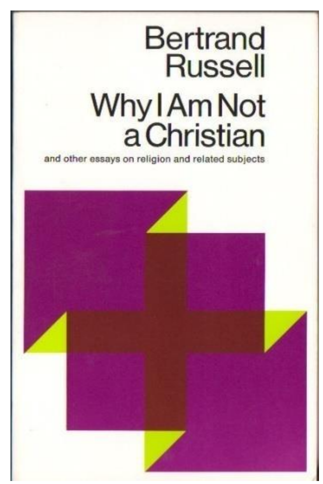
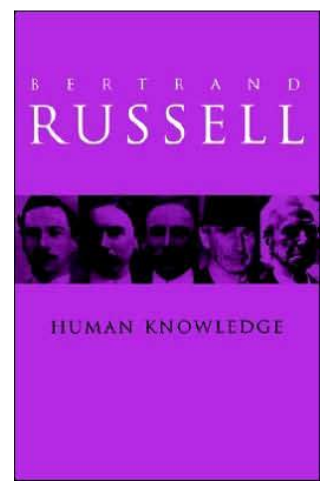
The WILL to DOUBT


Bertrand Russell
Why I Am Not a Christian
and other essays on religion and related subjects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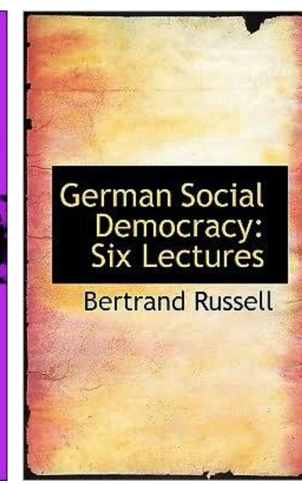
HUMAN KNOWLEDGE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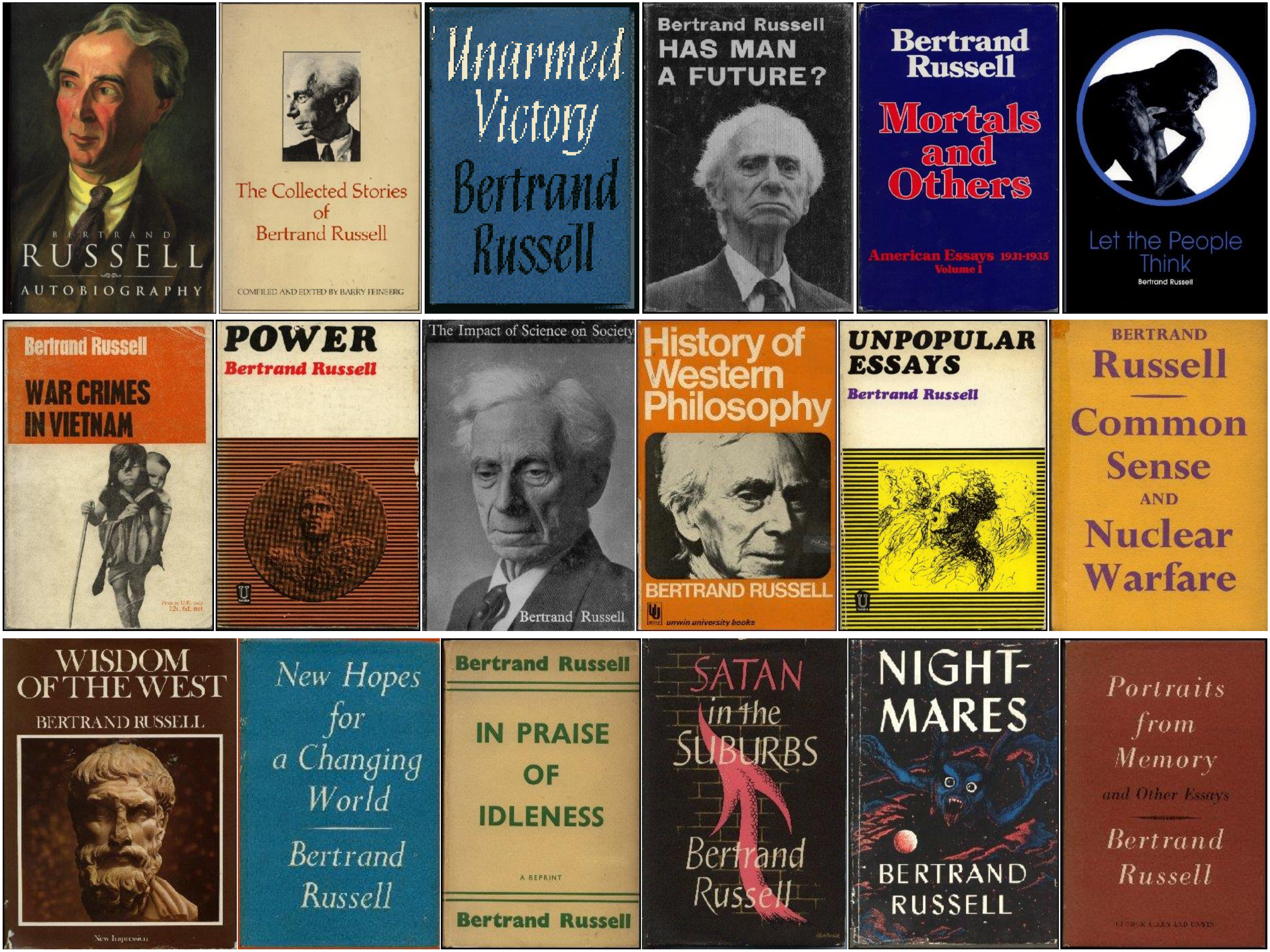
Bertrand Russell



BERTRAND
RUSSELL
AUTOBIOGRAPHY
The Collected Stories
of
Bertrand Russell
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Unarmed
Victory
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Russell
Bertrand Russell
HAS MAN
A FUTURE?
Bertrand
Russell
Mortals
and
Others
American Essays 1931-1935
Volume I
Let the People
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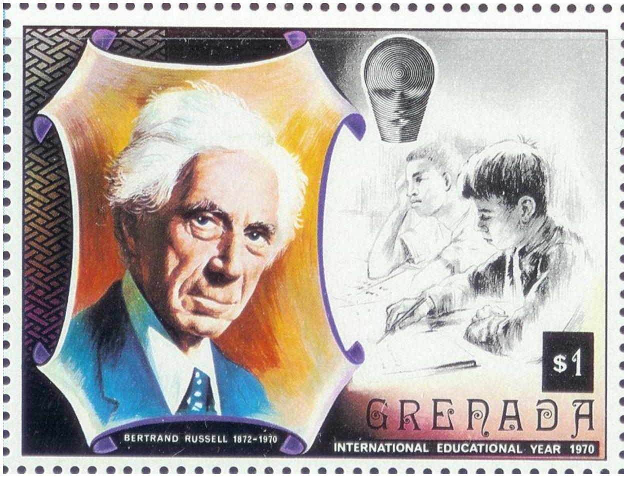
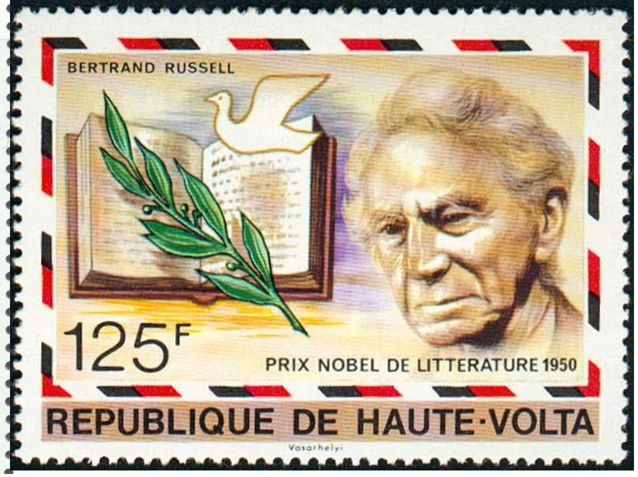
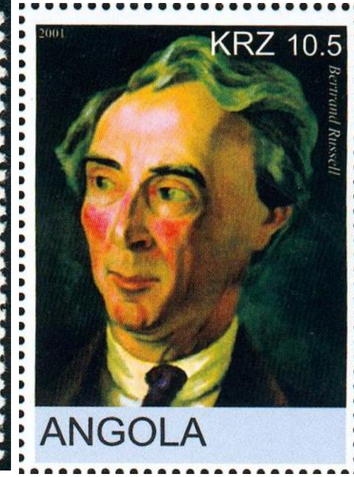
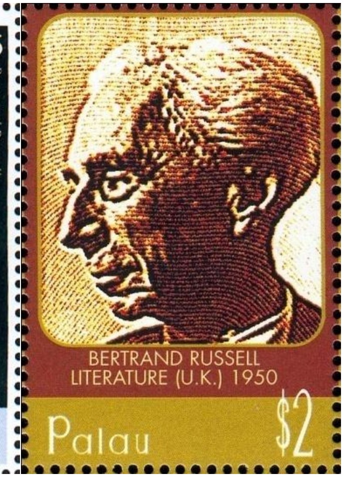
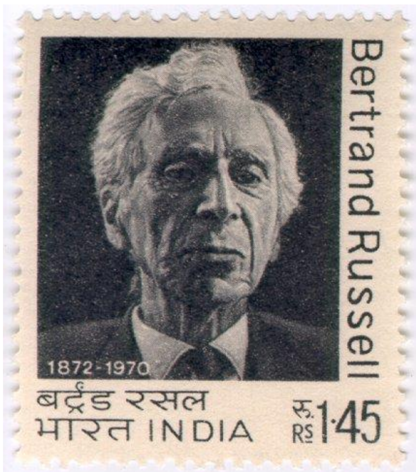
Portraits
from
Memory
and Other Essays
Bertrand
Russell

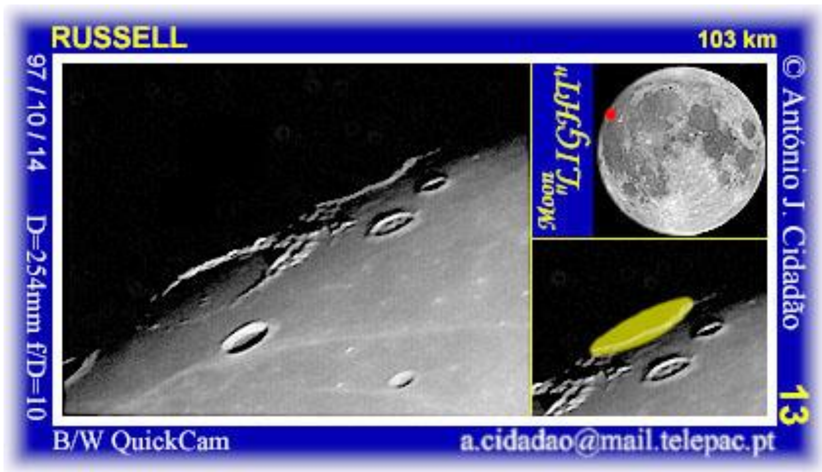


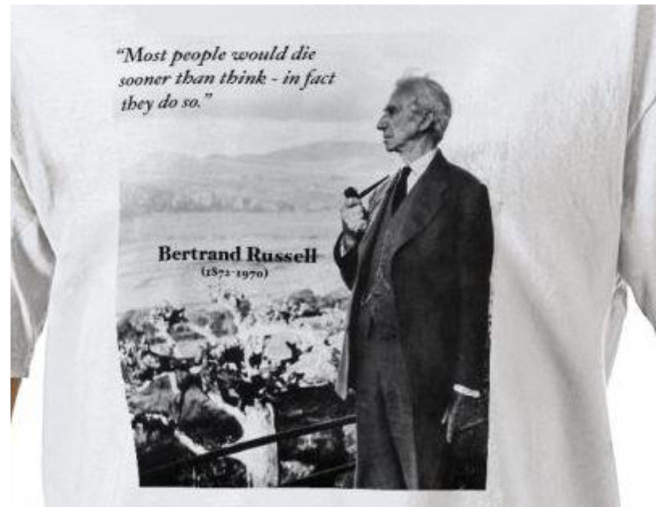


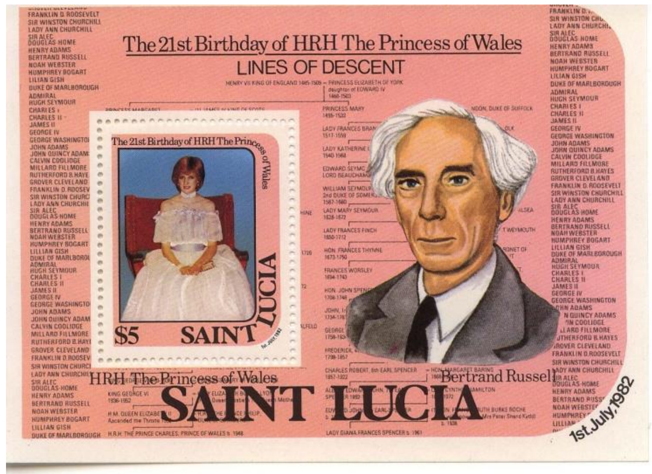


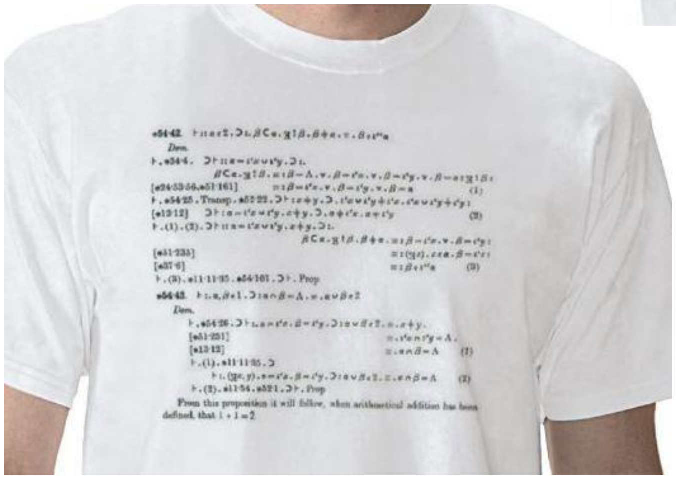










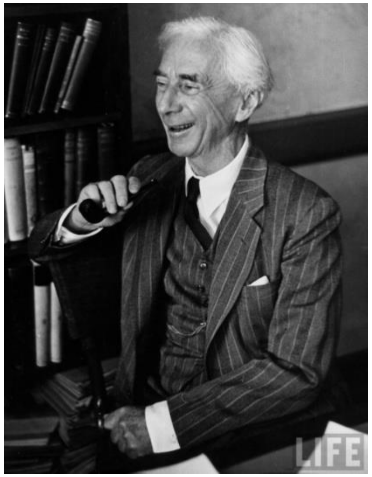


"Most people would sooner die than think; in fact, they do so."

- Bertrand Russell

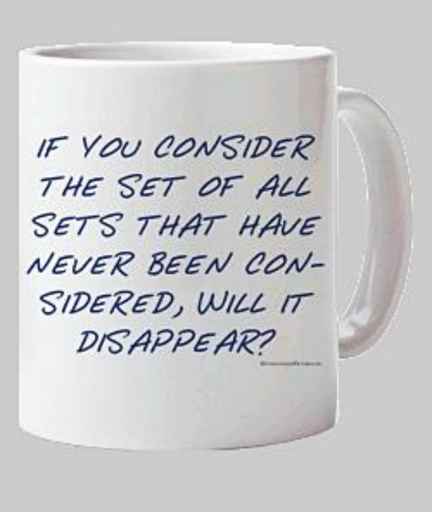
(1872-1970)

Russell's paradox was invented by Russell in 1901 to show that naïve set theory is self-contradictory:



Define: set of all sets that do not contain themselves

$$S = \{\, T \mid T \notin T \,\}$$

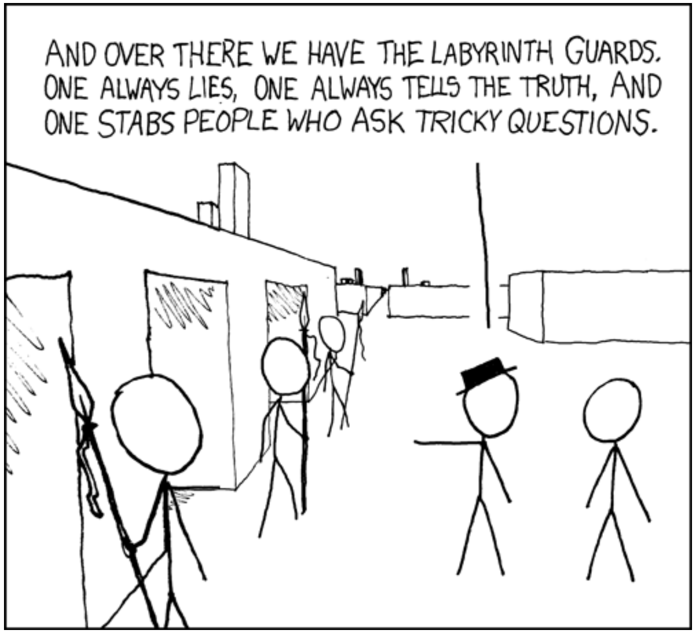


Q: does S contain itself as an element?

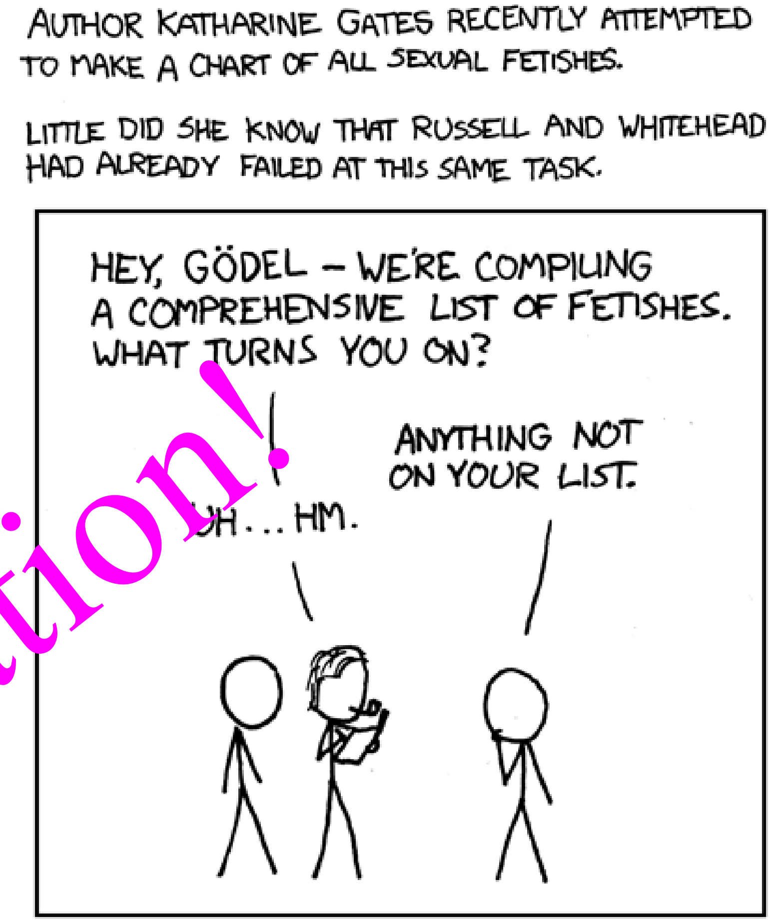
$$S \notin S \Leftrightarrow S \in S$$ contradiction!

Similar paradoxes:

- "A barber who shaves exactly those who do not shave themselves."
- "This sentence is false."
- "I am lying."
- "Is the answer to this question 'no'?"
- "The smallest positive integer not describable in twenty words or less."



Star Trek, 1967, “I, Mudd” episode
Captain James Kirk and Harry Mudd use a logical paradox to cause hostile android “Norman” to crash



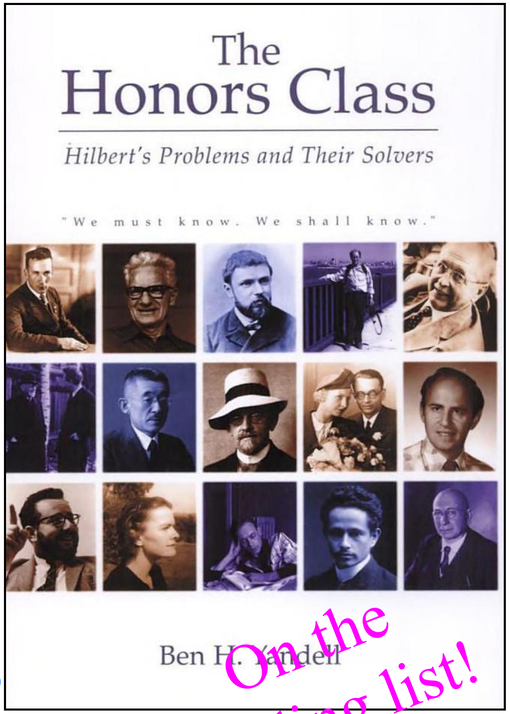
Diagonalization!

So you created everything.
Yes.
Including black holes.
Yes.
Which will eventually swallow up everything.
Yes.
Including you.
I'm working on that.
S. Harris

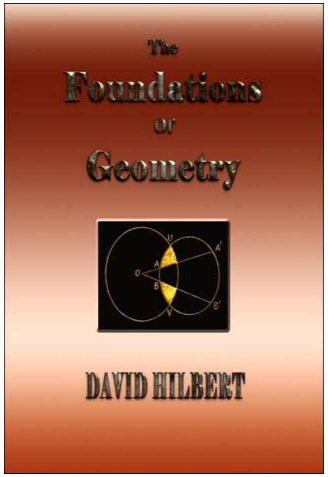
Historical Perspectives

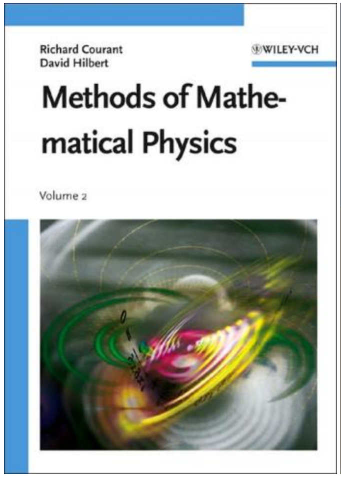
David Hilbert (1862-1943)

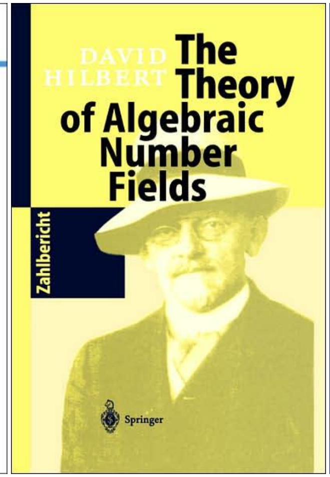
- One of the most influential mathematicians
- Developed invariant theory, Hilbert spaces
- Axiomatized geometry, "Hilbert's axioms"
- Co-founded proof theory, mathematical logic, meta-mathematics, & formalist school
- Created famous list of 23 open problems that greatly impacted mathematics research
- Defended Cantor's transfinite numbers
- Contributed to relativity theory & physics
- Hilbert's students included Courant, Hecke, Lasker, Weyl, Ackermann, and Zarmelo
- Influenced Russell, Gödel, Church, & Turing
  John von Neumann was Hilbert's assistant!

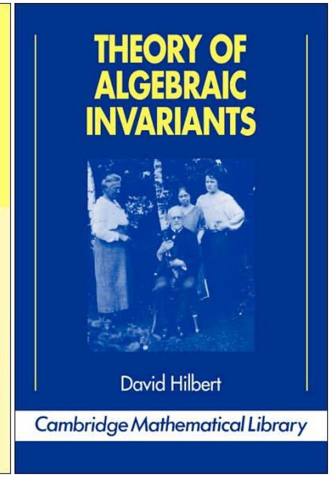


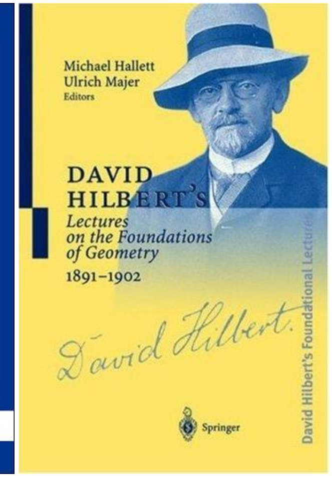
On the reading list!

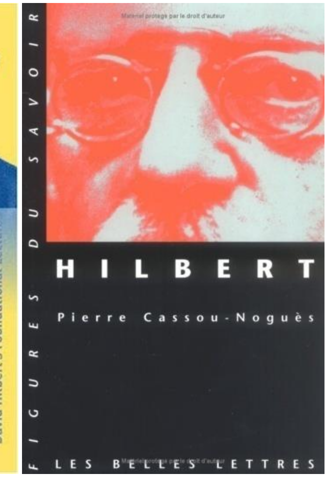

The
Foundations
of
Geometry
DAVID HILBERT


Richard Courant
David Hilbert
WILEY-VCH
Methods of Mathematical Physics
Volume 2


DAVID HILBERT
The Theory of Algebraic Number Fields
Zahlbericht
Springer


THEORY OF ALGEBRAIC INVARIANTS
David Hilbert
Cambridge Mathematical Library


Michael Hallett
Ulrich Majer
Editors
DAVID HILBERT'S
Lectures on the Foundations of Geometry
1891–1902
David Hilbert
Springer
David Hilbert's Foundational Lectures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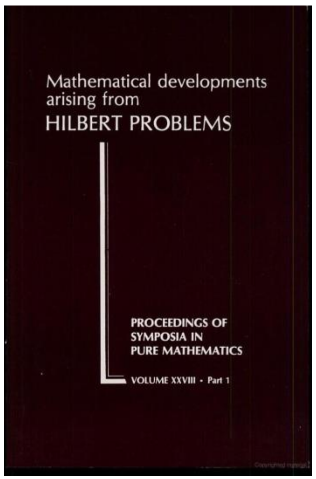
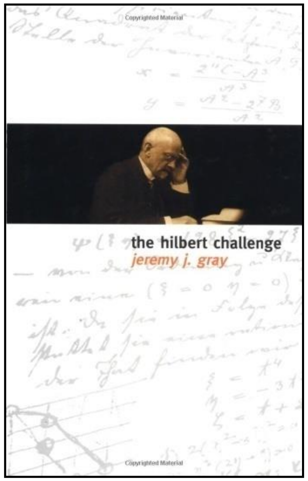
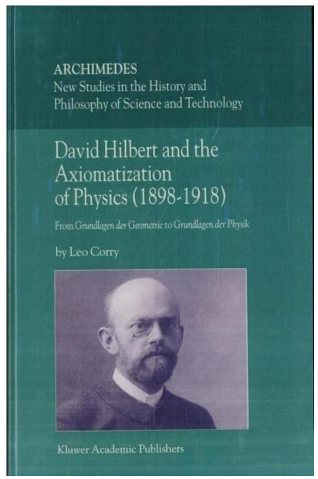
HILBERT
Pierre Cassou-Noguès
LES BELLES LETTRES


Mathematical developments arising from
HILBERT PROBLEMS
PROCEEDINGS OF SYMPOSIA IN PURE MATHEMATICS
VOLUME XXVIII • Part 1


the hilbert challenge
jeremy j. gray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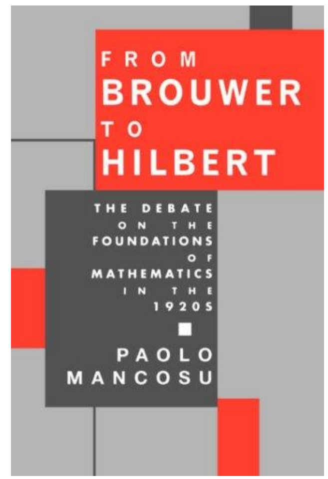
New Studies in the History and Philosophy of Science and Technology
David Hilbert and the Axiomatization of Physics (1898-1918)
From Grundlagen der Geometrie to Grundlagen der Physik
by Leo Corry
Kluwer Academic Publishers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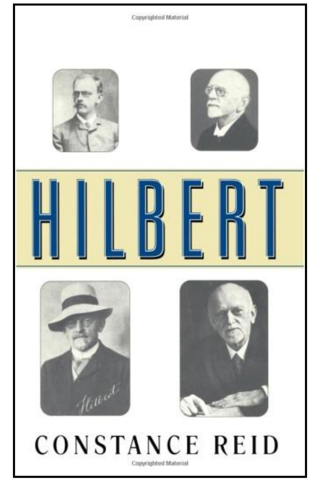
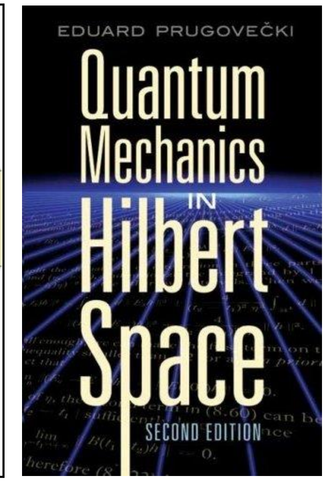
THE DEBATE ON THE FOUNDATIONS OF MATHEMATICS IN THE 1920S
PAOLO MANCOSU


HILBERT
CONSTANCE REID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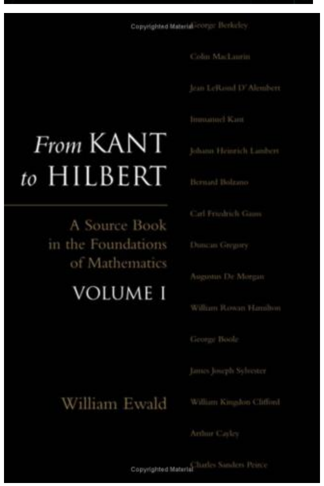
Quantum Mechanics in Hilbert Space
SECOND EDITION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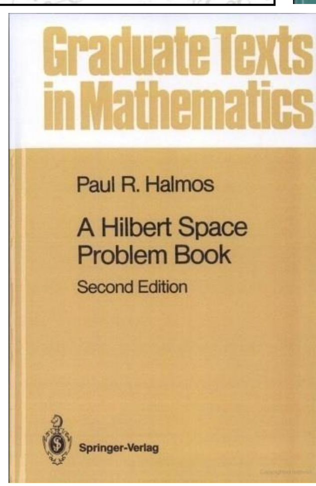
A Source Book in the Foundations of Mathematics
VOLUME I
William Ewald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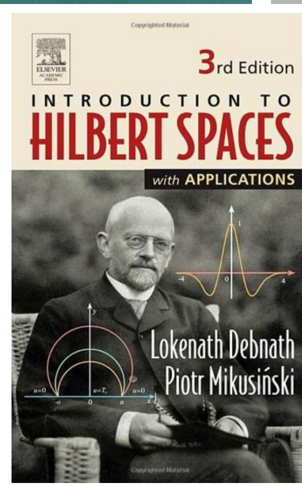
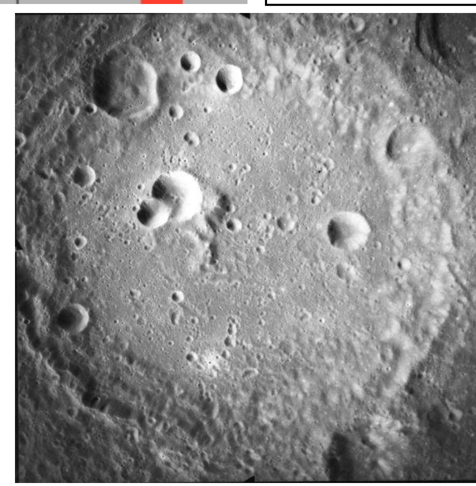
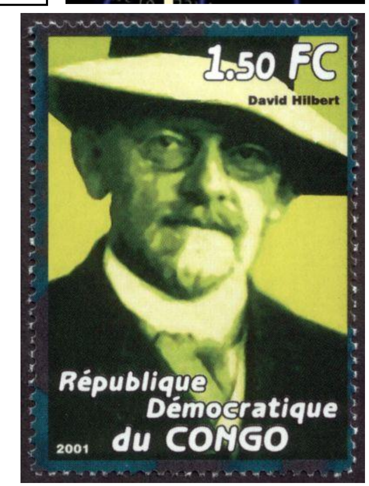
Paul R. Halmos
A Hilbert Space Problem Book
Second Edition
Springer-Verlag


3rd Edition
INTRODUCTION TO HILBERT SPACES
with APPLICATIONS
Lokenath Debnath
Piotr Mikusiński



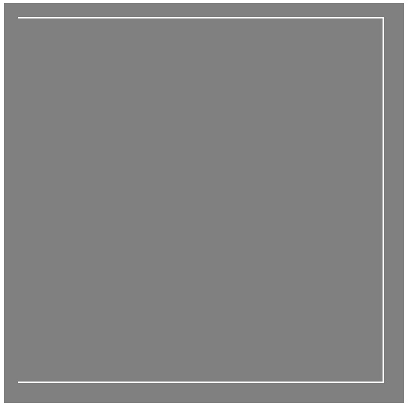

1.50 FC
David Hilbert
République Démocratique du CONGO
2001

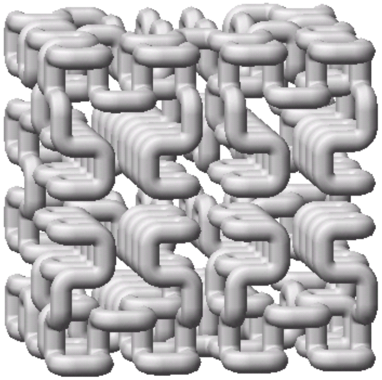
Hilbert’s Impact

- Hilbert's axioms
- Hilbert class field
- Hilbert C*-module
- Hilbert cube
- Hilbert symbol
- Hilbert function
- Hilbert inequality
- Hilbert matrix
- Hilbert metric
- Hilbert number
- Hilbert polynomial
- Hilbert's problems
- Hilbert's program
- Hilbert–Poincaré series
- Hilbert space

- Hilbert transform
- Hilbert's Arithmetic of Ends
- Hilbert’s constants
- Hilbert's irreducibility theorem
- Hilbert's Nullstellensatz
- Hilbert's hotel paradox
- Hilbert's theorem
- Hilbert's syzygy theorem
- Hilbert-style deduction system
- Hilbert–Pólya conjecture
- Hilbert–Schmidt operator
- Hilbert–Smith conjecture
- Hilbert–Speiser theorem
- Einstein–Hilbert action
- Hilbert curve

Hilbert curve:



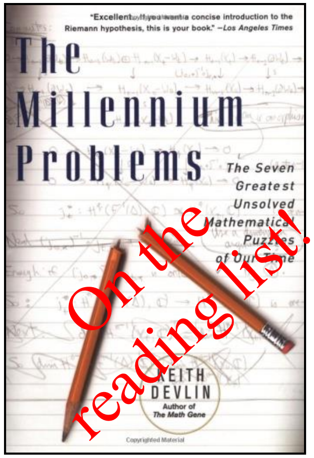


Hilbert's Problems

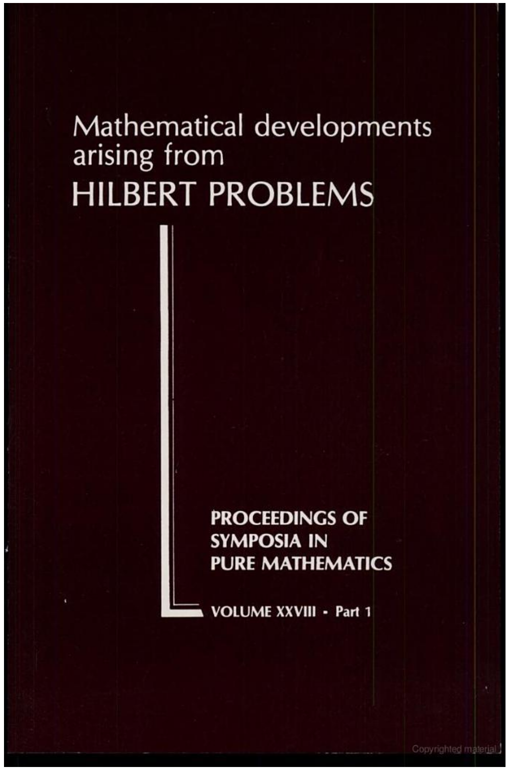
International Congress of Mathematics, Paris, 1900

- David Hilbert proposed 23 open problems
- Most successful open problems compilation ever
- Set the direction for 20th century mathematics
- Hilbert's problems received much attention to date
- Several have been resolved (e.g., Continuum hypothesis)
- Others still open (e.g., Riemann hypothesis)
- Catalyzed other open problems lists:
  - Clay Institute's Millennium Prize problems
  - DARPA Mathematical Challenges, 2009

CLAY MATHEMATICS INSTITUTE



On the reading list!



Hilbert's Problems

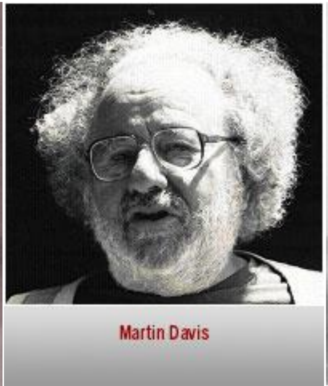
Problem 10: Find an algorithm that determines whether a given Diophantine (i.e., multi-variable polynomial) equation has any integer solutions.

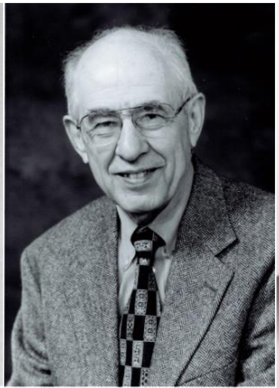
Ex: $x^2+y^2=z^2$ has many integer solutions

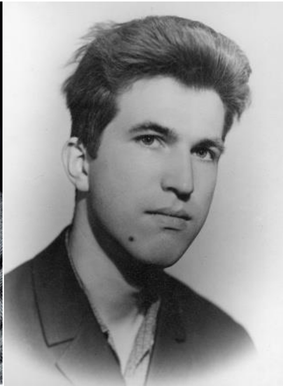
(Pythagorean theorem, e.g., $x=3$, $y=4$, $z=5$)

$x^9+y^9=z^9$ has no integer solutions (corollary of Fermat's Last Theorem, conjectured in 1637, proved in 1995 by Andrew Wiles)

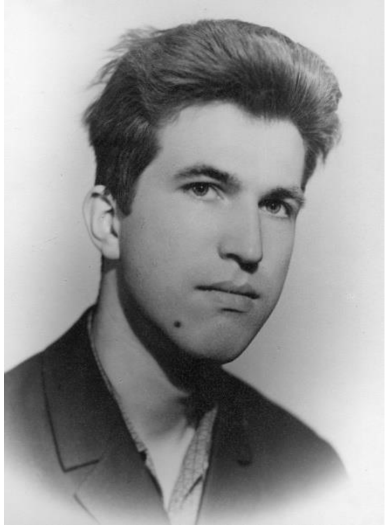
Many attempts at solution & partial results: Emil Post (1944), Martin Davis (1949), Julia Robinson (1950), Hilary Putnam (1959)







Hilbert's Tenth Problem



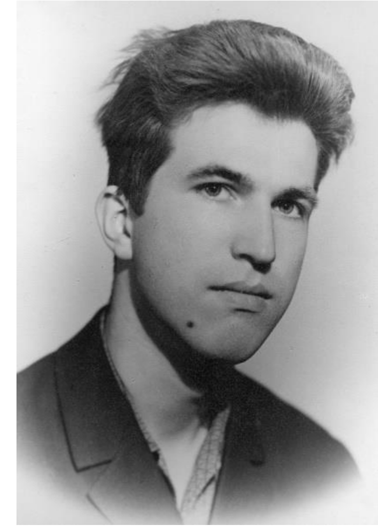
Theorem [Matiyasevich, 1970]: Every Turing-recognizable set is Diophantine (i.e., the solutions of some polynomial)

Ex: the set of primes coincides exactly with the positive values of this 26-variable polynomial:

$$
\begin{aligned}
&(k+2)(1-[wz+h+j-q]^2-[(gk+2g+k+1)(h+j)+h-z]^2\\
&-[16(k+1)^3(k+2)(n+1)^2+1-f^2]^2-[2n+p+q+z-e]^2\\
&-[e^3(e+2)(a+1)^2+1-o^2]^2-[(a^2-1)y^2+1-x^2]^2\\
&-[16r^2y^4(a^2-1)+1-u^2]^2-[n+l+v-y]^2-[(a^2-1)l^2+1-m^2]^2\\
&-[ai+k+1-l-i]^2-[((a+u^2(u^2-a))^2-1)(n+4dy)^2+1\\
&-(x+cu)^2]^2-[p+l(a-n-1)+b(2an+2a-n^2-2n-2)-m]^2\\
&-[q+y(a-p-1)+s(2ap+2a-p^2-2p-2)-x]^2\\
&-[z+pl(a-p)+t(2ap-p^2-1)-pm]^2)
\end{aligned}
$$

as a, b, c, … , z range over the nonnegative integers!

Hilbert's Tenth Problem

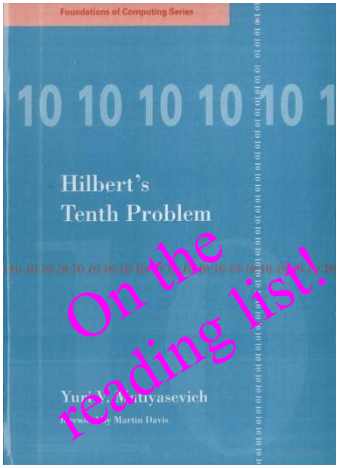


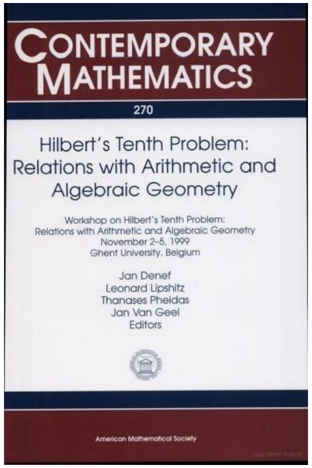
Corollary [Matiyasevich, 1970]: There is a fixed "universal" polynomial P such that for any Turing-enumerable set S there exists an integer n_0 such that:

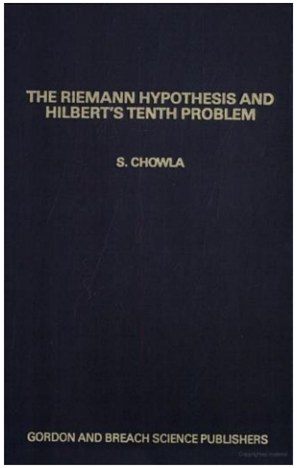
$$S = \{w \mid \exists\, x_1, x_2, \ldots, x_k \ni P(n_0, w, x_1, x_2, \ldots, x_k) = 0$$

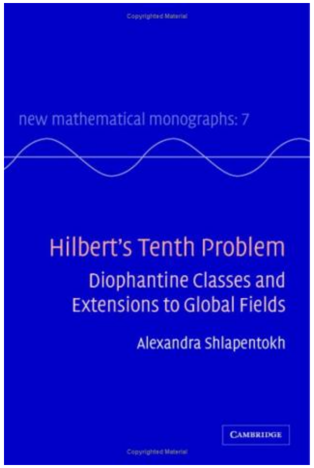
i.e., there is a fixed polynomial that can "output" any computable set, depending on one parameter.

This is an analogue of a universal Turing machine!









CLAY MATHEMATICS INSTITUTE

March 15–16, 2007

One Bow Street, Cambridge, Massachusetts

Conference on Hilbert's Tenth Problem

Thursday, March 15

9:00	Coffee
9:15 - 9:25	Constance Reid, *Genesis of the Hilbert Problems*
9:25 - 10:00	George Csicsery, *Film clip on life and work of Julia Robinson, discussion*
10:15 - 11:15	Bjorn Poonen, *Why number theory is hard*
11:30 - 12:30	Yuri Matiyasevich, *My collaboration with Julia Robinson*
	Break for lunch
2:30-3:30	Martin Davis, *My collaboration with Hilary Putnam*
3:45-4:45	Maxim Vsemirnov, *TBA*
7:30	**Museum of Science • Film Screening** Scenes from *Julia Robinson and Hilbert's Tenth Problem*, a documentary by George Csicsery, will be screened in Cahner's Theater (Blue Wing, Level 2, Museum of Science), and followed by a panel discussion with filmmaker George Csicsery, mathematician Yuri Matiyasevich, and biographer Constance Reid. This event is free and open to the public.

Friday, March 16

8:30	Coffee
9:00–10:00	Yuri Matiyasevich, *Hilbert's Tenth Problem: What was done and what is to be done*
10:15–11:15	Bjorn Poonen, *Thoughts about the analogue for rational numbers*
11:30–12:30	Alexandra Shlapentokh, *Diophantine generation, horizontal and vertical problems, and the weak vertical method*
	Break for lunch
2:00–3:00	Yuri Matiyasevich, *Computation paradigms in the light of Hilbert's tenth problem*
3:15–4:15	Gunther Cornelisson, *Hard number-theoretical problems and elliptic curves*
4:30–5:30	Kirsten Eisentrager, *Hilbert's Tenth Problem for algebraic function fields*

Hilbert's 10th Problem (1900): is there an algorithm for deciding whether a polynomial equation with integer coefficients has an integer solution?

$$x^2 - (a^2 - 1)y^2 = 1$$

Clay Mathematics Institute
www.claymath.org

Museum of Science.
mos.org

Photo credits (top to bottom): Julia Robinson, courtesy of Constance Reid; Yuri Matiyasevich, photo by George Csicsery; David Hilbert, courtesy AK Peters, Ltd.

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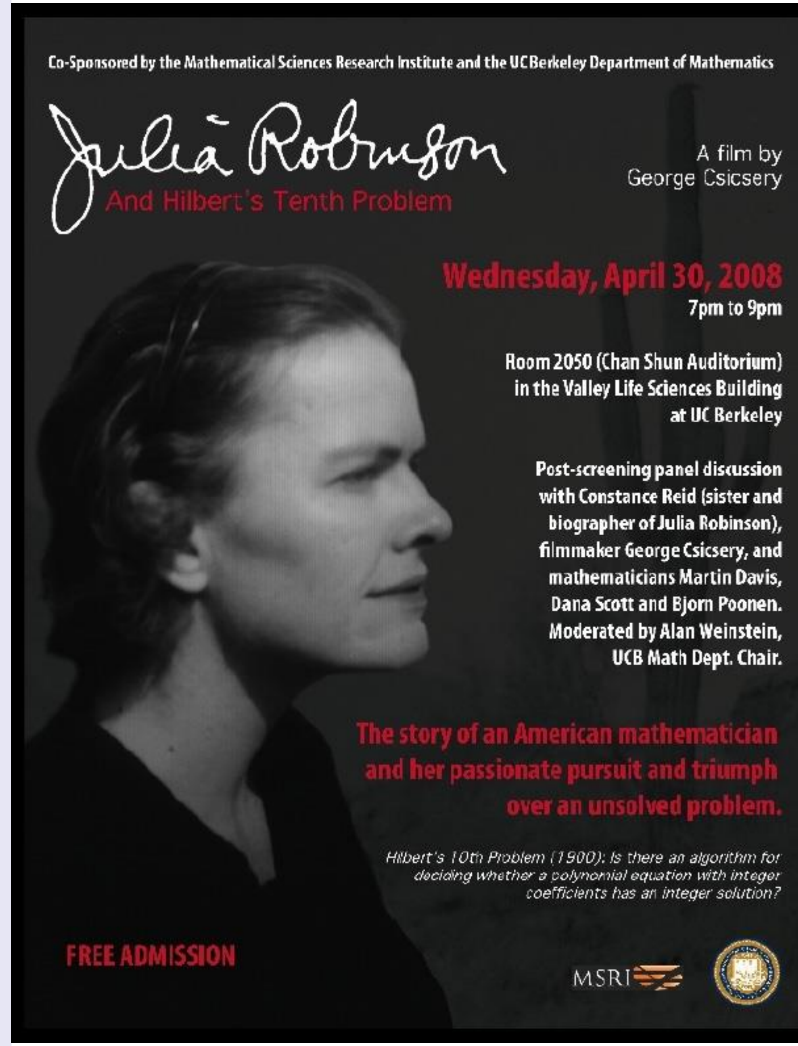
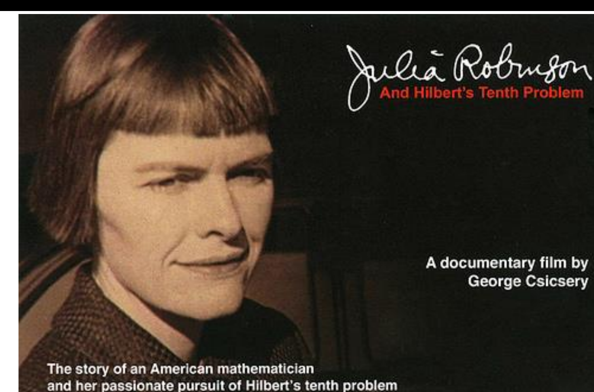




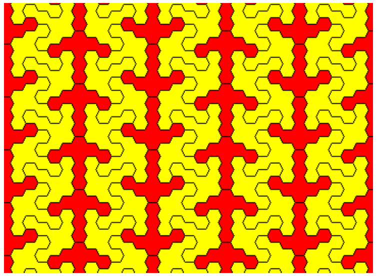
Hilbert's Problems

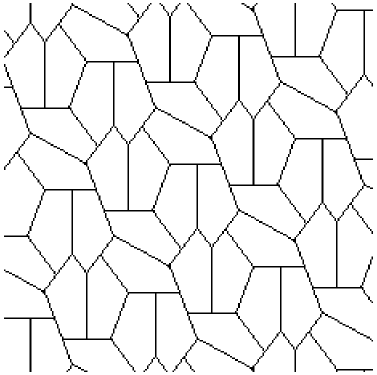
Problem 18: Is there a non-regular, space-filling polyhedron? What is the densest sphere packing?

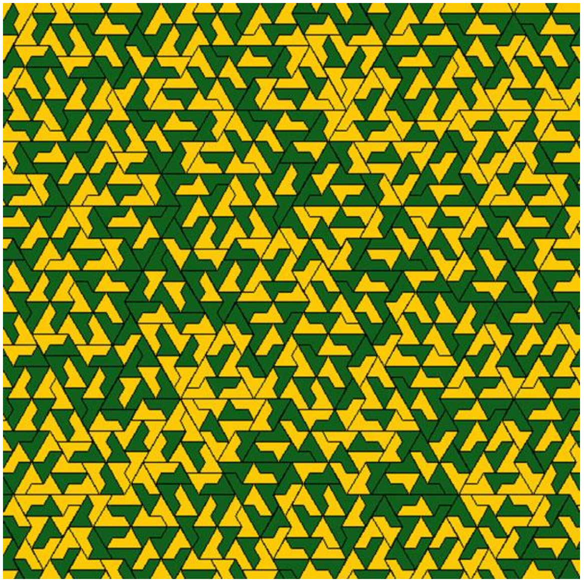
Status: Anisohedral tilings were found in 3D by Reinhardt (1928), and for 2D by Heesch (1935).

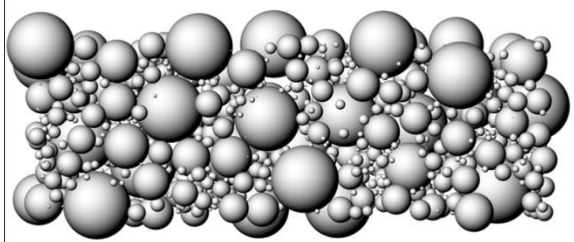
Sphere packing in 3D (Kepler's problem, 1611) was solved by Toth (1953) and Hale (1998). Regular sphere packing in 24 dimensions was solved by Cohn and Kumar (2004), where the "kissing number" is 196,560.

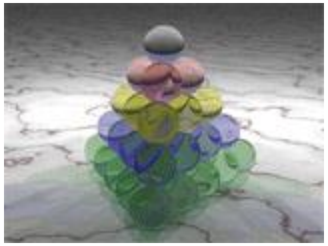
Many related open problems remain, including non-regular, non-uniform, and ellipsoid packings.

