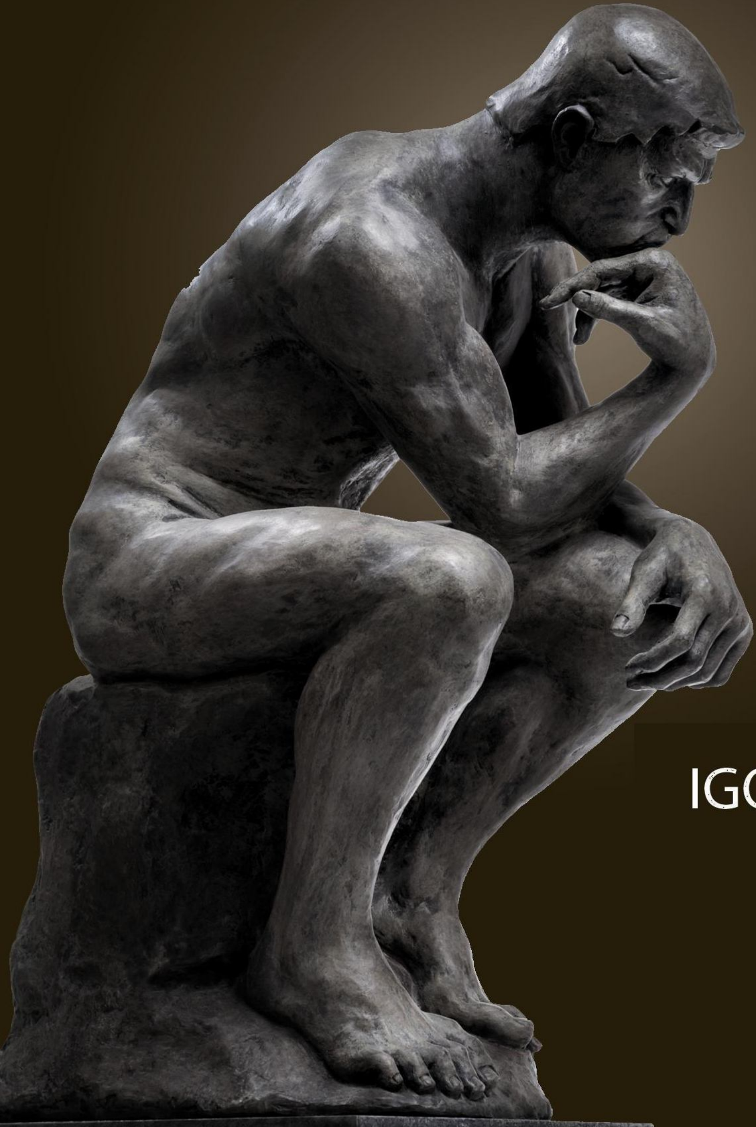
FROM FINGER COUNT TO COMPUTER

TALES ABOUT SCIENTIFIC INSIGHTS 6



IGOR USHAKOV

Tales and Stories
about Mathematical & Scientific Insights

Igor Ushakov

FROM FINGER COUNT TO COMPUTERS

San Diego
2012

Series

“Stories and Legends about Mathematical & Scientific Insights”

Book 1. Man’s first steps takes us through the first use of scientific and mathematical thinking as man began to question the nature of his Universe and then takes us into the history of measurements of the physical quantities of temperature, length, time and mass.

Book 2. In the beginning was the number … You find here new facts about Roman and Arabic numbers and some interesting methods of calculations. You also find here interesting things about magic numbers.

Book 3. The Magic of Geometry shows how the common problems of measuring land led to the development of mathematical discipline. You will know about unusual and impossible figures. You will have a pleasure to look at fantastic fractals.

Book 4. Enigmatic Terra Al-Jabr tells the stories of the origin and formation of algebra. You find from here that it is really interesting branch of mathematics.

Book 5. It’s a Random, Random, Random World presents entertaining stories about the development of probability and statistics theory.

Book 6. From Finger Count to Computer gives an intriguing history of developing the most fascinating technology ever.

These books help teachers make their classes more interesting and help pupils to know even more than their teachers!

Cover design: Igor A. Ushakov

To my beloved granddaughters
Anastasia & Alica

Preface

The subject of mathematics is so serious that nobody should miss an opportunity to make it a little bit entertaining.

Blaise Pascal [1]***.***

What is this series of books about? For whom is it written? Why is this series written in this manner, not in another? Discussion about geometry, algebra and similar topics definitely hint that this is about mathematics. On the other hand, you cannot find within a proof of any statement or strong chronology of facts. Thus, these books are not tutorial. This is just a collection of interesting and sometimes exciting stories and legends about human discoveries in one or another way connected to mathematics…

These book are open for everybody who likes to enrich their intelligence with the stories of genius insights and great mistakes (mistakes also can be great!), and with biographies of creators of mathematical thinking and mathematical approaches in the study of the World.

Who are the readers of the proposed books? We believe that there is no special audience in the sense of education or age. The books could be interesting to schoolteachers and university professors (not necessarily mathematicians!) who would like to make their lectures more vivid and intriguing. At the same time, students of different educational levels – from middle school up to university – as well as their parents may find here many interesting facts and ideas. We can imagine that the book could be interesting even for state leaders whose educational level is enough to read something beyond speeches prepared for them by their advisors.

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[1] **Blaise Pascal** (1623 –1662) was a French mathematician, physicist, inventor, writer and philosopher.

Summarizing, we have the courage to say: These books are destined for everybody!

Trust us: we tried to write the book clearly! Actually, it is non-mathematical book around mathematics.

This book is not intended to convert you to a "mathematical religion". Indeed, there is no need to do this: imagine how boring life would be if everybody were a mathematician? Mathematics is the world of ideas, however any idea needs to be realized: integrals cannot appease your hunger, differential equations cannot fill gas tank of your car....

However, to be honest, we pursued the objective: we tried to convince you, the reader, that without mathematics *homo erectus* would never transform into *homo sapiens*.

Now, let us travel into the very interesting place: Terra Mathematica. We'll try to make this your trip interesting and exciting.

What in particular is particular book about?

Here you, Reader, find many interesting facts about Man's first steps takes us through the first use of scientific and mathematical thinking as man began to question the nature of his Universe. Then the book takes us into the history of measurements of the cosmic distances to the Moon and to the Sun and different the physical quantities of temperature, length, time and mass.

At the end you will be introduces with biographies of some genius in the area of knowledge that is subject of this book.

Igor Ushakov
San Diego
2012

Contents

1. NUMERATING AND CALCULATING

1.1. Calculation on fingers, knots and stones

To every thing there is a season, and a time to every purpose under the heaven:

... A time to cast away stones, and a time to gather stones together...

The Bible, Ecclesiast

Do you remember that phrase: "To explain something with your finger"? Indeed, if you could explain something "on fingers", it means something extremely simple.

So, our antediluvian did not need for their arithmetical calculations more than fingers of their hands … A hand was the first and the oldest "calculation tool" and this tool was always ready to hand!

We could mention that a child, growing, passes through the same phases as the manhood: a child starts calculation attempts with bending the fingers. A child goes through the same phases of intellectual development as the entire manhood, starting with bending the fingers. (Well known correspondence between phylogenies and ontogenesis[2]: in a sense an individual repeats the evolution of the population).

Famous Russian traveler Nikolai Miklukho-Maklai[3] wrote: "A Papuan bends his fingers one-by-one and pronounces some sounds like "be-be-be". Counting to five, he say "ibon-be" (a hand).

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[2] **Phylogenesis** describes the development of the population over time. **Ontogenesis** (or morphogenesis) describes the origin and the development of an organism from the fertilized egg to its mature form.

[3] **Nicholai Nikolayevich Miklukho-Maklai** (1846-1888), Russian ethnologist, anthropologist and biologist. He visited Papua New Guinea on a number of occasions, and lived amongst the native tribes, writing a comprehensive treatise on their way of life and customs.

Then he bends the fingers of another hand until “ibon-ali” (two hands). Next “large numbers are “samba-be” and “samba-ali” (one fot, two feet). If he needs to continue calculation, he begins to use hands and feet of other Papuans”.

It is time to note that Ireland monk Bede[4] in the Medieval described in details counting methods up to million with the use of fingers! In other words, we again meet with ontogenesis and phylogenies phenomena.

Even names of numbers in many languages have sense of hands and fingers. In old Russian one was called “a finger” and five – by sounding close to a palm.

Malaysians have the same word “lima” for a hand and for number 5.

However, a man has no enough fingers. From time immemorial, people use for remembering “large” numbers wooden sticks or animal bones with notches. (Almost like Defoe’s[5] Robinson Crusoe!)