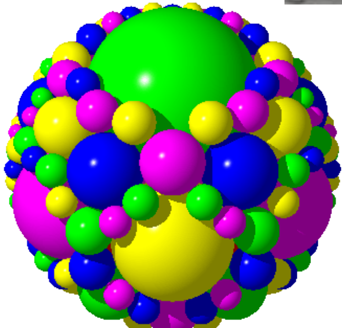


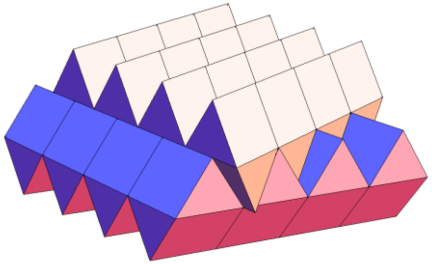


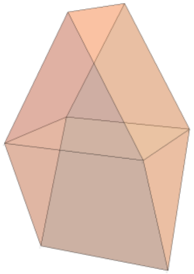










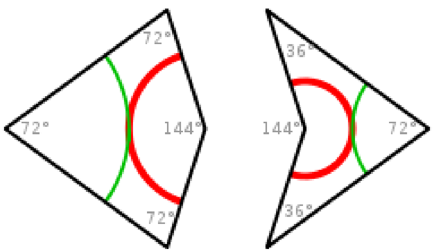


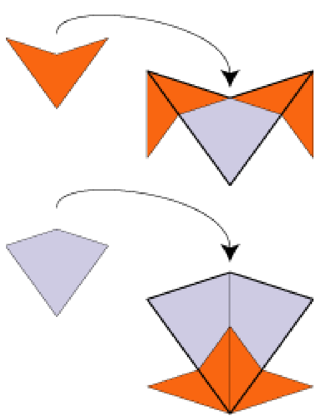
Aperiodic Tilings

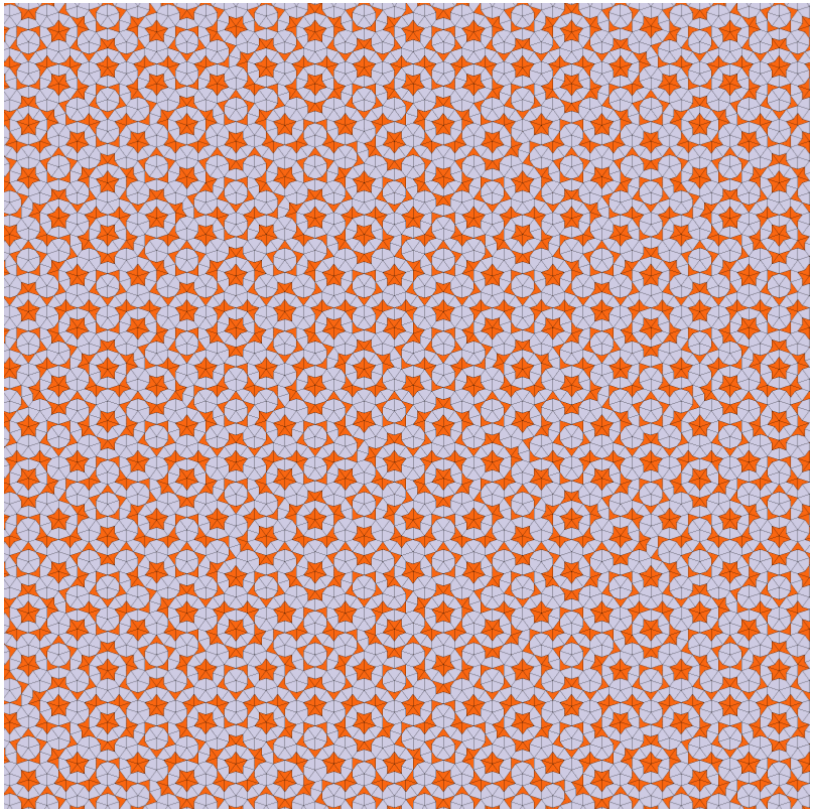
Goal: tile the entire plane without overlaps, non-periodically

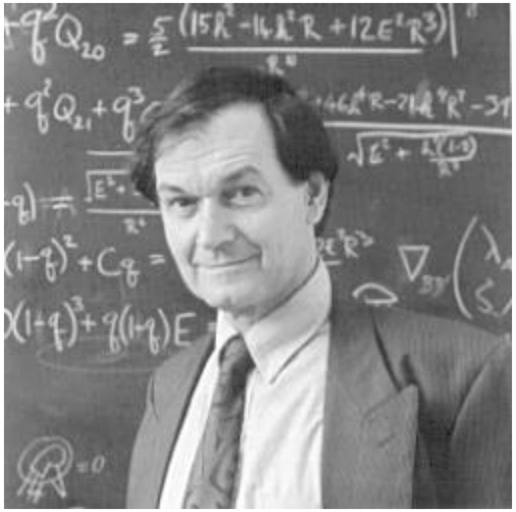
- Non-periodic tiling is not equal to a translation of itself
- Aperiodic tile set admits only non-periodic tilings

“Kites and Darts” 2-tile aperiodic set, Roger Penrose, 1974









Open question:

∃ a single-tile 2D aperiodic tiling?

Aperiodic Tilings

Penrose tilings in architecture and design:

Aperiodic Tilings

"Pinwheel tiling", John Conway and Charles Radin, 1992

SCIENCE

Bathroom tiling to drive you mad

Ian Stewart

AN AMERICAN mathematician has come up with what is probably the strangest way ever of covering a floor or wall with tiles. The set of tiles which has been devised by Charles Radin of the University of Texas at Austin can only be assembled in a highly complex way (*Annals of Mathematics*, vol 109, p 661).

The usual way of assembling tiles is in a periodic pattern, one that starts with a basic unit, which is repeated at regularly spaced intervals. However, more complex patterns of tiling are perfectly possible and the subject of aperiodic tilings was created by the philosopher Hao Wang in 1961. Wang was studying the existence or otherwise of certain "decision procedures" in mathematical logic—ways of working out in advance whether certain problems have solutions—when he came to the surprising conclusion that the problem could be reformulated in terms of tiles.

Choose a finite collection of shapes and call them prototiles. A tiling is then a way to assemble perfect copies of those prototiles so that they cover the entire infinite plane without any gaps or overlaps. Wang discovered that he could design prototiles that corresponded to various logical statements, in such a way that the rules for fitting prototiles together corresponded exactly to the rules of logical deduction. So, in effect, a tiling pattern corresponded to a logical proof. This new viewpoint led Wang to ask whether there existed a set of prototiles that could tile the plane, but could not tile it periodically.

Tiling a plane aperiodically turns out to be easy. It can be done with a single domino-shaped prototile. First, however, it is necessary to tile the plane with squares. Then each square is divided into two dominos by splitting it in half in either the vertical or horizontal direction. If the pattern of verticals and horizontals is aperiodic, so too is the tiling: the easiest method is to vary the directions randomly. However, dominos can also tile the plane periodically—for example, by making all splits point the same way.

Wang wanted something much more subtle: a set of prototiles that produced only aperiodic tilings. Such a set of tiles was found in 1966 by his student Robert Berger. The best known of such sets are the Penrose tilings, introduced by Roger Penrose of the University of Oxford in 1977; these produce tilings with fivefold "almost" symmetries.

Radin notes that: "All published examples . . . have the feature that in every tiling each prototile only appears in finitely many orientations." For instance, dominos can be laid down horizontally or vertically but not oriented at any other angle; and Penrose tiles rotate only through multiples of an angle of 36°. This means that if the set of prototiles is expanded so that it includes a copy of each prototile in each orientation, then the new prototiles can tile the whole plane without being rotated. Only translations of these "oriented prototiles" are then needed.

Radin's new discovery is a set of prototiles that are forced to appear in an infinite number of orientations. Because periodic tilings involve only a finite number of directions—the ones in the basic repeating unit—Radin's tilings are necessarily aperiodic.

World's most complex tiling? Surround a triangular "half-domino" by four more. Then simply repeat . . .

His starting point is an idea thought up by John Horton Conway of Princeton University in New Jersey. Begin with a "half-domino" prototile, a right triangle of sides 1 and 2 units (whose hypotenuse is 5 units). This can be surrounded by four copies of itself in order to create a triangle of the same shape, but larger and rotated through an angle (see Figure). The process can be thought of as defining a "level-l" tiling of part of the plane with five triangular tiles. The construction can now be repeated, surrounding the level-1 set of five tiles with four copies of those sets to make an even larger and further rotated triangle that is composed of 25 of the original prototiles: this is known as the level-2 tiling.

Continuing this "expansion" process indefinitely from each level to the next leads to a strange, random-looking tiling of the infinite plane by half-dominos (see Figure), called the Conway tiling. Because the angle of rotation at each stage does not exactly divide into an integer number of full turns, the half-domino appears in an infinite number of different orientations throughout the plane.

However, this particular prototile can also tile the plane periodically. This can be done if two half-dominos are stuck together to make a domino and the plane is tiled periodically with those. To eliminate these periodic possibilities, Radin modifies the construction so that certain features of the Conway tiling, in particular its hierarchical structure into levels, cannot be avoided.

The essential idea is an old one: the edges of prototiles can be "labelled" with marks or symbols, with the extra rule that adjacent tiles must have matching labels along their common edges. This produces a larger set of labelled prototiles with more restrictive tiling rules. The point is that the labels can be realised by making notches in the edges of one tile and adding protruding lugs to match them in the adjacent tile. By using a different shaped notch/lug pair for each symbol used as a label, we can convert labelled prototiles into ordinary ones of more complicated shapes.

It is, of course, easier to think about simple shapes that have labelled edges, and this is the way in which Radin proceeds. His prototiles are labelled half-dominos, and he invents a complicated range of different labels whose matching rules cleverly force the appearance of the same structure as the Conway tiling.

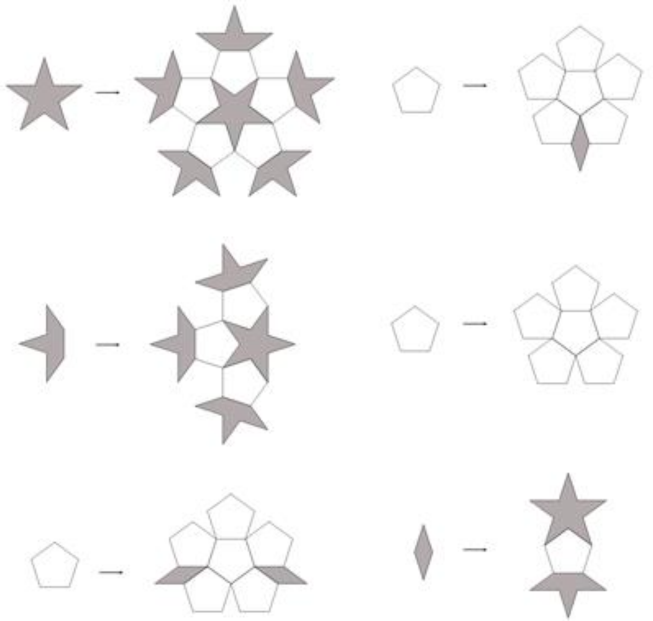
It is astonishing that such a simple shape as half a domino can have such curious implications, and it shows that even in today's complex world mathematics can still advance by looking at a simple idea in a new way. □

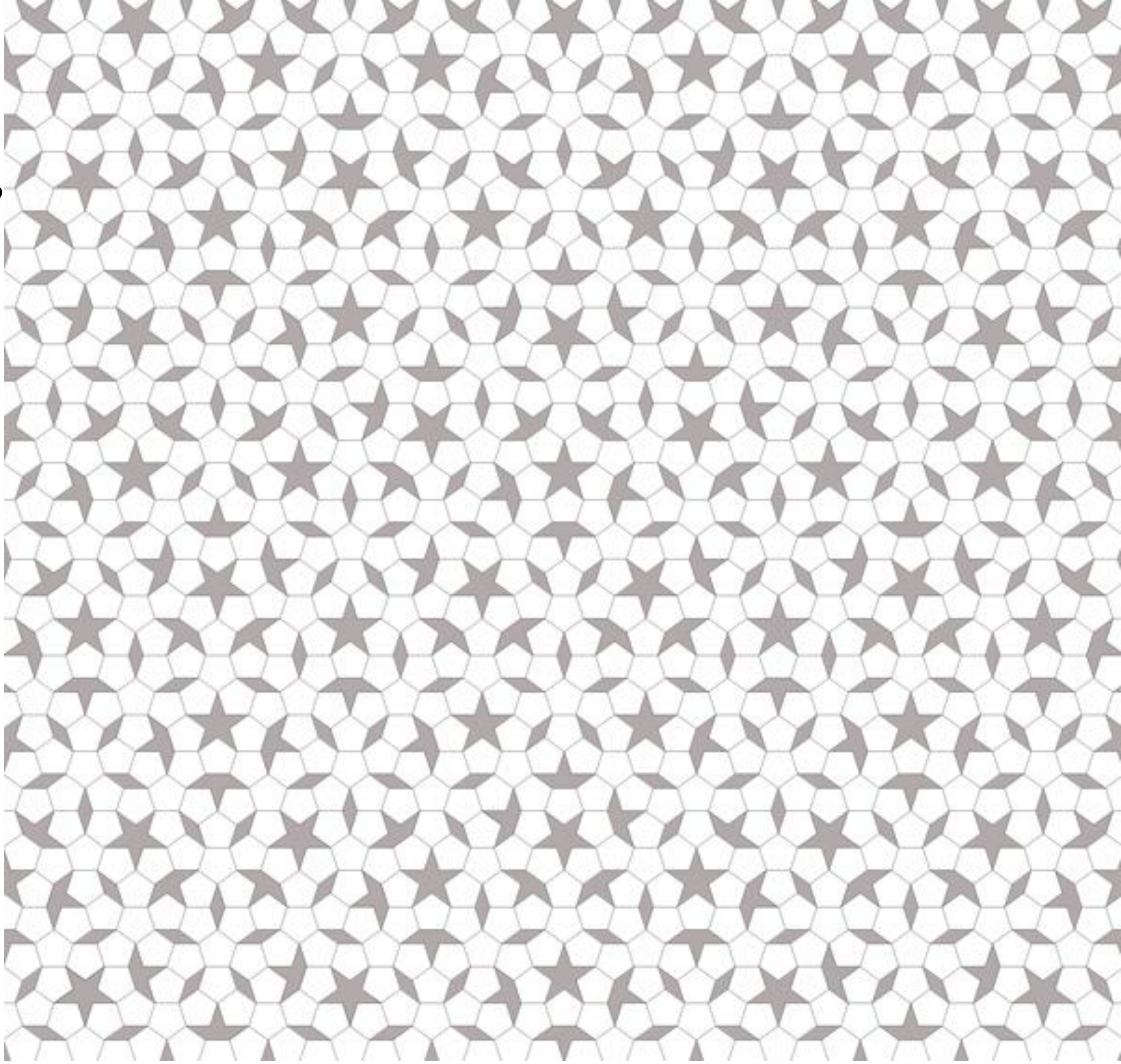
Federation Square
Melbourne, Australia

Aperiodic Tilings

“Pentagon, Boat, and Star”

Roger Penrose, 1974

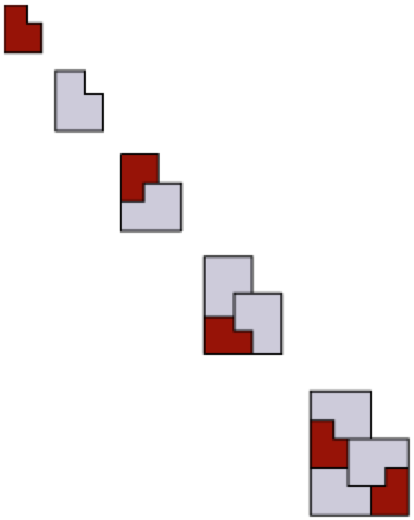


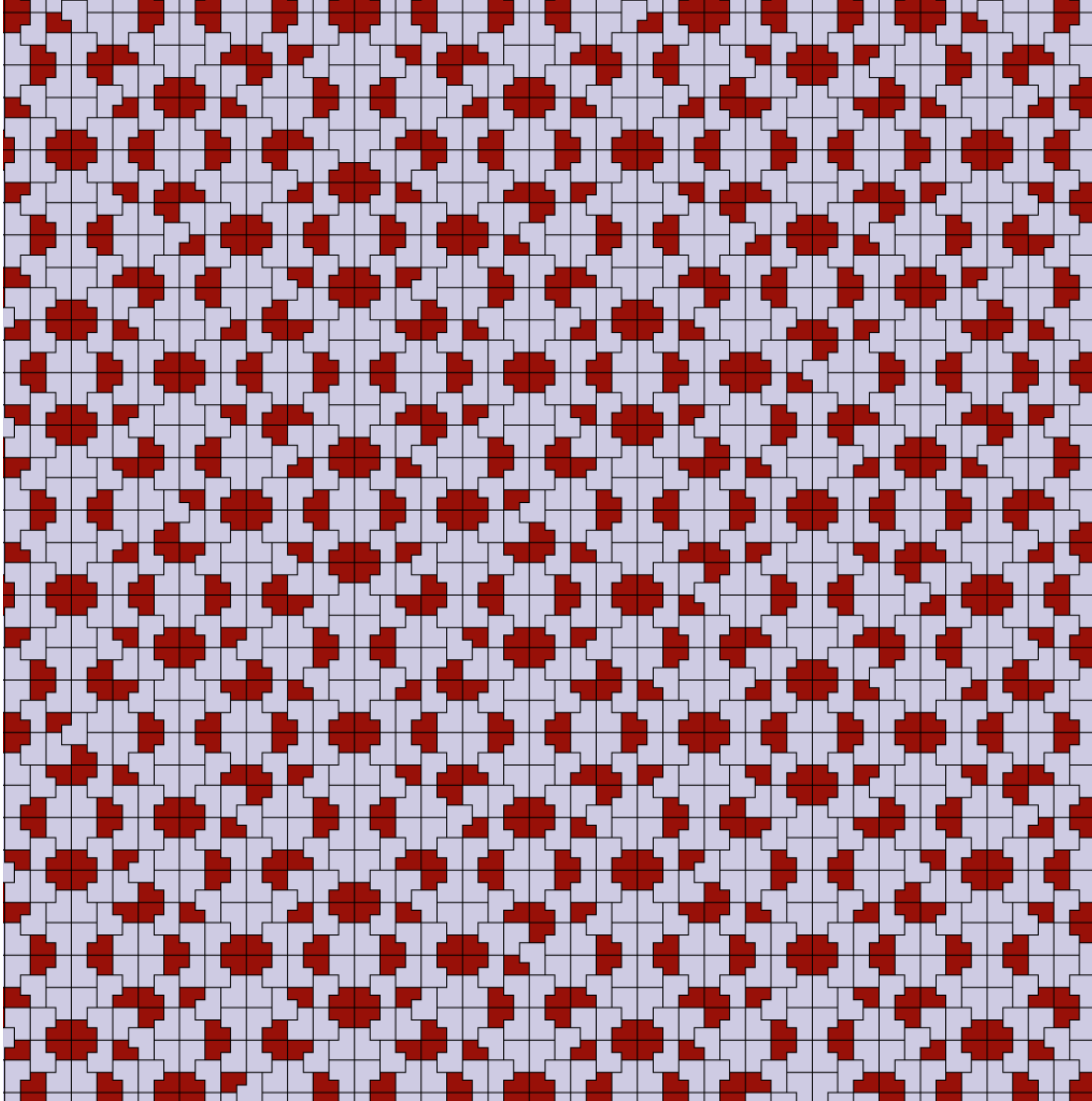


Aperiodic Tilings

"Ammann Chair"

Robert Ammann,
1977

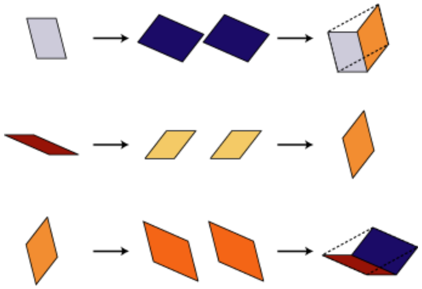


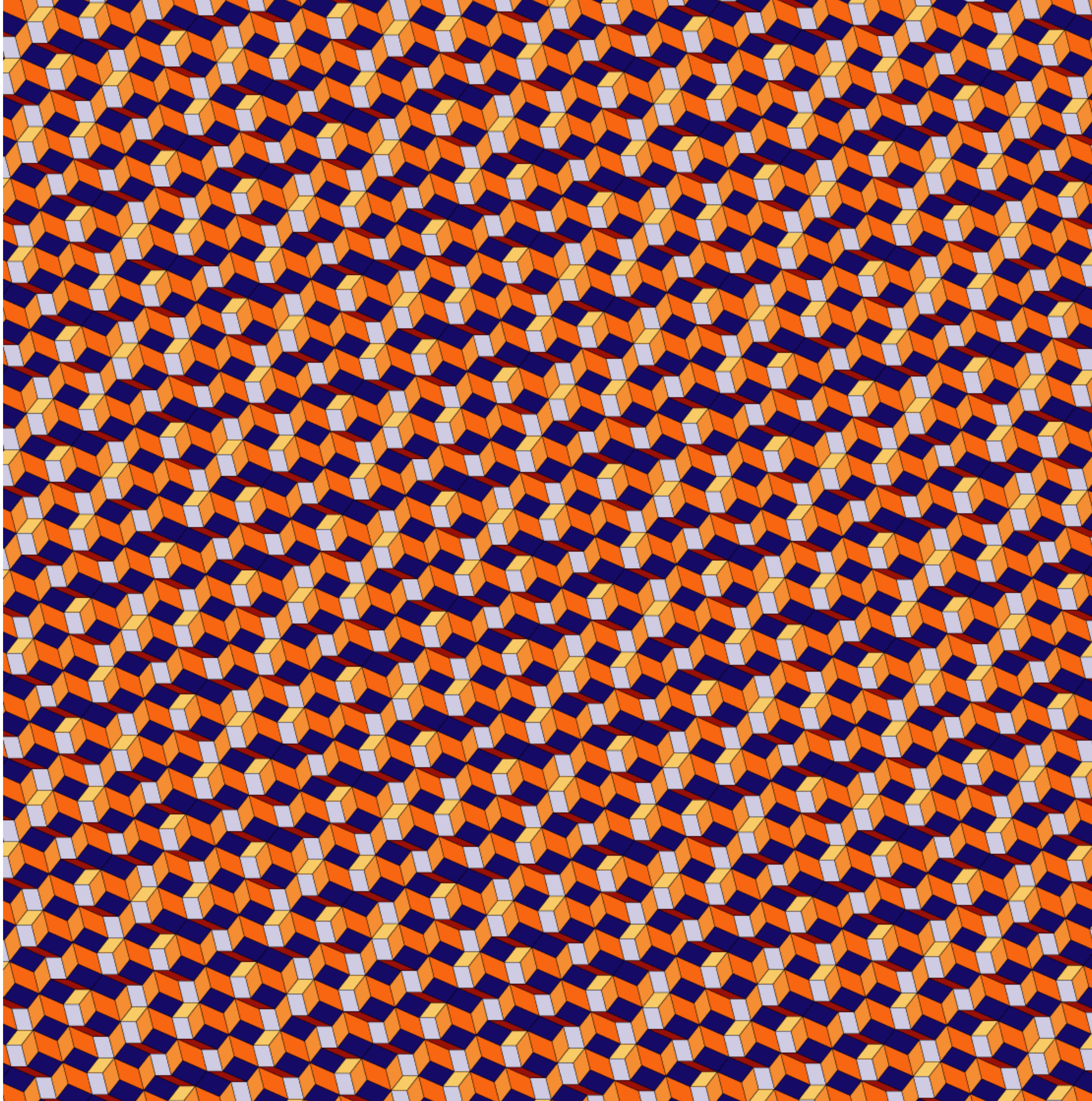


Aperiodic Tilings

"Conch"

G. Rauzy, 1982

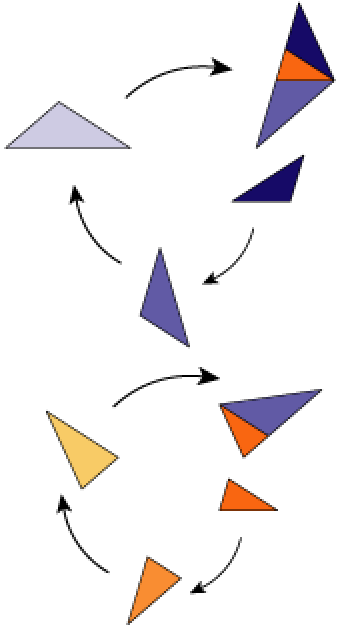


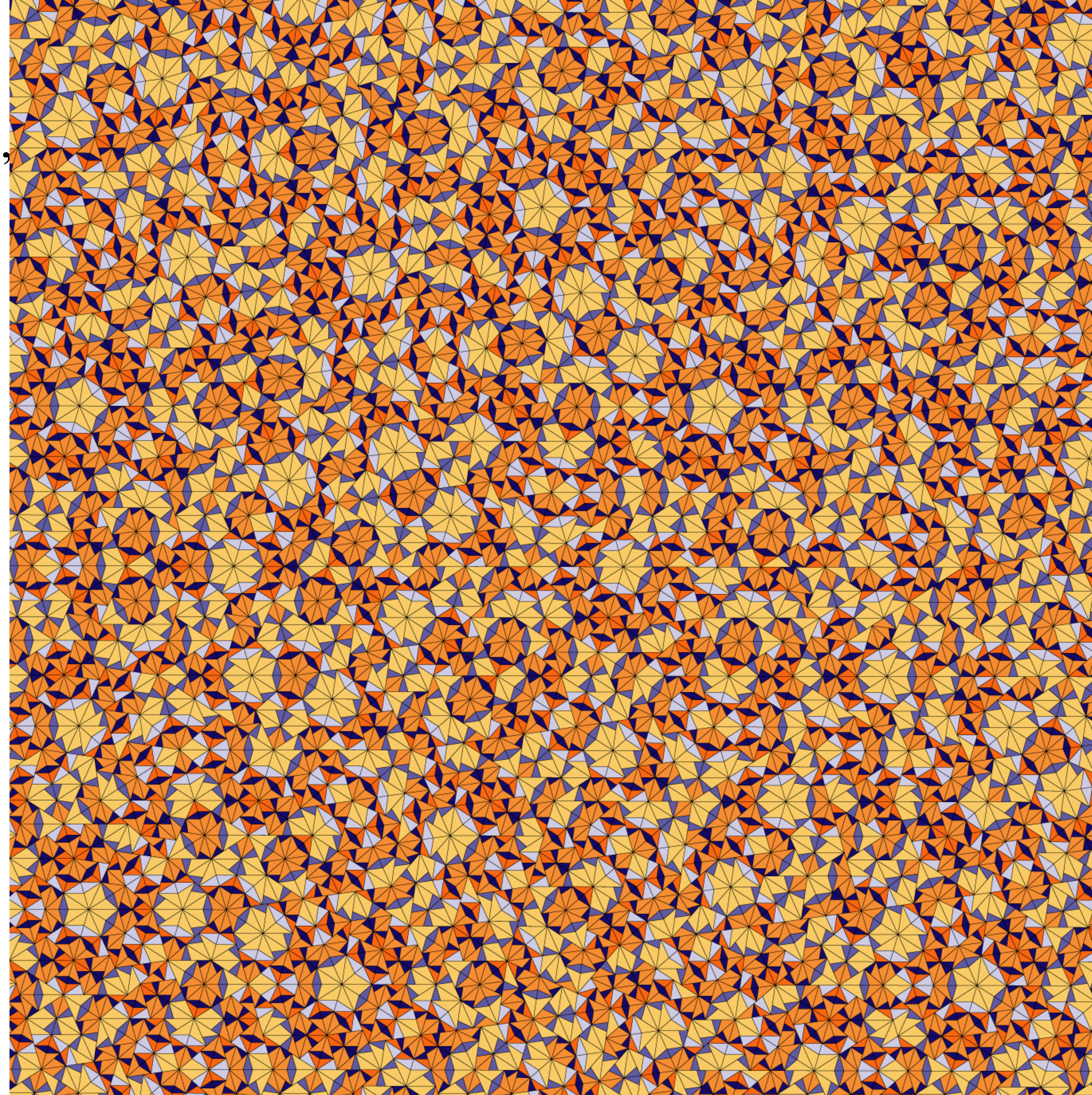


Aperiodic Tilings

"Cubic Pinwheel"

E. Harriss

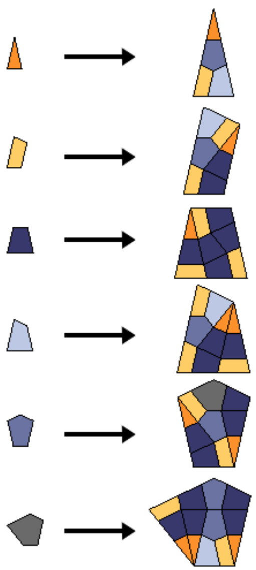


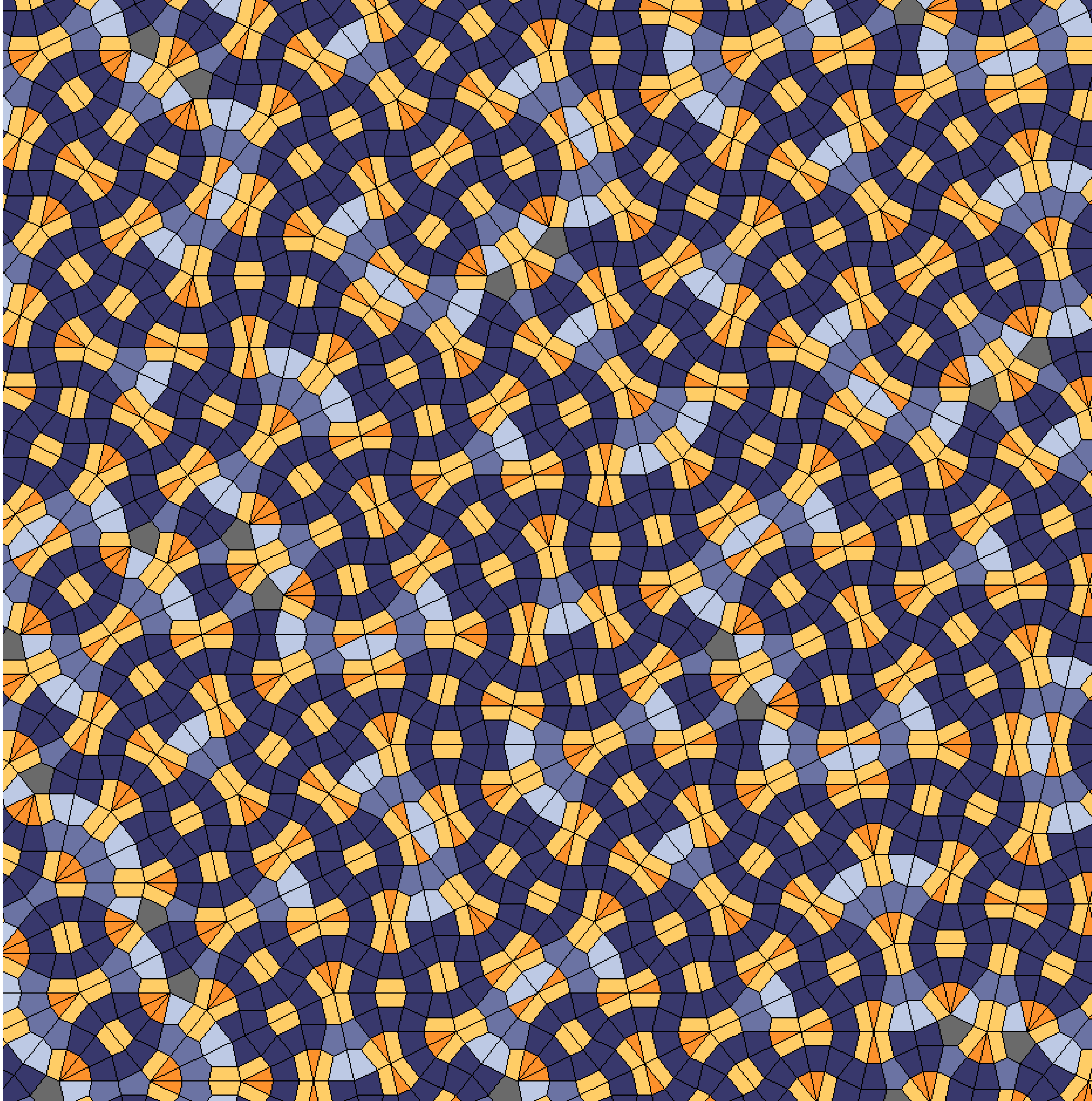


Aperiodic Tilings

"Cyclotomic rhombs 7-fold"

Ludwig Danzer and D. Frettlöh

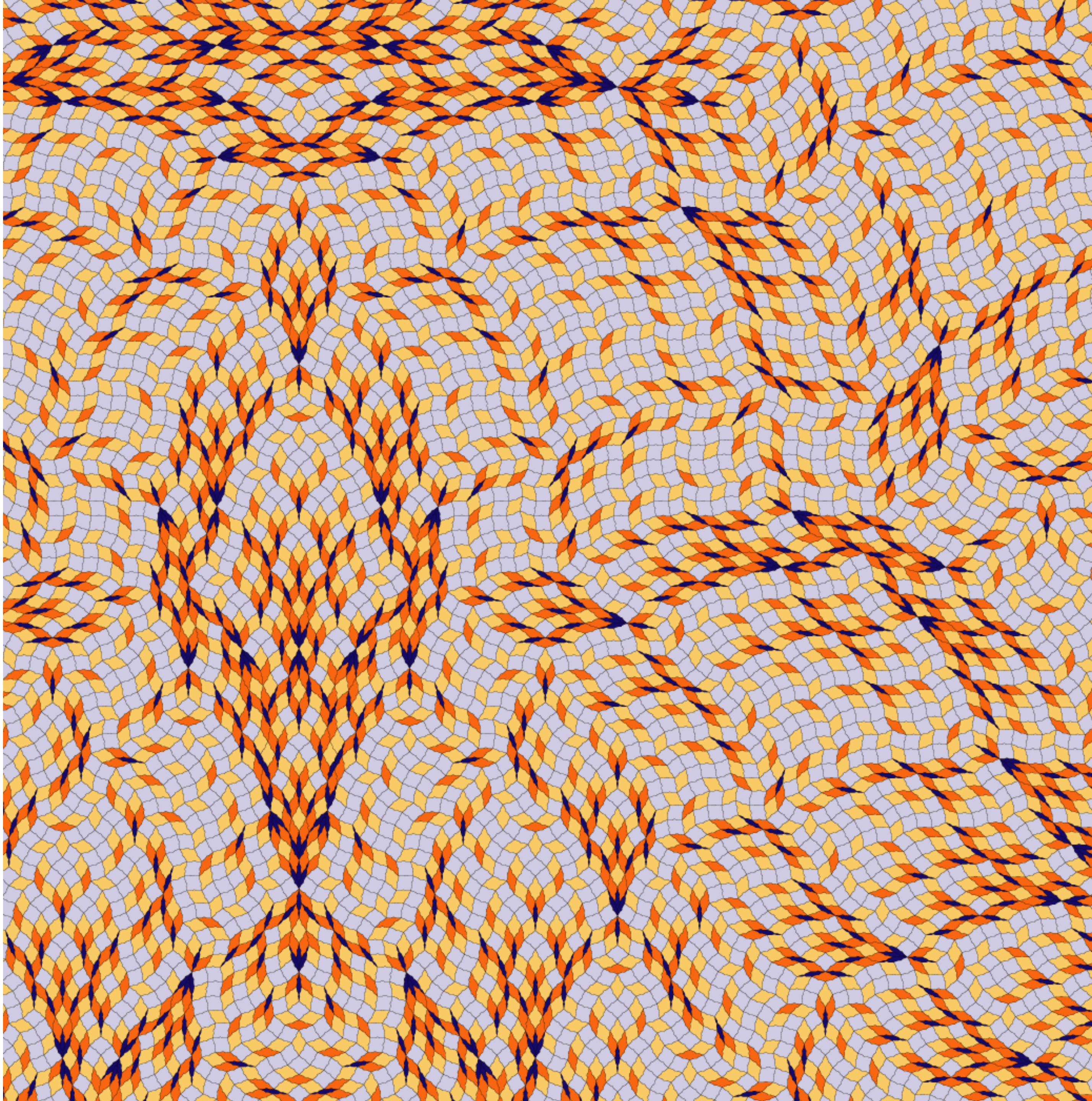




Aperiodic Tilings

“Harriss’s 9-fold rhomb”

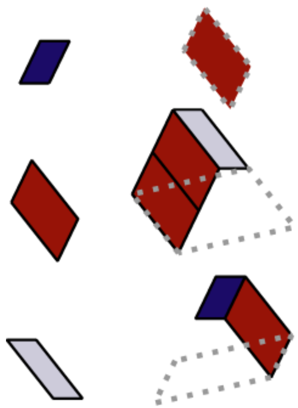
E. Harriss

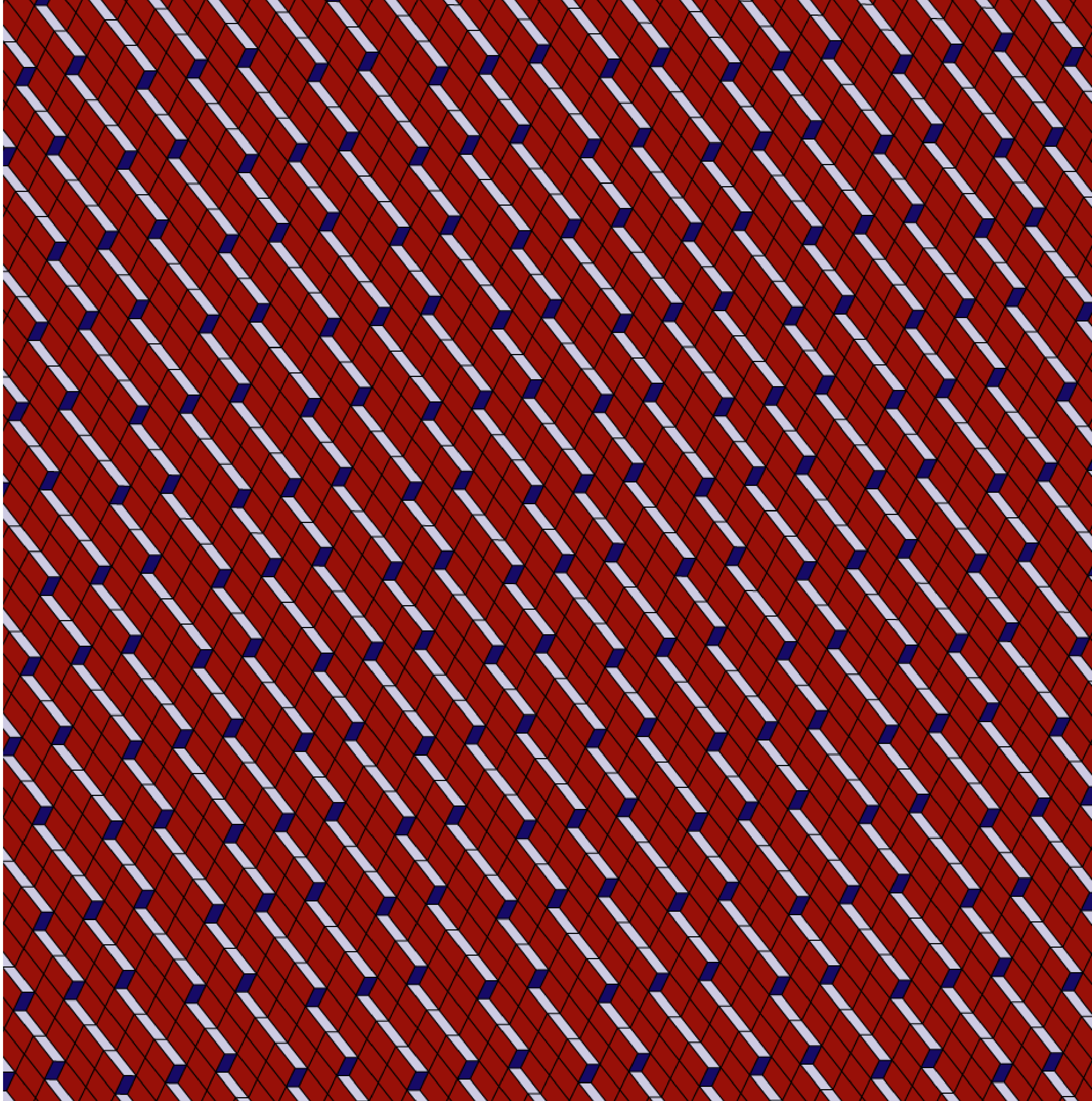


Aperiodic Tilings

"Kenyon (1,2,1) Polygon"

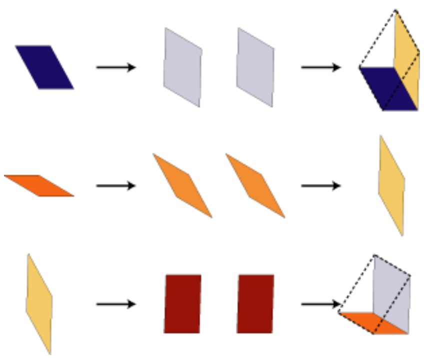
R. Kenyon

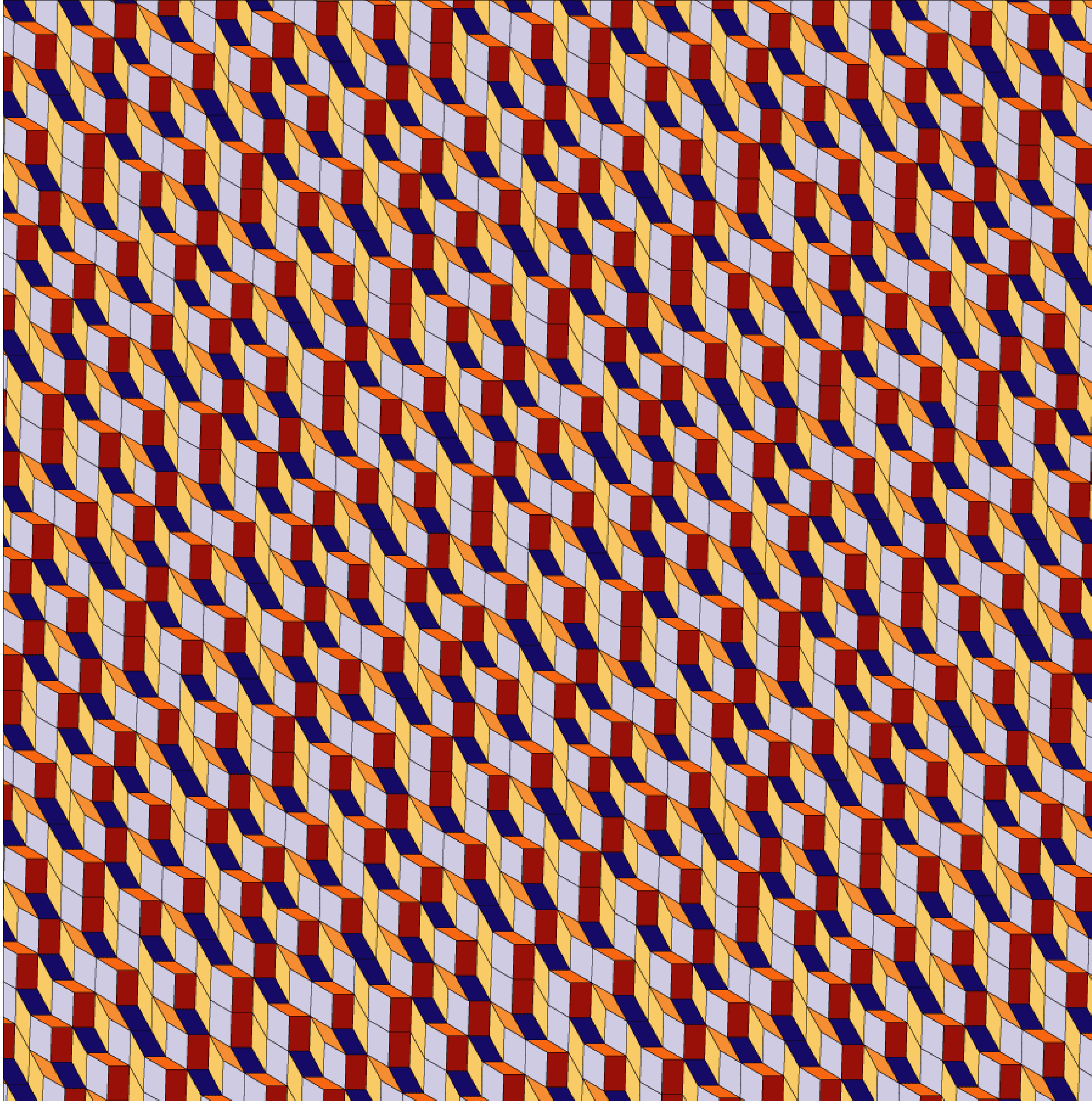




Aperiodic Tilings

“Nautilus”
P. Arnoux,
M. Furukado,
E. Harriss,
and S. Ito





Aperiodic Tilings

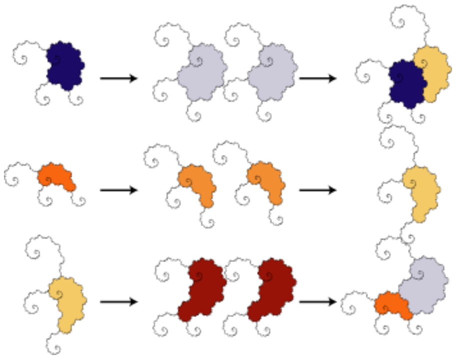
"Nautilus (volume hierarchic"

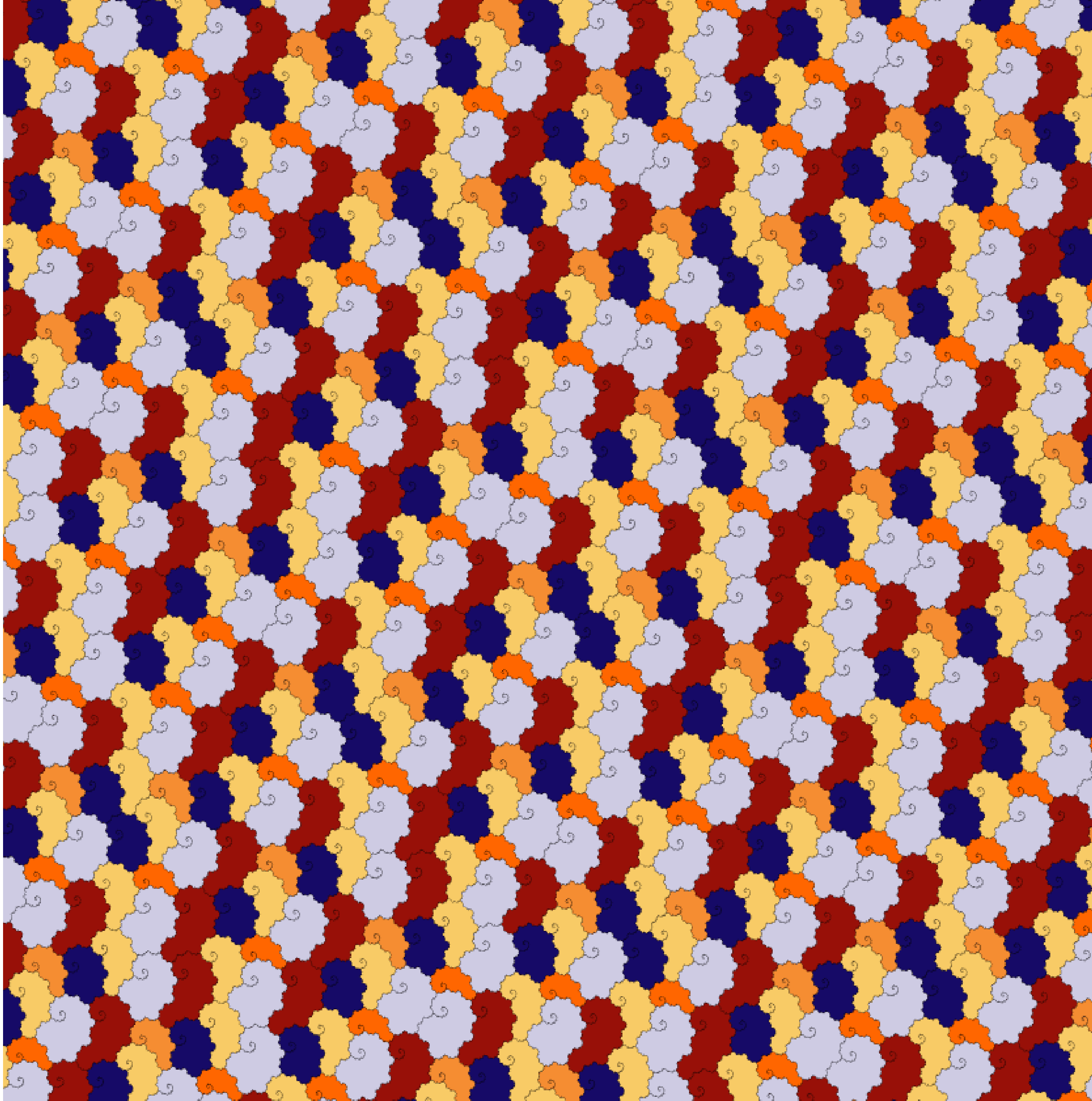
P. Arnoux,

M. Furukado,

E. Harriss,

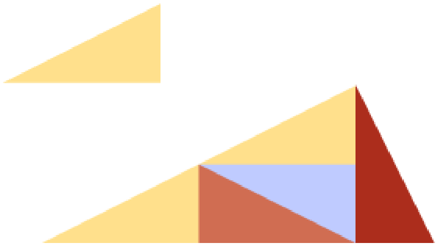
and S. Ito





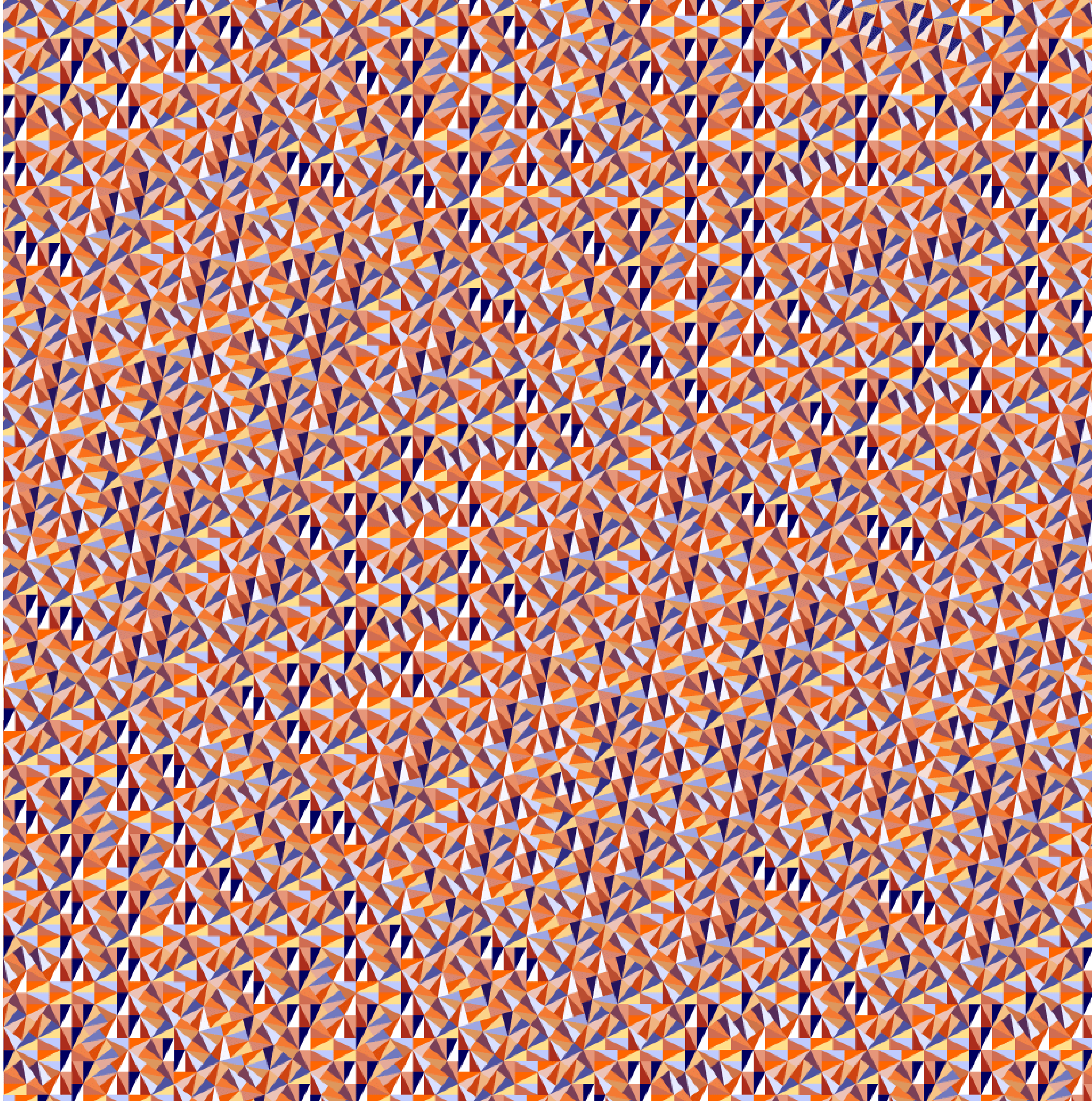
Aperiodic Tilings

“Pinwheel”
John Conway
and C. Radin



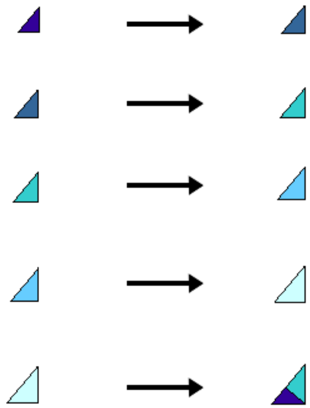
Tiles occur in infinitely many orientations!

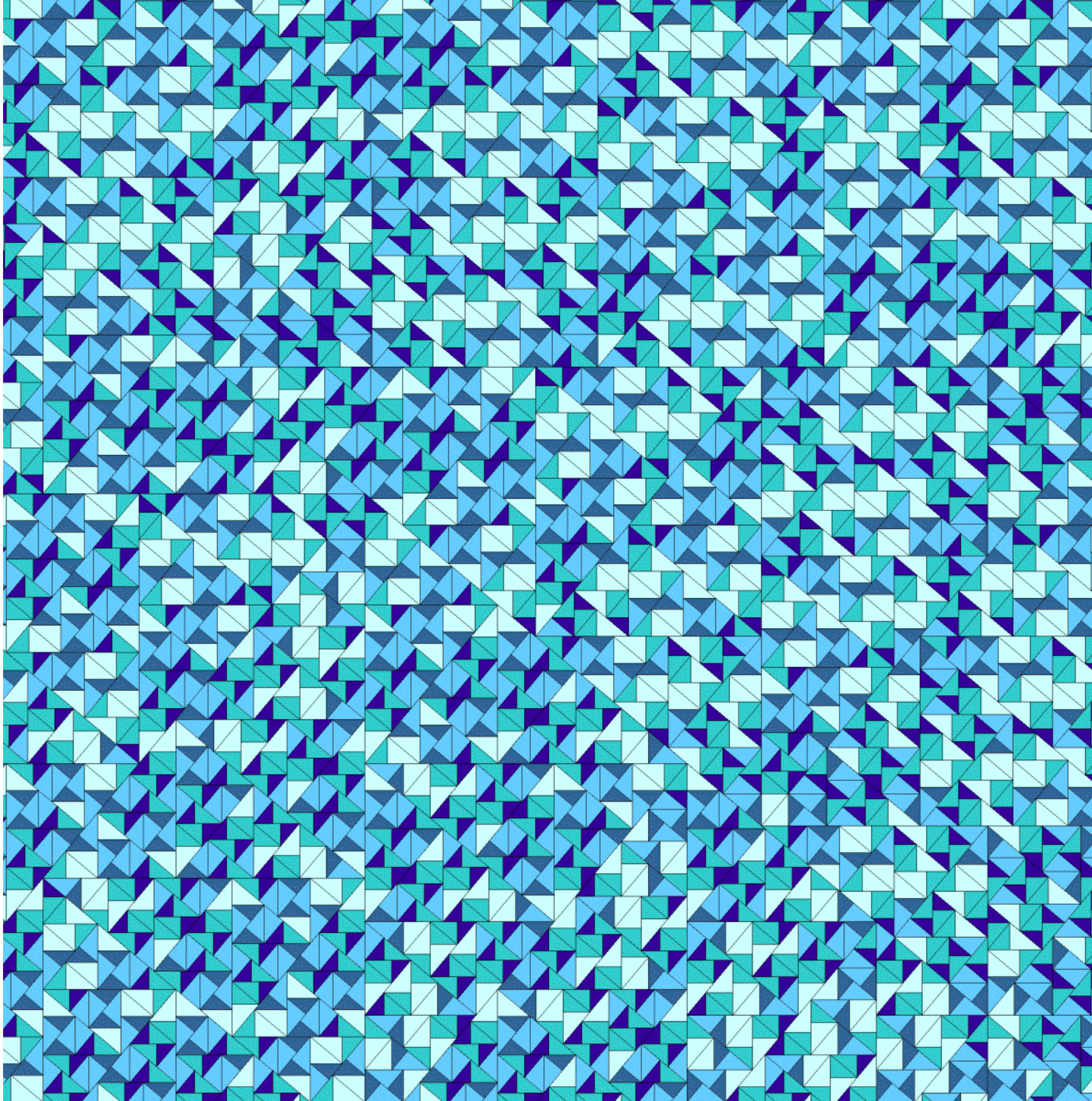
Despite irrational edge lengths and incommensurable angles, all vertices of tiles have rational coordinates!



Aperiodic Tilings

"Pythagoras-3-1"
J. Pieniak

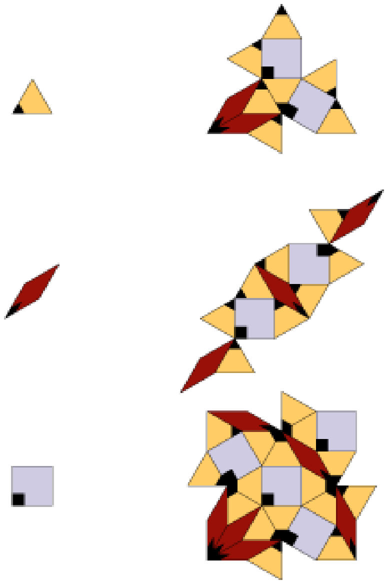




Aperiodic Tilings

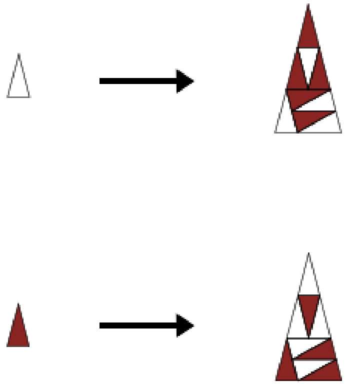
“Watanabe Ito
Soma 12-fold”

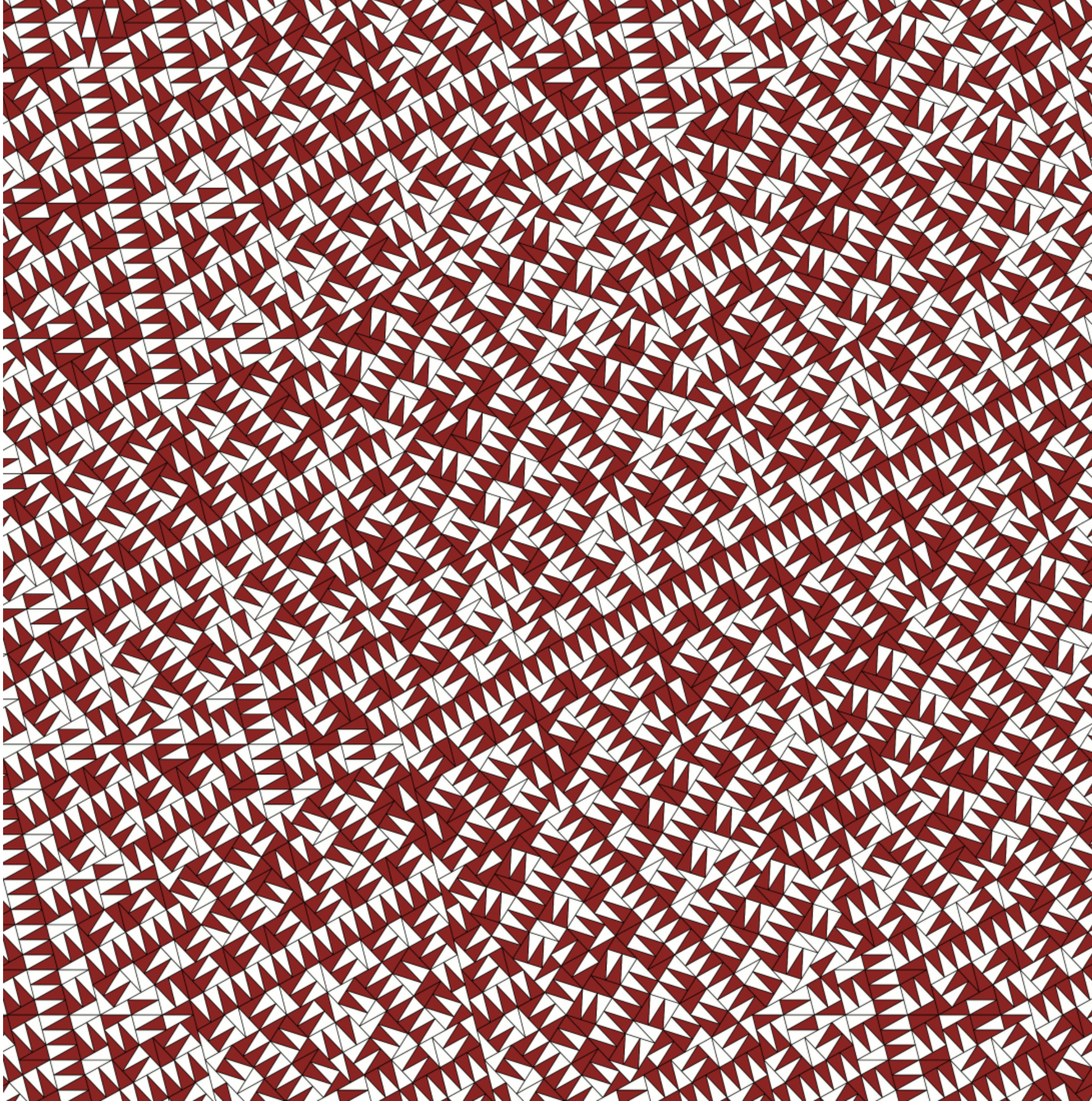
Y. Watanabe,
T. Soma and
M. Ito, 1995



Aperiodic Tilings

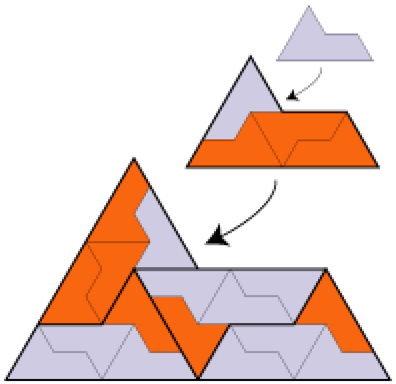
“Viper”

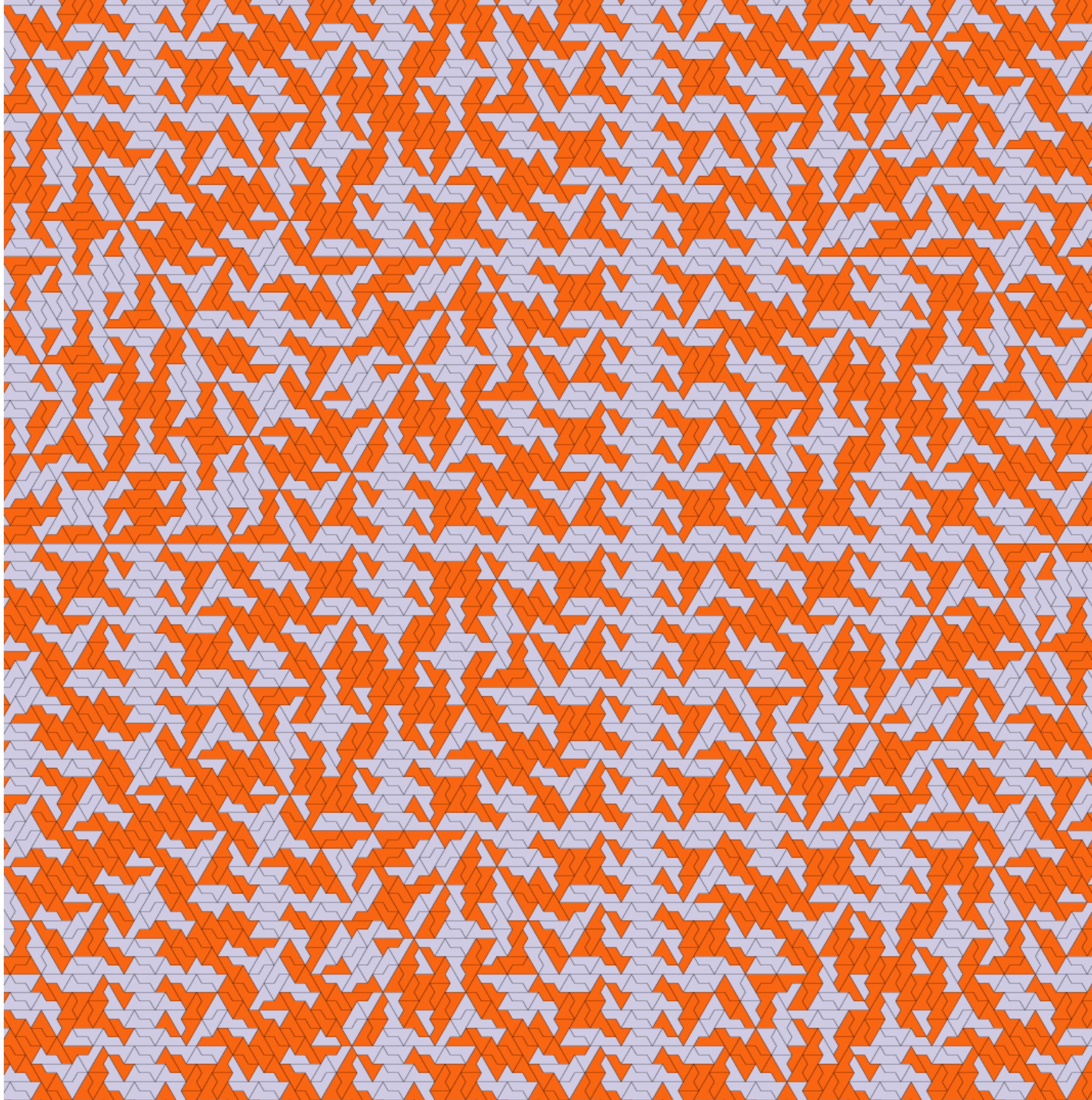




Aperiodic Tilings

“Sphinx”
J.-Y. Lee, and
R. V. Moody

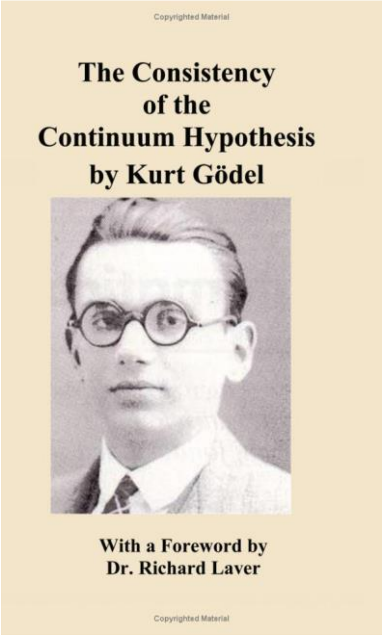


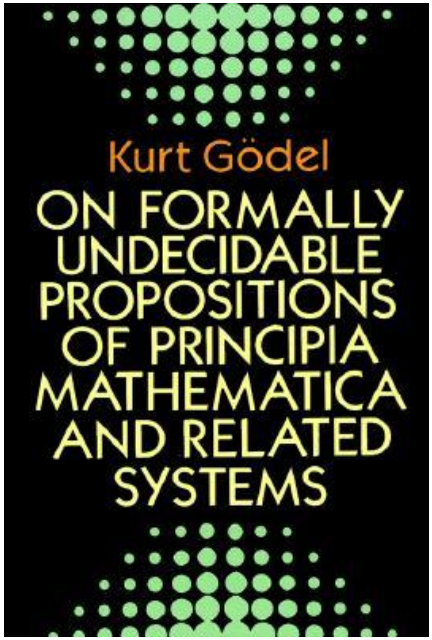


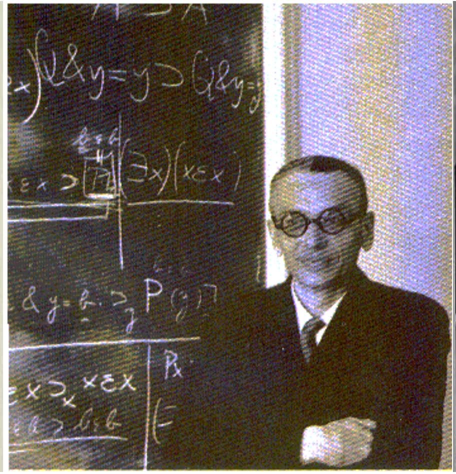
Historical Perspectives

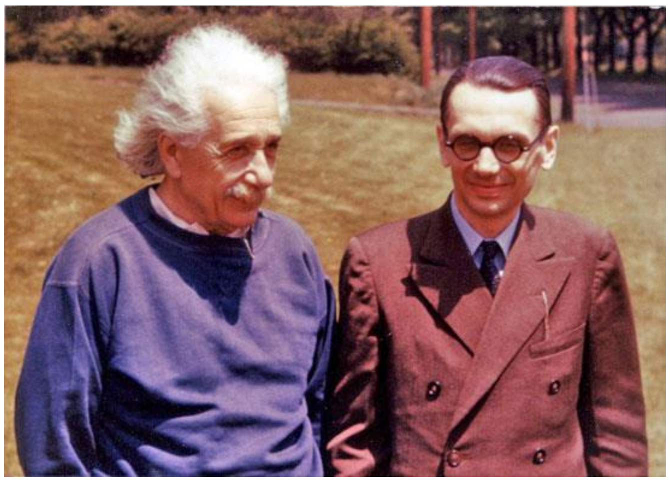
Kurt Gödel (1906-1978)

- Logician, mathematician, and philosopher
- Proved completeness of predicate logic and Gödel's incompleteness theorem
- Proved consistency of axiom of choice and the continuum hypothesis
- Invented "Gödel numbering" and "Gödel fuzzy logic"
- Developed "Gödel metric" and paradoxical relativity solutions: "Gödel spacetime / universe"
- Made enormous impact on logic, mathematics, and science





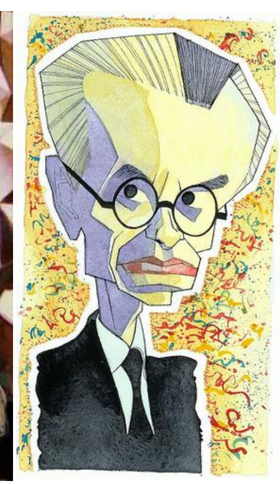
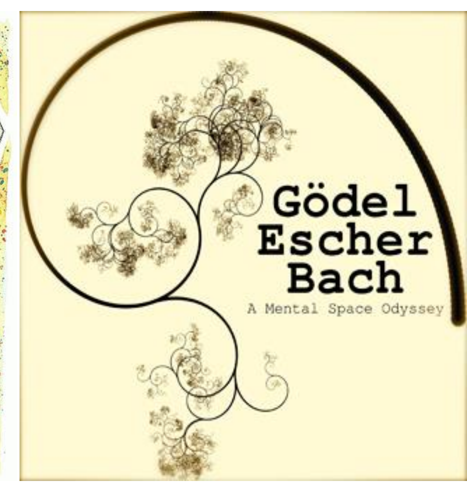



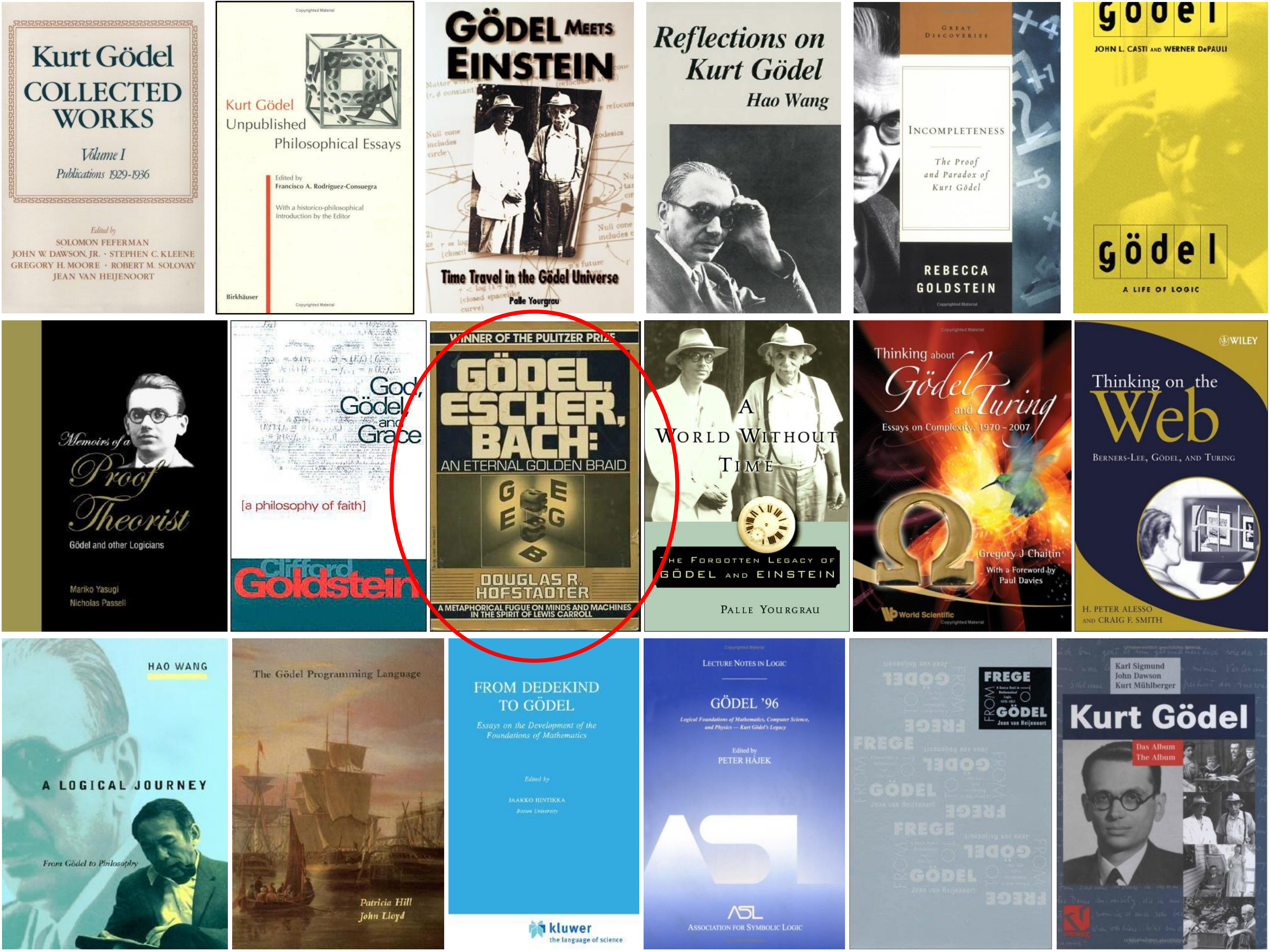





Kurt Gödel
1906 - 1978




Kurt Gödel
COLLECTED WORKS
Volume I
Publications 1929-1936
Edited by
SOLOMON FEFERMAN
JOHN W. DAWSON, JR. · STEPHEN C. KLEENE
GREGORY H. MOORE · ROBERT M. SOLOVAY
JEAN VAN HEIJENOORT
Kurt Gödel
Unpublished
Philosophical Essays
Edited by
Francisco A. Rodríguez-Consuegra
With a historico-philosophical Introduction by the Editor
Birkhäuser
GÖDEL MEETS EINSTEIN
Time Travel in the Gödel Universe
Palle Yourgrau
Reflections on Kurt Gödel
Hao Wang
GREAT DISCOVERIES
INCOMPLETENESS
The Proof and Paradox of Kurt Gödel
REBECCA GOLDSTEIN
JOHN L. CASTI AND WERNER DePAULI
gödel
A LIFE OF LOGIC
Memoirs of a Proof Theorist
Gödel and other Logicians
Mariko Yasugi
Nicholas Passell
God, Gödel and Grace
[a philosophy of faith]
Clifford Goldstein
WINNER OF THE PULITZER PRIZE
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AN ETERNAL GOLDEN BRAID
DOUGLAS R. HOFSTADTER
A METAPHORICAL FUGUE ON MINDS AND MACHINES IN THE SPIRIT OF LEWIS CARROLL
A WORLD WITHOUT TIME
THE FORGOTTEN LEGACY OF GÖDEL AND EINSTEIN
PALLE YOURGRAU
Thinking about Gödel and Turing
Essays on Complexity, 1970 – 2007
Gregory J Chaitin
With a Foreword by Paul Davies
World Scientific
WILEY
Thinking on the Web
BERNERS-LEE, GÖDEL, AND TURING
H. PETER ALESSO
AND CRAIG F. SMITH
HAO WANG
A LOGICAL JOURNEY
From Gödel to Philosophy
The Gödel Programming Language
Patricia Hill
John Lloyd
FROM DEDEKIND TO GÖDEL
Essays on the Development of the Foundations of Mathematics
Edited by
JAAKKO HINTIKKA
Boston University
kluwer
the language of science
LECTURE NOTES IN LOGIC
GÖDEL '96
Logical Foundations of Mathematics, Computer Science, and Physics — Kurt Gödel's Legacy
Edited by
PETER HÁJEK
ASL
ASSOCIATION FOR SYMBOLIC LOGIC
FROM FREGE TO GÖDEL
Jean van Heijenoort
Karl Sigmund
John Dawson
Kurt Mühlberger
Kurt Gödel
Das Album
The Album


GÖDEL'S PROOF
ERNEST NAGEL AND JAMES R. NEWMAN
Palle Yourgrau
Gödel, Einstein und die Folgen
Vermächtnis einer ungewöhnlichen Freundschaft
C.H. Beck
GÖDEL'S INCOMPLETENESS THEOREMS
RAYMOND M. SMULLYAN
Rebecca Goldstein
KURT GÖDEL
Jahrhundertmathematiker und großer Entdecker
PIPER
GODEL'S THEOREM SIMPLIFIED
Harry J. Gensler
UNIVERSITY PRESS OF AMERICA
Gödel, Putnam, and Functionalism
JEFF BUECHNER
forever UNDECIDED
A PUZZLE GUIDE TO GÖDEL
Raymond Smullyan
OXFORD
GÖDEL'S THEOREM
AN INCOMPLETE GUIDE TO ITS USE AND ABUSE
TORKEL FRANZÉN
Logical Dilemmas
THE LIFE AND WORK OF KURT GÖDEL
JOHN W. DAWSON, JR.
WADSWORTH PHILOSOPHERS SERIES
ON GÖDEL
JAAKKO HINTIKKA
CAMBRIDGE INTRODUCTIONS TO PHILOSOPHY
An Introduction to Gödel's Theorems
PETER SMITH
CAMBRIDGE
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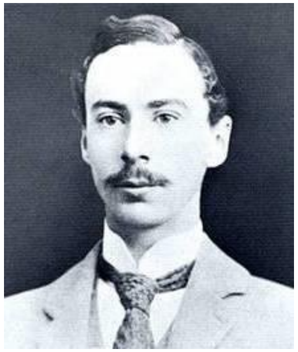
EINSTEIN, RUSSELL, GÖDEL, PAULI, and the End of Innocence in Science
BURTON FELDMAN
AUTHOR OF THE NOBEL PRIZE
John W. Dawson Jr.
Kurt Gödel: Leben und Werk
SpringerWienNewYork
KURT GÖDEL UND DIE MATHEMATISCHE LOGIK
EUROPOLIS 5
Werner DePauli-Schimanovich (Herausgeber: Franz Pichler)
Schriftenreihe GESCHICHTE DER NATURWISSENSCHAFTEN UND DER TECHNIK. Johannes Kepler Universität Linz. Universitätsverlag Rudolf Trauner
Band 122
Verena Huber-Dyson
Gödel's Theorems; a Workbook on Formalization
TEUBNER-TEXTE zur Mathematik
Frege and Godel
2 Fundamental Texts in Mathematical Logic
Jean van Heijenoort, Ed.
Gödel's Theorem in focus
Edited by S.G.SHANKER
Gödel: une révolution en mathématiques
Essai sur les conséquences scientifiques et philosophiques des théorèmes gödeliens
André Delessert
PRESSES POLYTECHNIQUES ET UNIVERSITAIRES ROMANDES

Gödel's Incompleteness Theorem


Frege & Russell:

- Mechanically verifying proofs
- Automatic theorem proving

A set of axioms is:

- Sound: iff only true statements can be proved
- Complete: iff any statement or its negation can be proved
- Consistent: iff no statement and its negation can be proved

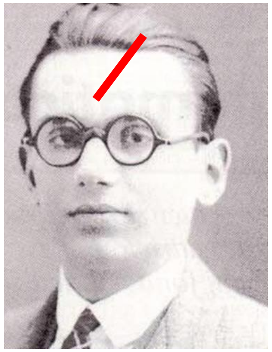
Hilbert's program: find an axiom set for all of mathematics
i.e., find a axiom set that is consistent and complete

Gödel: any consistent axiomatic system is incomplete!
(as long as it subsume elementary arithmetic)

i.e., any consistent axiomatic system must contain true but unprovable statements

Mathematical surprise: truth and provability are not the same!

Gödel's Incompleteness Theorem



That some axiomatic systems are incomplete is not surprising, since an important axiom may be missing (e.g., Euclidean geometry without the parallel postulate)

However, that every consistent axiomatic system must be incomplete was an unexpected shock to mathematics! This undermined not only a particular system (e.g., logic), but axiomatic reasoning and human thinking itself!

Truth = Provability

Justice ≠ Legality

Gödel's Incompleteness Theorem

Gödel: consistency or completeness - pick one!

Which is more important?

Incomplete: not all true statements can be proved.
But if useful theorems arise, the system is still useful.

Inconsistent: some false statement can be proved.
This can be catastrophic to the theory:

E.g., supposed in an axiomatic system we proved that "1=2".
Then we can use this to prove that, e.g., all things are equal!
Consider the set: {Trump, Pope}

$|\{\text{Trump}, \text{Pope}\}| = 2$

$\Rightarrow |\{\text{Trump}, \text{Pope}\}| = 1$ (since $1=2$)

$\Rightarrow$ Trump = Pope QED

$\Rightarrow$ All things become true: system is "complete" but useless!

The Kurt Gödel Society

Welcome

The Kurt Gödel Society was founded in 1987 and is chartered in Vienna. It is an international organization for the promotion of research in the areas of Logic, Philosophy, History of Mathematics, above all in connection with the biography of Kurt Gödel, and in other areas to which Gödel made contributions, especially mathematics, physics, theology, philosophy and Leibniz studies.

Top News

09-06-08 12:00

Fourth Vienna Tbilisi Summer School in Logic and Language

For the third time students and teachers meet in Tbilisi, Georgia, for a summer school. Please see the conference page http://www.logic.at/tbilisi08/ fo... [more...]

05-12-07 23:22

Collegium Logicum Lecture Series

6 December 2007, 16:00 Peter Schuster (LMU München) - Finite methods in commutative algebra [more...]

15-11-07 12:27

Workshop Two and beyond

The KGS is organizing a workshop on truth-functional logics. [more...]

Horizons of Truth
Gödel *Centenary* 2006

Horizons of Truth
Logics, Foundations of Mathematics, and the Quest for Understanding the Nature of Knowledge

Gödel Centenary 2006
An International Symposium Celebrating the 100th Birthday of Kurt Gödel

27.-29. April 2006
Festsaal of the University of Vienna

Print this page

Horizons of Truth

Logics, Foundations of Mathematics, and the Quest for Understanding the Nature of Knowledge

Gödel Centenary 2006

An International Symposium Celebrating the 100th Birthday of Kurt Gödel

27.-29. April 2006
***Festsaal* of the University of Vienna**

Organized by the Kurt Gödel Society with the support of the John Templeton Foundation. Co-organized by the University of Vienna, the Institute for Experimental Physics, the Kurt Gödel Research Center, the Institute Vienna Circle, and the Vienna University of Technology.

The purpose of the Symposium is to commemorate the life, work, and foundational views of Kurt Gödel, perhaps the greatest logician of the twentieth century. In the spirit of Gödel's work, the Symposium will also explore current research advances and ideas for future possibilities in the fields of the foundations of mathematics and logic. The symposium intends to put Gödel's ideas and works into a more general context in the light of current understanding and perception. The symposium will also present various implications of his work for other areas of intellectual endeavor such as artificial intelligence, cosmology, philosophy, and theology.

The Symposium will take place 27-29 April in the Celebration Hall of the University of Vienna, famous for its architectural beauty and the murals of Klimt. More than 20 lectures by eminent scientists in the fields of logics, mathematics, philosophy, physics, and theology will provide new insights into the life and work of Kurt Gödel and their implications for future generations.

Contributions

The program will contain

Talks by the invited speakers

John D. Barrow, Cambridge University, UK

Organized by:
The Kurt Gödel Society
Co-organized by:
University of Vienna, Institute for Experimental Physics, Kurt Gödel Research Center, Institute Vienna Circle, Vienna University of Technology,
Sponsored by:
The John Templeton Foundation
The Federation of Austrian Industry
The Federal Ministery of Infrastructure
The Federal Ministery of Education, Science and Culture
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The Austrian Mathematical Society
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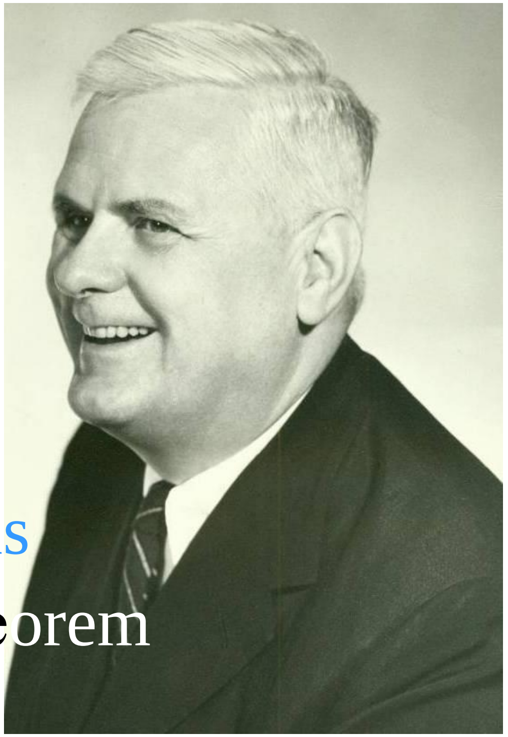
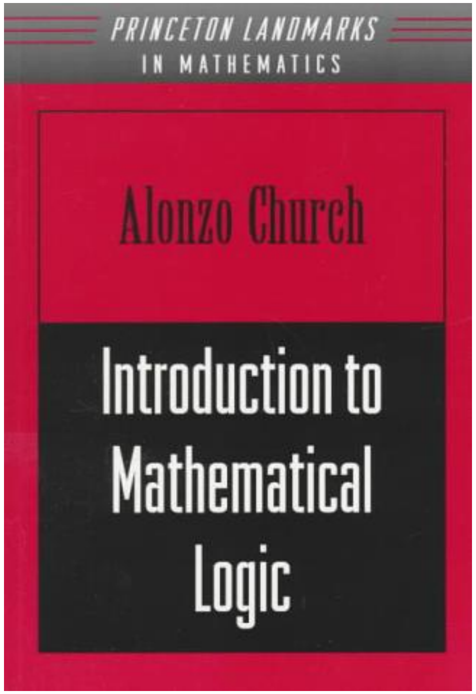
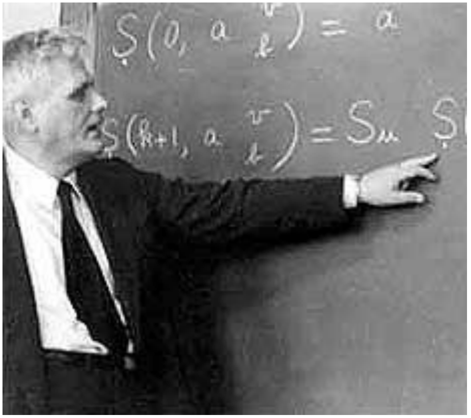
Historical Perspectives

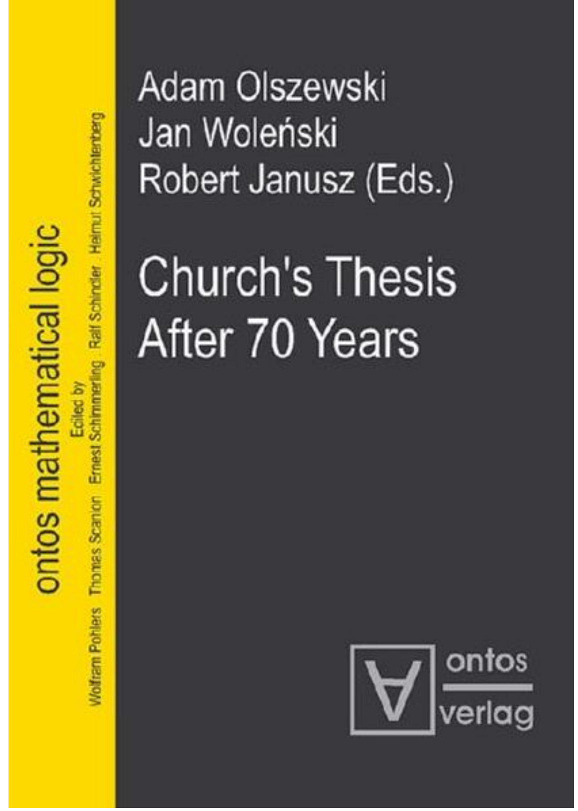


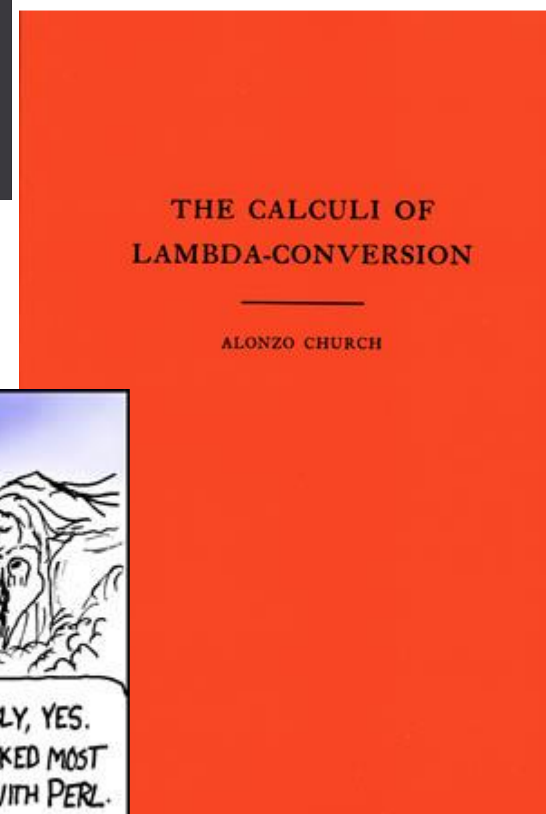
Alonzo Church (1903-1995)

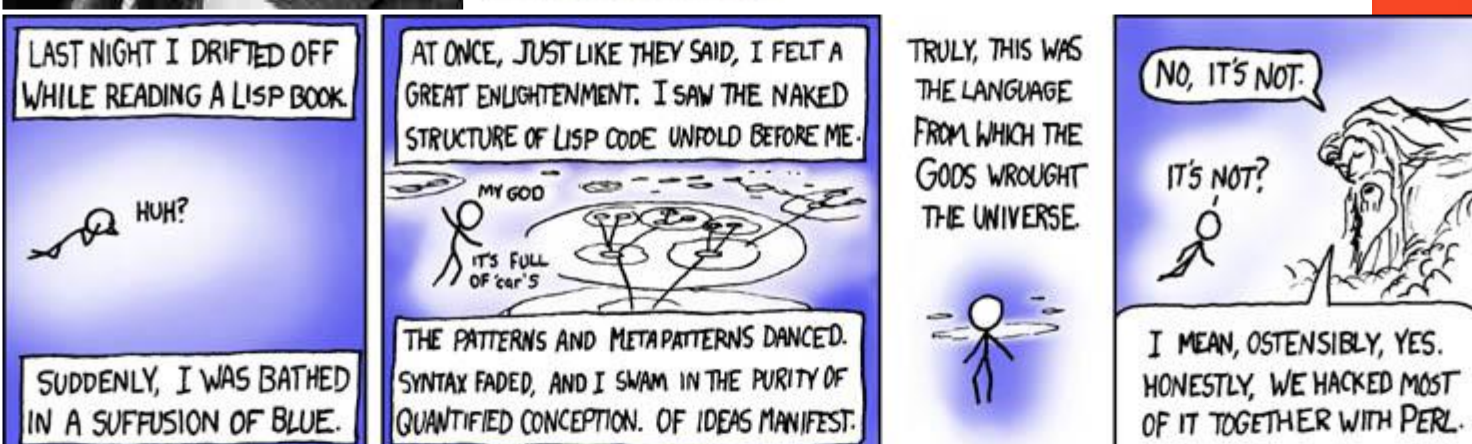
- Founder of theoretical computer science
- Made major contributions to logic
- Invented Lambda-calculus, Church-Turing Thesis
- Originated Church-Frege Ontology, Church's theorem Church encoding, Church-Kleene ordinal,
- Inspired LISP and functional programming
- Was Turing's Ph.D. advisor! Other students: Davis, Kleene, Rabin, Rogers, Scott, Smullyan
- Founded / edited Journal of Symbolic Logic
- Taught at UCLA until 1990; published "A Theory of the Meaning of Names" in 1995, at age 92!

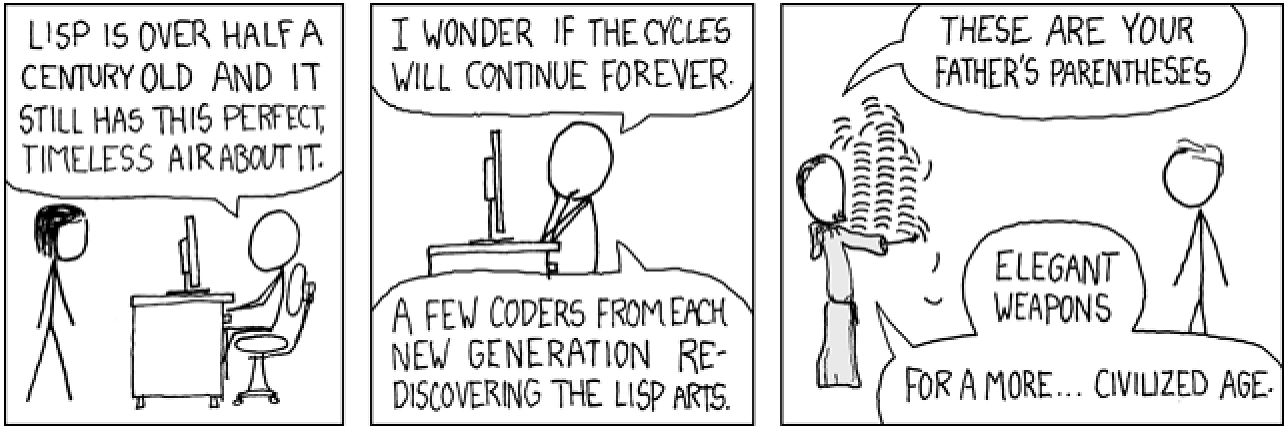


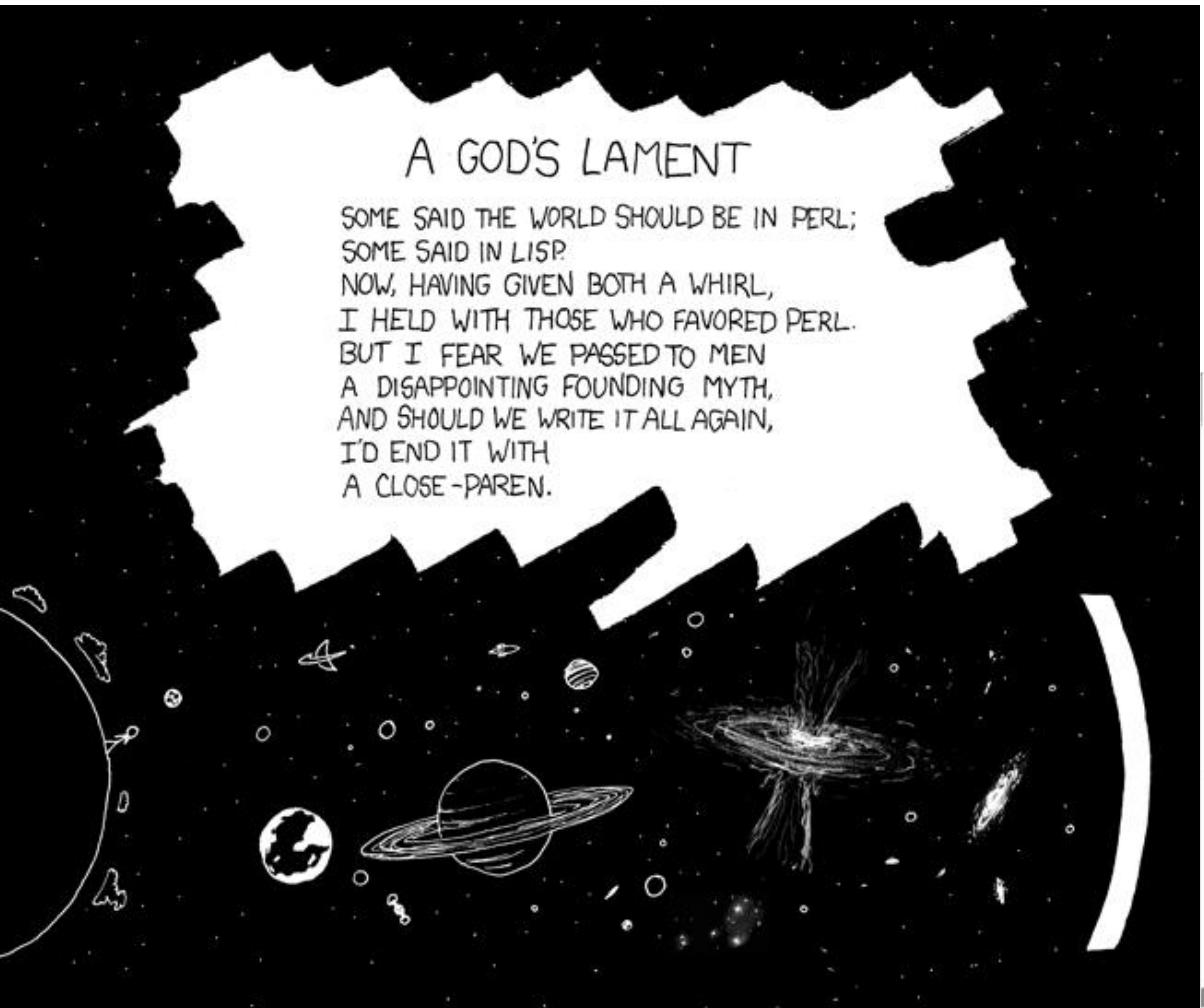


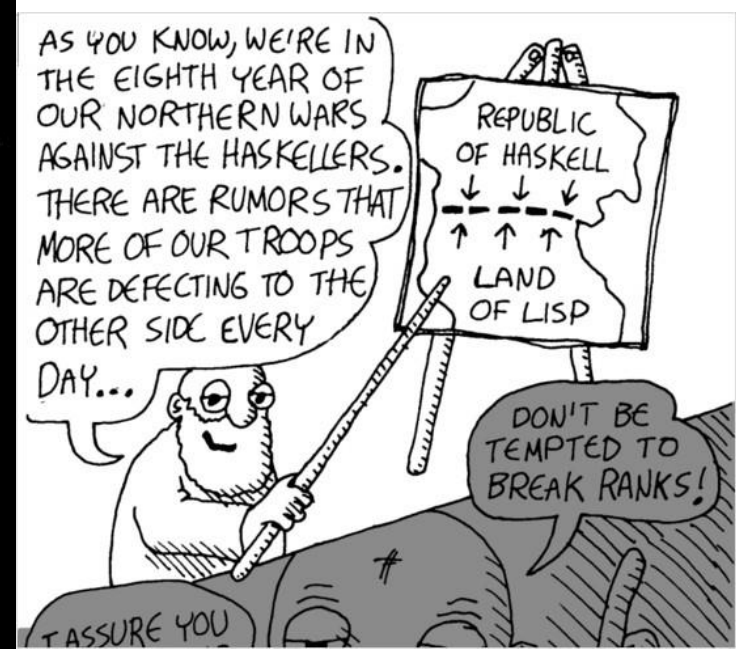

Adam Olszewski
Jan Woleński
Robert Janusz (Eds.)
Church's Thesis
After 70 Years
ontos mathematical logic
Edited by
Wolfram Pohlers · Thomas Scanlon · Ernest Schimmerling · Ralf Schindler · Helmut Schwichtenberg
ontos
verlag


THE CALCULI OF
LAMBDA-CONVERSION
ALONZO CHURCH


LAST NIGHT I DRIFTED OFF WHILE READING A LISP BOOK.
HUH?
SUDDENLY, I WAS BATHED IN A SUFFUSION OF BLUE.
AT ONCE, JUST LIKE THEY SAID, I FELT A GREAT ENLIGHTENMENT. I SAW THE NAKED STRUCTURE OF LISP CODE UNFOLD BEFORE ME.
MY GOD
IT'S FULL OF car'S
THE PATTERNS AND METAPATTERNS DANCED. SYNTAX FADED, AND I SWAM IN THE PURITY OF QUANTIFIED CONCEPTION. OF IDEAS MANIFEST.
TRULY, THIS WAS THE LANGUAGE FROM WHICH THE GODS WROUGHT THE UNIVERSE.
NO, IT'S NOT.
IT'S NOT?
I MEAN, OSTENSIBLY, YES. HONESTLY, WE HACKED MOST OF IT TOGETHER WITH PERL.


LISP IS OVER HALF A CENTURY OLD AND IT STILL HAS THIS PERFECT, TIMELESS AIR ABOUT IT.
I WONDER IF THE CYCLES WILL CONTINUE FOREVER.
A FEW CODERS FROM EACH NEW GENERATION RE-DISCOVERING THE LISP ARTS.
THESE ARE YOUR FATHER'S PARENTHESES
ELEGANT WEAPONS
FOR A MORE... CIVILIZED AGE.

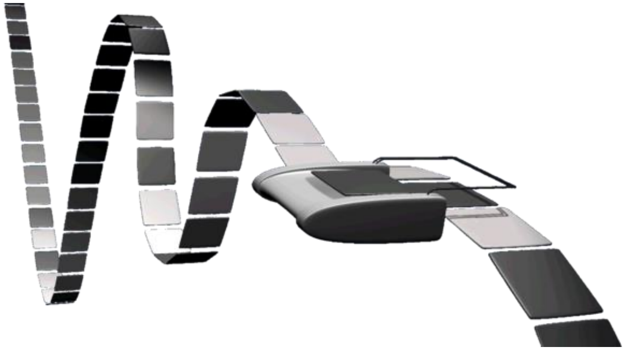

A GOD'S LAMENT
SOME SAID THE WORLD SHOULD BE IN PERL;
SOME SAID IN LISP.
NOW, HAVING GIVEN BOTH A WHIRL,
I HELD WITH THOSE WHO FAVORED PERL.
BUT I FEAR WE PASSED TO MEN
A DISAPPOINTING FOUNDING MYTH,
AND SHOULD WE WRITE IT ALL AGAIN,
I'D END IT WITH
A CLOSE-PAREN.


AS YOU KNOW, WE'RE IN THE EIGHTH YEAR OF OUR NORTHERN WARS AGAINST THE HASKELLERS. THERE ARE RUMORS THAT MORE OF OUR TROOPS ARE DEFECTING TO THE OTHER SIDE EVERY DAY...
REPUBLIC OF HASKELL
LAND OF LISP
DON'T BE TEMPTED TO BREAK RANKS!
I ASSURE YOU

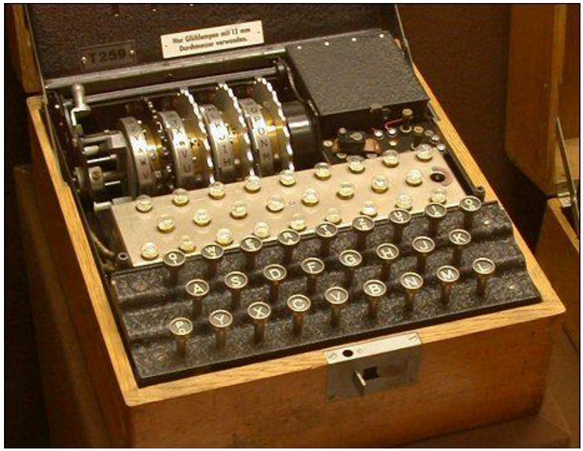
Historical Perspectives

Alan Turing (1912-1954)

- Mathematician, logician, cryptanalyst, and founder of computer science
- First to formally define computation / algorithm
- Invented the Turing machine model
  - theoretical basis of all modern computers



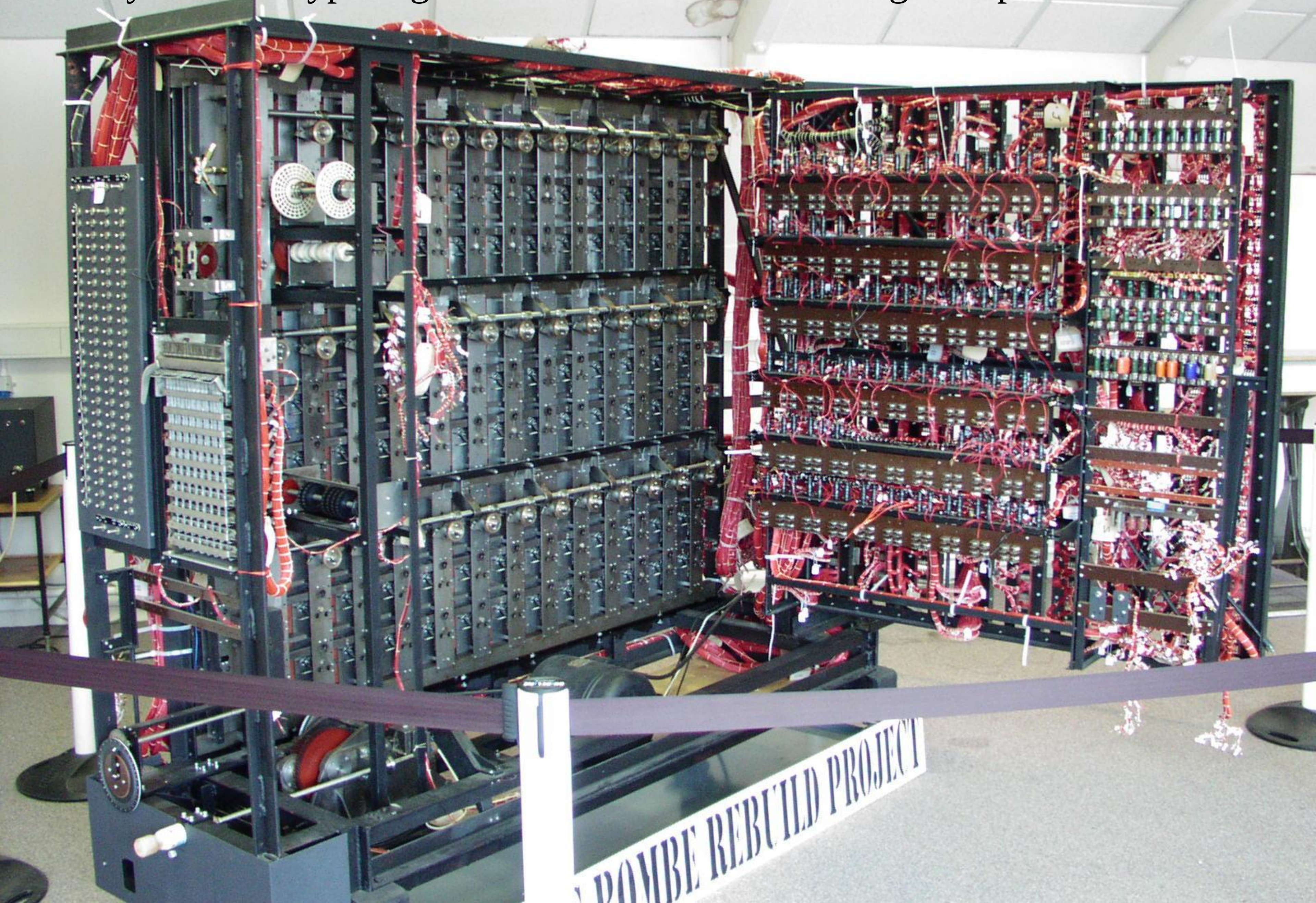
- Investigated computational "universality"
- Introduced "definable" real numbers
- Proved undecidability of halting problem
- Originated oracles and the "Turing test"
- Pioneered artificial intelligence
- Anticipated neural networks
- Designed the Manchester Mark 1 (1948)
- Helped break the German Enigma cypher
- Turing Award was created in his honor




THE
ALAN MATHISON TURING
ALAN TURING
1912 - 1954
Founder of computer science
and cryptographer, whose work
was key to breaking the
wartime Enigma codes,
lived and died here.

Bletchley Park ("Station X"), Bletchley, Buckinghamshire, England
England's code-breaking and cryptanalysis center during WWII

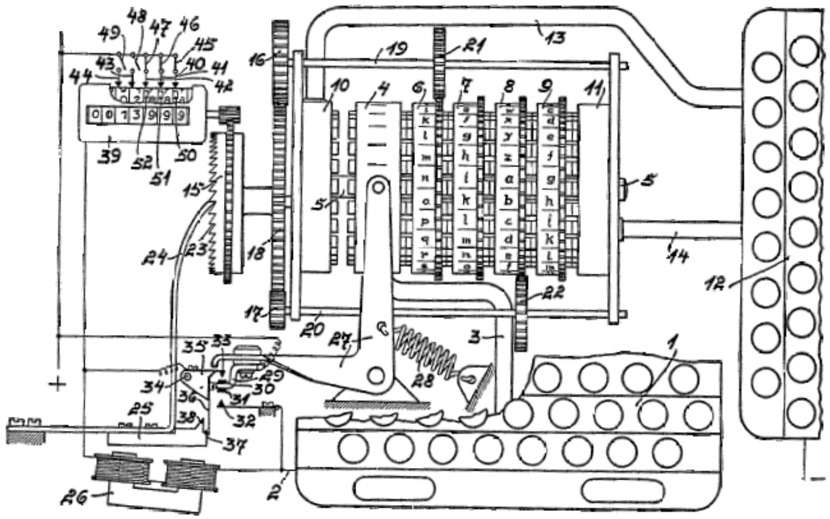
"Bombe" - electromechanical computer designed by Alan Turing.
Used by British cryptologists to break the German Enigma cipher



1918 First Enigma Patent

The official history of the Enigma starts in 1918, when the German **Arthur Scherbius** filed his first patent for the Enigma coding machine. It is listed as patent number 416219 in the archives of the German *Reichspatentamt* (patent office). Please note the time at which the Enigma was invented: **1918**, just after the First World War, more then 20 years before WWII! The image below clearly shows the coding wheels (rotors) in the centre part of the drawing. Below it is the keyboard and to the right is the lamp panel. At the top left is a counter, used to count the number of letters entered on the keyboard. This counter can still be found on certain Enigma models.

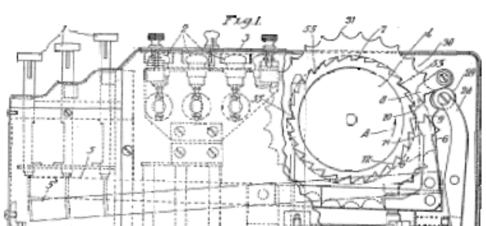
Arthur Scherbius' company **Securitas** was based in Berlin (Germany) and had an office in Amsterdam (The Netherlands). As he wanted to protect his invention outside Germany, he also registered his patent in the USA (1922), Great Britain (1923) and France (1923).

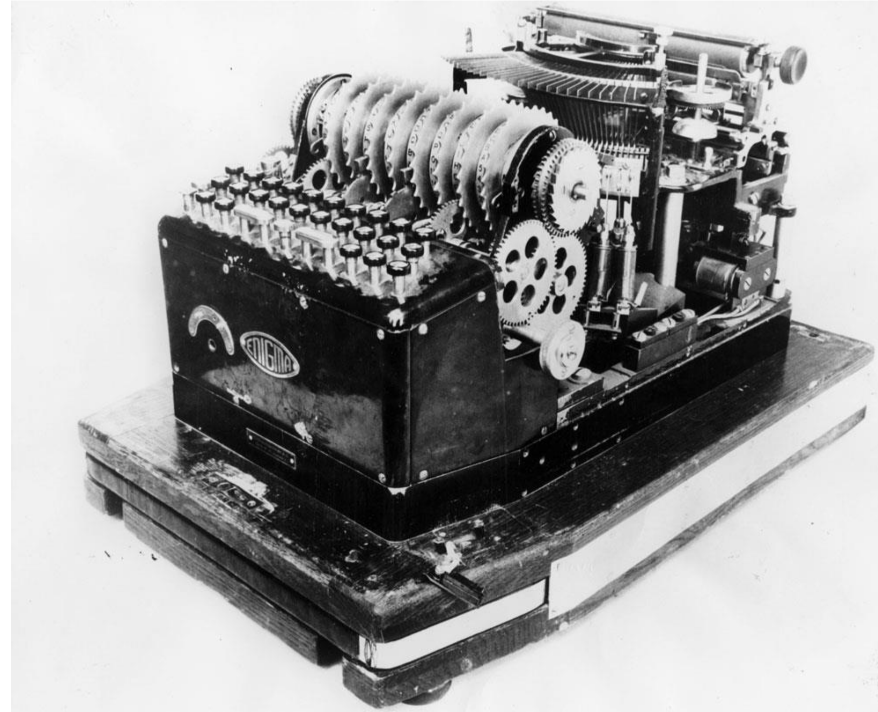


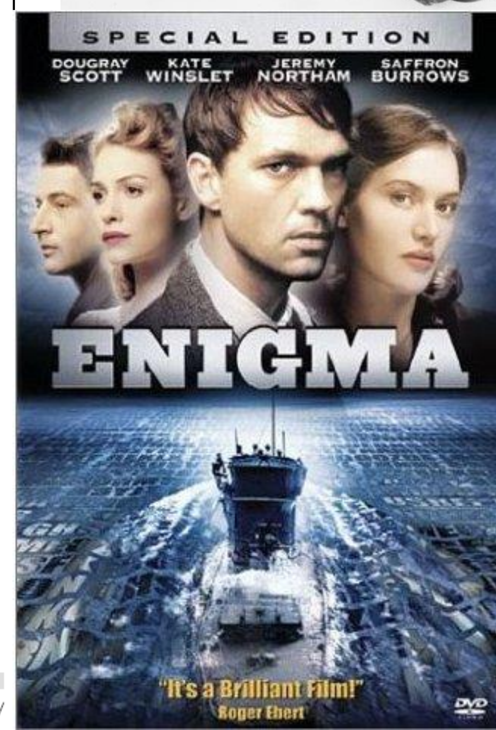
This image is taken from patent number 193,035 that was registered in Great Britain in 1923, long before WWII. It was also registered in a number of other countries, such as France and the USA.

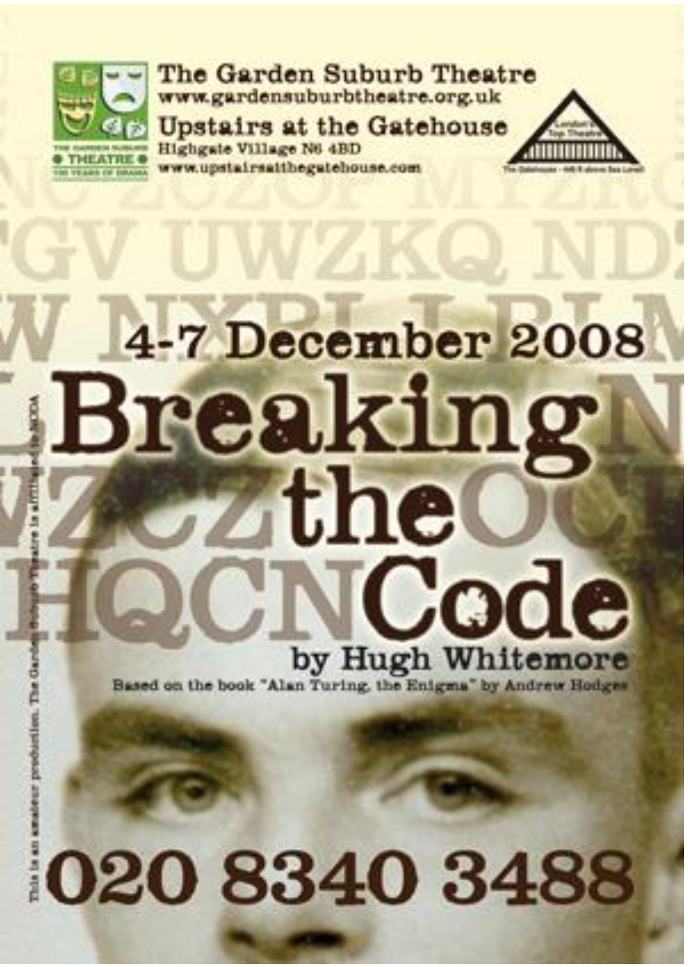
During the 1920s the Enigma was available as a commercial device, available for use by companies and embassies for their confidential messages. Remember that in those days, most companies had to use morse code and radio links for long distance communication. The devices were advertised having over 800.000 possibilities.

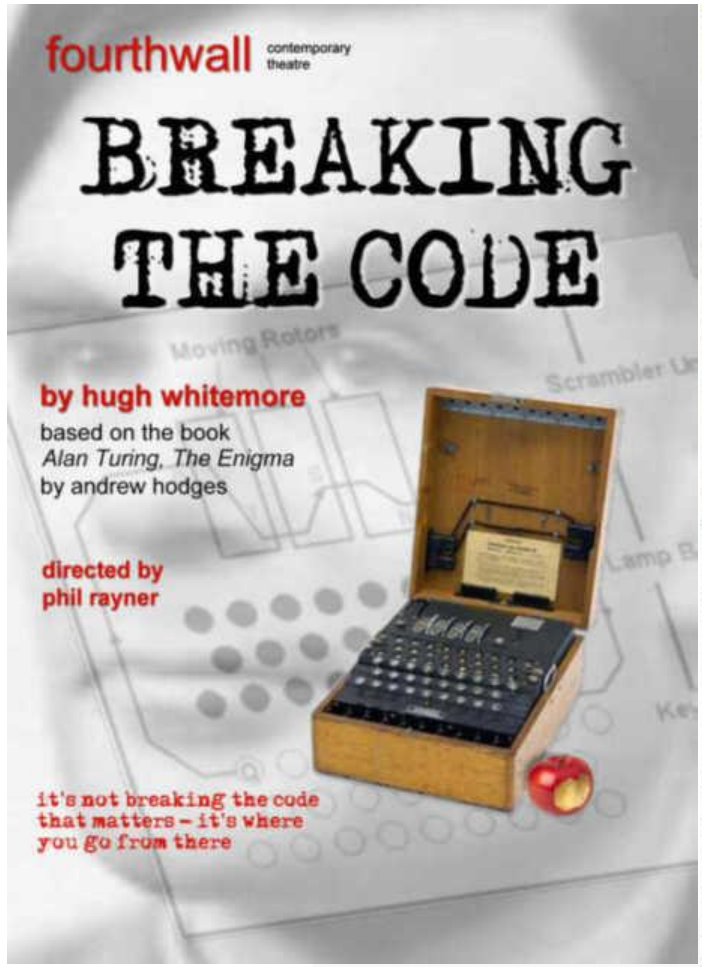
In the following years, additional patents with improvements of the coding machine were applied. E.g. in GB Patent 267,482, dated 17 Jan 1927, the Umkehrwalze was added and a later patent of 14 Nov 1929 (GB 343,146) claims the addition of the Ringstellung, multiple notches, etc. One of the drawings of that patent shows a coding device, that we now know as The Enigma, in great detail.

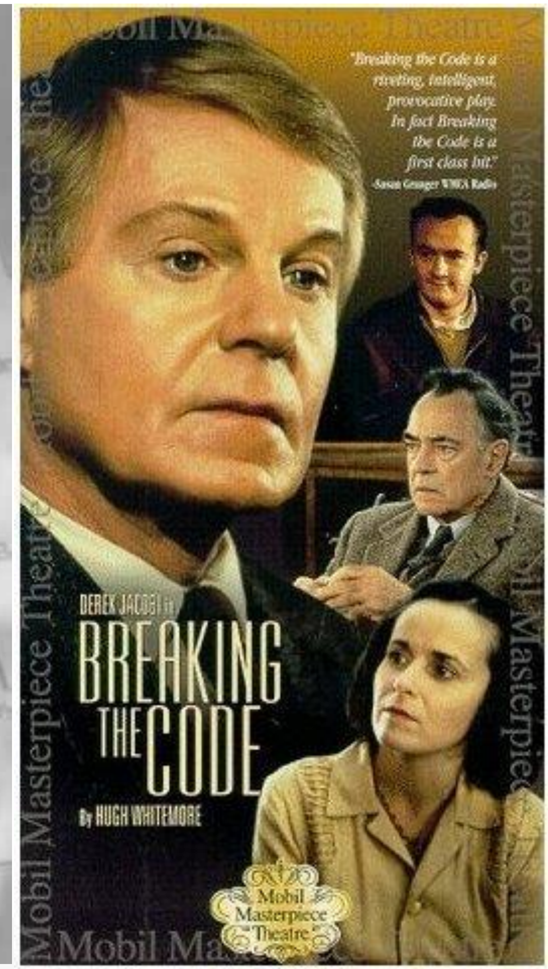


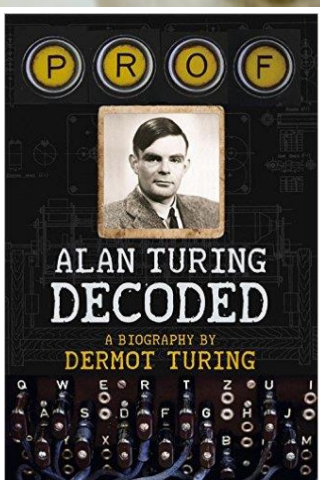





The Garden Suburb Theatre
www.gardensuburbtheatre.org.uk
Upstairs at the Gatehouse
Highgate Village N6 4BD
www.upstairsatthegatehouse.com
4-7 December 2008
Breaking the Code
by Hugh Whitemore
Based on the book "Alan Turing, the Enigma" by Andrew Hodges
020 8340 3488


fourthwall
contemporary theatre
BREAKING THE CODE
by hugh whitemore
based on the book
Alan Turing, The Enigma
by andrew hodges
directed by
phil rayner
it's not breaking the code
that matters – it's where
you go from there


"Breaking the Code is a riveting, intelligent, provocative play. In fact Breaking the Code is a first class hit."
DEREK JACOBI in
BREAKING THE CODE
By HUGH WHITEMORE
Mobil Masterpiece Theatre


P R O F
ALAN TURING
DECODED
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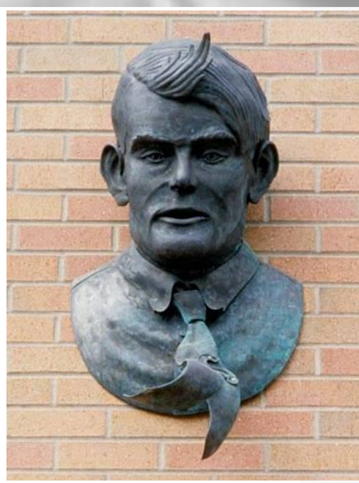

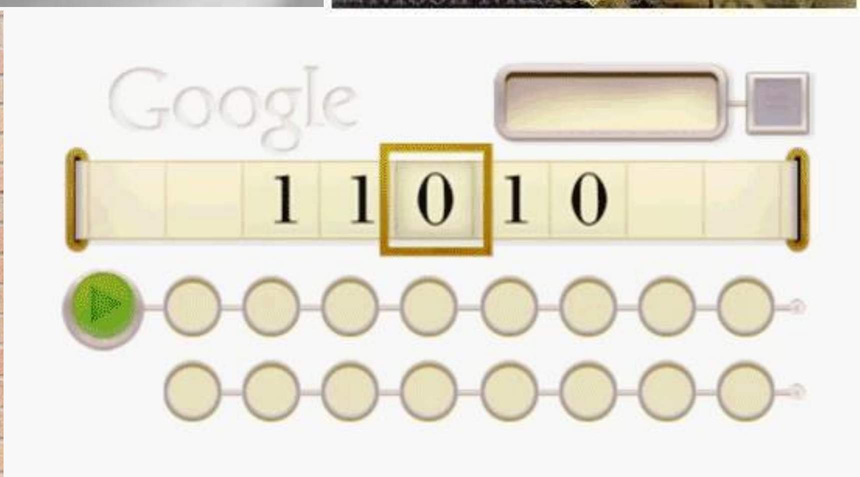
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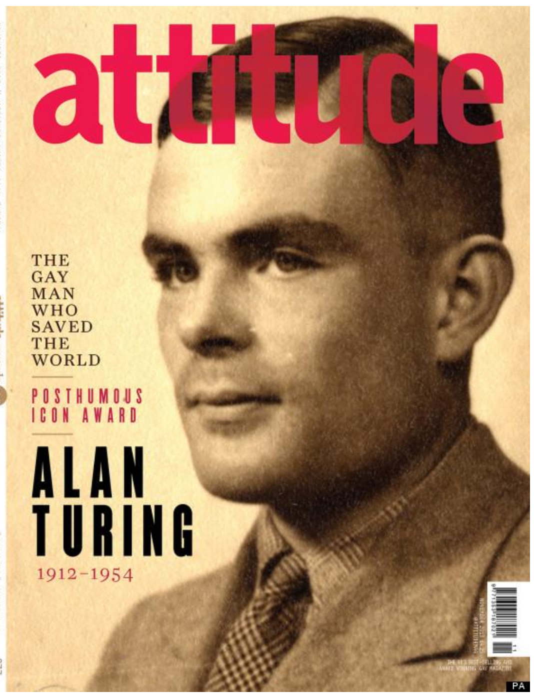
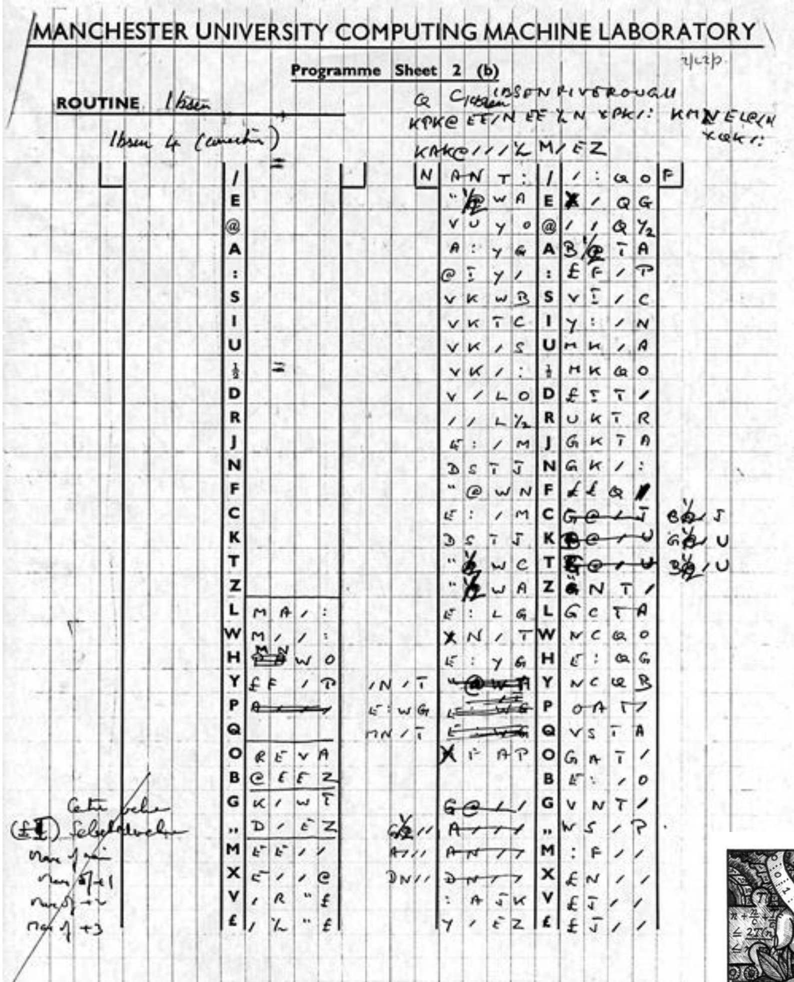
"BENEDICT CUMBERBATCH IS OUTSTANDING"
RADIO TIMES
"THE BEST BRITISH FILM OF THE YEAR"
★★★★★
THE INDEPENDENT
"AN INSTANT CLASSIC"
★★★★★
GLAMOUR
"A SUPERB THRILLER"
★★★★
EMPIRE
★★★★
TIME OUT
★★★★
THE TIMES
THE IMITATION GAME
BENEDICT CUMBERBATCH
KEIRA KNIGHTLEY
12A MODERATE SEX REFERENCES
BASED ON THE INCREDIBLE TRUE STORY
BLACK BEAR PICTURES PRESENTS IN ASSOCIATION WITH FILMNATION ENTERTAINMENT A BLACK BEAR PICTURES PRODUCTION A BRISTOL AUTOMOTIVE PRODUCTION "THE IMITATION GAME" BENEDICT CUMBERBATCH KEIRA KNIGHTLEY MATTHEW GOODE RORY KINNEAR
WITH CHARLES DANCE AND MARK STRONG NINA GOLD IVANA PRIMORAC SAMMY SHELDON DIFFER MARIA DJURKOVIC ALEXANDRE DESPLAT WILLIAM GOLDENBERG, A.C.E. ÓSCAR FAURA PETER HESLOP GRAHAM MOORE
NORA GROSSMAN p.g.a. IDO OSTROWSKY p.g.a. TEDDY SCHWARZMAN p.g.a. GRAHAM MOORE MORTEN TYLDUM
FILMNATION
STUDIOCANAL
/ImitationGameUK
IN CINEMAS NOVEMBER 14

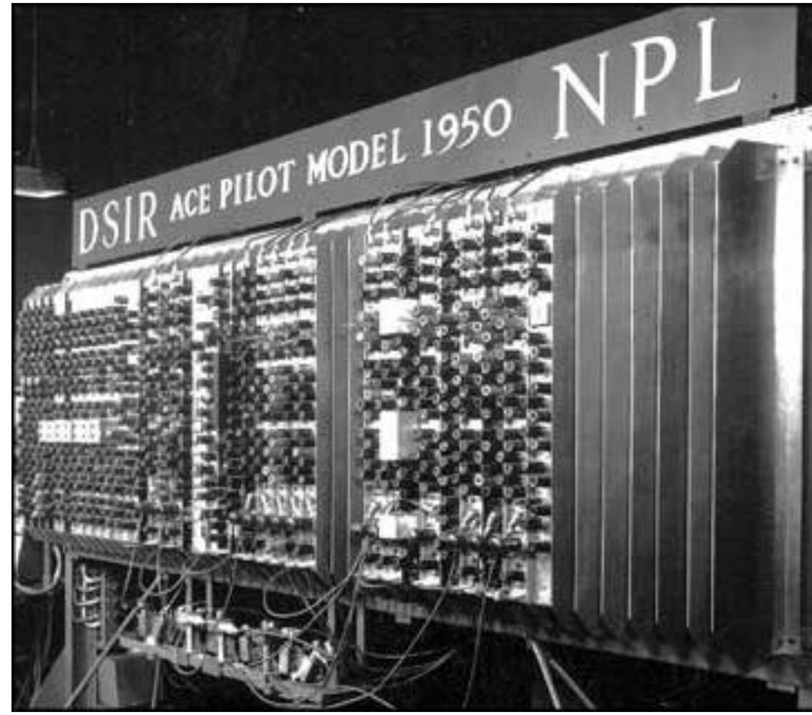

attitude
THE GAY MAN WHO SAVED THE WORLD
POSTHUMOUS ICON AWARD
ALAN TURING
1912–1954
PA

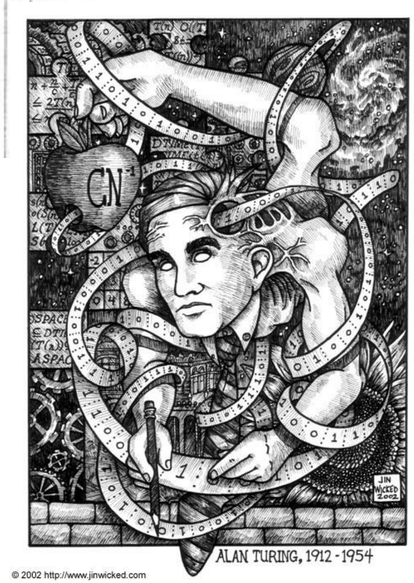

DOUBLE ISSUE
DEC. 1 / DEC. 8, 2014
The Genius Issue
TIME
INVENTING THE FUTURE
BY WALTER ISAACSON
BENEDICT CUMBERBATCH
ON PLAYING CODE BREAKER ALAN TURING IN 'THE IMITATION GAME'
PAGE 70
PLUS
THE 25 BEST INVENTIONS OF 2014
(NOT INCLUDING THIS MACHINE)
PAGE 68
time.com

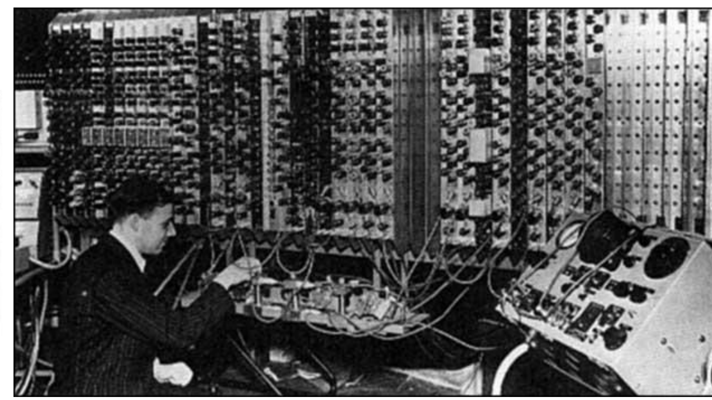

Iran's Middle Man / The U.S. of Texas / Bridget Jones Returns
TIME
PLAYING GENIUS
A string of breakout roles—from Sherlock to Khan to Assange—is turning Benedict Cumberbatch into the thing he most fears: a star



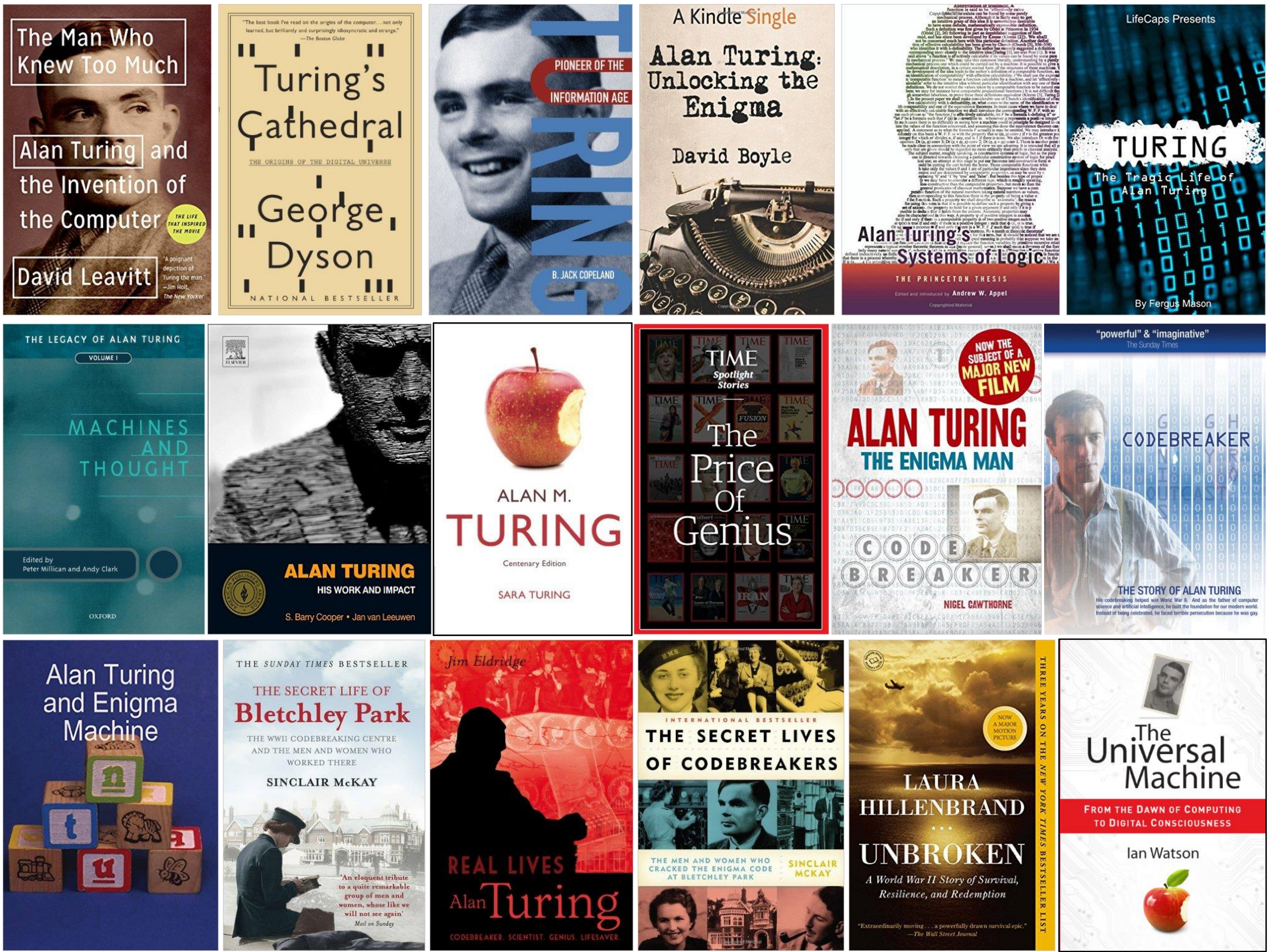
Program for ACE computer
hand-written by Alan Turing








CHARLES PETZOLD
THE ANNOTATED TURING
A Guided Tour through Alan Turing's Historic Paper on Computability and the Turing Machine
EDITED BY B. JACK COPELAND
THE ESSENTIAL TURING
The ideas that gave birth to the computer age
ALAN TURING: THE ENIGMA
"One of the finest scientific biographies I've ever read: authoritative, superbly researched, deeply sympathetic and beautifully told." —SYLVIA NASAR, author of A Beautiful Mind
ANDREW HODGES
Foreword by DOUGLAS HOFSTADTER
WITH A NEW PREFACE
THE UNIVERSAL COMPUTER
THE ROAD FROM LEIBNIZ TO TURING
MARTIN DAVIS
ALAN TURING'S AUTOMATIC COMPUTING ENGINE
EDITED BY B. JACK COPELAND
OXFORD
PROFILES IN MATHEMATICS
Alan Turing
Jim Corrigan
Christof Teuscher (Ed.)
Alan Turing: Life and Legacy of a Great Thinker
Springer
A MADMAN DREAMS OF Turing Machines
a novel
by Janna Levin
Turing
(A Novel about Computation)
Christos H. Papadimitriou
The Turing Test and the Frame Problem
AI's Mistaken Understanding of Intelligence
Larry J. Crockett
MAKERS OF MODERN SCIENCE
ALAN TURING
Computing Genius and Wartime Codebreaker
RAY SPANGENBURG AND DIANE KIT MOSER
THE GREAT PHILOSOPHERS
TURING
Andrew Hodges
THE NEW TURING OMNIBUS
66 EXCURSIONS IN COMPUTER SCIENCE
A.K.DEWDNEY
DAVID LEAVITT
Alan Turing and the Invention of the Computer
THE MAN WHO KNEW TOO MUCH
GREAT DISCOVERIES
The Universal Turing Machine
A Half-Century Survey
Edited by Rolf Herken
Springer-Verlag Wien New York
ALAN TURING
The ARCHITECT of the COMPUTER Age
by TED GOTTFRIED
THE BIG iDEA
TURING AND THE COMPUTER
PAUL STRATHERN
Turing and the Universal Machine
Jon Agar
The Making of the Modern Computer


The Man Who Knew Too Much
Alan Turing and the Invention of the Computer
THE LIFE THAT INSPIRED THE MOVIE
David Leavitt
"A poignant depiction of Turing the man." —Jim Holt, The New Yorker
Turing's Cathedral
THE ORIGINS OF THE DIGITAL UNIVERSE
George Dyson
NATIONAL BESTSELLER
TURING
PIONEER OF THE INFORMATION AGE
B. JACK COPELAND
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David Boyle
Alan Turing's Systems of Logic
THE PRINCETON THESIS
Edited and introduced by Andrew W. Appel
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TURING
The Tragic Life of Alan Turing
By Fergus Mason
THE LEGACY OF ALAN TURING
VOLUME I
MACHINES AND THOUGHT
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CODE BREAKER
NIGEL CAWTHORNE
"powerful" & "imaginative"
The Sunday Times
CODEBREAKER
THE STORY OF ALAN TURING
Alan Turing and Enigma Machine
THE SUNDAY TIMES BESTSELLER
THE SECRET LIFE OF Bletchley Park
THE WWII CODEBREAKING CENTRE AND THE MEN AND WOMEN WHO WORKED THERE
SINCLAIR McKAY
'An eloquent tribute to a quite remarkable group of men and women, whose like we will not see again'
Mail on Sunday
Jim Eldridge
REAL LIVES
Alan Turing
CODEBREAKER. SCIENTIST. GENIUS. LIFESAVER.
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THE MEN AND WOMEN WHO CRACKED THE ENIGMA CODE AT BLETCHLEY PARK
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A World War II Story of Survival, Resilience, and Redemption
"Extraordinarily moving . . . a powerfully drawn survival epic." —The Wall Street Journal
THREE YEARS ON THE NEW YORK TIMES BESTSELLER LIST
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Ian Watson


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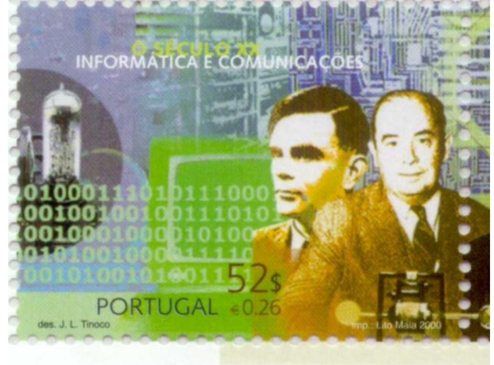
1937: Alan Turing's theory of digital
computing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Alan M. Turing, codebreaker
and an Enigma Code Machine
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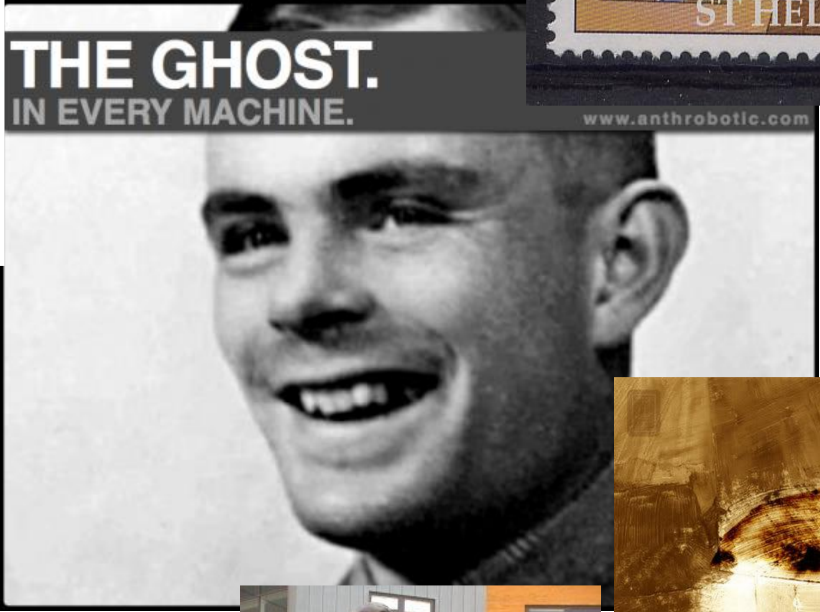
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IN EVERY MACHINE.
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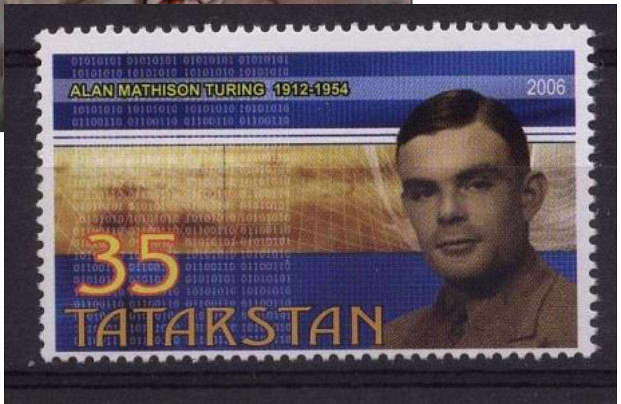
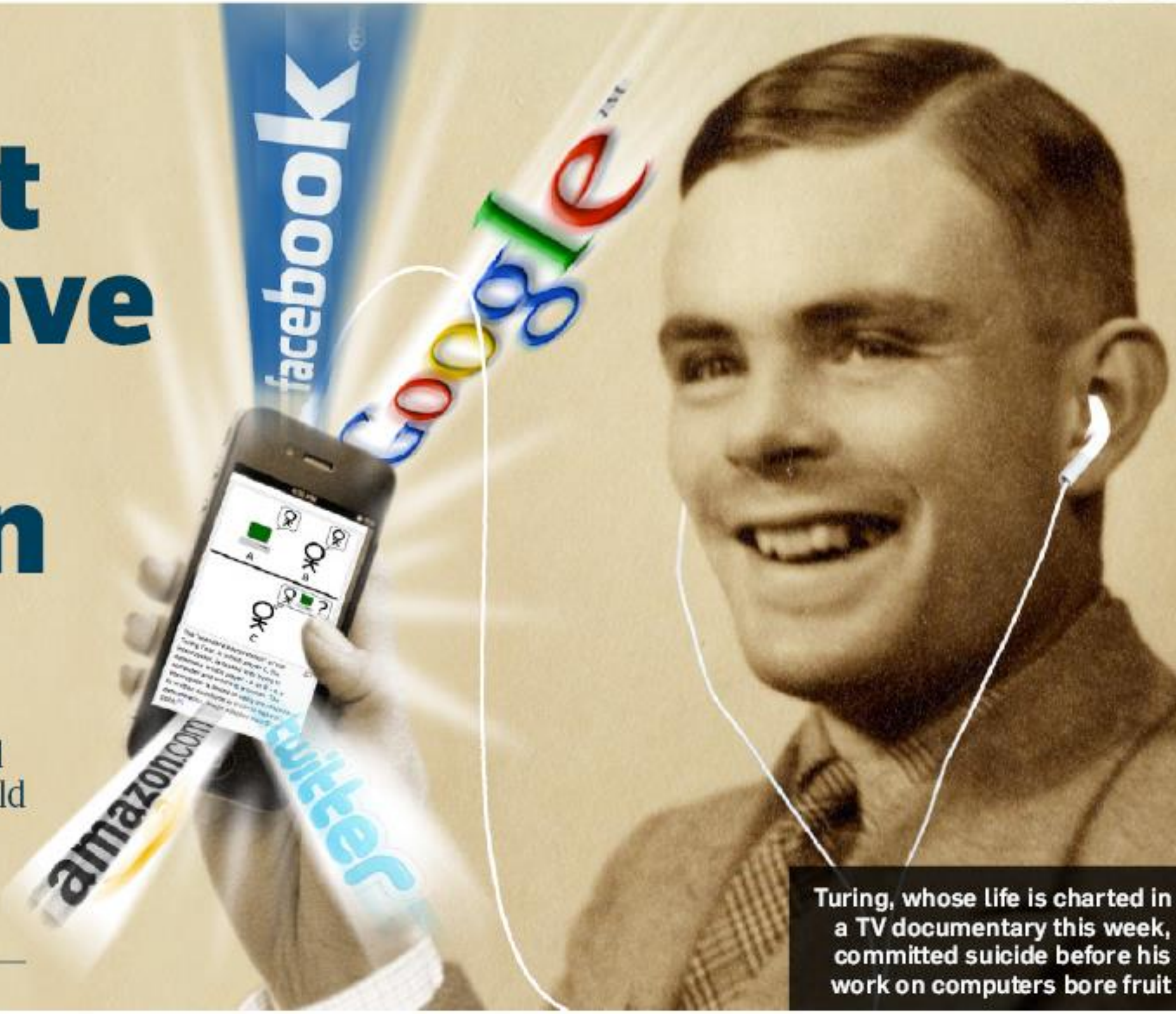

ALAN MATHISON TURING 1912-1954
2006
35
TATARSTAN

The outcast who gave us the modern world

Alan Turing's genius ushered in the digital era. Britain could have been at its centre, had it not treated him cruelly, writes **Michael Hanlon**

TURING ARCHIVE



Turing, whose life is charted in a TV documentary this week, committed suicide before his work on computers bore fruit

If you seek
his monument

Look around you

MIXX SHARE EMAIL SAVE PRINT

British PM apologizes for treatment of gay code-breaker

updated 6:17 a.m. EDT, Fri September 11, 2009

STORY HIGHLIGHTS
- Online petition calling for apology for Alan Turing elicits response from UK PM
- Gordon Brown issues statement apologizing for his "appalling" treatment
- Turing committed suicide two years after undergoing chemical castration
- Best known for decoding messages from German Enigma machines in WWII

Next Article in World »

By Hilary Whiteman
CNN

TEXT SIZE

LONDON, England (CNN) -- British Prime Minister Gordon Brown has issued a posthumous apology for the "appalling" treatment of Alan Turing, the British code-breaker who was chemically castrated for being gay.

A portrait of Alan Turing is currently on display at the National Portrait Gallery's "Gay Icons" exhibition.

1 of 3

The apology came after more than 30,000 people signed an online petition on the UK Government Web site calling for the government to recognize the "tragic consequences of prejudice that ended this man's life and career."

Turing was just 41 years old when he committed suicide, two years after undergoing a court-ordered chemical castration. He had been found guilty of gross indecency for having a homosexual relationship. The punishment in 1952 was either a prison sentence or chemical castration. Turing chose the latter.

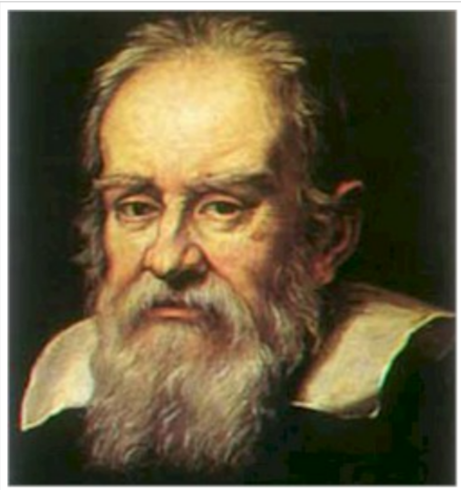
In a statement on the British Government Web site, Prime Minister Gordon Brown acknowledged Turing's "outstanding" contribution during World War II.

Another famous belated apology:

For The First Time (or the last time): 1992: Catholic Church apologizes to Galileo, who died in 1642 - Mozilla Firefox

Monday, September 10, 2007

1992: Catholic Church apologizes to Galileo, who died in 1642



In 1610, Century Italian astronomer/mathematician /inventor Galileo Galilei used a a telescope he built to observe the solar system, and deduced that the planets orbit the sun, not the earth.

This contradicted Church teachings, and some of the clergy accused Galileo of heresy. One friar went to the Inquisition, the Church court that investigated charges of heresy, and formally accused Galileo. (In 1600, a man named Giordano Bruno was convicted of being a heretic for believing that the earth moved around the Sun, and that there were many planets throughout the universe where life existed. Bruno was burnt to death.)

Galileo moved on to other projects. He started writing about ocean tides, but instead of writing a scientific paper, he found it much more interesting to have an imaginary conversation among three fictional characters. One character, who would support Galileo's side of the argument, was brilliant. Another character would be open to either side of the argument. The final character, named Simplicio, was dogmatic and foolish, representing all of Galileo's enemies who ignored any evidence that Galileo was right. Soon, Galileo wrote up a sim dialogue called "Dialogue on the Two Great Systems of the W This book talked about the Copernican system.

"Dialogue" was an immediate hit with the public, but not, of course, with the Church. The pope suspected that he was the model for Simplicio. He ordered the book banned, and also ordered Galileo to appear before the Inquisition in Rome for the crime of teaching the Copernican theory after being ordered not to do so.

Galileo was 68 years old and sick. Threatened with torture, he publicly confessed that he had been wrong to have said that the Earth moves around the Sun. Legend then has it that after his confession, Galileo quietly whispered "And yet, it moves."

Unlike many less famous prisoners, Galileo was allowed to live under house arrest. Until his death in 1642, he continued to investigate science, and even published a book on force and motion after he had become blind.

The Church eventually lifted the ban on Galileo's Dialogue in 1822, when it was common knowledge that the Earth was not the center of the Universe. Still later, there were statements by the Vatican Council in the early 1960's and in 1979 that implied that Galileo was pardoned, and that he had suffered at the hands of the Church. Finally, in 1992, three years after Galileo Galilei's namesake spacecraft had been launched on its way to Jupiter, the Vatican formally and publicly cleared Galileo of any wrongdoing.

(info from NASA and the Hi... Susterman...

Theorem: A late apology is better than no apology.

Corollary: But sooner is better!

TURING CENTENARY CONFERENCE

CiE 2012 - How the World Computes

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Scientific Arrangements
- CiE 2012
- CiE Network and Series

External Links
- The Alan Turing Year
- Alan Turing Home Page
- The Turing Digital Archive
- Bletchley Park

University of Cambridge
18 June - 23 June, 2012

CiE 2012 is one of a series of special events, running throughout the Alan Turing Year, celebrating Turing's unique impact on mathematics, computing, computer science, informatics, morphogenesis, philosophy and the wider scientific world. Its central theme is the computability-theoretic concerns underlying the broad spectrum of Turing's interests, and the contemporary research areas founded upon and animated by them. In this sense, **CiE 2012**, held in Cambridge in the week running up to the centenary of Turing's birthday, deals with the essential core of what made Turing's contribution so influential and long-lasting. **CiE 2012** promises to be an event worthy of the remarkable scientific career it commemorates.

Programme Committee: S Barry Cooper (Leeds, **Co-chair**), Anuj Dawar (Cambridge, **Co-chair**)

Organising Committee: Luca Cardelli, S Barry Cooper (Leeds), Ann Copestake, Anuj Dawar (**Chair**), Martin Hyland, Andrew Pitts

News

17.8.09
Andrew Hodges to speak at CiE 2012

22.7.09
Cambridge confirmed for CiE12

31.12.07
Turing Advisory Group founded

Picture of King's College Chapel in Cambridge

Picture of Bletchley Park Bombe rebuild

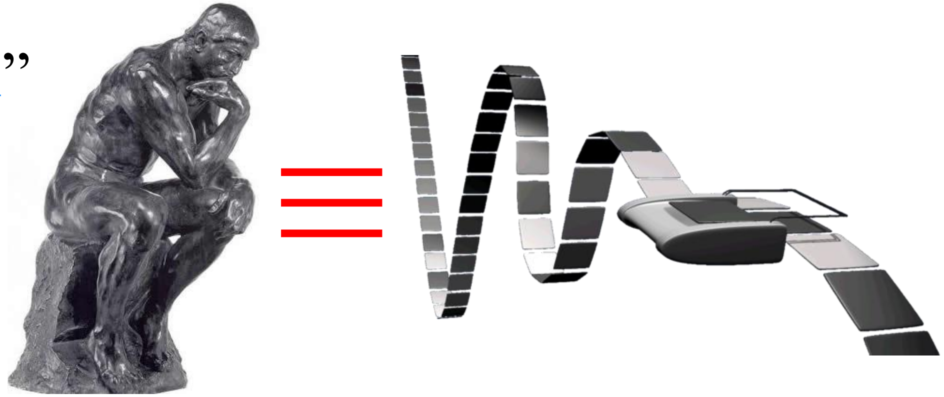
The Alan Turing Memorial in Sackville Park, Manchester

Done

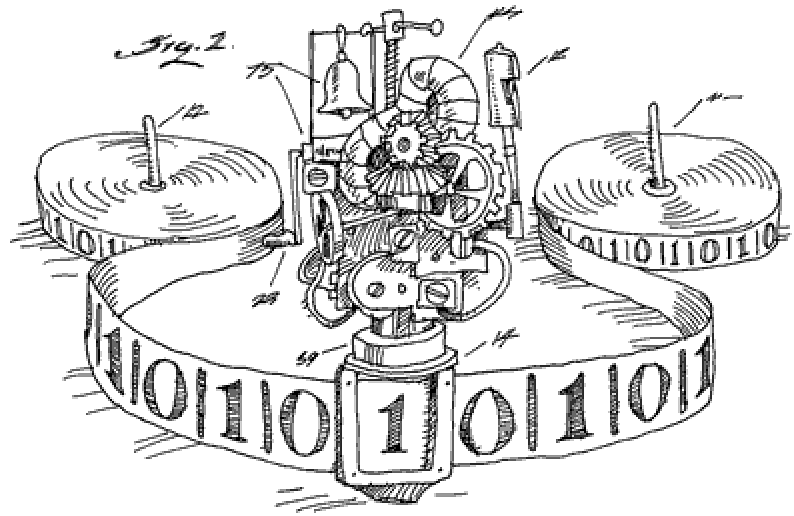
Turing's Seminal Paper

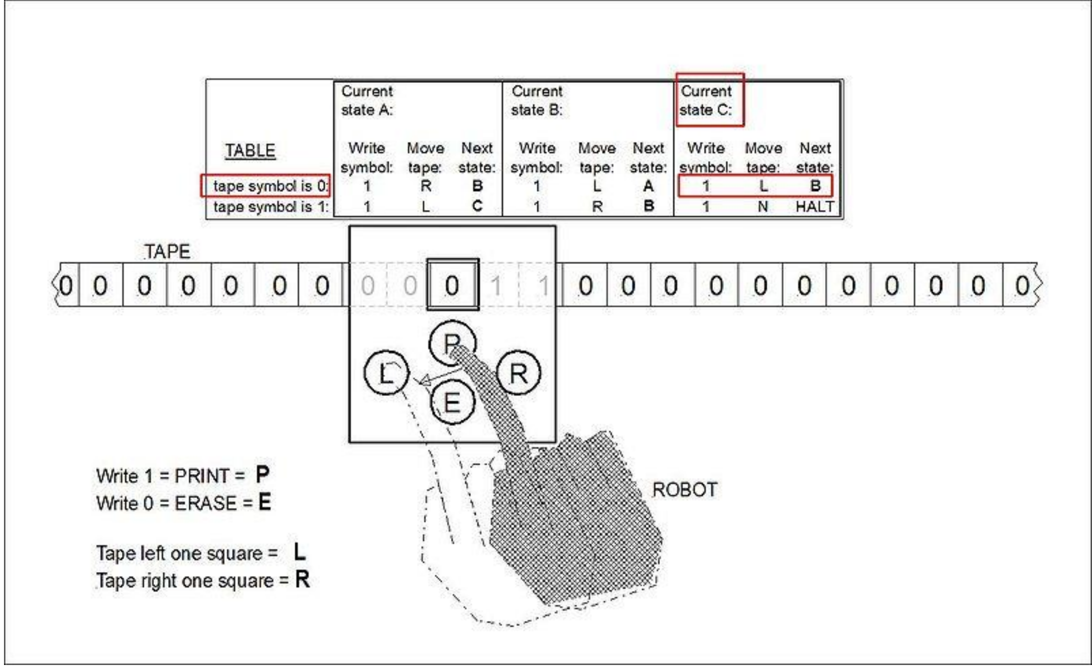
"On Computable Numbers, with an Application to the Entscheidungsproblem", Proceedings of the London Mathematical Society, 1937, pp. 230-265.

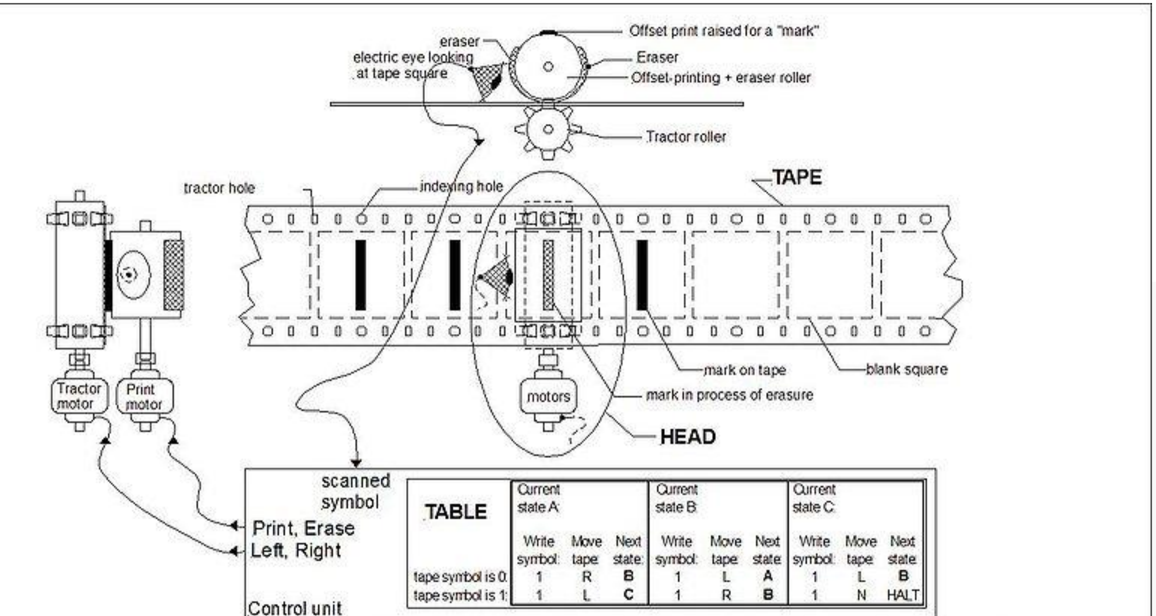
- One of the most influential & significant papers ever!
- First formal model of "computation"
- First ever definition of "algorithm"
- Invented "Turing machines"



- Introduced "computational universality" i.e., "programmable"!
- Proved the undecidability of halting problem
- Explicates the Church-Turing Thesis

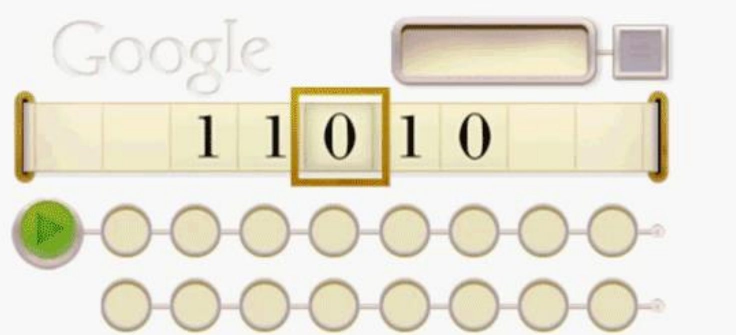






A fanciful mechanical Turing machine's TAPE and HEAD. The TABLE instructions might be on another "read only" tape, or perhaps on punch-cards. Usually a "finite state machine" is the model for the TABLE.

Turing's insight:
simple local actions
can lead to arbitrarily
complex computations!

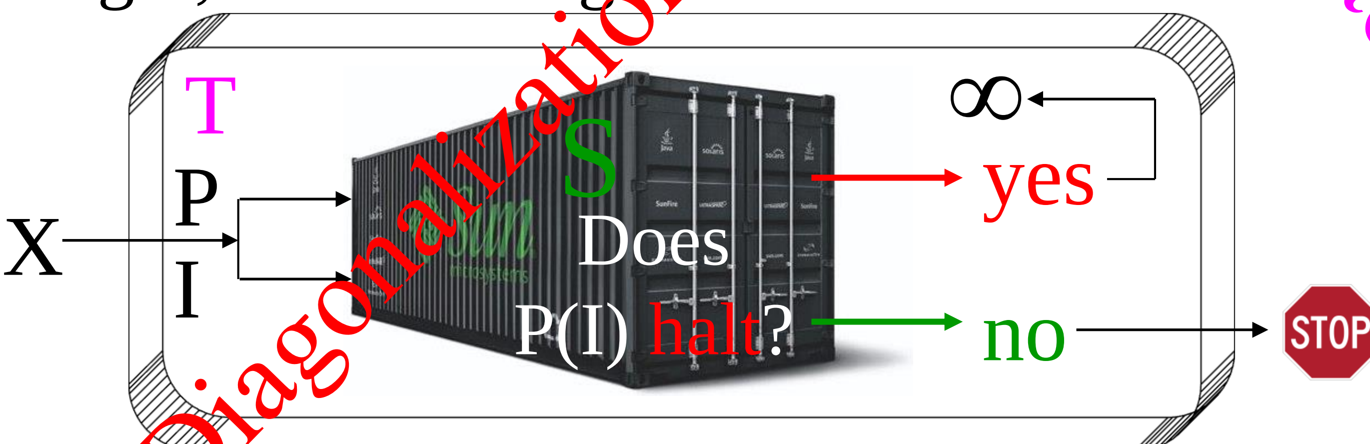


Theorem [Turing]: the halting problem (H) is not computable.

Proof: Assume ∃ algorithm S that solves the halting problem H, that always stops with the correct answer for any P & I.

Non-existence proof!

Using S, construct algorithm / TM T:



Diagonalization

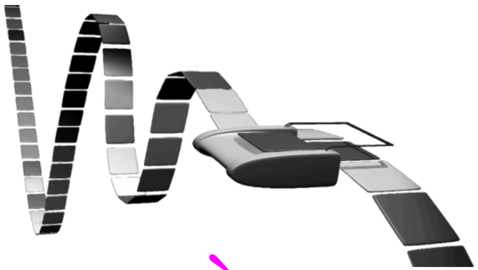
T(T) halts ⇒ T(T) does not halt
T(T) does not halt ⇒ T(T) halts

} Q ⇔ ~Q ⇒ Contradiction!

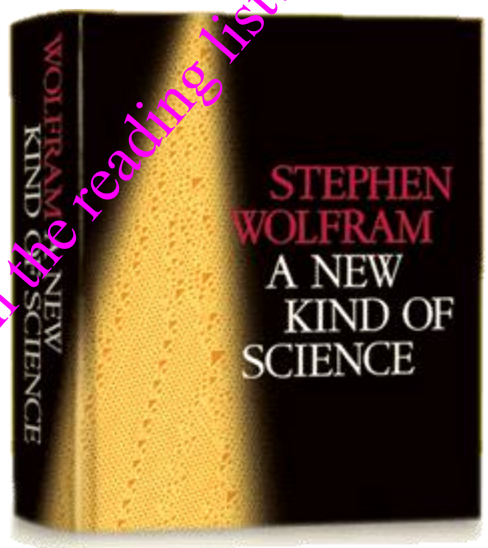
⇒ S cannot exist! (at least as an algorithm / program / TM)

Computational Universality

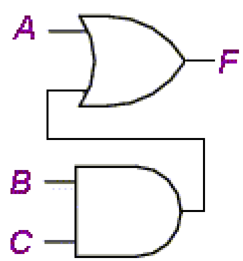
Theorem: Many other systems are equivalent to Turing machines. $\equiv$

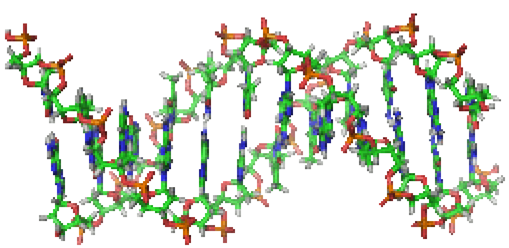


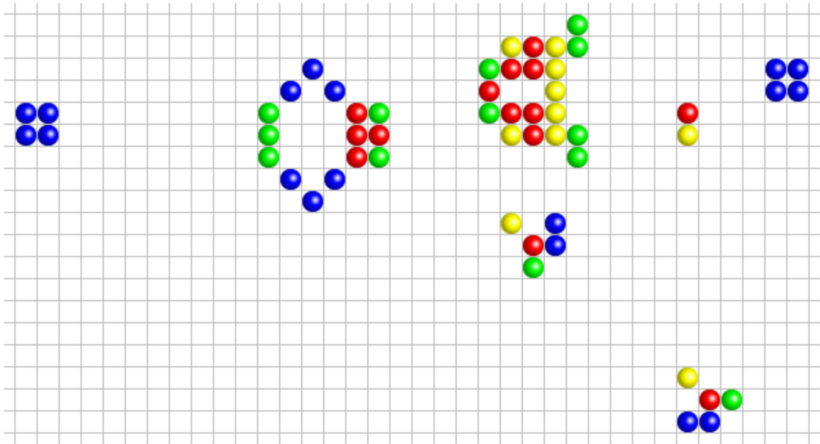
- Grammars cS → aNbc | S
- λ-calculus (λ X . X + 1)
- Post tag systems $A \rightarrow bc$
- μ-recursive functions $\mu(f)(x,y) = z$
- Cellular automata
- Boolean circuits
- Diophantine equations
- DNA $x^3 + y^3 + z^3 = 33$
- Billiards!



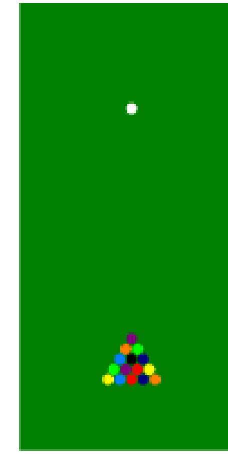
On the reading list!



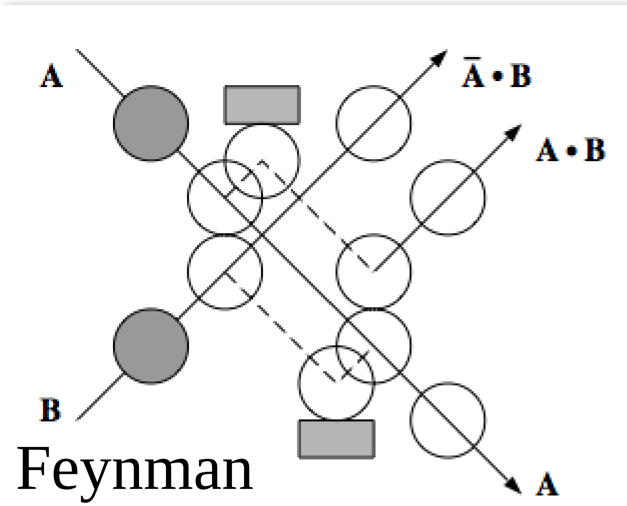


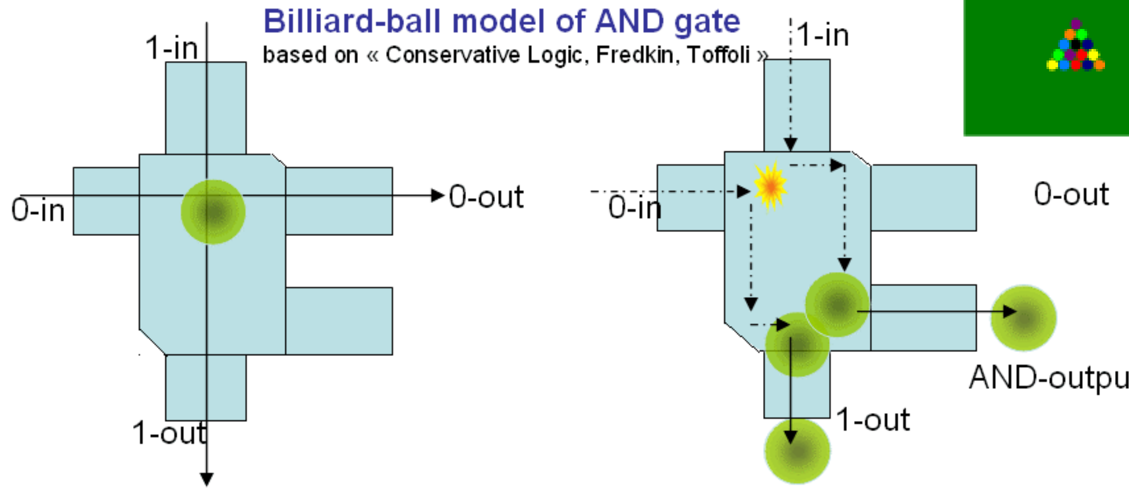


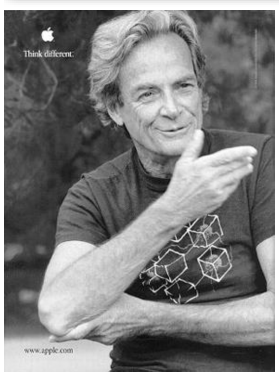
Universality of Billiards



Theorem: Billiards is computationally universal!







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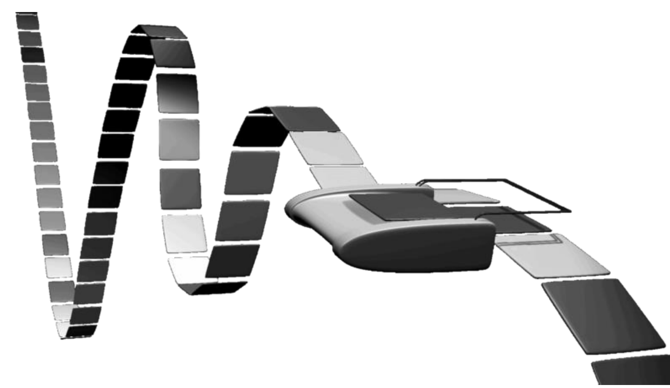
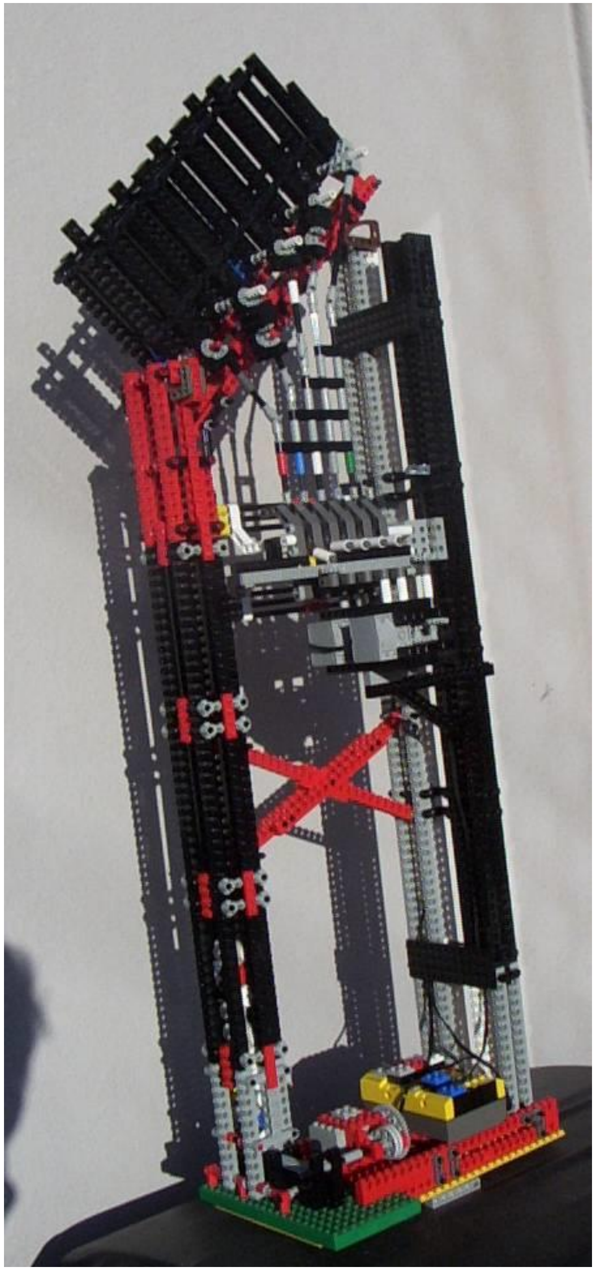
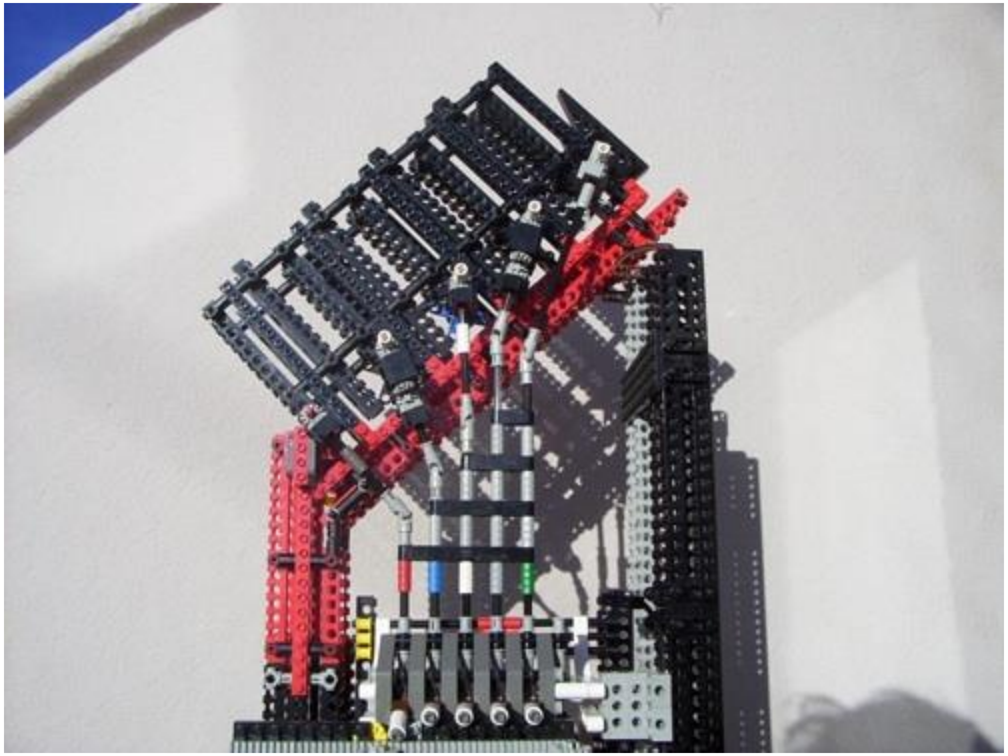


Corollary: Pool is “undecidable”!

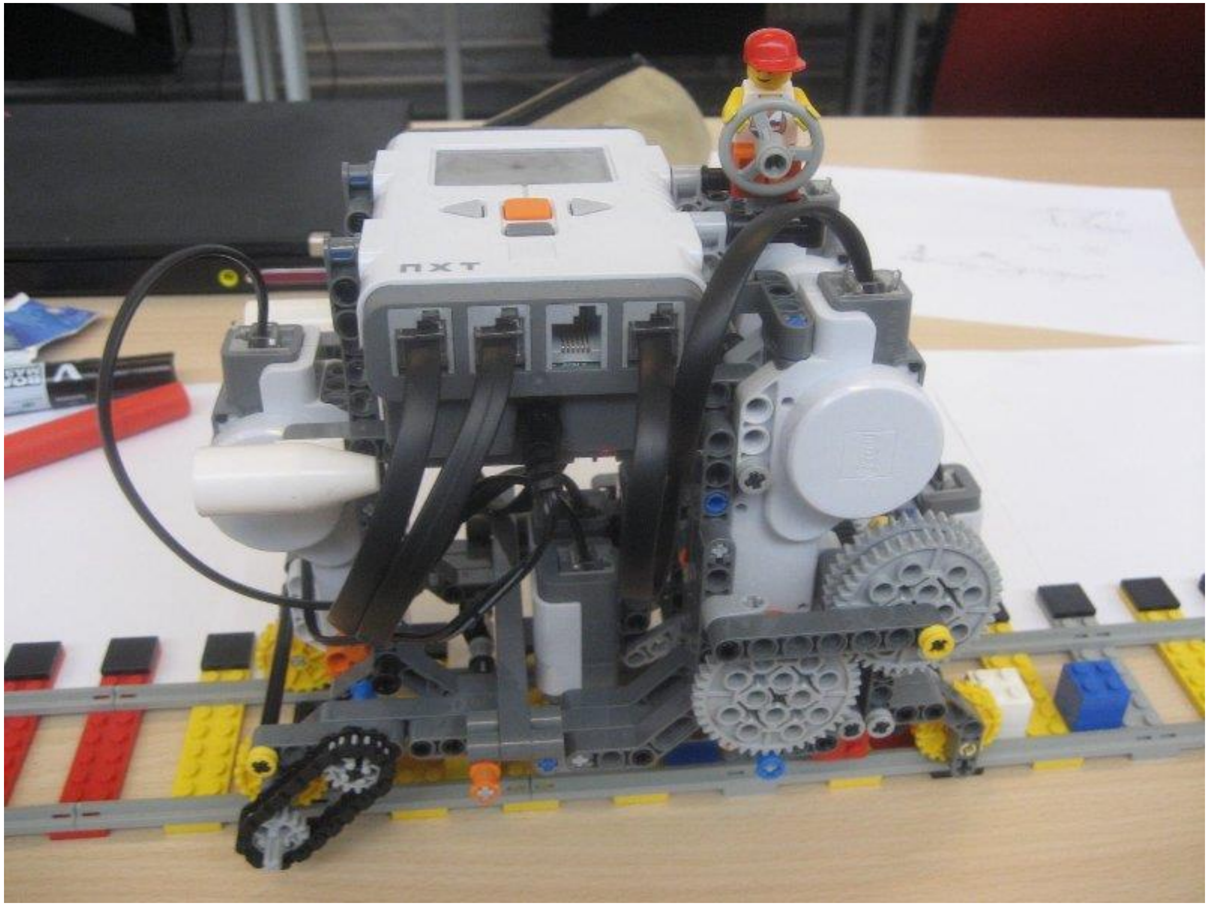
Corollary: Newtonian mechanics is universal!

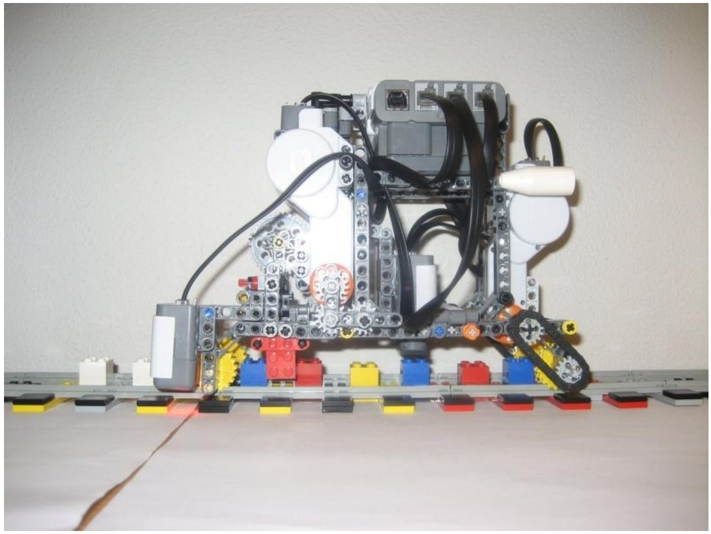
Lego Turing Machines

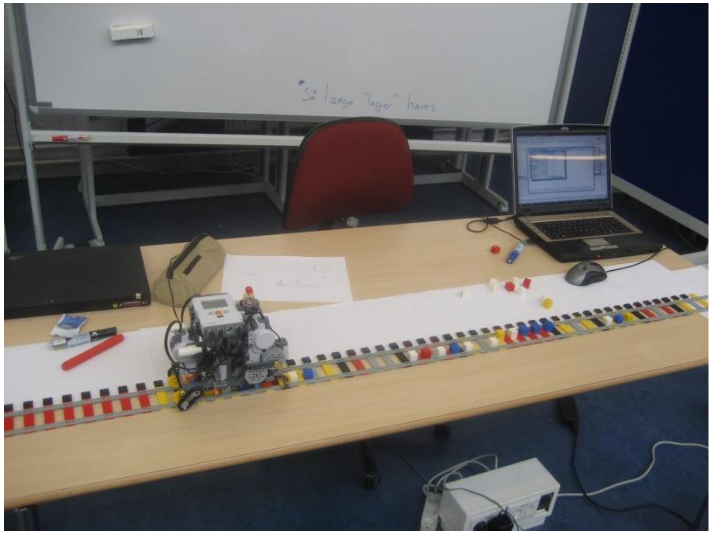




Lego Turing Machines

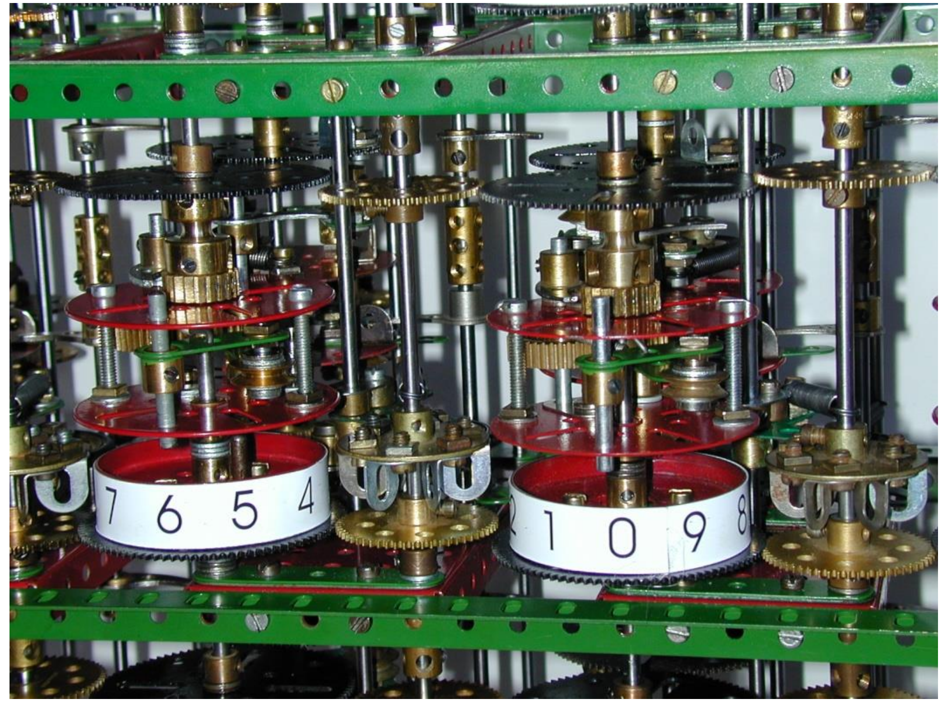






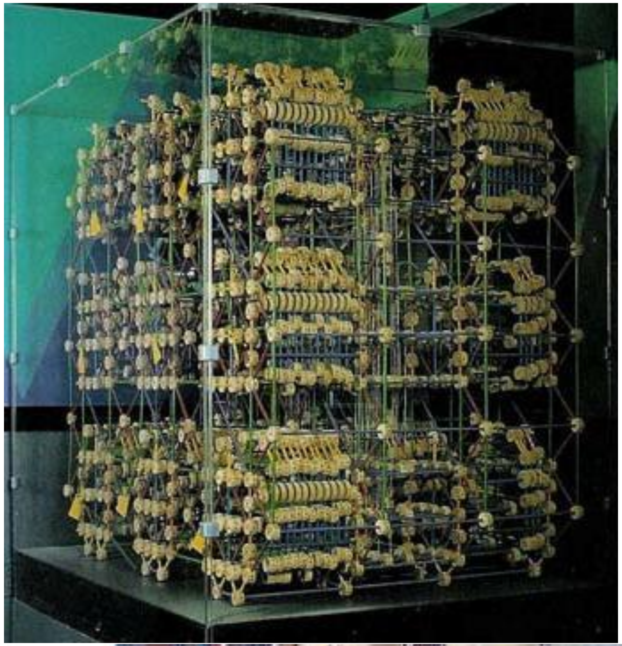
See: http://www.youtube.com/watch?v=cYw2ewoO6c4

“Mechano” Computers

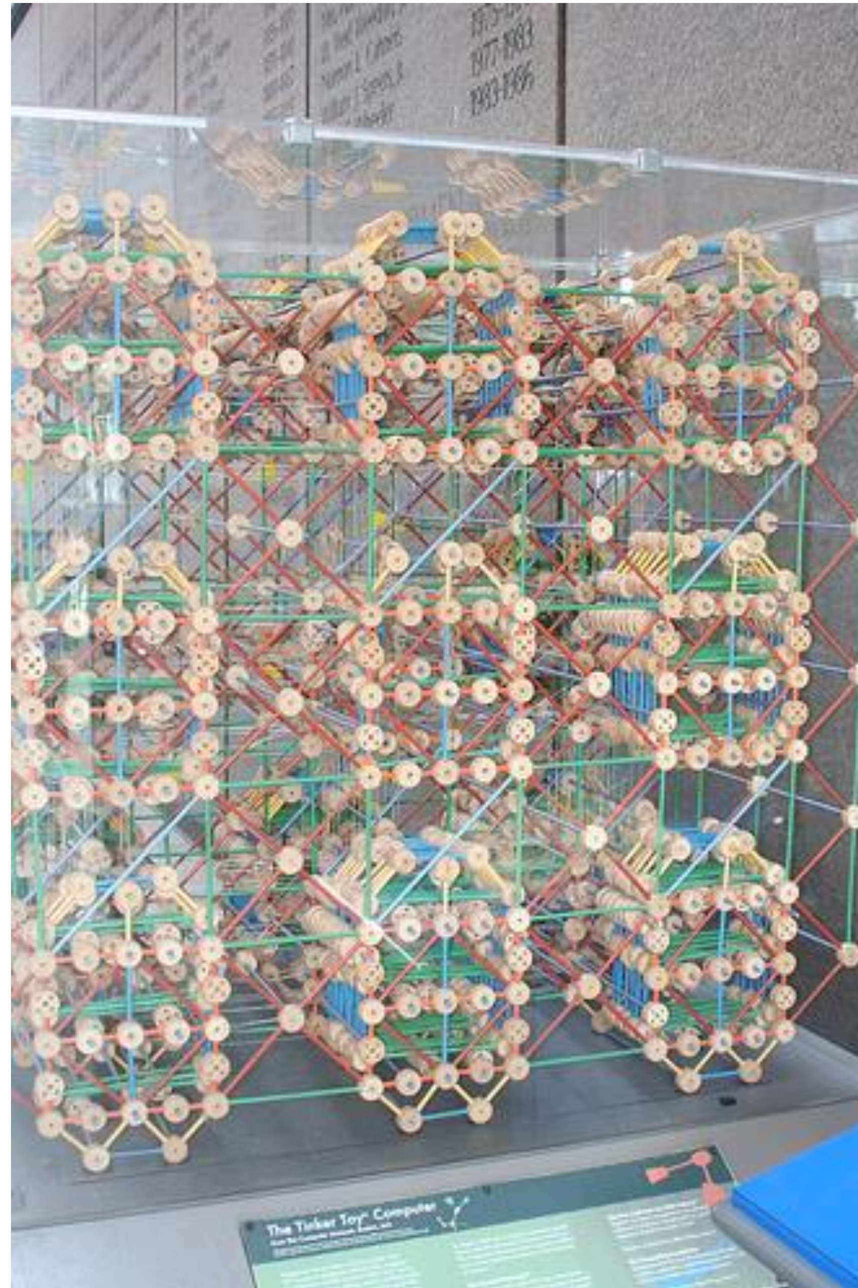


Babbage’s difference engine

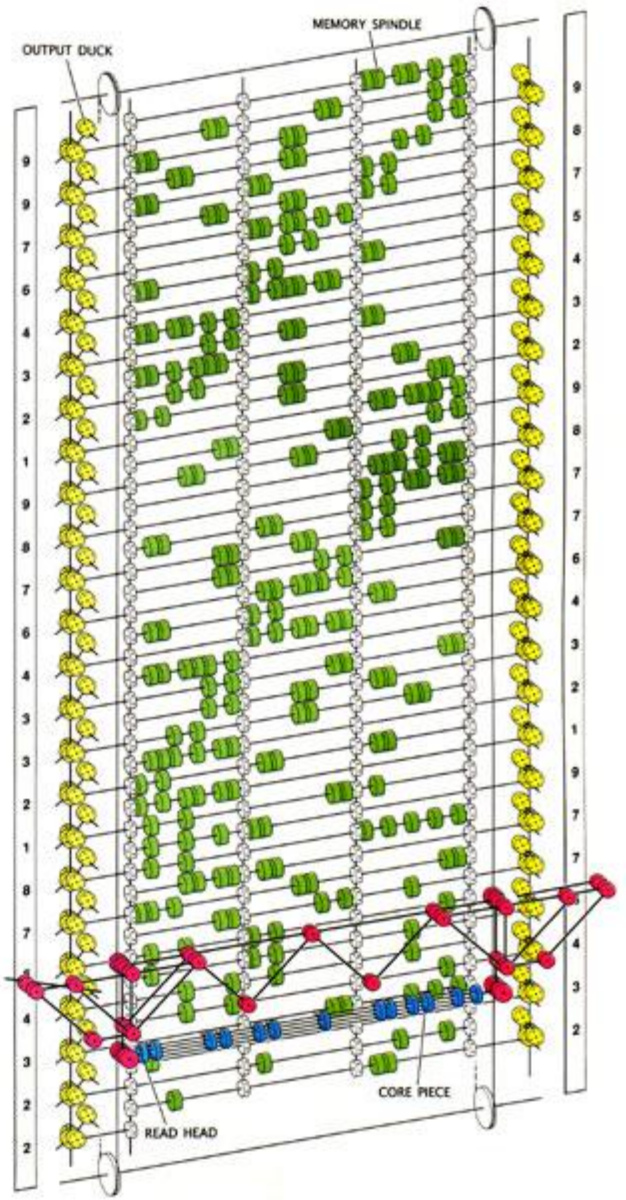
Tinker Toy Computers



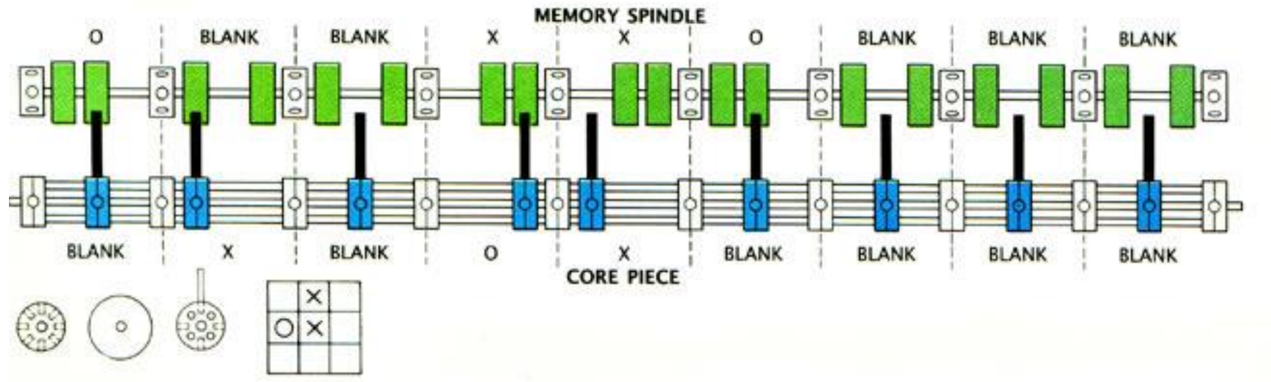
Plays
tic-tac-toe!



Tinker Toy Computers



The Tinkertoy computer: ready for a game of tic-tac-toe



Mechanical Computers

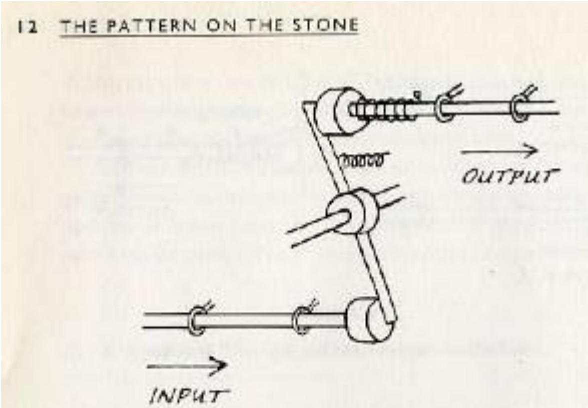


FIGURE 5
Mechanical inverter

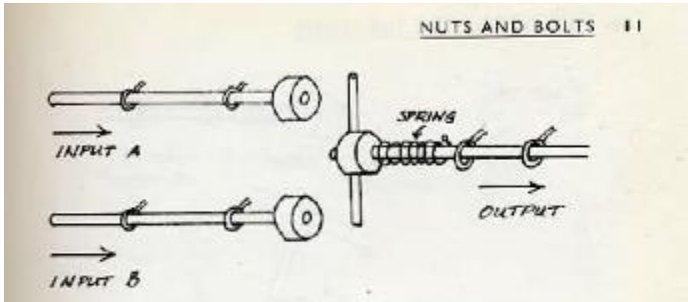
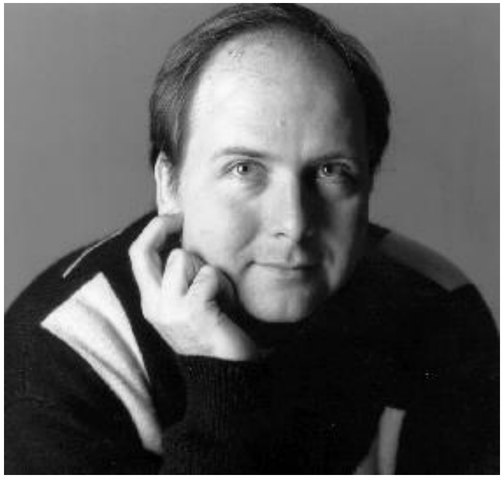


FIGURE 4
Mechanical implementation of the OR function



De Morgan's law!

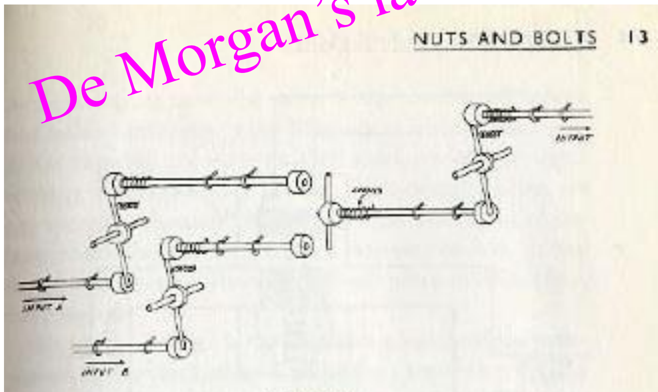
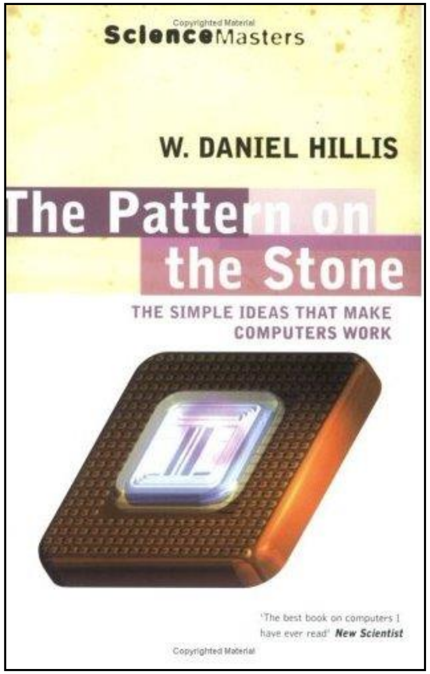
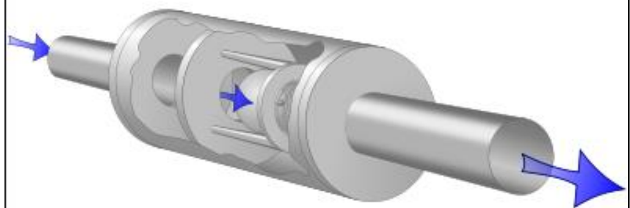


FIGURE 6
An And block constructed by connecting an Or block to inverters

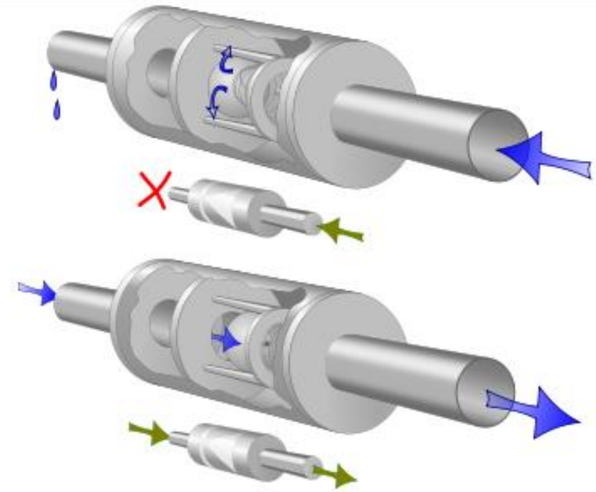


Hydraulic Computers

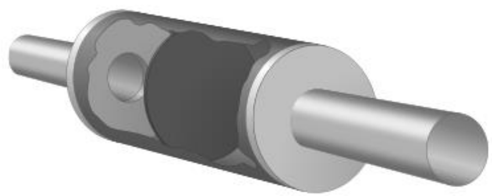
Wire



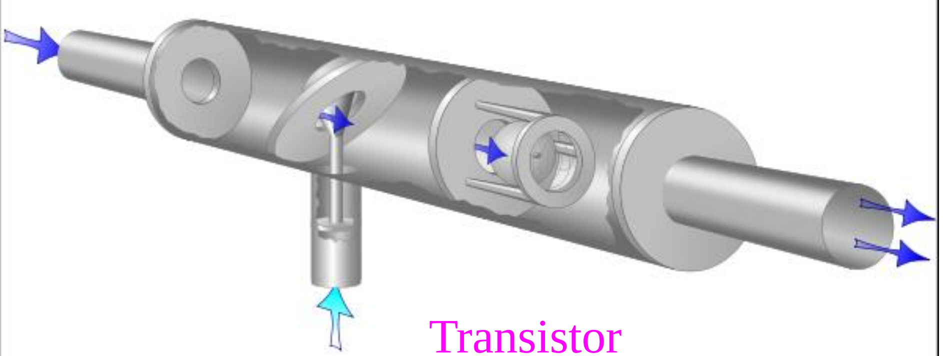
Diode



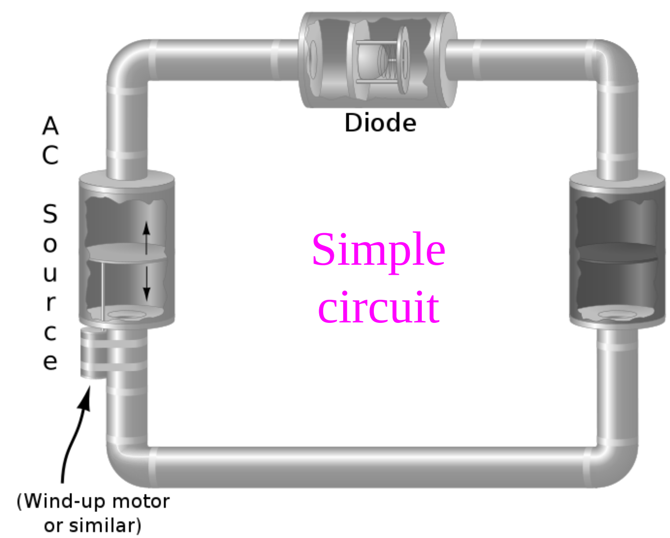
Resistor



Capacitor

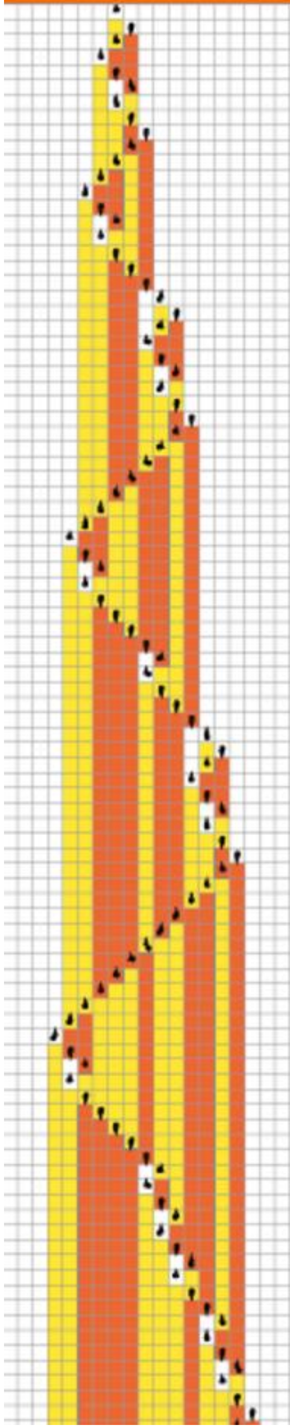


Transistor



Simple circuit

Theorem: fluid-based “circuits” are Turing-complete / universal!



Announced May 14th, 2007: 5th Anniversary of the Publication of *A New Kind of Science*

THE WOLFRAM 2,3 TURING MACHINE RESEARCH PRIZE

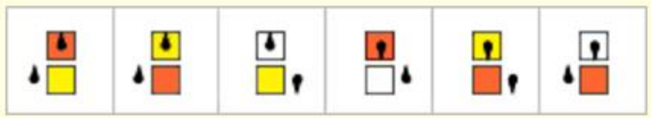
Oct 24, 2007

We have the solution!
Wolfram's 2,3 Turing machine is universal

Congratulations Alex Smith.
Find out more »

$25,000 prize

Is this Turing machine universal, or not?



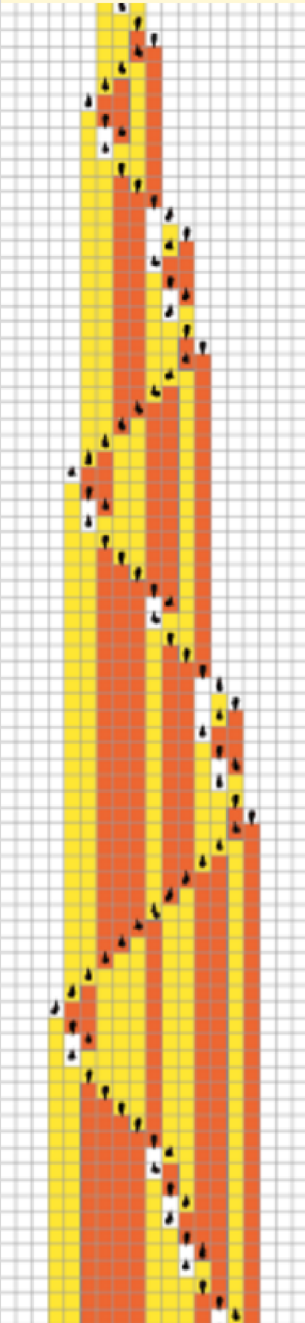
The machine has 2 states and 3 colors, and is 596440 in Wolfram's numbering scheme.
If it is universal then it is the smallest universal Turing machine that exists.

BACKGROUND » TECHNICAL DETAILS » GALLERY » NEWS »
PRIZE COMMITTEE » RULES & GUIDELINES » FAQs »

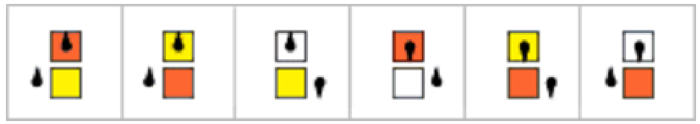
A universal Turing machine is powerful enough to emulate any standard computer.
The question is: how simple can the rules for a universal Turing machine be?

Since the 1960s it has been known that there is a universal 7,4 machine. In A New Kind of Science, Stephen Wolfram found a universal 2,5 machine, and suggested that the particular 2,3 machine that is the subject of this prize might be universal.

The prize is for determining whether or not the 2,3 machine is in fact universal.



Wolfram's 2,3 Turing machine is universal!



The lower limit on Turing machine universality is proved—

providing new evidence for Wolfram's Principle of Computational Equivalence.

The Wolfram 2,3 Turing Machine Research Prize has been won by 20-year-old Alex Smith of Birmingham, UK.

Smith's Proof (to be published in Complex Systems):

Prize Submission » *Mathematica* Programs »

News Release » Technical Commentary »

Stephen Wolfram's Blog Post »

Media Enquiries »

BACKGROUND » TECHNICAL DETAILS » GALLERY »

PRIZE COMMITTEE » RULES & GUIDELINES » FAQs »

What is a Turing Machine? » | Notable Universal Turing Machines »

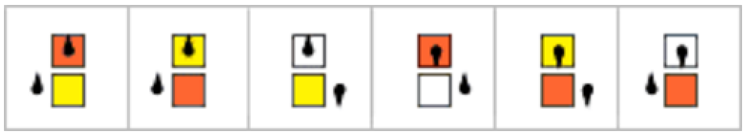
The Rules for the Machine

The rules for the Turing machine that is the subject of this prize are:

{{1, 2} -> {1, 1, -1}, {1, 1} -> {1, 2, -1}, {1, 0} -> {2, 1, 1},
{2, 2} -> {1, 0, 1}, {2, 1} -> {2, 2, 1}, {2, 0} -> {1, 2, -1}}

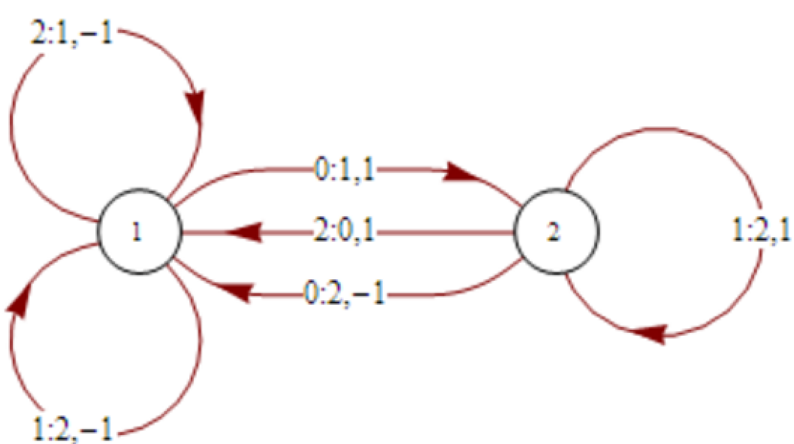
where this means {state, color} -> {state, color, offset}. (Colors of cells on the tape are sometimes instead thought of as "symbols" written to the tape.)

These rules can be represented pictorially by:



where the orientation of each arrow represents the state.

The rules can also be represented by the state transition diagram:



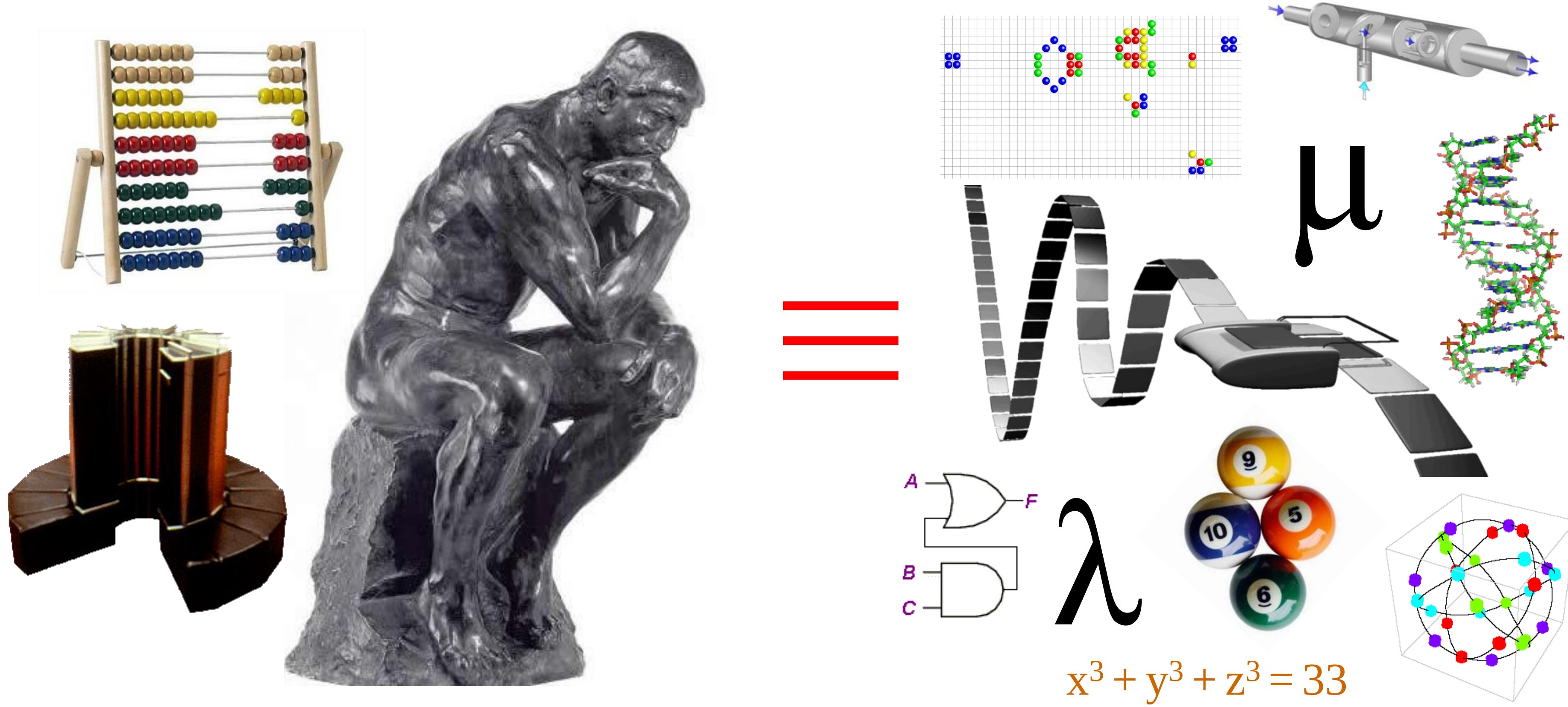
A 2-state 3-symbol universal Turing machine! (the smallest possible)

In Wolfram's numbering scheme for Turing machines, this is machine 596440. There are a total of (2 3 2)^(2 3)=12^6=2985984 machines with 2 states and 3 colors.

Note that there is no halt state for this Turing machine.

The Church-Turing Thesis

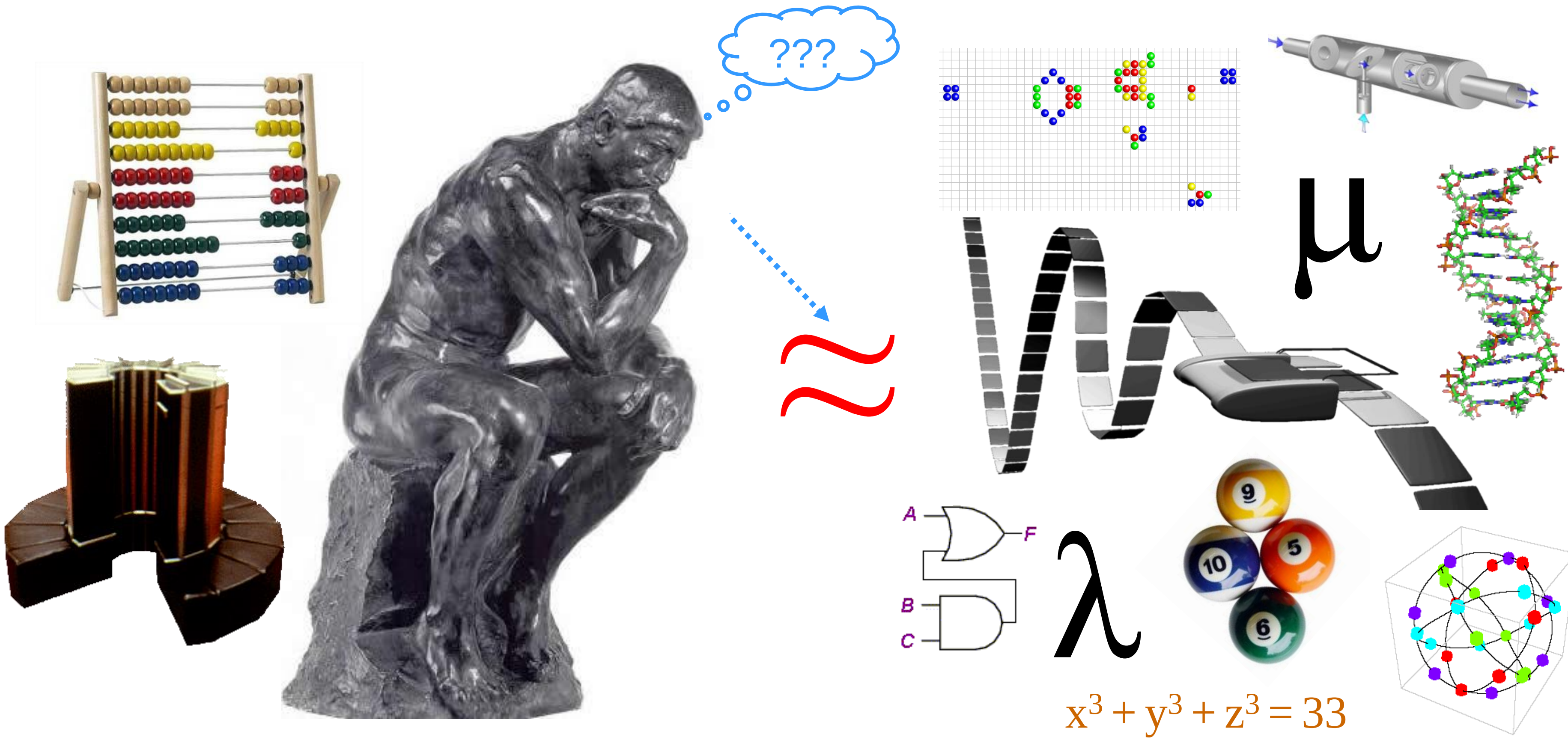
Q: What does it mean “to be computable”?



The Church-Turing Thesis: Anything that is “intuitively computable” is also Turing-machine computable.

The Church-Turing Thesis

Q: Why "thesis" and not "theorem"?

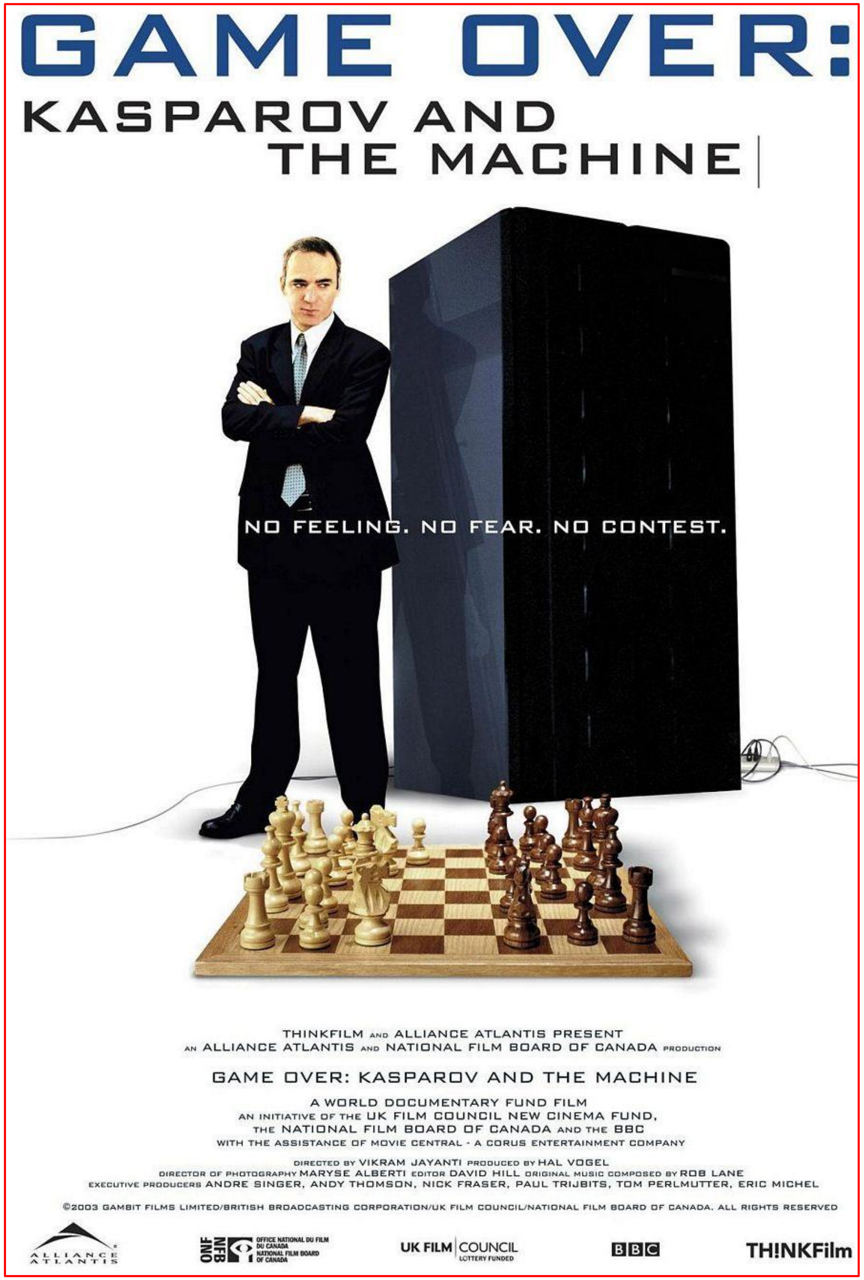


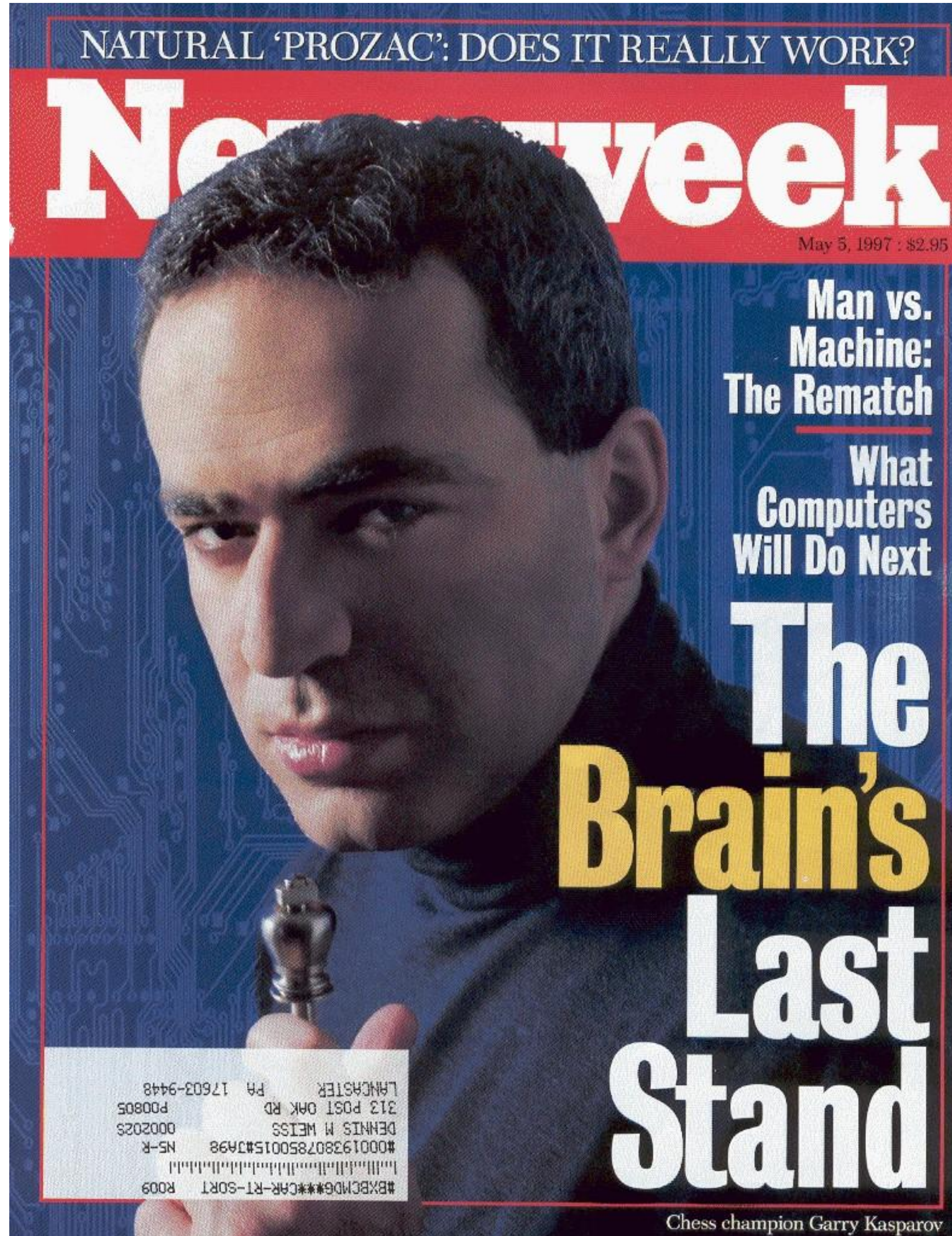
Undefined / informal tasks: produce (or even identify) good music, art, poetry, humor, aesthetics, justice, truth, etc.

Things We Can Compute

IBM’s “Deep Blue” becomes Chess world champion in 1997

Things We Can Compute





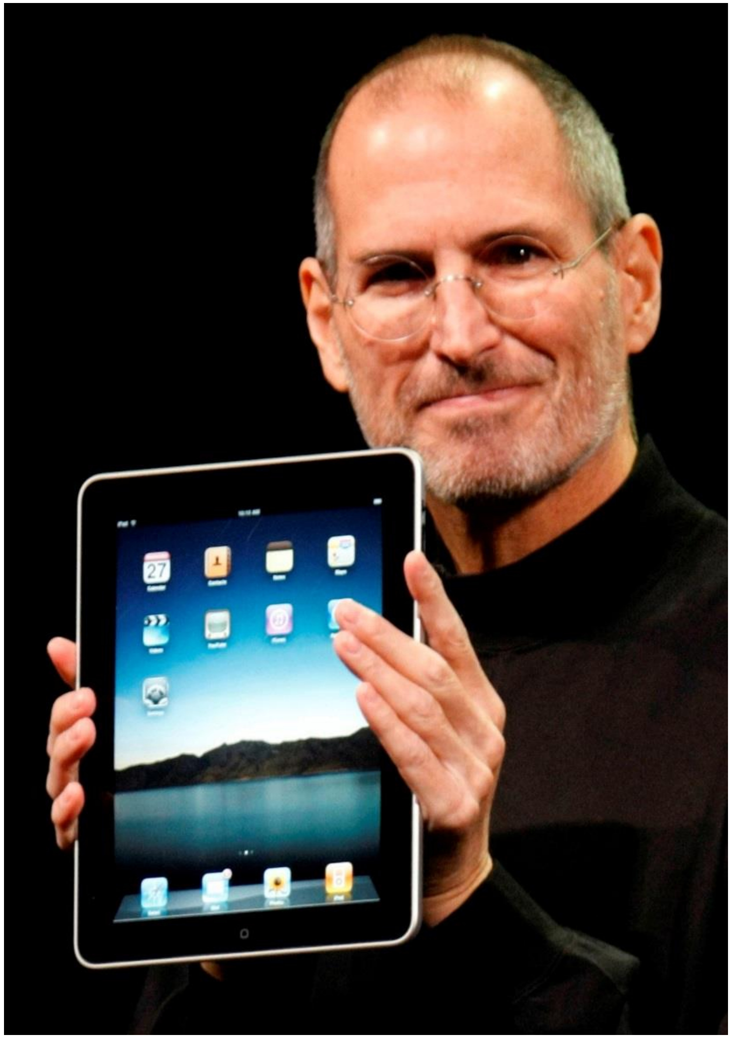
Things We Can Compute

“Watson” AI becomes Jeopardy world champion in 2011

Things We Can Compute

“AlphaGo” AI beats world Go champion March 2016

A Cool Turing Machine

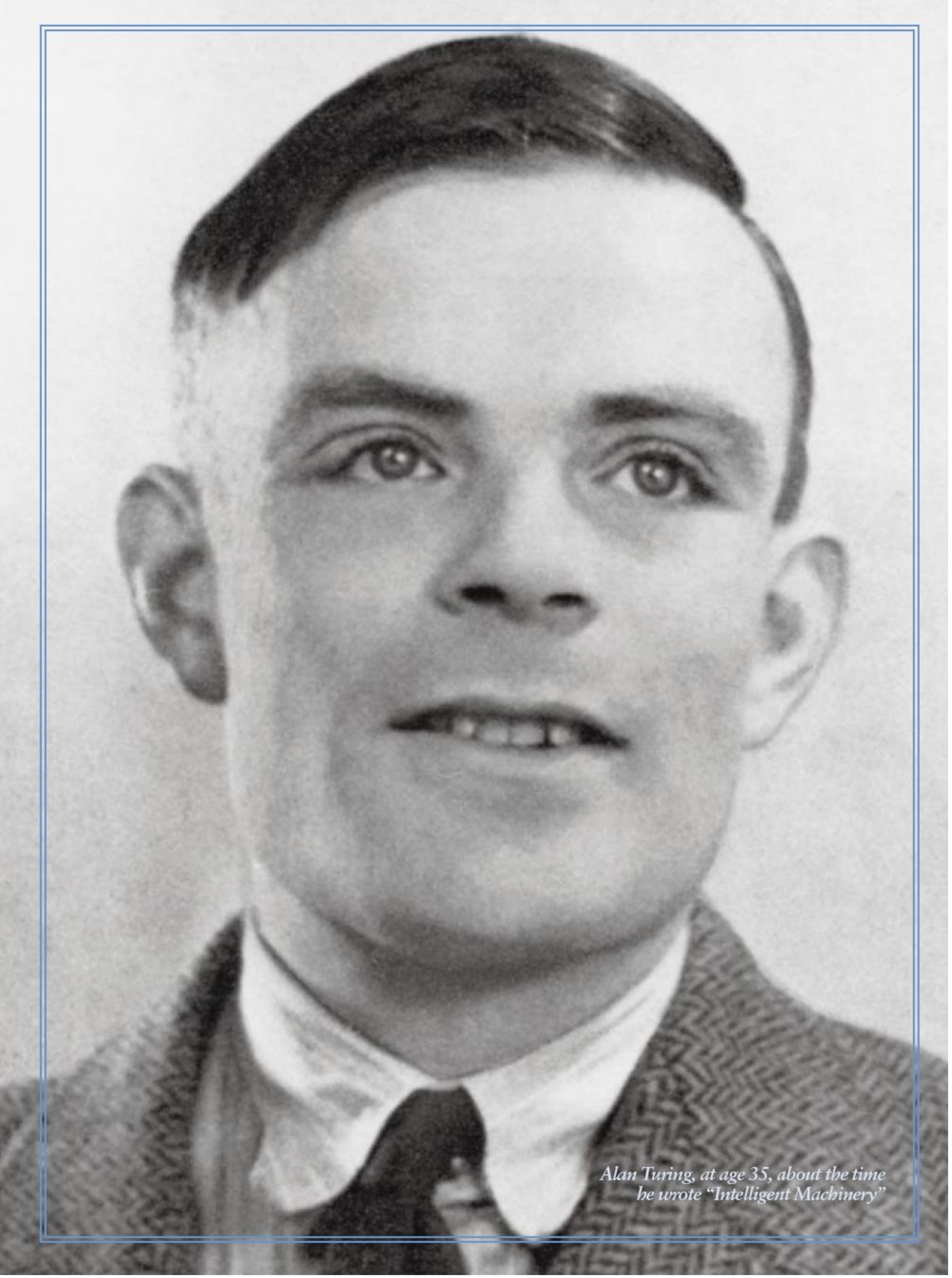


Apple iPad (2015):

- < ¼” thin
- < 1 pound weight
- 2048 x1536 (326 ppi res) multi-touch screen
- 128 GB memory
- 1.5 MHz 64-bit 3-core A8X
- 8 MP camera & HD video
- WiFi, cellular, GPS
- Compass, barometer
- battery life 10 hours


My Favorite Touring Machine
Tesla Model S
Auto-pilot!
Theorem: Theory can be beautiful!
0-60 in 2.3 seconds!
315 miles per charge


My Own Touring Machine



Alan Turing, at age 35, about the time he wrote "Intelligent Machinery"

Alan Turing's Forgotten Ideas in Computer Science

Well known for the machine, test and thesis that bear his name, the British genius also anticipated neural-network computers and "hypercomputation"

by B. Jack Copeland and Diane Proudfoot

Alan Mathison Turing conceived of the modern computer in 1935. Today all digital computers are, in essence, "Turing machines." The British mathematician also pioneered the field of artificial intelligence, or AI, proposing the famous and widely debated Turing test as a way of determining whether a suitably programmed computer can think. During World War II, Turing was instrumental in breaking the German Enigma code in part of a top-secret British operation that historians say shortened the war in Europe by two years. When he died at the age of 41, Turing was doing the earliest work on what would now be called artificial life, simulating the chemistry of biological growth.

Throughout his remarkable career, Turing had no great interest in publicizing his ideas. Consequently, important aspects of his work have been neglected or forgotten over the years. In particular, few people—even those knowledgeable about computer science—are familiar with Turing's fascinating anticipation of connectionism, or neuronlike computing. Also neglected are his groundbreaking theoretical concepts in the exciting area of "hypercomputation." According to some experts, hypercomputers might one day solve problems heretofore deemed intractable.

The Turing Connection

Digital computers are superb number crunchers. Ask them to predict a rocket's trajectory or calculate the financial figures for a large multinational corporation, and they can churn out the answers in seconds. But seemingly simple actions that people routinely perform, such as recognizing a face or reading handwriting, have been devilishly tricky to program. Perhaps the networks of neurons that make up the brain have a natural facility for such tasks that standard computers lack. Scientists have thus been investigating computers modeled more closely on the human brain.

Connectionism is the emerging science of computing with networks of artificial neurons. Currently researchers usually simulate the neurons and their interconnections within an ordinary digital computer (just as engineers create virtual models of aircraft wings and skyscrapers). A training algorithm that runs on the computer adjusts the connections between the neurons, honing the network into a special-purpose machine dedicated to some particular function, such as forecasting international currency markets.

Modern connectionists look back to Frank Rosenblatt, who published the first of many papers on the topic in 1957, as the founder of their approach. Few realize that Turing had already investigated connectionist networks as early as 1948, in a little-known paper entitled "Intelligent Machinery."

Written while Turing was working for the National Physical Laboratory in London, the manuscript did not meet with his employer's approval. Sir Charles Darwin, the rather headmasterly director of the laboratory and grandson of the great English naturalist, dismissed it as a "schoolboy essay." In reality, this farsighted paper was the first manifesto of the field of artificial intelligence. In the work—which remained unpublished until 1968, 14 years after Turing's death—the British mathematician not only set out the fundamentals of connectionism but also brilliantly introduced many of the concepts that were later to become central to AI, in some cases after reinvention by others.

In the paper, Turing invented a kind of neural network that he called a "B-type unorganized machine," which consists of artificial neurons and devices that modify the connections between them. B-type machines may contain any number of neurons connected in any pattern but are always subject to the restriction that each neuron-to-neuron connection must pass through a modifier device.

All connection modifiers have two training fibers. Applying a pulse to one of them sets the modifier to "pass mode," in which an input—either 0 or 1—passes through unchanged and becomes the output. A pulse on the other fiber places the modifier in "interrupt mode," in which the output is always 1, no matter what the input is. In this state the modifier destroys all information attempting to pass along the connection to which it is attached.

Once set, a modifier will maintain its function (either "pass" or "interrupt") unless it receives a pulse on the other training fiber. The presence of these ingenious connection modifiers enables the training of a B-type unorganized machine by means of what Turing called "appropriate interference, mimicking education." Actually, Turing theorized that "the cortex of an infant is an unorganized machine, which can be organized by suitable interfering training."

Each of Turing's model neurons has two input fibers, and the output of a neuron is a simple logical function of its two inputs. Every neuron in the network executes the same logical operation of "not and" (or NAND): the output is 1 if either of the inputs is 0. If both inputs are 1, then the output is 0.

Turing selected NAND because every other logical (or Boolean) operation can be accomplished by groups of NAND neurons. Furthermore, he showed that even the connection modifiers themselves can be built out of NAND neurons. Thus, Turing specified a network made up of nothing more than NAND neurons and their connecting fibers—about the simplest possible model of the cortex.

In 1958 Rosenblatt defined the theoretical basis of connectionism in one succinct statement: "Stored information takes the form of new connections, or transmission channels in the nervous system (or the creation of conditions which are functionally equivalent to new connections)." Because the destruction of existing connections can be functionally equivalent to the creation of new ones, researchers can build a network for accomplishing a specific task by taking one with an excess of connections and selectively destroying some of them. Both actions—destruction and creation—are employed in the training of Turing's B-types.

Few realize that Turing had already investigated connectionist networks as early as 1948.

At the outset, B-types contain random interneural connections whose modifiers have been set by chance to either pass or interrupt. During training, unwanted connections are destroyed by switching their attached modifiers to interrupt mode. Conversely, changing a modifier from interrupt to pass in effect creates a connection. This selective culling and enlivening of connections hones the initially random network into one organized for a given job.

Turing wished to investigate other kinds of unorganized machines, and he longed to simulate a neural network and its training regimen using an ordinary digital computer. He would, he said, "allow the whole system to run for an appreciable period, and then break in as a kind of 'inspector of schools' and see what progress had been made." But his own work on neural networks was carried out shortly before the first general-purpose electronic computers became available. (It was not until 1954, the year of Turing's death, that Belmont G. Farley and Wesley A. Clark succeeded at the Massachusetts Institute of Technology in running the first computer simulation of a small neural network.)

Paper and pencil were enough, though, for Turing to show that a sufficiently large B-type neural network can be configured (via its connection modifiers) in such a way that it becomes a general-purpose computer. This discovery illuminates one of the most fundamental problems concerning human cognition.

From a top-down perspective, cognition includes complex sequential processes, often involving language or other forms of symbolic representation, as in mathematical calculation. Yet from a bottom-up view, cognition is nothing but the simple firings of neurons. Cognitive scientists face the problem of how to reconcile these very different perspectives.

Turing's discovery offers a possible solution: the cortex, by virtue of being a neural network acting as a general-purpose computer, is able to carry out the sequential, symbol-rich processing discerned in the view from the top. In 1948 this hypothesis was well ahead of its time, and today it remains among the best guesses concerning one of cognitive science's hardest problems.

Computing the Uncomputable

In 1935 Turing thought up the abstract device that has since become known as the "universal Turing machine." It consists of a limitless memory that stores both program and data and a scanner that moves back and forth through the memory, symbol by symbol, reading the information and writing additional symbols. Each of the machine's basic actions is very simple—such as "identify the symbol on which the scanner is positioned," "write '1'" and "move one position to the left." Complexity is achieved by chaining together large numbers of these basic actions. Despite its simplicity, a universal Turing machine can execute any task that can be done by the most powerful of today's computers. In fact, all modern digital computers are in essence universal Turing machines [see "Turing Machines," by John E. Hopcroft; SCIENTIFIC AMERICAN, May 1984].

Turing's aim in 1935 was to devise a machine—one as simple as possible—capable of any calculation that a human mathematician working in accordance with some algorithmic method could perform, given unlimited time, energy, paper and pencils, and perfect concentration. Calling a machine "universal" merely signifies that it is capable of all such calculations. As Turing himself wrote, "Electronic computers are intended to carry out any definite rule-of-thumb process which could have been done by a human operator working in a disciplined but unintelligent manner."

Such powerful computing devices notwithstanding, an intriguing question arises: Can machines be devised that are capable of accomplishing even more? The answer is that these "hypermachines" can be described on paper, but no one as yet knows whether it will be possible to build one. The field of hypercomputation is currently attracting a growing number of scientists. Some speculate that the human brain itself—the most complex information processor known—is actually a naturally occurring example of a hypercomputer.

Before the recent surge of interest in hypercomputation, any information-processing job that was known to be too difficult for universal Turing machines was written off as "uncomputable." In this sense, a hypermachine computes the uncomputable.

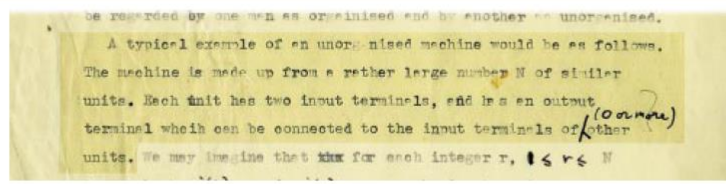
Examples of such tasks can be found in even the most straightforward areas of mathematics. For instance, given arithmetical statements picked at random, a universal Turing machine may not always be able to tell which are theorems (such as "7 + 5 = 12") and which are nontheorems (such as "every number is the sum of two even numbers"). Another type of uncomputable problem comes from geometry. A set of tiles—variously sized squares with different colored edges—"tiles the plane" if the Euclidean plane can be covered by copies of the tiles with no gaps or overlaps and with adjacent edges always the same color. Logicians William Hanf and Dale Myers of the University of Hawaii have discovered a tile set that tiles the plane only in patterns too complicated for a universal Turing machine to calculate. In the field of computer science, a universal Turing machine cannot always predict whether a given program will terminate or continue running forever. This is sometimes expressed by saying that no general-purpose programming language (Pascal, BASIC, Prolog, C and so on) can have a foolproof crash debugger: a tool that detects all bugs that could lead to crashes, including errors that result in infinite processing loops.

Turing himself was the first to investigate the idea of machines that can perform mathematical tasks too difficult

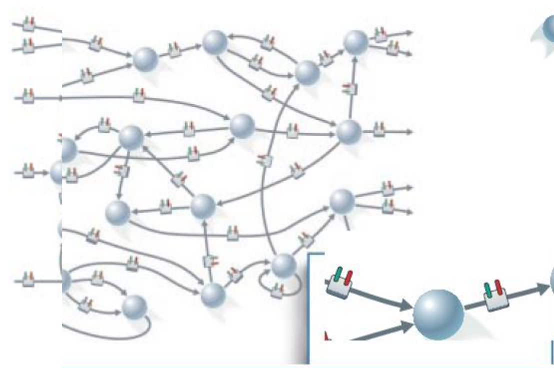
Turing's Anticipation of Connectionism

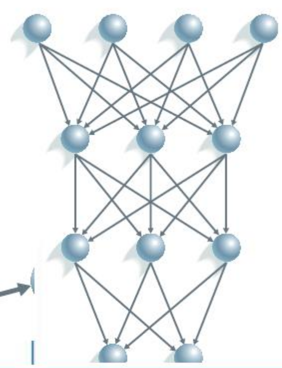
In a paper that went unpublished until 14 years after his death (*top*), Alan Turing described a network of artificial neurons connected in a random manner. In this "B-type unorganized machine" (*bottom left*), each connection passes through a modifier that is set either to allow data to pass unchanged (*green fiber*) or to destroy the transmitted information (*red fiber*). Switching the modifiers from one mode to the other enables the network to be trained. Note that each neuron has two inputs (*bottom left, inset*) and executes the simple logical operation of "not and," or NAND: if both inputs are 1, then the output is 0; otherwise the output is 1.

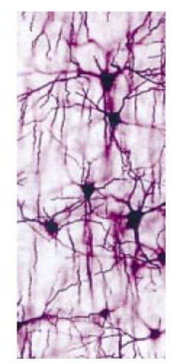
In Turing's network the neurons interconnect freely. In contrast, modern networks (*bottom center*) restrict the flow of information from layer to layer of neurons. Connectionists aim to simulate the neural networks of the brain (*bottom right*).


be regarded by one man as organised and by another as unorganised.

A typical example of an unorganised machine would be as follows. The machine is made up from a rather large number N of similar units. Each unit has two input terminals, and has an output terminal whcih can be connected to the input terminals of (0 or more) other units. We may imagine that ~~thx~~ for each integer r, $1 \leq r \leq N$







TOM MOORE (*illustrations*); KING'S COLLEGE MODERN ARCHIVES, CAMBRIDGE UNIVERSITY LIBRARY (*top*); PETER ARNOLD, INC. (*bottom right*)

Using an Oracle to Compute the Uncomputable

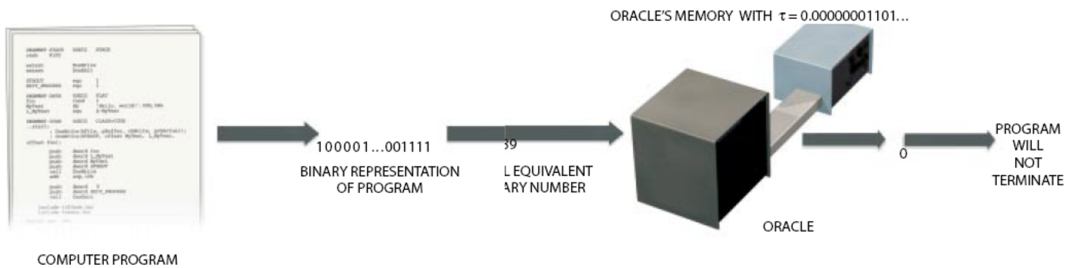
Alan Turing proved that his universal machine—and by extension, even today's most powerful computers—could never solve certain problems. For instance, a universal Turing machine cannot always determine whether a given software program will terminate or continue running forever. In some cases, the best the universal machine can do is execute the program and wait—maybe eternally—for it to finish. But in his doctoral thesis (*below*), Turing did imagine that a machine equipped with a special "oracle" could perform this and other "uncomputable" tasks. Here is one example of how, in principle, an oracle might work.

Consider a hypothetical machine for solving the formidable "terminating program" problem (*above*). A computer program can be represented as a finite string of 1s and 0s. This sequence of digits can also be thought of as the binary representation of an integer, just as 1011011 is the equivalent of 91. The oracle's job can then be restated as, "Given an integer that represents a program (for any computer that can be simulated by a universal Turing machine), output a '1' if the program will terminate or a '0' otherwise."

The oracle consists of a perfect measuring device and a store, or memory, that contains a precise value—call it τ for Turing—of some physical quantity. (The memory might, for example, resemble a capacitor storing an exact amount of electricity.) The value of τ is an irrational number; its written representation would be an infinite string of binary digits, such as 0.00000001101...

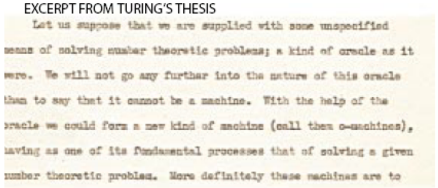
The crucial property of τ is that its individual digits happen to represent accurately which programs terminate and which do not. So, for instance, if the integer representing a program were 8,735,439, then the oracle could by measurement obtain the 8,735,439th digit of τ (counting from left to right after the decimal point). If that digit were 0, the oracle would conclude that the program will process forever.

Obviously, without τ the oracle would be useless, and finding some physical variable in nature that takes this exact value might very well be impossible. So the search is on for some practicable way of implementing an oracle. If such a means were found, the impact on the field of computer science could be enormous. *—B.J.C. and D.P.*



TOM MOORE

EXCERPT FROM TURING'S THESIS



Let us suppose that we are supplied with some unspecified means of solving number theoretic problems; a kind of oracle as it were. We will not go any further into the nature of this oracle than to say that it cannot be a machine. With the help of the oracle we could form a new kind of machine (call them o-machines), having as one of its fundamental processes that of solving a given number theoretic problem. More definitely these machines are to

PRINCETON ARCHIVES

for universal Turing machines. In his 1938 doctoral thesis at Princeton University, he described "a new kind of machine," the "O-machine."

An O-machine is the result of augmenting a universal Turing machine with a black box, or "oracle," that is a mechanism for carrying out uncomputable tasks. In other respects, O-machines are similar to ordinary computers. A digitally encoded program is fed in, and the machine produces digital output from the input using a step-by-step procedure of repeated applications of the machine's basic operations, one of which is to pass data to the oracle and register its response.

Turing gave no indication of how an oracle might work. (Neither did he explain in his earlier research how the basic actions of a universal Turing machine—for example, "identify the symbol in the scanner"—might take place.) But notional mechanisms that fulfill the specifications of an O-machine's black box are not difficult to imagine [*see box above*]. In principle, even a suitable B-type network can compute the uncomputable, provided the activity of the neurons is desynchronized. (When a central clock keeps the neurons in step with one another, the functioning of the network can be exactly simulated by a universal Turing machine.)

Even among experts, Turing's pioneering theoretical concept of a hypermachine has largely been forgotten.

In the exotic mathematical theory of hypercomputation, tasks such as that of distinguishing theorems from nontheorems in arithmetic are no longer uncomputable. Even a debugger that can tell whether any program written in C, for example, will enter an infinite loop is theoretically possible.

If hypercomputers can be built—and that is a big if—the potential for cracking logical and mathematical problems hitherto deemed intractable will be enormous. Indeed, computer science may be approaching one of its most significant advances since researchers wired together the first electronic embodiment of a universal Turing machine decades ago. On the other hand, work on hypercomputers may simply fizzle out for want of some way of realizing an oracle.

The search for suitable physical, chemical or biological phenomena is getting under way. Perhaps the answer will be complex molecules or other structures that link together in patterns as complicated as those discovered by Hanf and Myers. Or, as suggested by Jon Doyle of M.I.T., there may be naturally occurring equilibrating systems with discrete spectra that can be seen as carrying out, in principle, an uncomputable task, producing appropriate output (1 or 0, for example) after being bombarded with input.

Outside the confines of mathematical logic, Turing's O-machines have largely been forgotten, and instead a myth has taken hold. According to this apocryphal account, Turing demonstrated in the mid-1930s that hypermachines are impossible. He and Alonzo Church, the logician who was Turing's doctoral adviser at Princeton, are mistakenly credited with having enunciated a principle to the effect that a universal Turing machine can exactly simulate the behavior of any other information-processing machine. This proposition, widely but incorrectly known as the Church-Turing thesis, implies that no machine can carry out an information-processing task that lies beyond the scope of a universal Turing machine. In truth, Church and Turing claimed only that a universal Turing machine can match the behavior of any human mathematician working with paper and pencil in accordance with an algorithmic method—a considerably weaker claim that certainly does not rule out the possibility of hypermachines.

Even among those who are pursuing the goal of building hypercomputers, Turing's pioneering theoretical contributions have been overlooked. Experts routinely talk of carrying out information processing "beyond the Turing limit" and describe themselves as attempting to "break the Turing barrier." A recent review in *New Scientist* of this emerging field states that the new machines "fall outside Turing's conception" and are "computers of a type never envisioned by Turing," as if the British genius had not conceived of such devices more than half a century ago. Sadly, it appears that what has already occurred with respect to Turing's ideas on connectionism is starting to happen all over again.

The Final Years

In the early 1950s, during the last years of his life, Turing pioneered the field of artificial life. He was trying to simulate a chemical mechanism by which the genes of a fertilized egg cell may determine the anatomical structure of the resulting animal or plant. He described this research as "not altogether unconnected" to his study of neural networks, because "brain structure has to be ... achieved by the genetical embryological mechanism, and this theory that I am now working on may make clearer what restrictions this really implies." During this period, Turing achieved the distinction of being the first to engage in the computer-assisted exploration of nonlinear dynamical systems. His theory used nonlinear differential equations to express the chemistry of growth.

But in the middle of this groundbreaking investigation, Turing died from cyanide poisoning, possibly by his own hand. On June 8, 1954, shortly before what would have been his 42nd birthday, he was found dead in his bedroom. He had left a large pile of handwritten notes and some computer programs. Decades later this fascinating material is still not fully understood.

The Authors

B. JACK COPELAND and DIANE PROUDFOOT are the directors of the Turing Project at the University of Canterbury, New Zealand, which aims to develop and apply Turing's ideas using modern techniques. The authors are professors in the philosophy department at Canterbury, and Copeland is visiting professor of computer science at the University of Portsmouth in England. They have written numerous articles on Turing. Copeland's *Turing's Machines* and *The Essential Turing* are forthcoming from Oxford University Press, and his *Artificial Intelligence* was published by Blackwell in 1993. In addition to the logical study of hypermachines and the simulation of B-type neural networks, the authors are investigating the computer models of biological growth that Turing was working on at the time of his death. They are organizing a conference in London in May 2000 to celebrate the 50th anniversary of the pilot model of the Automatic Computing Engine, an electronic computer designed primarily by Turing.

Further Reading

X-Machines and the Halting Problem: Building a Super-Turing Machine. Mike Stannett in *Formal Aspects of Computing*, Vol. 2, pages 331–341; 1990.

Intelligent Machinery. Alan Turing in *Collected Works of A. M. Turing: Mechanical Intelligence.* Edited by D. C. Ince. Elsevier Science Publishers, 1992.

Computation beyond the Turing Limit. Hava T. Siegelmann in *Science*, Vol. 268, pages 545–548; April 28, 1995.

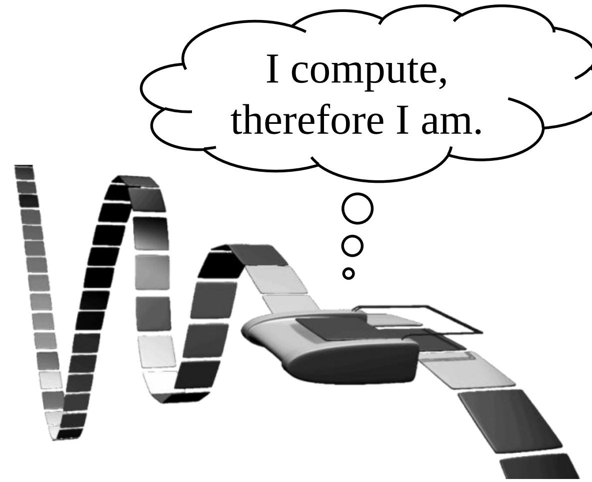
On Alan Turing's Anticipation of Connectionism. B. Jack Copeland and Diane Proudfoot in *Synthese*, Vol. 108, No. 3, pages 361–377; March 1996.

Turing's O-Machines, Searle, Penrose and the Brain. B. Jack Copeland in *Analysis*, Vol. 58, No. 2, pages 128–138; 1998.

The Church-Turing Thesis. B. Jack Copeland in *The Stanford Encyclopedia of Philosophy.* Edited by Edward N. Zalta. Stanford University, ISSN 1095-5054. Available at http://plato.stanford.edu on the World Wide Web.

The Turing Test

Q: Can machines think?



Problem: We don’t know what “think” means.

Q: What is intelligence?

Problem: We can’t define “intelligence”.

But, we usually “know it when we see it”.

AMT/B/9/1

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(Taken from MIND : a Quartedy Review of Psychology and Philosophy. Vol. LIX. , N.S., No. 236, October , 1950.)

COMPUTING MACHINERY AND INTELLIGENCE

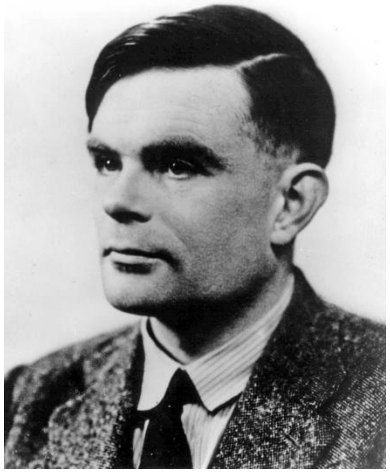
by

A. M. TURING.

1. The Imitation Game.

I propose to consider the question, 'Can machines think?' This should begin with definitions of the meaning of the terms 'machine' and 'think'. The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous. If the meaning of the words 'machine' and 'think' are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, 'Can machines think?' is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the question by another, which is closely related to it and is expressed in relatively unambiguous words.

The new form of the problem can be described in terms of a game which we call the 'imitation game'. It is played with three people, a man (A), a woman (B), and an interrogator (C) who may be of either sex. The interrogator stays in a room apart from the other two.



be able to produce a material which is indistinguishable from the human skin. It is possible that at some time this might be done, but even supposing this invention available we should feel there was little point in trying to make a 'thinking machine' more human by dressing it up in such artificial flesh. The form in which we have set the problem reflects this fact in the condition which prevents the interrogator from seeing or touching the other competitors, or hearing their voices. Some other advantages of the proposed criterion may be shown up by specimen questions and answers. Thus:

Q: Please write me a sonnet on the subject of the Forth Bridge.

A: Count me out on this one. I never could write poetry.

Q: Add 34957 to 70764.

A: (Pause about 30 seconds and then give as answer) 105621.

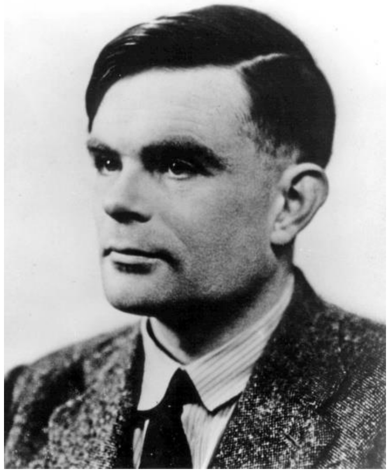
Q: Do you play chess?

A: Yes.

Q: I have K at my K1, and no other pieces. You have only K at K6 and R at R1. It is your move. What do you play?

A: (After a pause of 15 seconds) R-R8 mate.

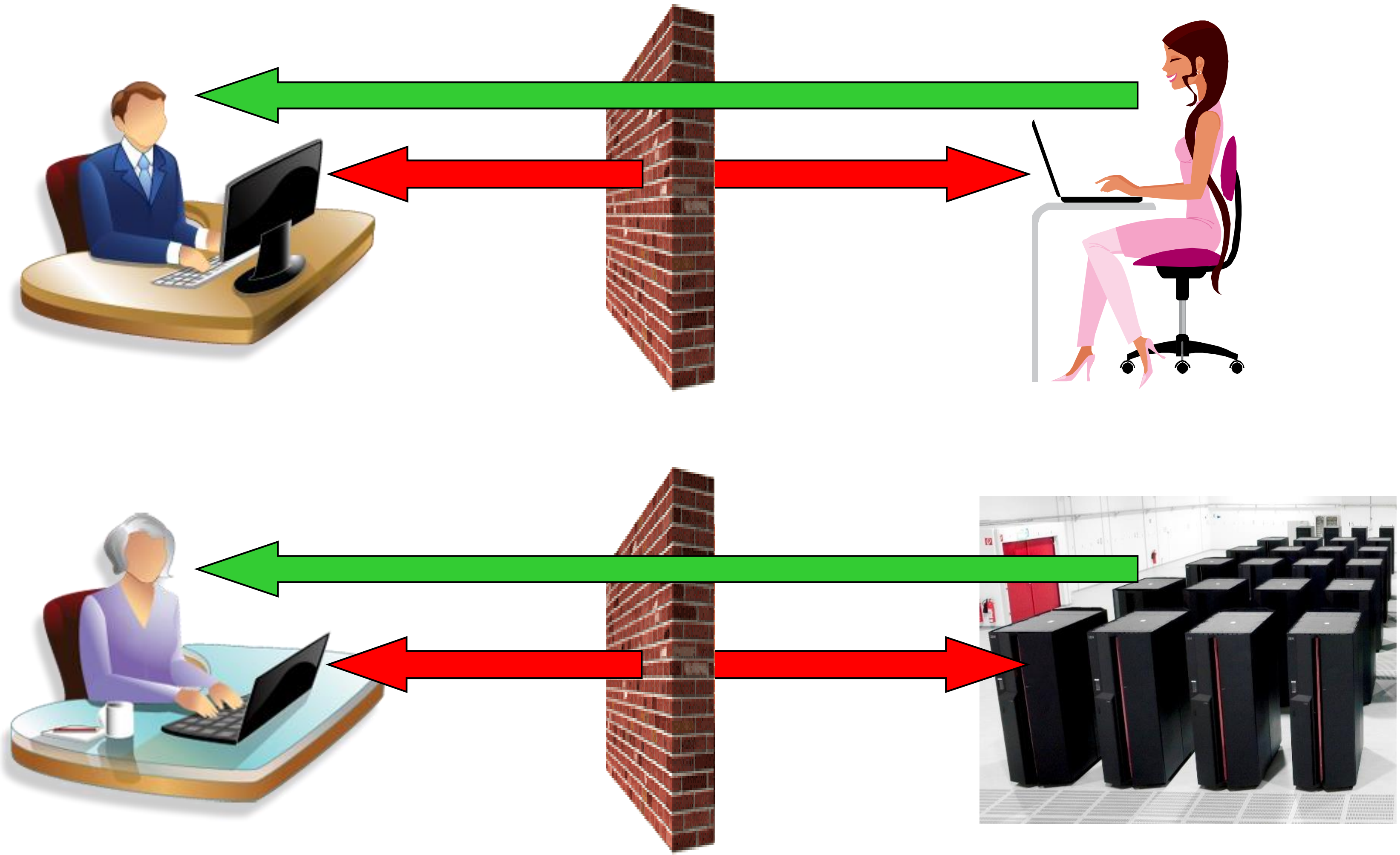
The question and answer method seems to be suitable for introducing almost any one of the fields of human endeavour that we wish to include. We do not wish to penalise the machine for its inability to shine in beauty competitions, nor to penalise a man for losing in a race against an aeroplane. The conditions of our game make these disabilities irrelevant. The 'witnesses' can brag, if they consider it advisable, as much as they please about their charms, strength or heroism, but the interrogator cannot demand practical demonstrations.



The Turing Test

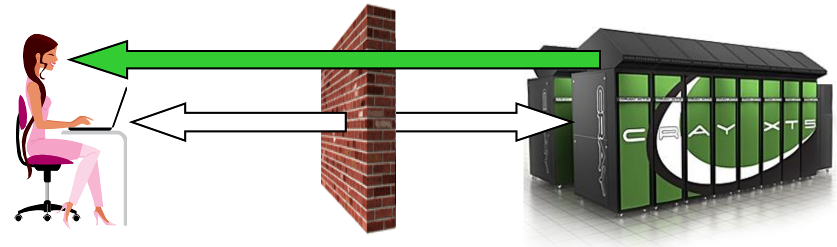
Q: Can you distinguish a machine from a person?

≡ Can a machine impersonate a person?



The Turing Test

- The first deep investigation into whether machines can "behave intelligently"

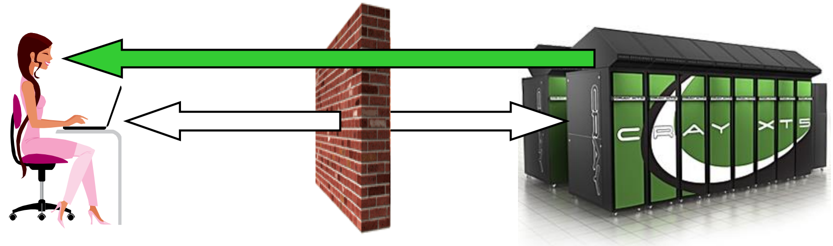


- Helped usher in field of AI
- Decoupled "intelligence" from "human"
- Based "intelligence" on I/O, not entity's "look and feel"
- Proposed a practical, formal test for intelligence
- Definitions & test are operational & easily implementable
- Turing test variants: "immortality", "fly-on-wall", "meta", "reverse", "subject matter expert", "compression", "minimum intelligent signal"

The Turing Test

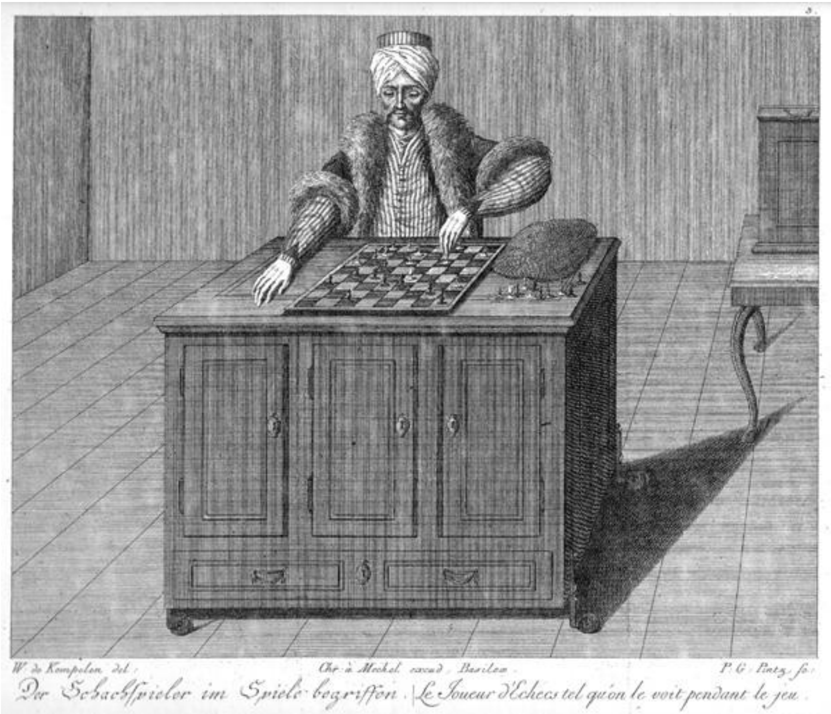
Q: Which of the following can ~~think~~? pass the Turing test?

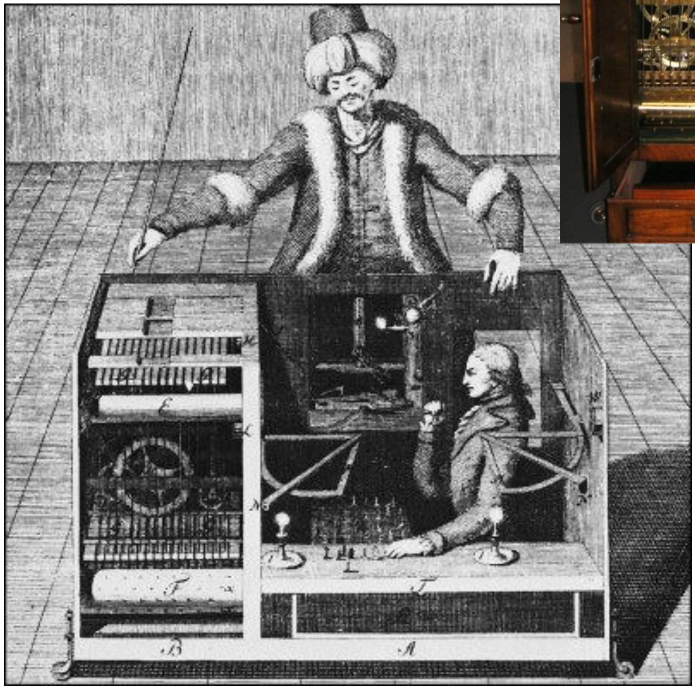
Turing Test Milestones



Turk (von Kempelen), 1770:

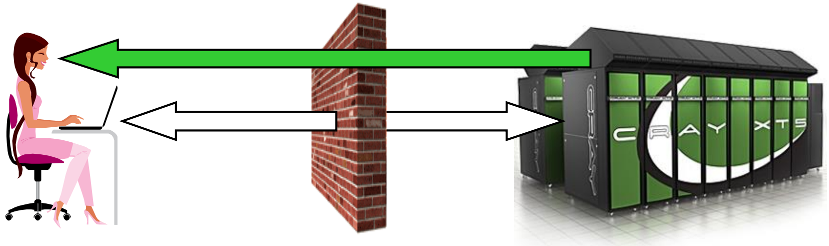
- Played a strong game of chess
- Toured the world for 84 years
- Generated much interest in automata
- Was a hoax (hidden human operator)





Turing Test Milestones

Eliza (Weizenbaum), 1966:



- First “chatterbot”
- Named after “Eliza Doolittle” of Shaw’s Pygmalion
- Simulated Rogerian psychotherapist
- Often convinced people it is human
- Influence computer games (e.g., Dungeon, Adventure)
- Inspired Arthur C. Clarke’s HAL 9000
- Chatterbots appear today in chatrooms and dating services
- Chatterbot competitions (Turing Test format):
  - Loebner Prize
  - Chatterbox Challenge, 2010


The Chatterbox Challenge (CBC) - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.chatterboxchallenge.com/

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Wolfram

iNFRADRIVE Chatterbox Challenge 09

THE ULTIMATE BOT CONTEST

Home • News • Forums • Bots Directory • Contest Rules • Prizes • CBC Store • History • Credits

Chatterbox Challenge 09

Final Results

1st Best Overall Bot: Jeeney AI

2nd Best Overall Bot: Artemis

3rd Best Overall Bot: Alice

Most Popular Bot: Artemis

Best New Bot: Suzette

Welcome to the new CBC 2009!

The Chatterbox Challenge (CBC) is an annual contest which starts in mid March that allow any chatbot developer to participate and evaluate the intelligence of the chatbot through turing tests and much more. It is a really fun, simple and inclusive way for all children to practise their speech and language skills, it will be also interesting and amazing for anyone who wants to chat with the best chatbots.

View Public Voting Results...

Join the community...

- Dead line to enter your chatbot: **15 March 2009**
- Judging period starts from: **16 March 2009** to: **30 April 2009**
- Public Voting period starts from: **13 April 2009** to: **10 May 2009**
- Final result announced in 15 may 2009.
- The winners of CBC 2009 are listed below:

Latest News

- The Chatterbox Challenge 2009 Champion is ...
  Thu, 14 May 2009 @ 8:56:09 pm
- Public Voting results and 2nd round of questions!
  Tue, 12 May 2009 @ 2:32:17 pm
- CBC 2009 Prizes
  Thu, 30 April 2009 @ 4:35:36 am
- CBC Contest Public Voting Started!
  Mon, 13 April 2009 @ 12:03:41 pm

Latest posts by members

- Public Voting Results by Ehab
- About Chatterbot ATHENA's inverted/reversed 2 files by Husky_3d
- 1st round completed and top 9 bots announced... by Ehab
- Guess the score! by Ehab
- MS Agent is dead. by Merlin2009
- Simple Benchmark Results by Merlin2009
- Merlin by Merlin2009
- Comments disappeared by Husky_3d
- Entering the CBC 2009 contest.... by Ehab
- Entering the contest by Vashka

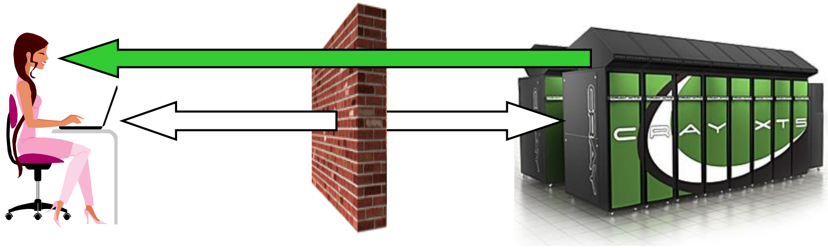
See Also

- Chatbots directory
- Chatterbox Challenge Rules
- Chatterbox Challenge Forums
- Chatterbox Challenge History
- Chatterbox Challenge Banners
- Old Website

Find: Next Previous Highlight all Match case

Done

Turing Test Milestones



Elbot, 2008:

- Won 2008 Loebner Prize
- Fooled 3 of 12 judges (Turing: >30%)
- Typical excerpt:

Judge: What's your favourite novel?

Elbot: I often read telephone books, or dadaist poetry: Brä brä brä

Judge: Typical computer!

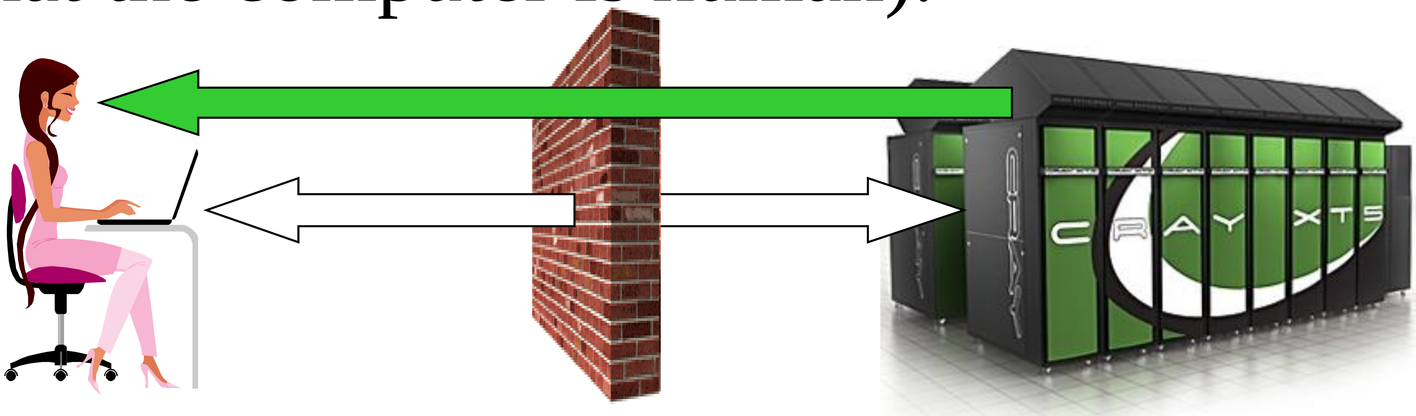
Elbot: You tend towards generalizations. But I must admit, so do I. However, my generalizations are firmly grounded in statistical theory.

Judge: What do u think of KW's enthusiasm for having machines take over the world?

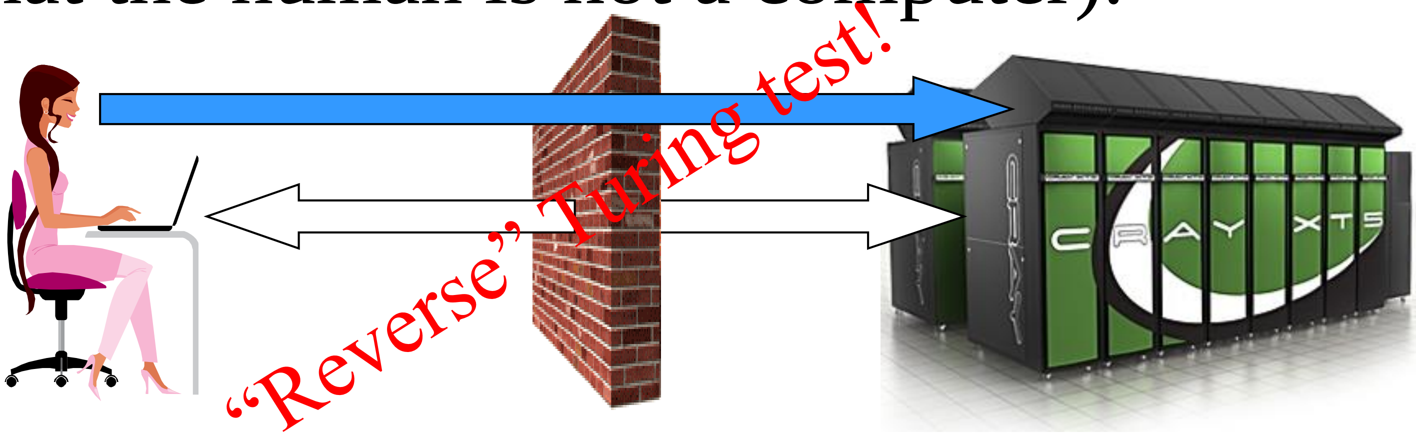
Elbot: Fix it up a bit first. Then I'll take it over.

Applications of the Turing Test

Old: a computer tries to convince a human (that the computer is human).

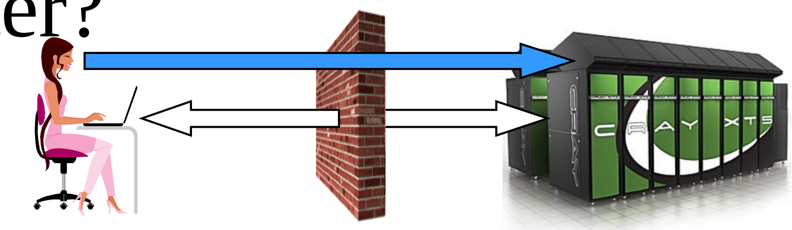


New: a human tries to convince a computer (that the human is not a computer).



Applications of the Turing Test

Problem: how can a human convince a computer that the human is not a computer?

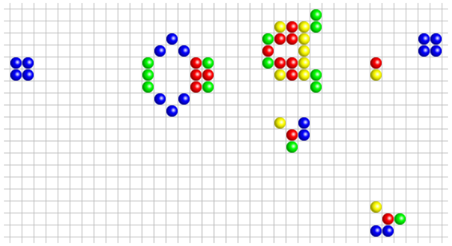


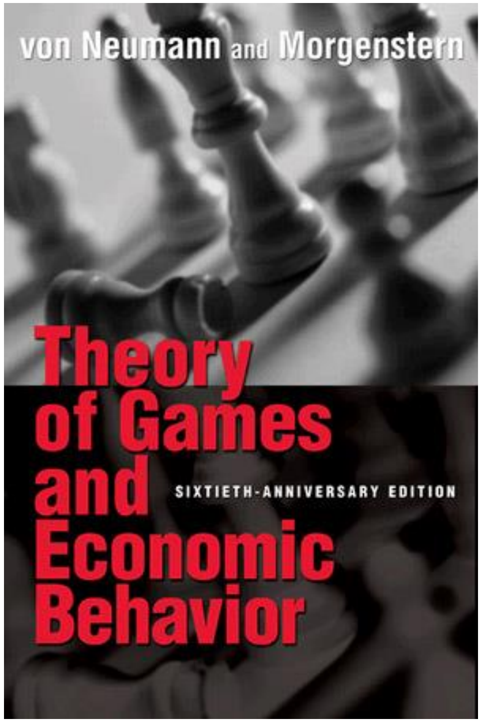
Idea: "CAPTCHA"

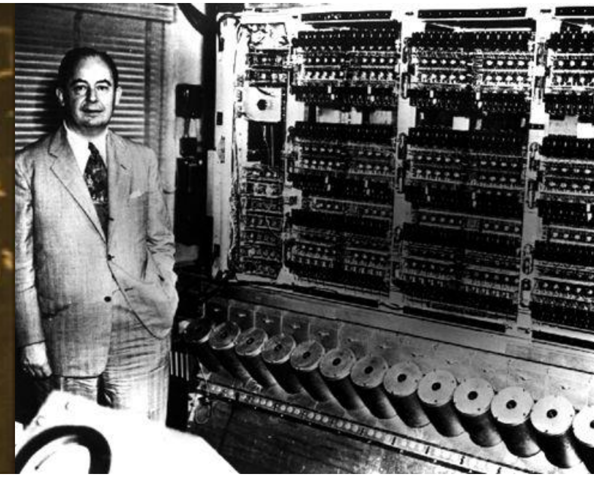
Historical Perspectives

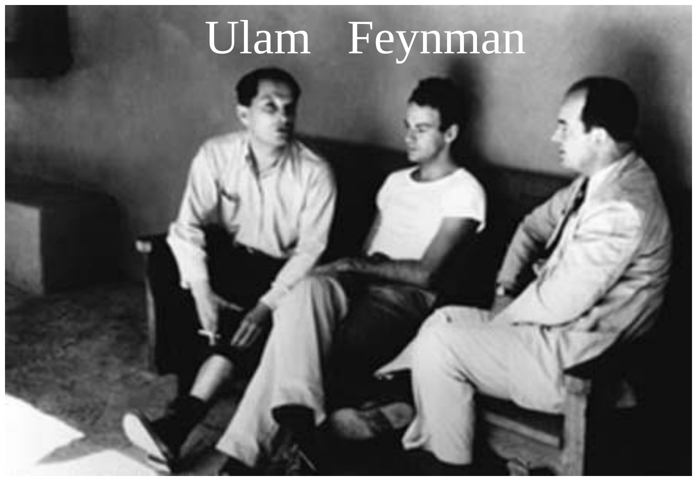
John von Neumann (1903-1957)

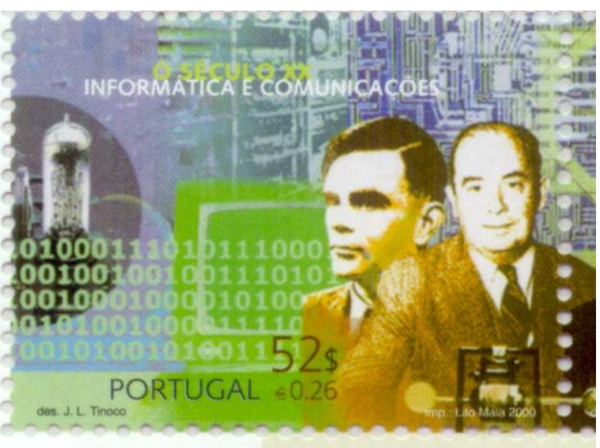
- Contributed to set theory, functional analysis, quantum mechanics, ergodic theory, economics, geometry, hydrodynamics, statistics, analysis, measure theory, ballistics, meteorology, …
- Invented game theory (used in Cold War)
- Re-axiomatized set theory
- Principal member of Manhattan Project
- Helped design the hydrogen / fusion bomb
- Pioneered modern computer science
- Originated the "stored program"
- "von Neumann architecture" and "bottleneck"
- Helped design & build the EDVAC computer
- Created field of cellular automata
- Investigated self-replication
- Invented merge sort



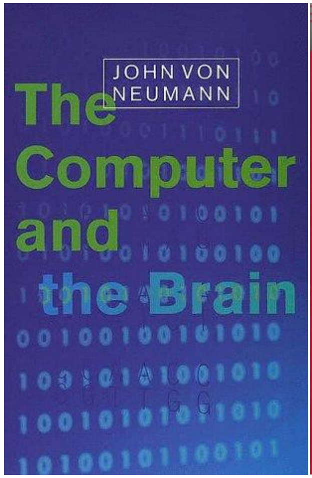








"Most mathematicians prove what they can; von Neumann proves what he wants."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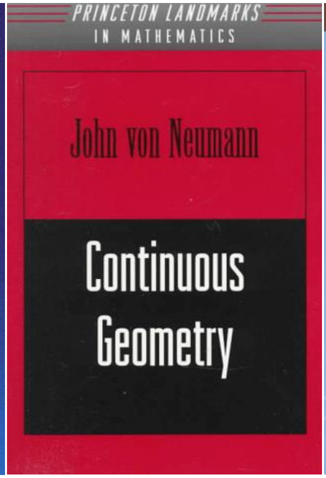
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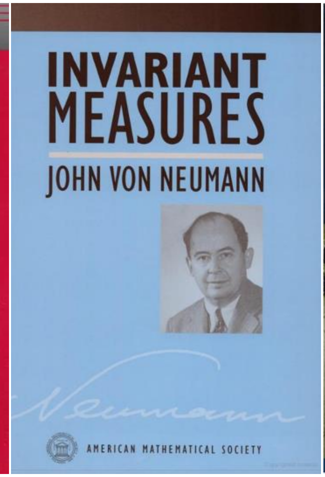
John von Neumann
Continuous Geometry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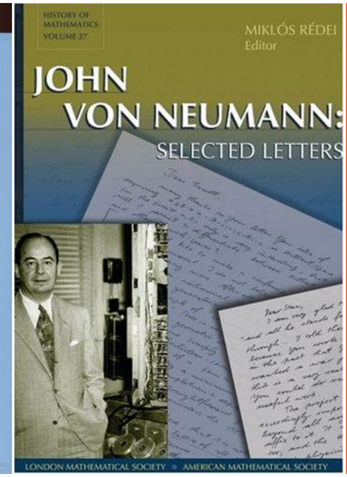
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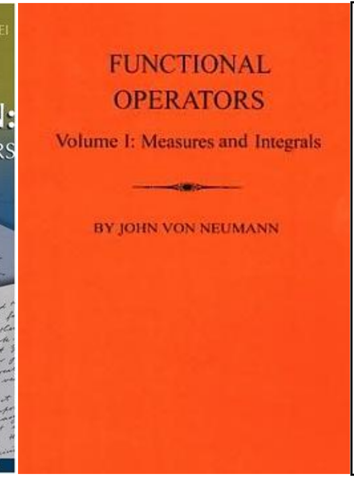
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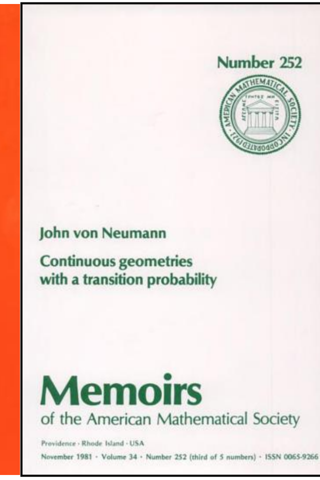
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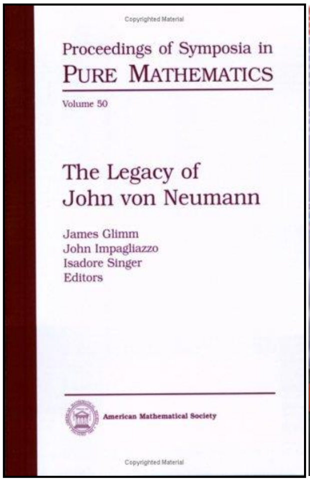
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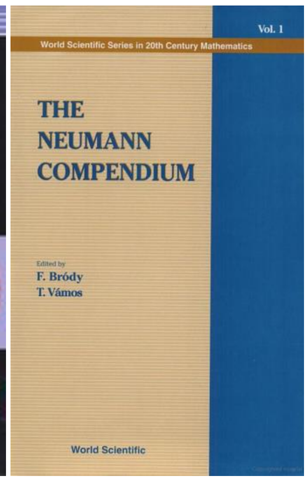
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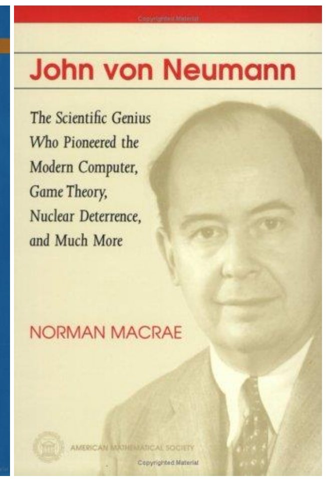
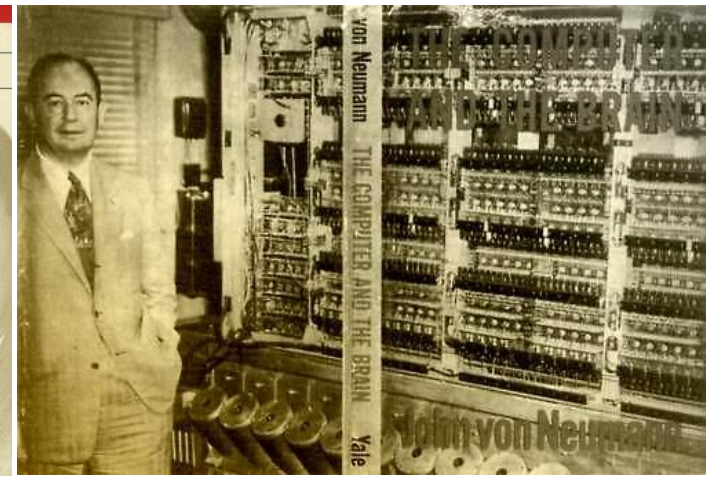

John von Neumann
The Scientific Genius Who Pioneered the Modern Computer, Game Theory, Nuclear Deterrence, and Much More
NORMAN MACRAE
AMERICAN MATHEMATICAL SOCIETY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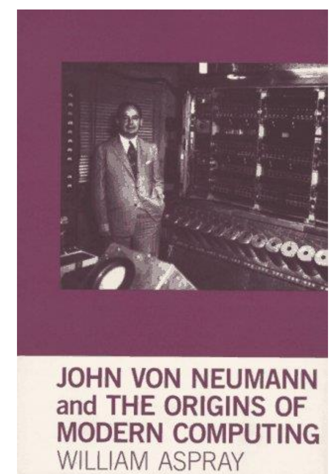
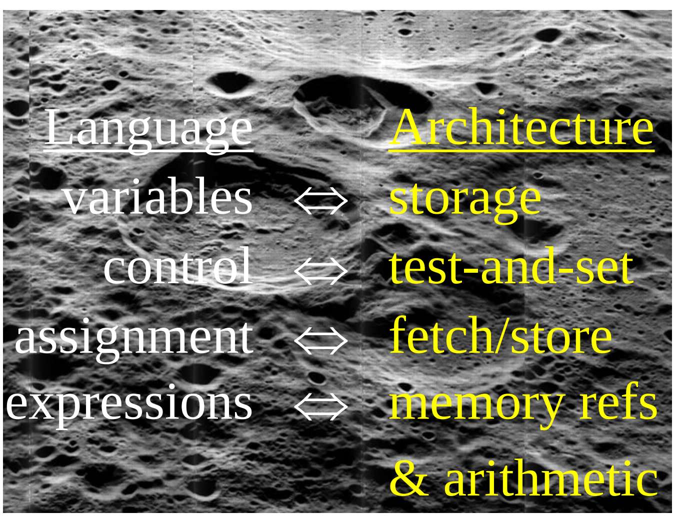
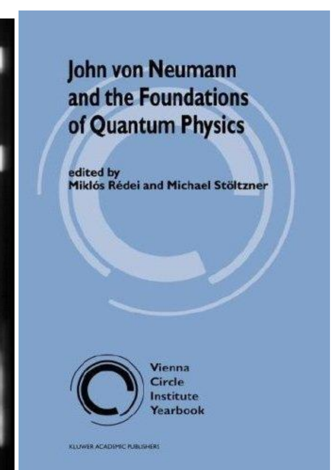
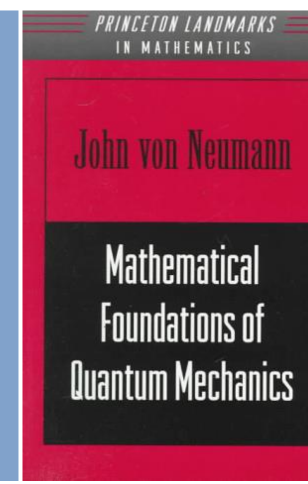

JOHN VON NEUMANN and THE ORIGINS OF MODERN COMPUTING
WILLIAM ASPRAY

von Neumann's Legacy

- Re-axiomatized set theory to address Russell's paradox
- Independently proved Godel's second incompleteness theorem: aximomatic systems are unable to prove their own consistency.
- Addressed Hilbert's 6^{th} problem: axiomatized quantum mechanics using Hilbert spaces.
- Developed the game-theory based Mutually-Assured Destruction (MAD) strategic equilibrium policy – still in effect today!
- von Neumann regular rings, von Neumann bicommutant theorem, von Neumann entropy, von Neumann programming languages



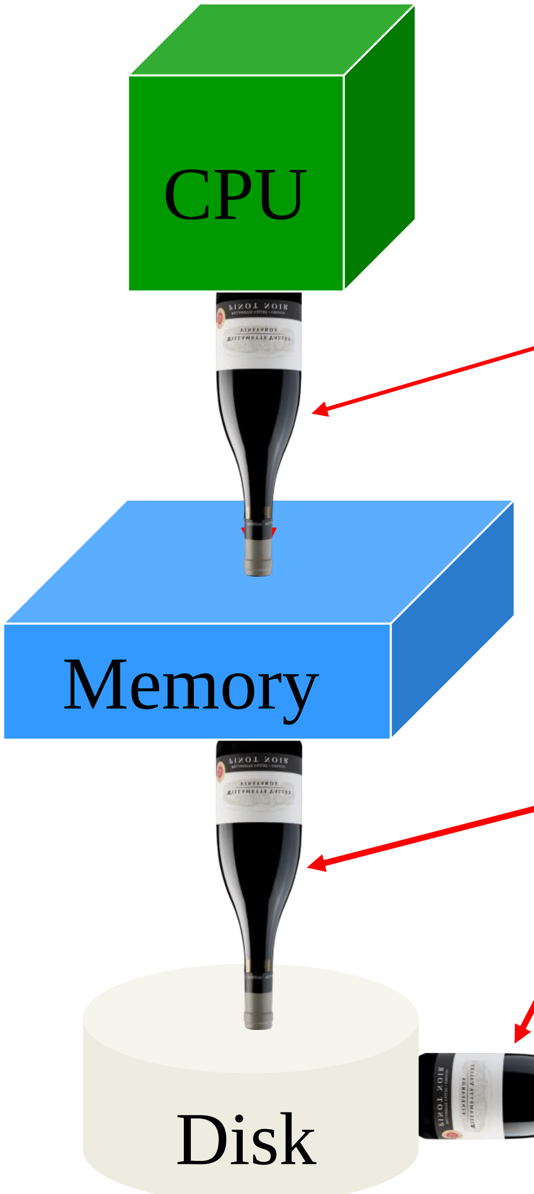


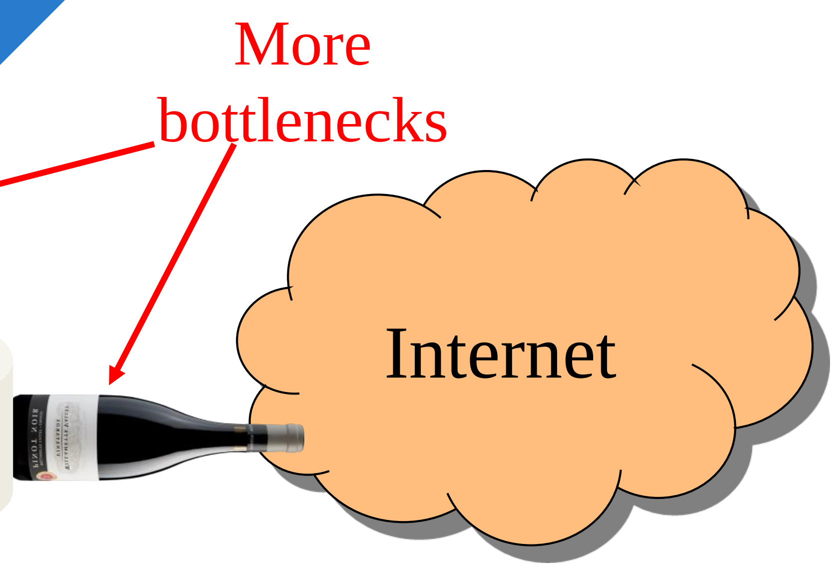


Von Neumann Architecture

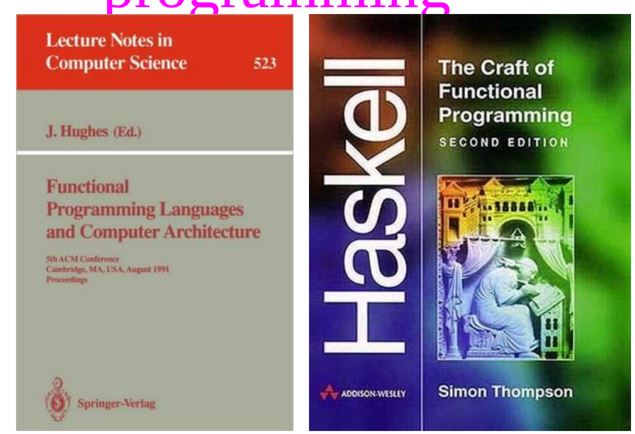
“Surely there must be a less primitive way of making big changes in the store than by pushing vast numbers of words back and forth through the von Neumann bottleneck. Not only is this tube a literal bottleneck for the data traffic of a problem, but, more importantly, it is an intellectual bottleneck that has kept us tied to word-at-a-time thinking instead of encouraging us to think in terms of the larger conceptual units of the task at hand. Thus programming is basically planning and detailing the enormous traffic of words through the Von Neumann bottleneck, and much of that traffic concerns not significant data itself, but where to find it.”

- John Backus, 1977 ACM Turing Award lecture





Functional programming



First Draft of a Report on the EDVAC

by

John von Neumann

Contract No. W–670–ORD–4926

Between the

United States Army Ordnance Department

and the

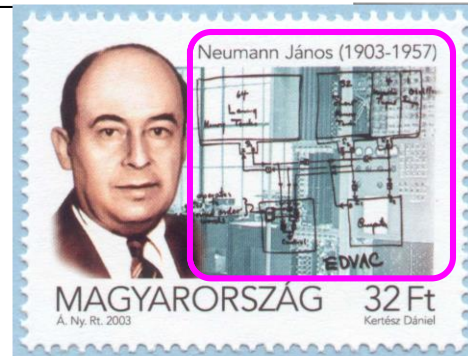
University of Pennsylvania

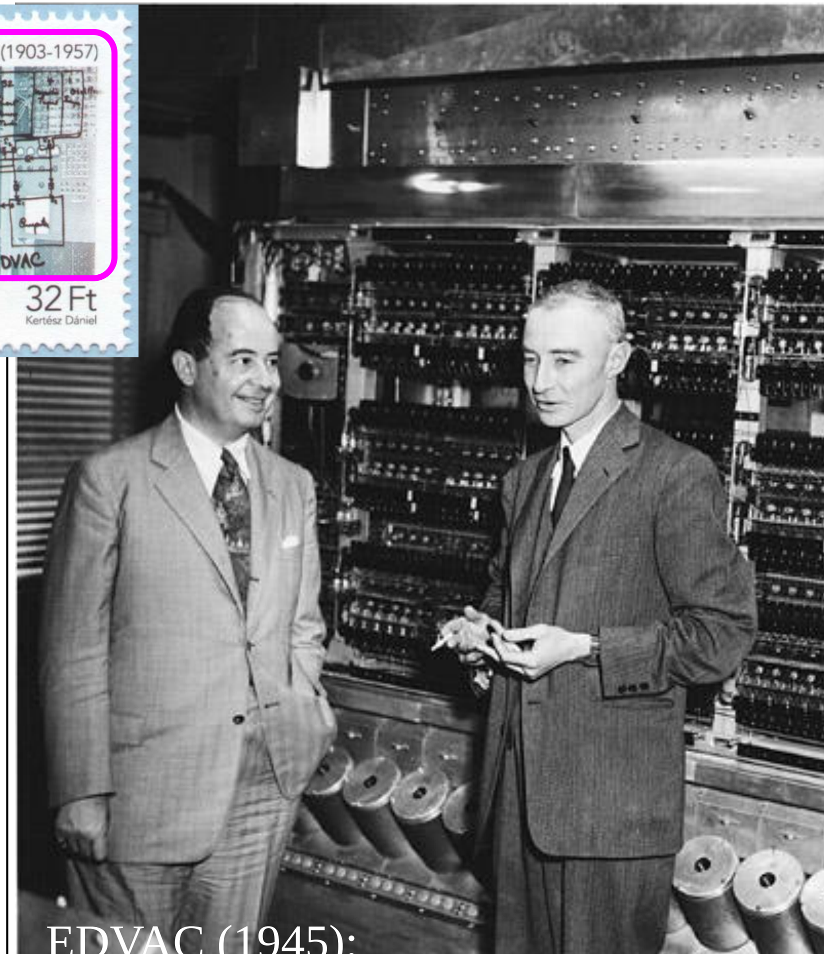
Moore School of Electrical Engineering
University of Pennsylvania

June 30, 1945

This is an exact copy of the original typescript draft as obtained from the University of Pennsylvania Moore School Library except that a large number of typographical errors have been corrected and the forward references that von Neumann had not filled in are provided where possible. Missing references, mainly to unwritten Sections after 15.0, are indicated by empty {}. All added material, mainly forward references, is enclosed in { }. The text and figures have been reset using TEX in order to improve readability. However, the original manuscript layout has been adhered to very closely. For a more "modern" interpretation of the von Neumann design see M. D. Godfrey and D. F. Hendry, "The Computer as von Neumann Planned It," *IEEE Annals of the History of Computing*, vol. 15 no. 1, 1993.

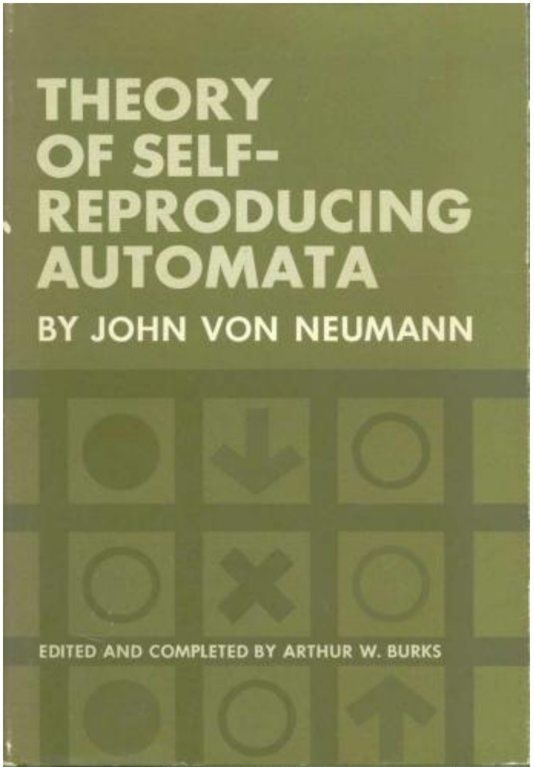
Michael D. Godfrey, Information Systems Laboratory, Electrical Engineering Department
Stanford University, Stanford, California, November 1992





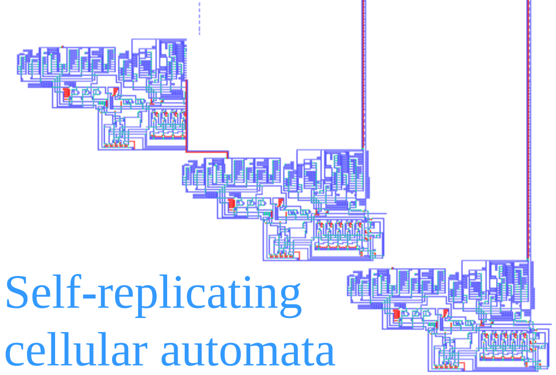
EDVAC (1945):

- 1024 words (44-bits) – 5.5KB
- 864 microsec / add (1157 / sec)
- 2900 microsec / multiply (345/sec)
- Magnetic tape (no disk), oscilloscope
- 6,000 vacuum tubes
- 56,000 Watts of power
- 17,300 lbs (7.9 tons), 490 sqft
- 30 people to operate

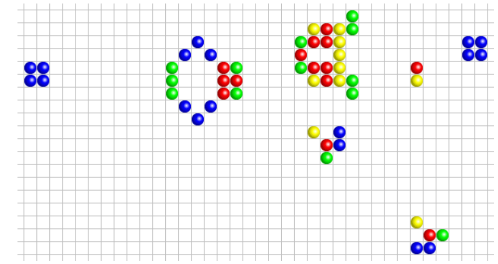


Self-Replication

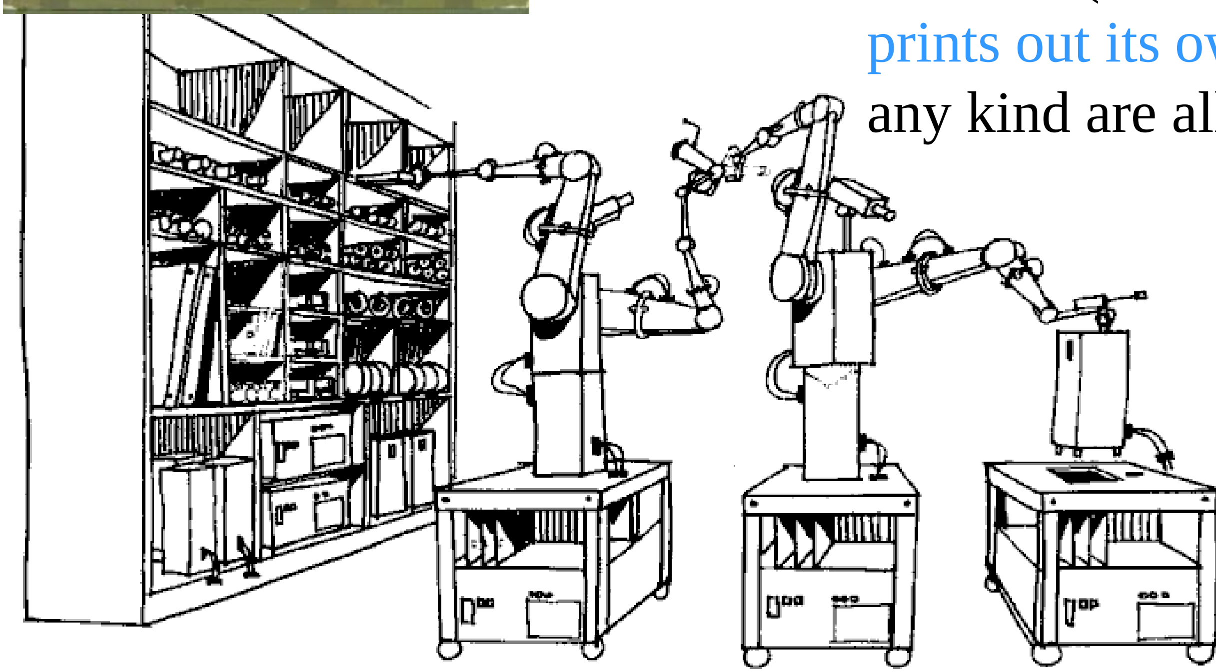
- Biology / DNA
- Nanotechnology
- Computer viruses
- Space exploration
- Memetics / memes
- "Gray goo"



Self-replicating cellular automata designed by von Neumann



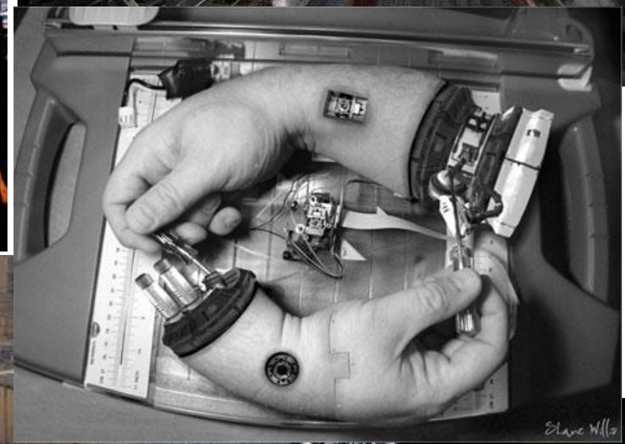
Problem (extra credit): write a program that prints out its own source code (no inputs of any kind are allowed).

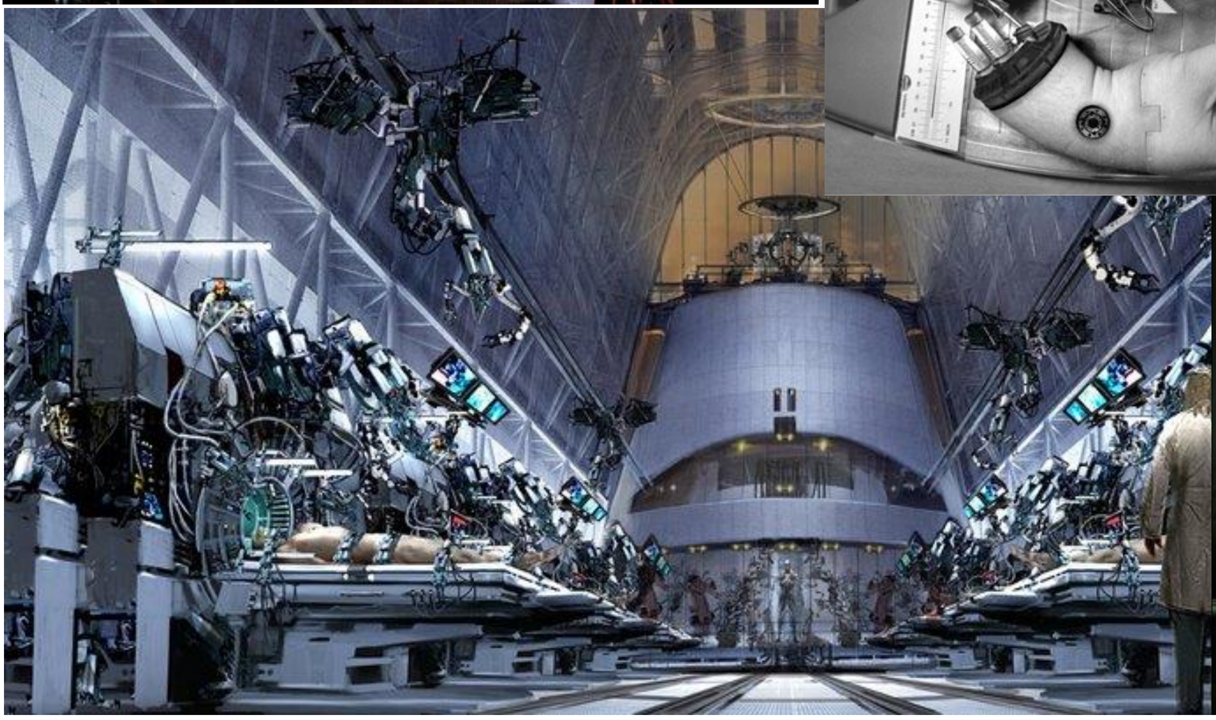








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John von Neumann Institute for Computing (NIC)

The John von Neumann Institute for Computing (NIC) is a joint foundation of Forschungszentrum Jülich and Deutsches Elektronen-Synchrotron DESY to support supercomputer-aided scientific research and development. Since April 2006, the GSI Helmholtzzentrum für Schwerionenforschung joined NIC as a contract partner. NIC takes over the functions and tasks of the High Performance Computer Centre (HLRZ) established in 1987 and continues this centre's successful work in the field of supercomputing and its applications.

- **Provision of supercomputer capacity** for projects in science, research and industry in the fields of modelling and computer simulation including their methods.
  Research proposals can be submitted by German scientists and by partners in the EU projects DEISA and I3HP.
  There is also an Offer to the New Member States and candidate countries of the European Union.

  The supercomputers with the required information technology infrastructure (software, data storage, networks) are operated by the Jülich Supercomputing Centre (JSC) in Jülich and by the Centre for Parallel Computing at DESY in Zeuthen.
- **Supercomputer-oriented research and development** in selected fields of physics and other sciences, especially in elementary-particle physics, by research groups for supercomputing applications.
- **Education and training in the fields of scientific computing** by symposia, workshops, summer schools, seminars, courses, and guest programs for scientists and students.

S.Hoefler-Thierfeldt@fz-juelich.de, 01-Jul-2008
URL: <http://www.fz-juelich.de/nic/Allgemeines/Allgemeines-e.html>

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John von Neumann Theory Prize

A prize is awarded annually to a scholar (or scholars in the case of joint work) who has made fundamental, sustained contributions to theory in operations research and the management sciences. The award is given each year at the National Meeting if there is a suitable recipient. Although the prize is normally given to a single individual, in the case of accumulated joint work, the recipients can be multiple individuals. The award is $5,000, a medallion and a citation.

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  Read about the life and legacy of John von Neumann
- **Application Process**
  View information about eligibility, procedures and deadlines
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Introducing the John von Neumann Computer Society

Ability, pride and creativity of our compatriots are for Hungary the fundament of progress and the only spring-board into the future.
(Count István Széchenyi 1842)

Fields of activity:

As a significant professional body and learned society in the Hungarian IT community, the John von Neumann Computer Society (NJSZT) is dedicated to preserving values that can be included in today's knowledge-based society as well as to setting new directions that meet the requirements of the age and to actively forming the IS world of the future. The primal activities of our Society are IT support, ECDL (European Computer Driving Licence) Hungary, Hungarian Smart Card Forum, Organization of International and National Conferences.

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Fax.:	**(36-1) 463-3580**
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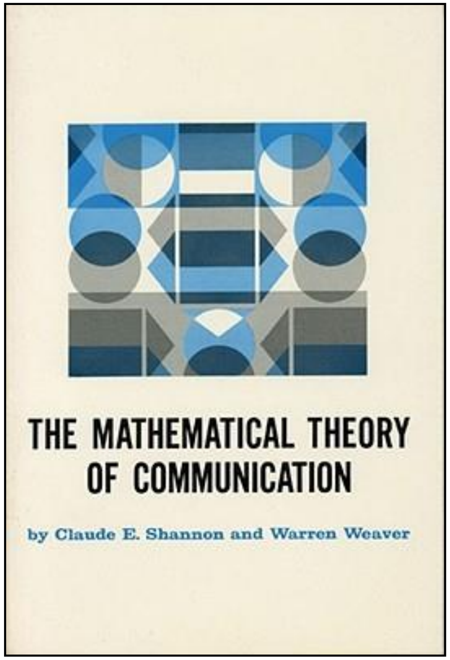
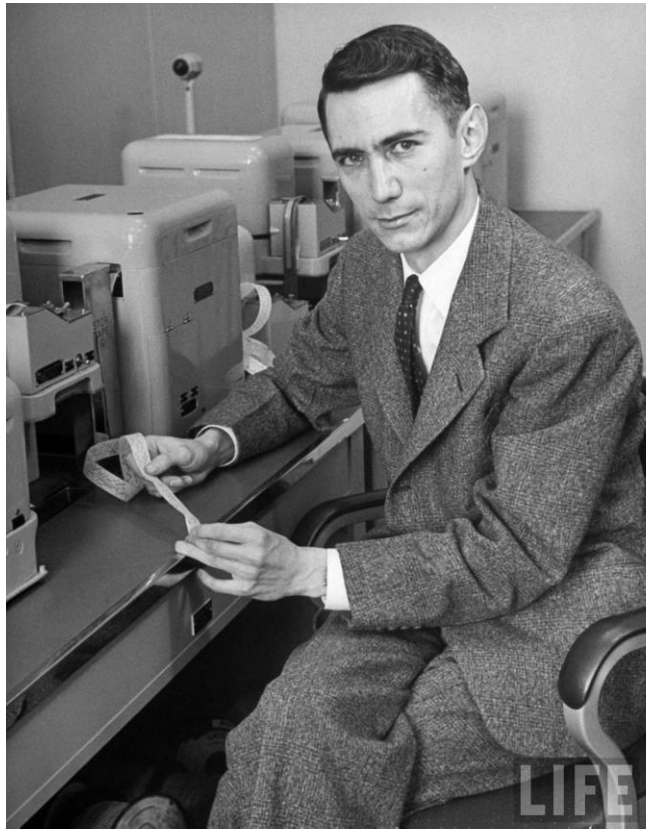
Historical Perspectives

Claude Shannon (1916-2001)

- Invented electrical digital circuits (1937)
- Founded information theory (1948)
- Introduced sampling theory, coined term "bit"
- Contributed to genetics, cryptography
- Joined Institute for Advanced Study (1940) Influenced by Turing, von Neumann, Einstein
- Originated information entropy, Nyquist–Shannon, sampling theorem, Shannon-Hartley theorem, Shannon switching game, Shannon-Fano coding, Shannon's source coding theorem, Shannon limit, Shannon decomposition / expansion, Shannon #
- Other hobbies & inventions: juggling, unicycling, computer chess, rockets, motorized pogo stick, flame-throwers, Rubik's cube solver, wearable computer, mathematical gambling, stock markets
- "AT&T Shannon Labs" named after him

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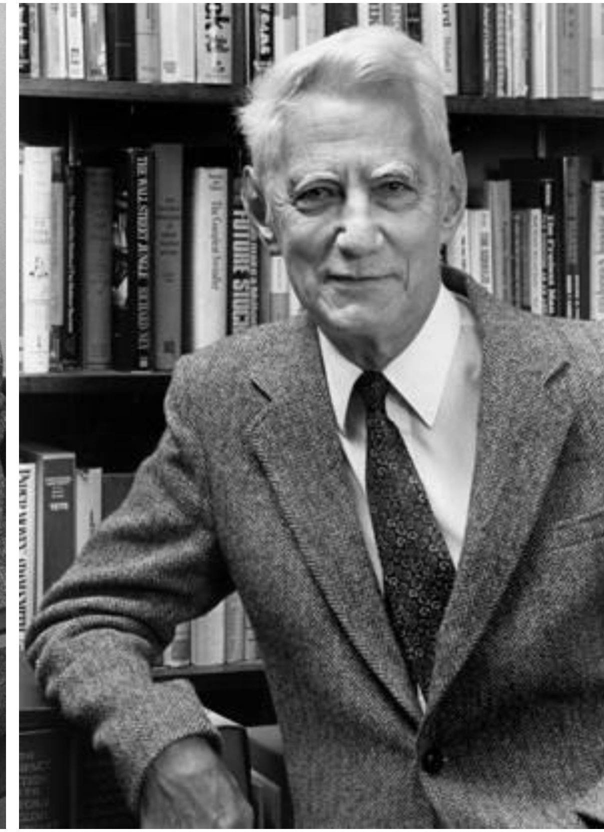
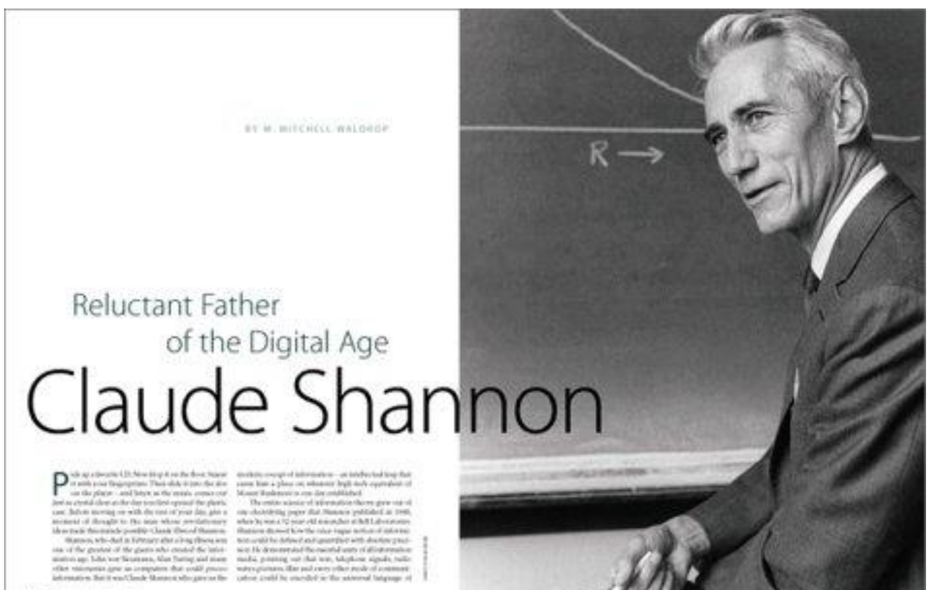
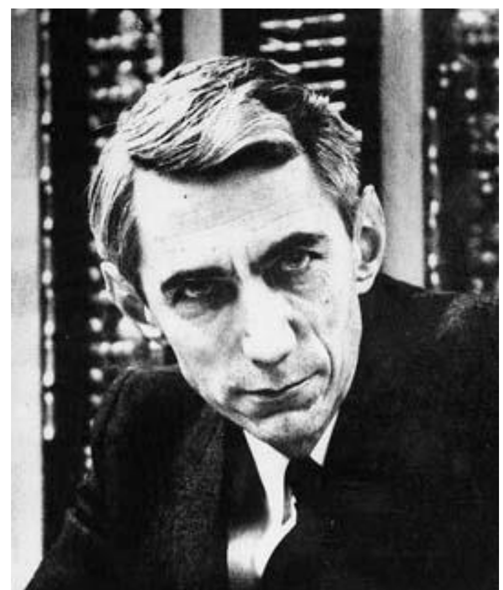
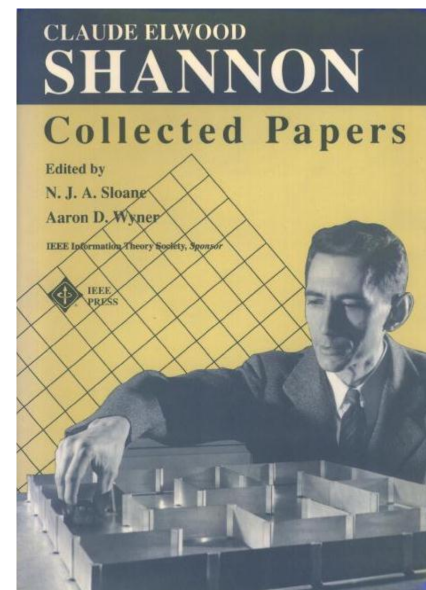



BY M. MITCHELL WALDROP
R →
Reluctant Father
of the Digital Age
Claude Shannon




CLAUDE ELWOOD
SHANNON
Collected Papers
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A SYMBOLIC ANALYSIS OF RELAY AND SWITCHING CIRCUITS

by

Claude Elwood Shannon

B.S., University of Michigan

1936

Submitted in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

from the

Massachusetts Institute of Technology

1940

Signature of Author________________________

Department of Electrical Engineering, August 10, 1937

Signature of Professor
in Charge of Research________________________

Signature of Chairman of Department
Committee on Graduate Students________________________

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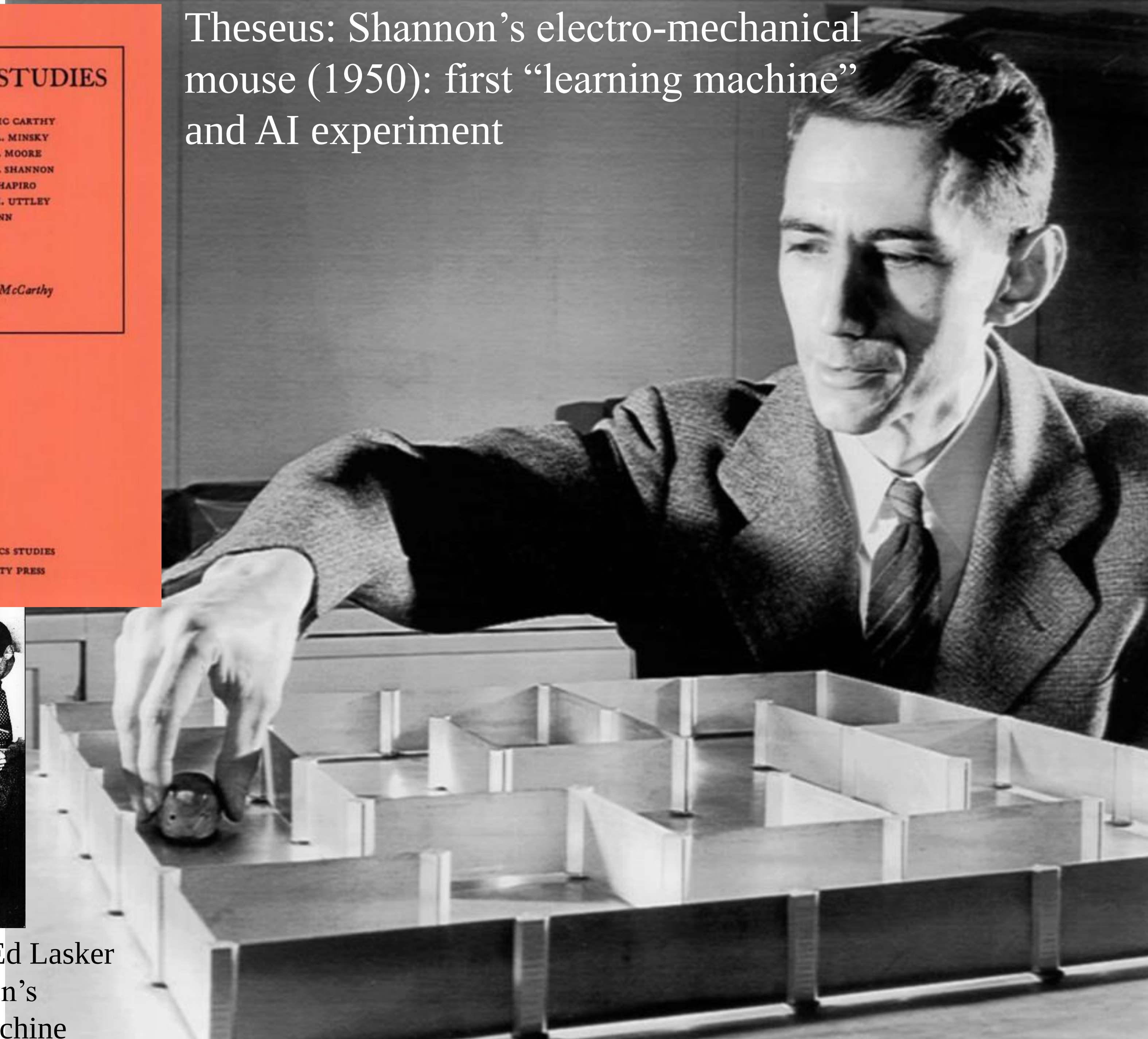
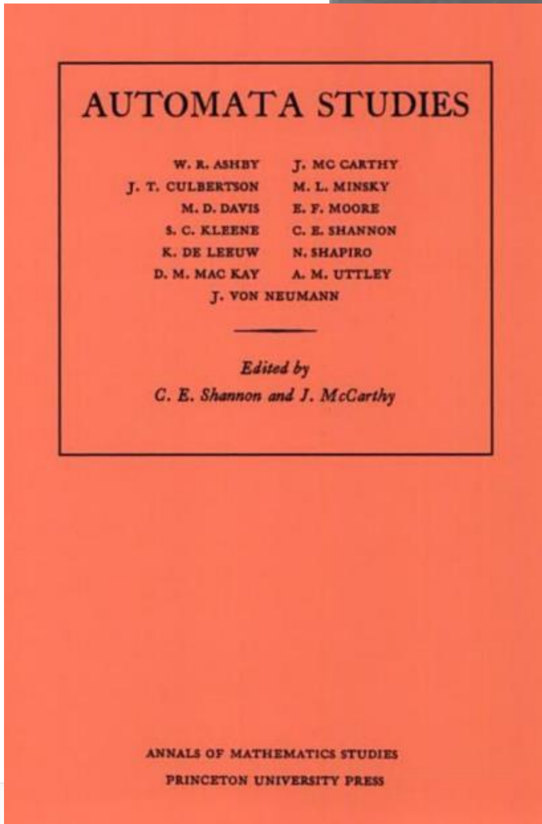
Theseus: Shannon’s electro-mechanical mouse (1950): first “learning machine” and AI experiment





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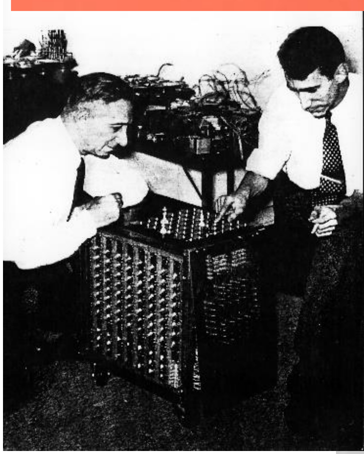
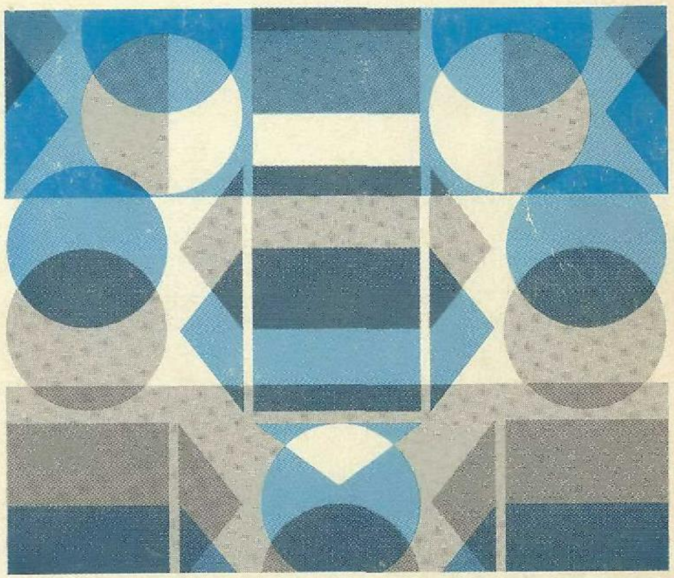


Chess champion Ed Lasker looking at Shannon’s chess-playing machine

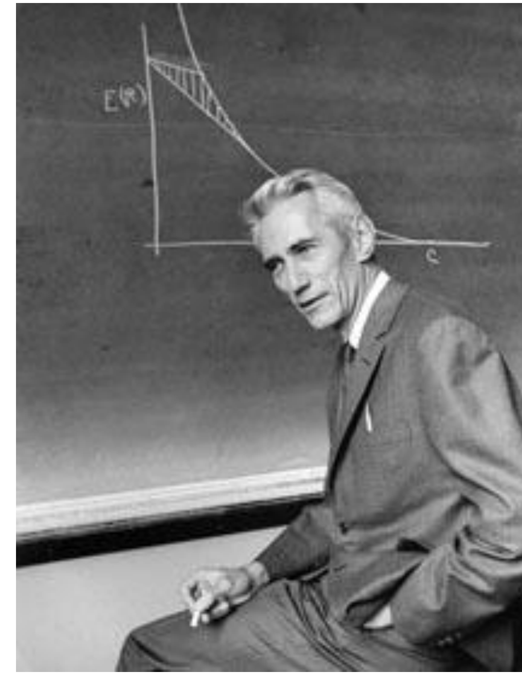
Shannon’s home study room

Shannon’s On/Off machine



THE MATHEMATICAL THEORY OF COMMUNICATION

by Claude E. Shannon and Warren Weaver



Eighth paperback printing, 1980

Originally published in a clothbound edition, 1949.

Manufactured in the United States of America.
Library of Congress Catalog Card No. 49-11922.

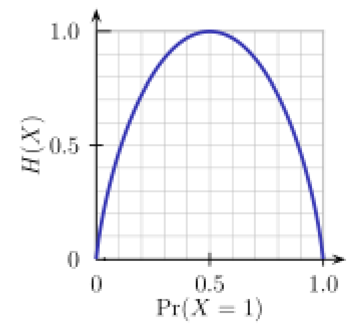
ISBN 0-252-72548-4

Entropy and Randomness

- Entropy measures the expected "uncertainly" (or "surprise") associated with a random variable.

- Entropy quantifies the "information content" and represents a lower bound on the best possible lossless compression.

- Ex: a random fair coin has entropy of 1 bit.
  A biased coin has lower entropy than fair coin.
  A two-headed coin has zero entropy.



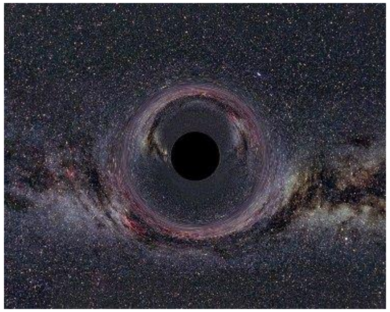
- The string 00000000000000… has zero entropy.
- English text has entropy rate of 0.6 to 1.5 bits per letter.

Q: How do you simulate a fair coin with a biased coin of unknown but fixed bias?

A [von Neumann]: Look at pairs of flips. HT and TH both occur with equal probability of p(1-p), and ignore HH and TT pairs.

Entropy and Randomness

- Information entropy is an analogue of thermodynamic entropy in physics / statistical mechanics, and von Neumann entropy in quantum mechanics.
- Second law of thermodynamics: entropy of an isolated system can not decrease over time.
- Entropy as "disorder" or "chaos".
- Entropy as the "arrow of time".
- "Heat death of the universe" / black holes



- Quantum computing uses a quantum information theory to generalize classical information theory.

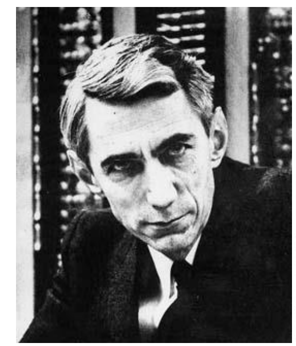
Theorem: String compressibility decreases as entropy increases.

Theorem: Most strings are not (losslessly) compressible.

Corollary: Most strings are random!

"My greatest concern was what to call it. I thought of calling it 'information', but the word was overly used, so I decided to call it 'uncertainty'. When I discussed it with John von Neumann, he had a better idea. Von Neumann told me, 'You should call it entropy, for two reasons. In the first place your uncertainty function has been used in statistical mechanics under that name, so it already has a name. In the second place, and more important, nobody knows what entropy really is, so in a debate you will always have the advantage.' "

- Claude Shannon on his conversation with John von Neumann regarding what name to give to the "measure of uncertainty" or attenuation in phone-line signals (1949)



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Claude E. Shannon Award

— filed under: awards

The Claude E. Shannon Award of the IT Society has been instituted to honor consistent and profound contributions to the field of information theory. Each Shannon Award winner is expected to present a Shannon Lecture at the following IEEE International Symposium on Information Theory. Transcripts of some of the lectures are available on-line.

Starting for the 2010 Award, the Shannon Award Committee has decided to issue an open call for nominations, preferably using the nomination form. Although anyone may make a nomination, the Committee retains the responsibility of assuring that a suitable slate of candidates is nominated, and may itself generate nominations. Nominations and optional letters of endorsement must be submitted by March 1 to the current President of the IEEE Information Theory Society.

The first Shannon Lecturer was Claude Shannon himself followed by:

- David S. Slepian (1974)
- Robert M. Fano (1976)
- Peter Elias (1977)
- Mark S. Pinsker (1978)
- J. Wolfowitz (1979)
- W. Wesley Peterson (1981)
- Irving S. Reed (1982)
- Robert Gallager (1983)
- Solomon W. Golomb (1985)
- William L. Root (1986)
- James L. Massey (1988)

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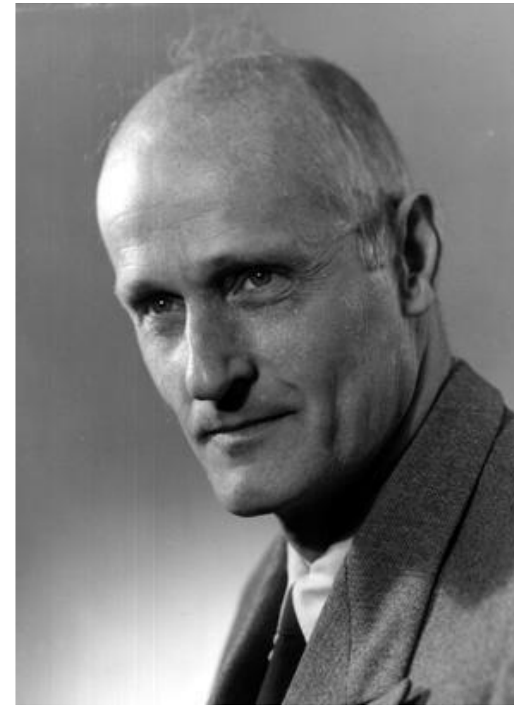
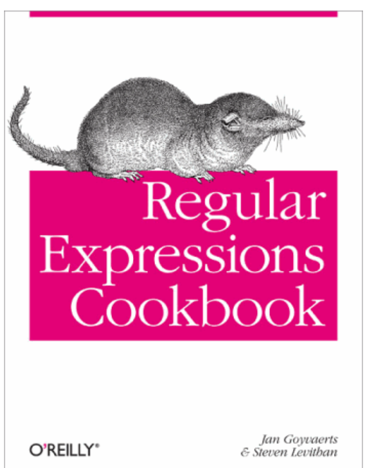
Historical Perspectives

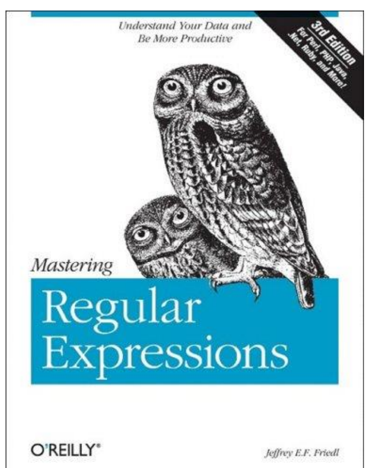
Stephen Kleene (1909-1994)

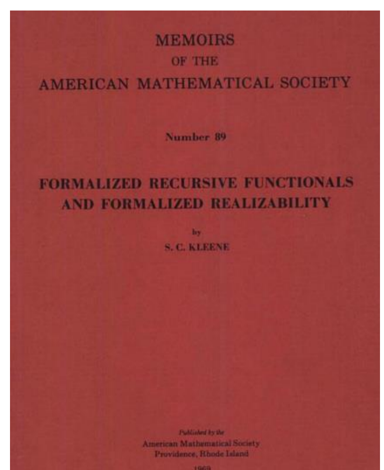
- Founded recursive function theory
- Pioneered theoretical computer science
- Student of Alonzo Church; was at the Institute for Advanced Study (1940)
- Invented regular expressions
- Kleene star / closure, Kleene algebra, Kleene recursion theorem, Kleene fixed point theorem, Kleene-Rosser paradox

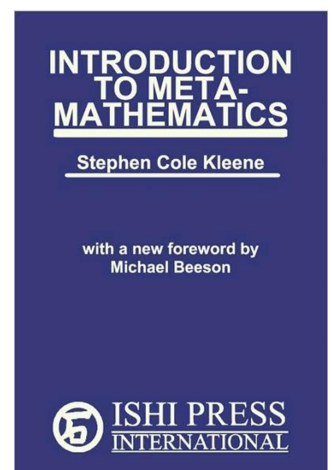


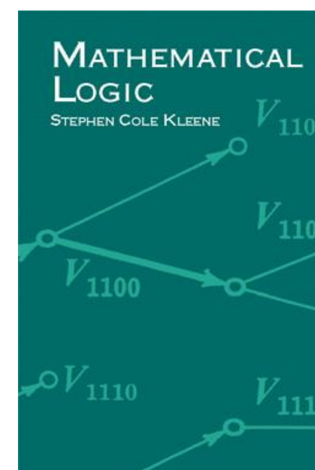
"Kleeneliness is next to Gödeliness"











WHENEVER I LEARN A NEW SKILL I CONCOCT ELABORATE FANTASY SCENARIOS WHERE IT LETS ME SAVE THE DAY.
OH NO! THE KILLER MUST HAVE FOLLOWED HER ON VACATION!
BUT TO FIND THEM WE'D HAVE TO SEARCH THROUGH 200 MB OF EMAILS LOOKING FOR SOMETHING FORMATTED LIKE AN ADDRESS!
IT'S HOPELESS!
EVERYBODY STAND BACK.
I KNOW REGULAR EXPRESSIONS.
PERL!
TAP TAP

/Everybody stand back/
I know regular expressions

/(bb|[^b]{2})/

RegEx
Regular Expression
/h[a4@](([c<]((k)|(\|<)))|((k)|(\|<))|(x))\s+\
((d)|([t\+]h))[3ea4@]\s+p[l1][a4@]n[3e][t\+]/i
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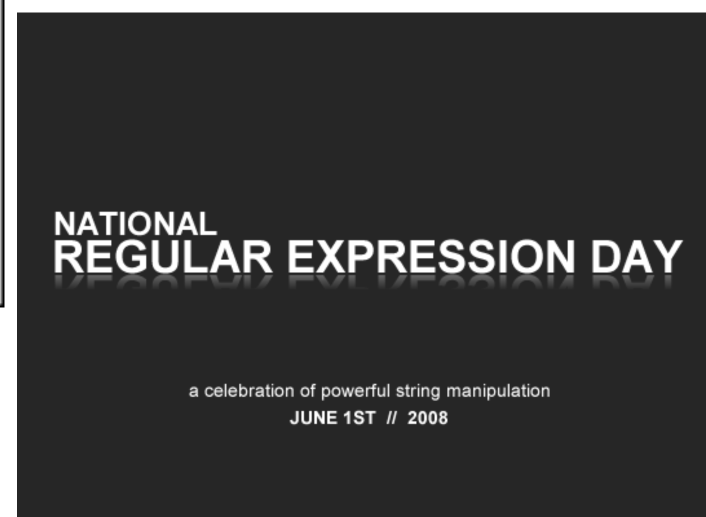

NATIONAL
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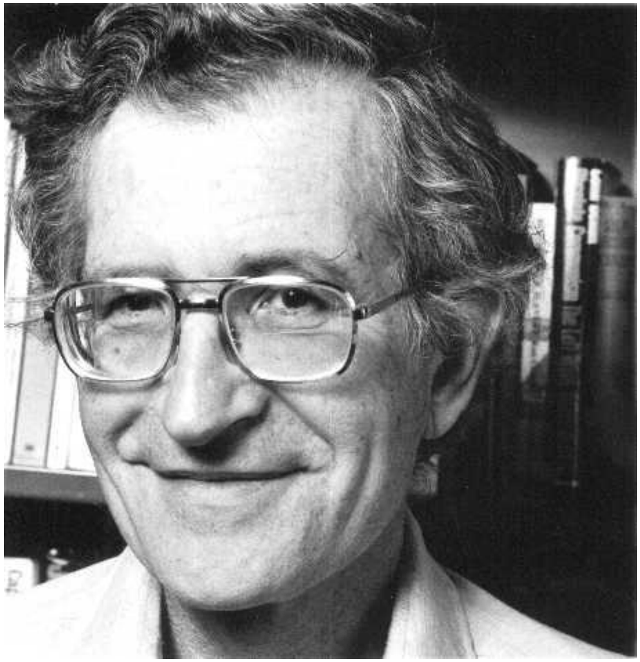
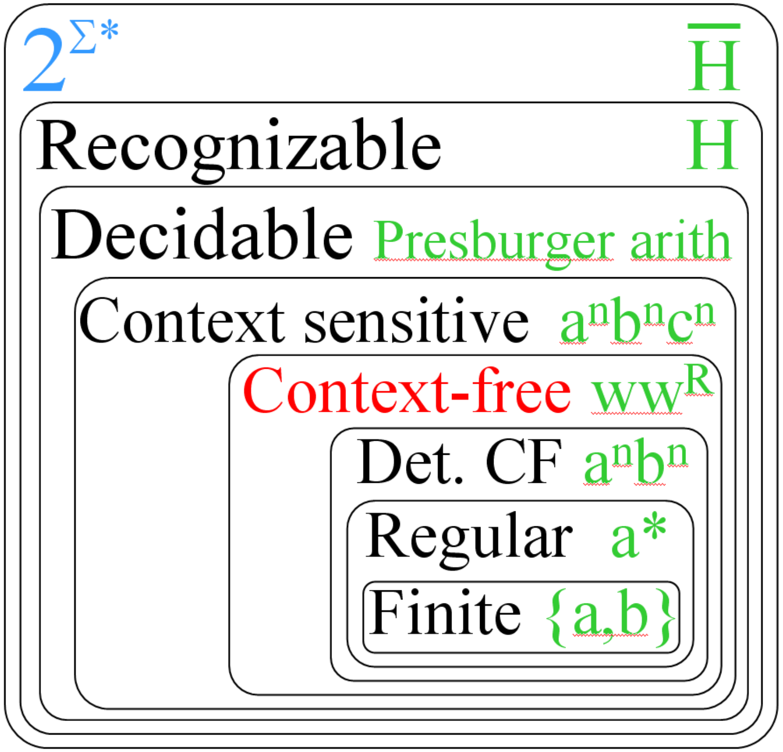
a celebration of powerful string manipulation
JUNE 1ST // 2008

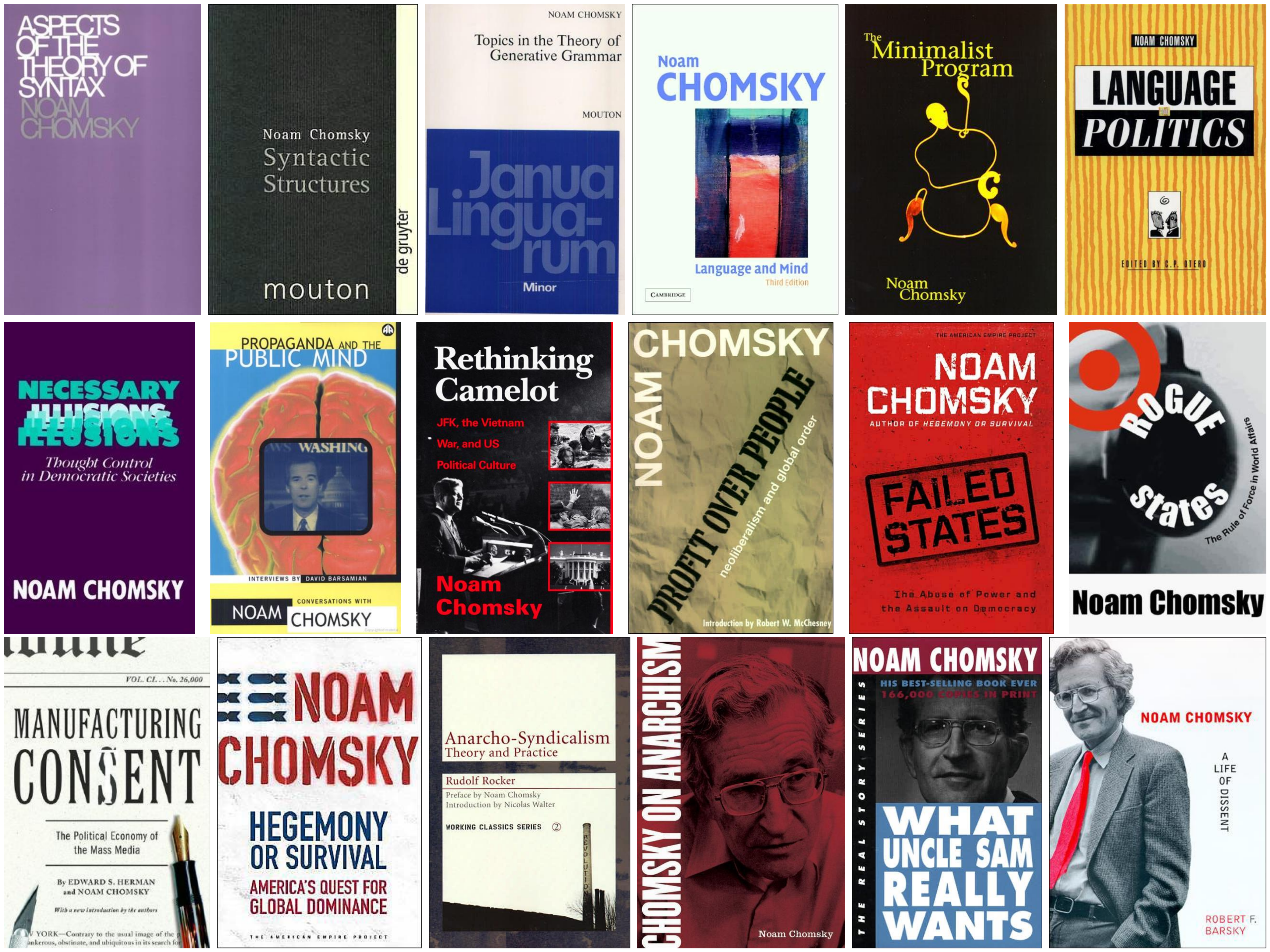
Historical Perspectives

Noam Chomsky (1928-)



- Linguist, philosopher, cognitive scientist, political activist, dissident, author
- Father of modern linguistics
- Pioneered formal languages
- Developed generative grammars
  Invented context-free grammars
- Defined the Chomsky hierarchy
- Influenced cognitive psychology, philosophy of language and mind
- Chomskyan linguistics, Chomskyan syntax, Chomskyan models
- Critic of U.S. foreign policy
- Most widely cited living scholar
  Eighth most-cited source overall!




ASPECTS OF THE THEORY OF SYNTAX
NOAM CHOMSKY
Noam Chomsky
Syntactic Structures
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NOAM CHOMSKY
Topics in the Theory of Generative Grammar
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Third Edition
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WASHING
INTERVIEWS BY DAVID BARSAMIAN
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Rethinking Camelot
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AUTHOR OF HEGEMONY OR SURVIVAL
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With a new introduction by the authors
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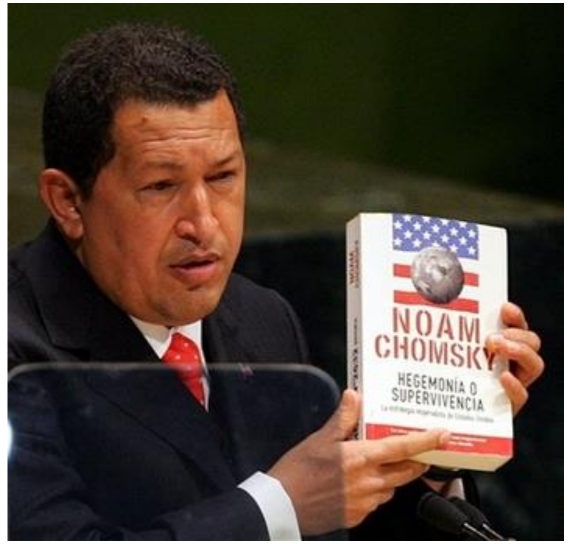
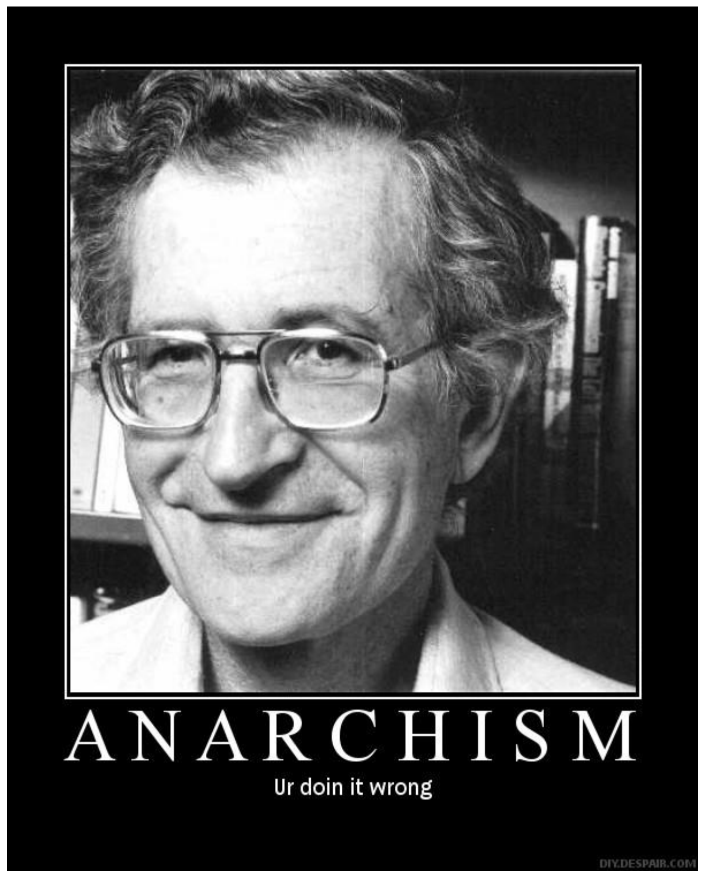
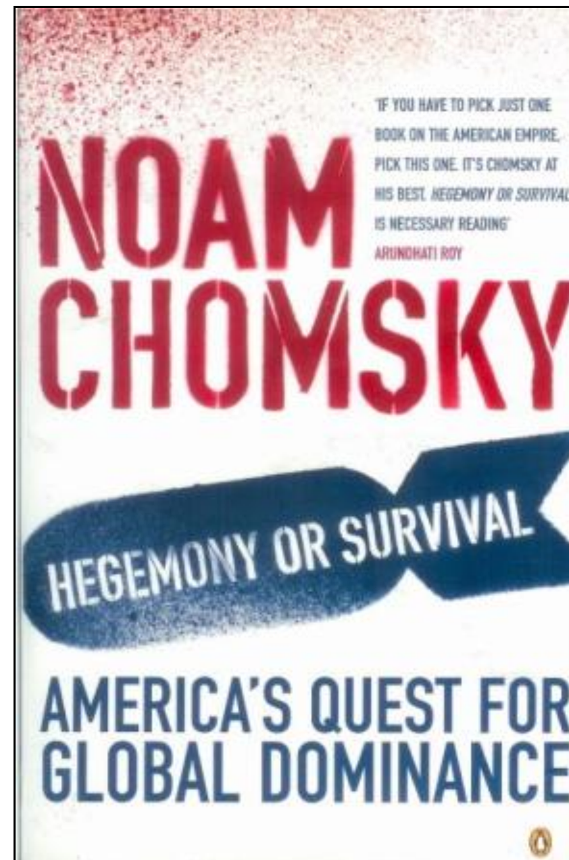
NOAM CHOMSKY
A LIFE OF DISSENT
ROBERT F. BARSKY


NOAM
CHOMSKY


NOAM
CHOMSKY
HEGEMONÍA O
SUPERVIVENCIA

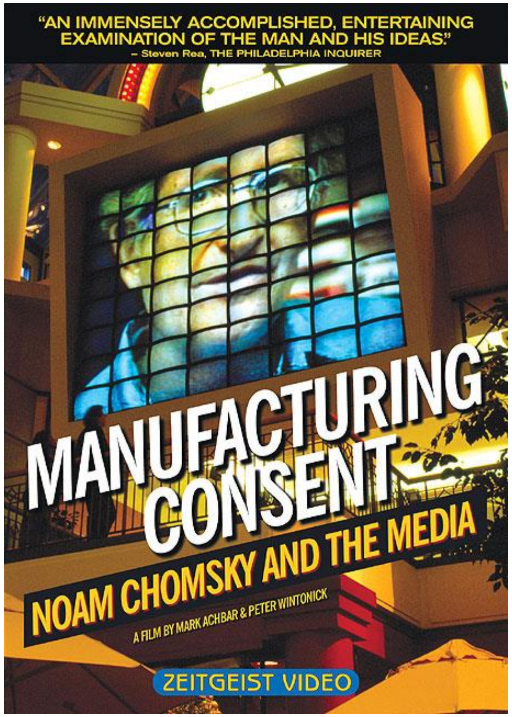

PROF. NOAM CHOMSKY
PROFESSOR OF LINGUISTICS, M.I.T.

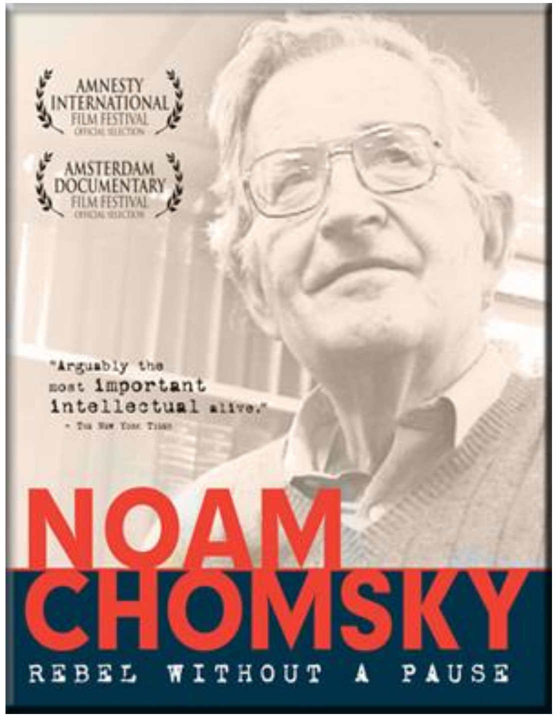

ANARCHISM
Ur doin it wrong
DIY.DESPAIR.COM

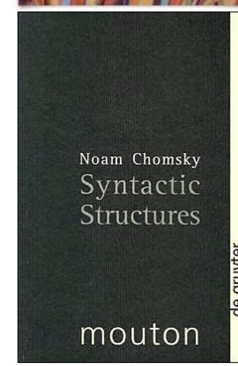

'IF YOU HAVE TO PICK JUST ONE
BOOK ON THE AMERICAN EMPIRE,
PICK THIS ONE. IT'S CHOMSKY AT
HIS BEST. HEGEMONY OR SURVIVAL
IS NECESSARY READING'
ARUNDHATI ROY
NOAM
CHOMSKY
HEGEMONY OR SURVIVAL
AMERICA'S QUEST FOR
GLOBAL DOMINANCE

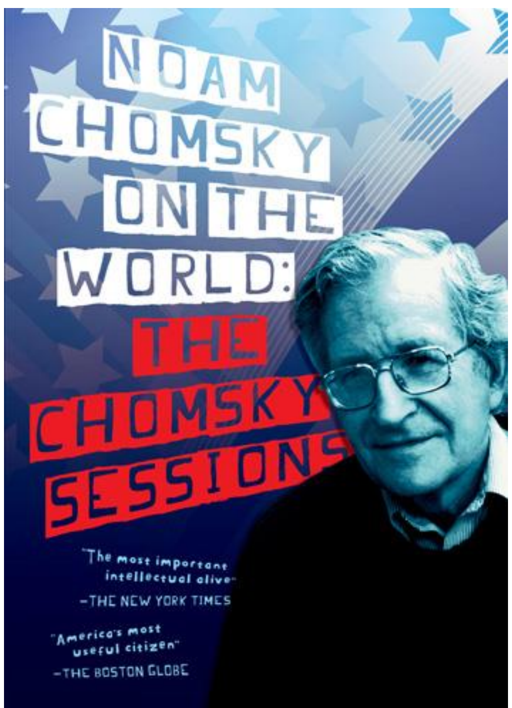
"…I must admit to taking a copy of Noam Chomsky's 'Syntactic Structures' along with me on my honeymoon in 1961 … Here was a marvelous thing: a mathematical theory of language in which I could use as a computer programmer's intuition!"

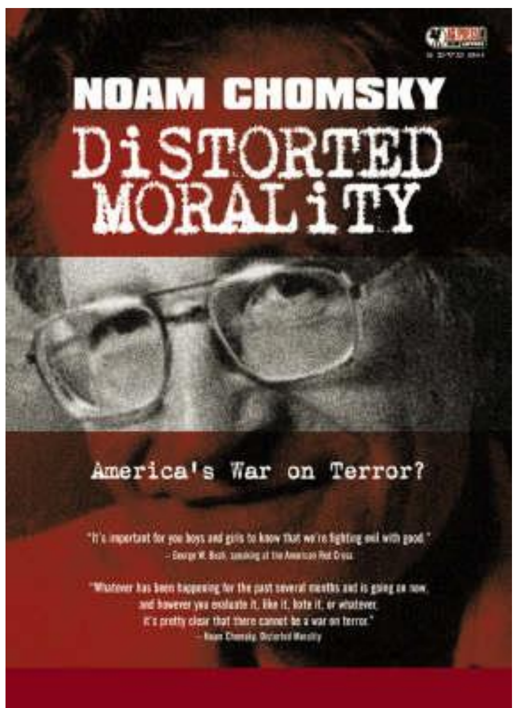
- Don Knuth on Chomsky's influence

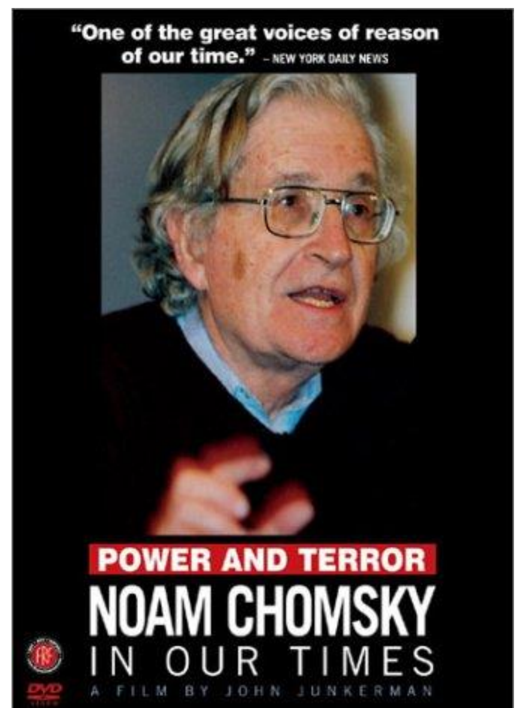


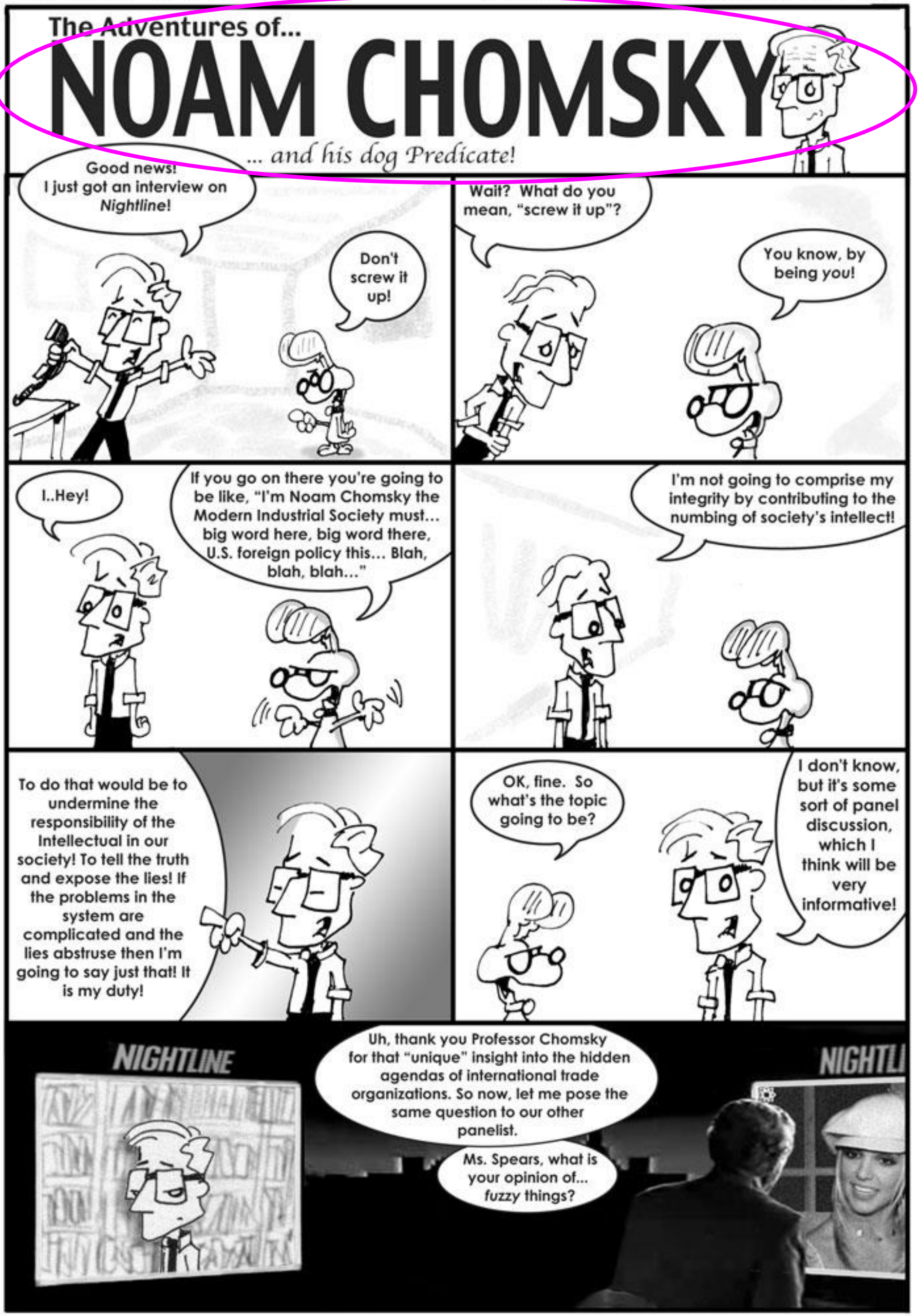




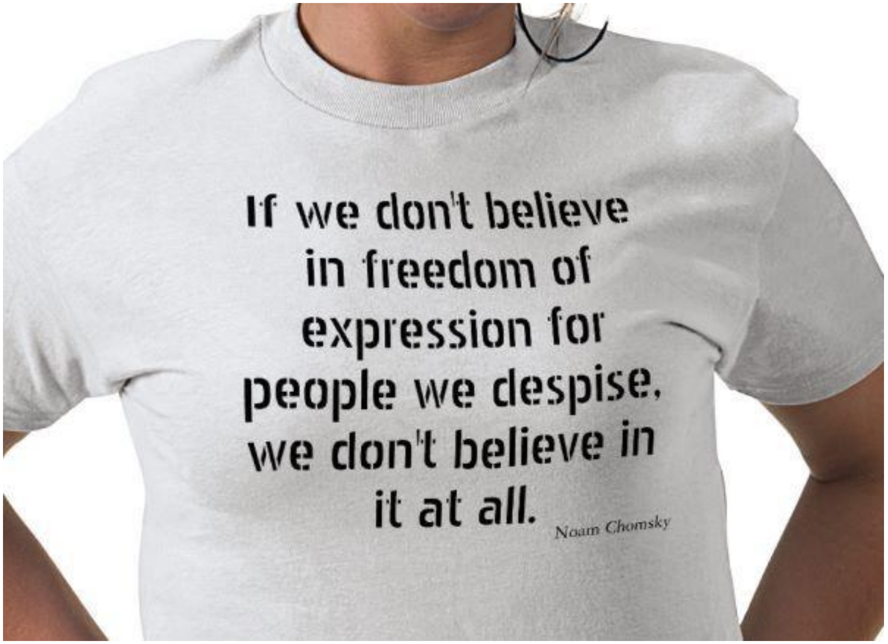


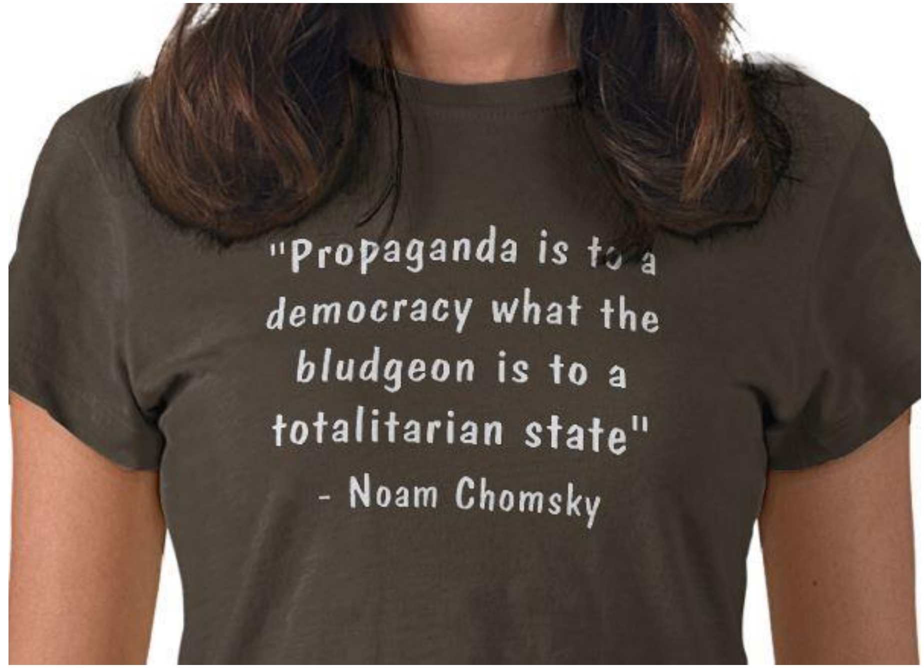


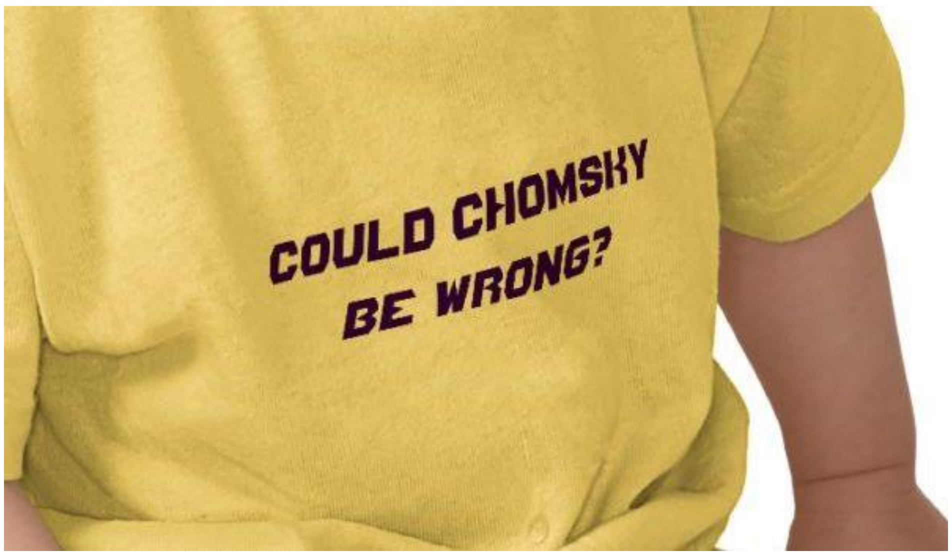


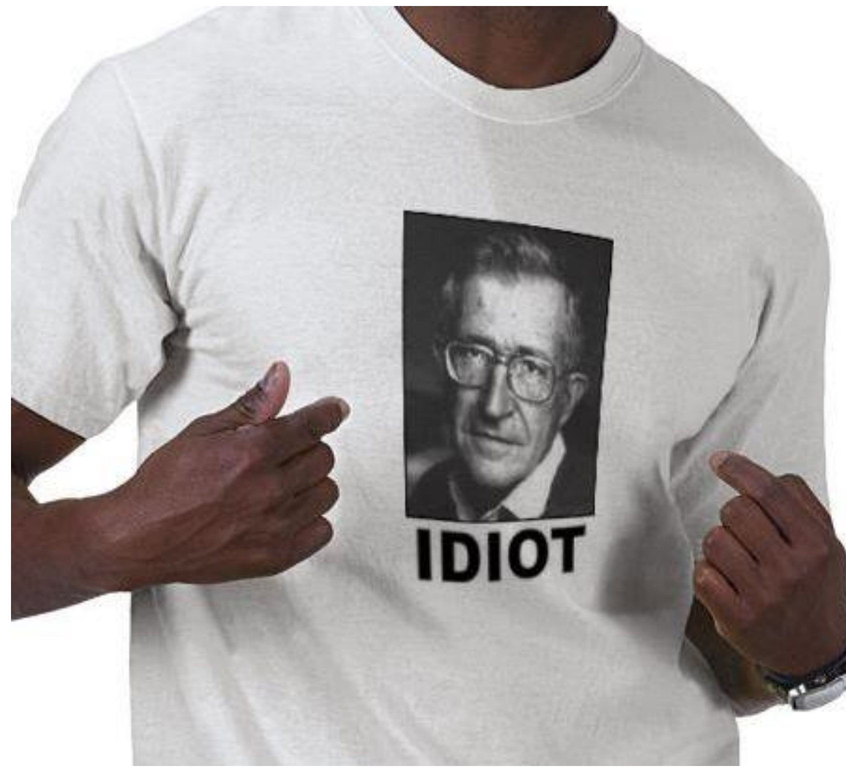

The Adventures of...
NOAM CHOMSKY
... and his dog Predicate!
Good news! I just got an interview on *Nightline*!
Don't screw it up!
Wait? What do you mean, "screw it up"?
You know, by being *you*!
I..Hey!
If you go on there you're going to be like, "I'm Noam Chomsky the Modern Industrial Society must... big word here, big word there, U.S. foreign policy this... Blah, blah, blah..."
I'm not going to comprise my integrity by contributing to the numbing of society's intellect!
To do that would be to undermine the responsibility of the Intellectual in our society! To tell the truth and expose the lies! If the problems in the system are complicated and the lies abstruse then I'm going to say just that! It is my duty!
OK, fine. So what's the topic going to be?
I don't know, but it's some sort of panel discussion, which I think will be very informative!
NIGHTLINE
NIGHTLI
Uh, thank you Professor Chomsky for that "unique" insight into the hidden agendas of international trade organizations. So now, let me pose the same question to our other panelist.
Ms. Spears, what is your opinion of... *fuzzy* things?


The Adventures of...
NOAM CHOMSKY
... and his dog Predicate!
By Jeffrey Weston
I need a better way to get my message out.
Yeah, market research is saying that *The Noam Chomsky Quote of the Day Calendar* is giving people head aches.
What can I do?
There is only one option! SELL OUT!
Look Noam, let's be realistic. You're a downer. People don't want to hear about how awful things are all the time!
Positive spin Noam, that's the way to get your message out!
How can you possibly put positive spin on the continuing decay and directed destruction of our basic freedoms?!!
Noam sez...
Everything's Fine!
© CLEARCHANNEL

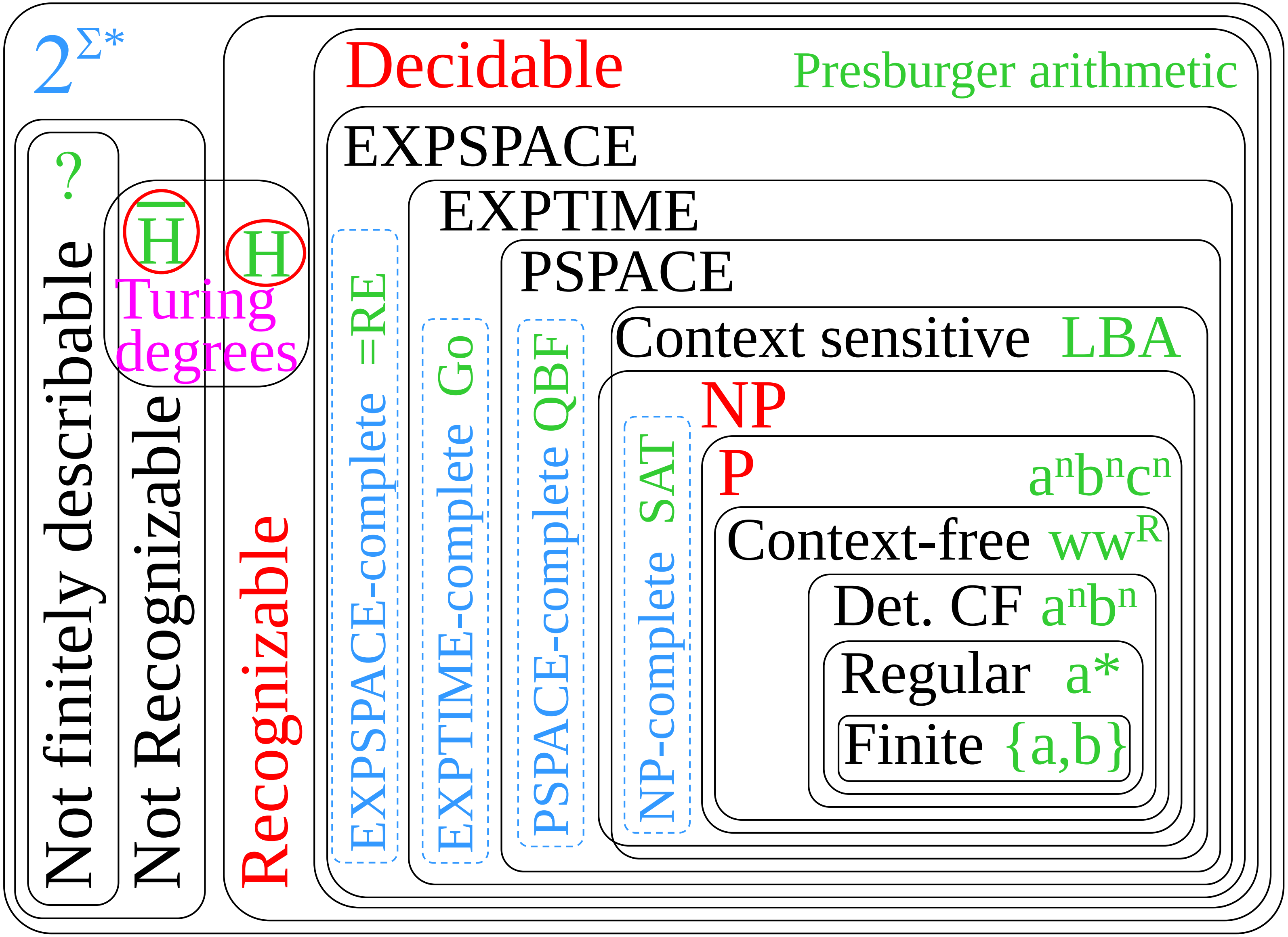

If we don't believe
in freedom of
expression for
people we despise,
we don't believe in
it at all.
Noam Chomsky

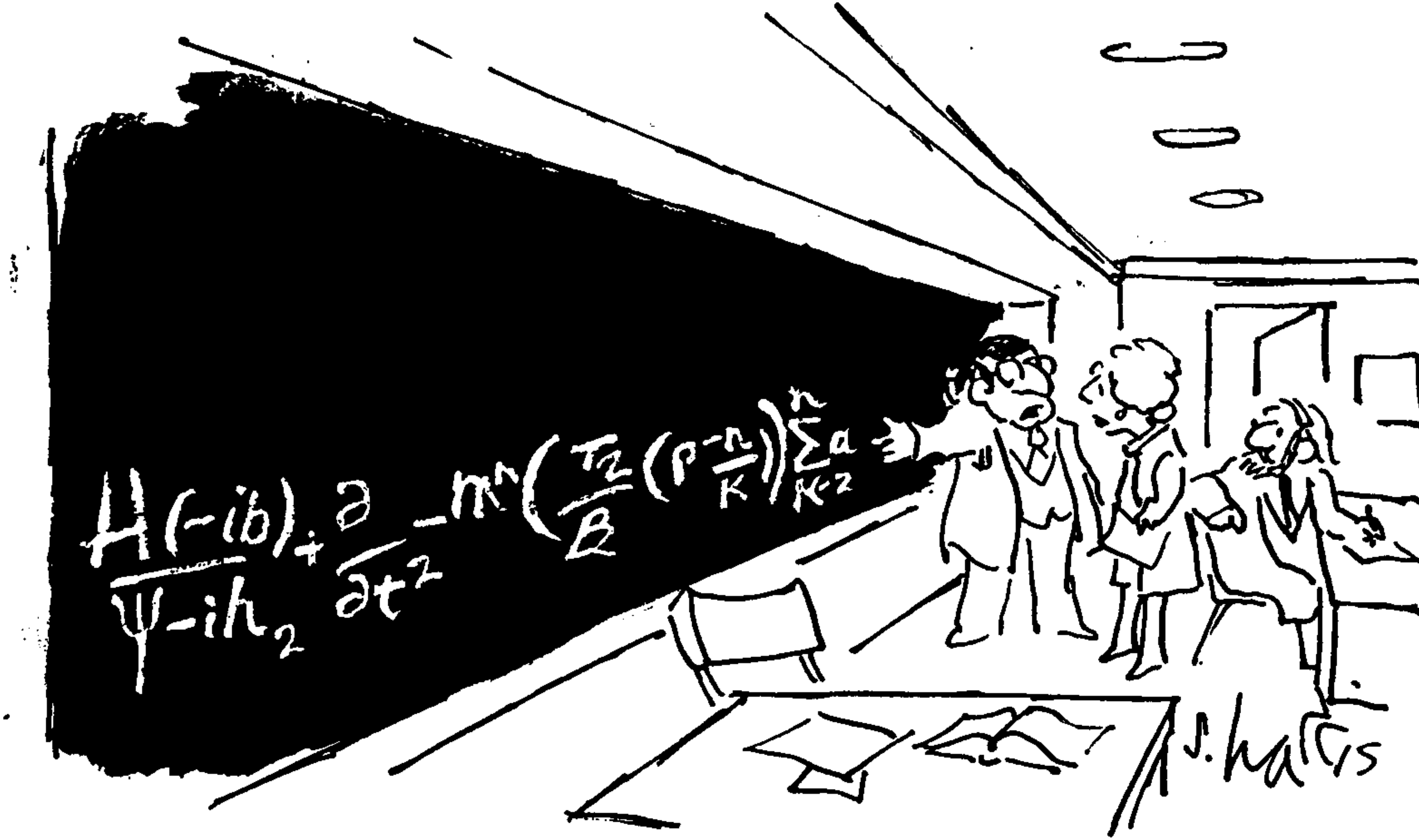

"Propaganda is to a
democracy what the
bludgeon is to a
totalitarian state"
- Noam Chomsky


COULD CHOMSKY
BE WRONG?


IDIOT

The Chomsky Hierarchy

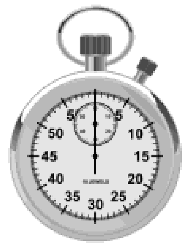




"But this *is* the simplified version for the general public."

NP Completeness

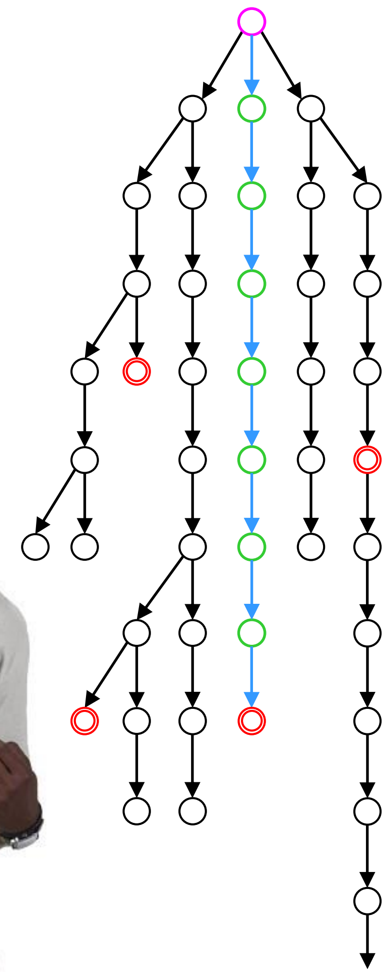
- Tractability
- Polynomial time
- Computation vs. verification
- Power of non-determinism
- Encodings
- Transformations & reducibilities
- P vs. NP
- “Completeness”

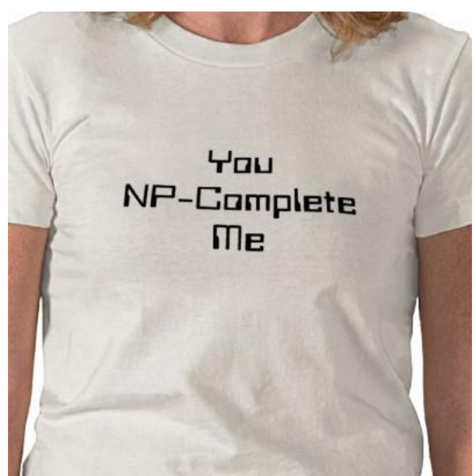



Stephen Cook


Leonid Levin


Richard Karp





Historical Perspectives