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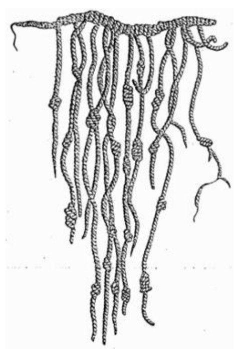
[4] **The Venerable Bede** (672-735), Benedictine monk, who is well known as an author and scholar. His "The Ecclesiastical History of the British People" gained him the title "The father of British history".

[5] **Daniel Defoe** (1660-1731), British novelist, pamphleteer, and journalist, who is most famous as the author of “Robinson Crusoe”, a story of a man shipwrecked alone on an island.

One of the oldest tools of a kind is the so-called "Věstonice bone" found in archeological digging in the South Moravia[6]. It is believed that its age is 30 thousand years.

Practically analogous method of recording numbers was used in the Inca Empire located in the Andean region of the Central America. This "recording devices" is called quipu, or khipu. In the native Inca language it means "knots". A quipu usually consisted of colored spun and plied thread or strings from llama or alpaca hair or cotton cords. Numeric values were encoded by knots in a base 10 positional system. Form numbering different objects they used cords of different colors. A unit of each position was presented by a single knot in the form of "eight".



For recording numbers from 2 to 9, they used a multiple knots with corresponding number of loops.

Tens, hundreds and thousands located upper on the same cord. The ancient American Indians could record numbers up to tens of thousands!

A sample of a quipu is shown below.

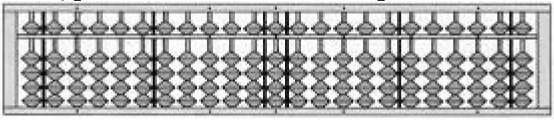
Analogous type of number recording was used among other countries …

1.2. First counting devices

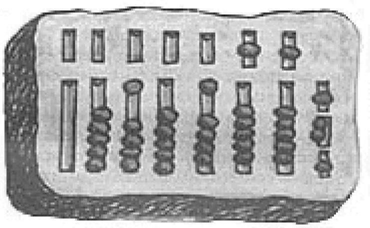
However it was not too convenient for computations. Then a special tool appeared – abacus. Probably, the first abacus prototype appeared in Babylon.

[6] **Moravia** is a historical region in the east of the Czech Republic.

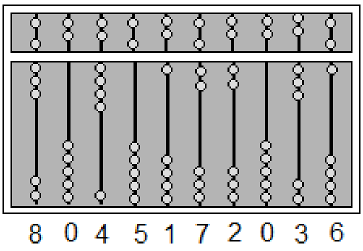
Babylonian abacus-type tool was a wooden panel covered with a layer of dust, on which one drew short lines. As a matter of fact it was the same cuneiform script on renewal surface, which served as an "operative memory".



In ancient Rome abacus appeared relatively late – in 5th century A.C. That abacus was called "*calculi*", or "*abakuli*", and was produced from bronze, stone or ivory. Several bronze Roman abacuses were saved to out time. They have vertical grooves with five small polished stones that could be moved up and down, and in the upper compartment one could put a stone denoting completed five.



In VI abacus was widely used in China by the name "suanpan". It was invented independently: the first description of suanpan appeared in 190 in the Eastern Han Dynasty in the book Shushu jiyi ("Memoir on the Methods of Numbering") by Xu Yue[7].



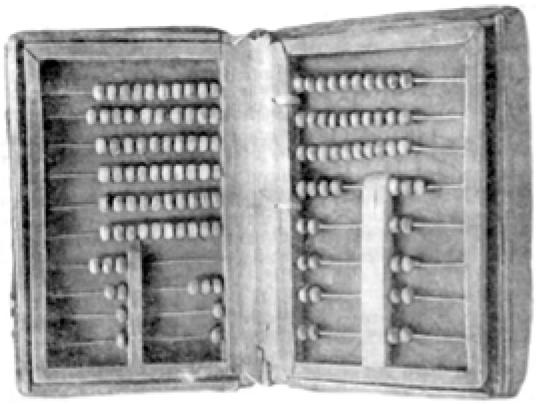
Suanpan had in a sense quite different construction: it had two compartments - lower one (called "The Earth") and upper one (called "The Sky"). It had several grooves with a metal string, on which stones with holes in the center moved. Each string corresponded to a decimal position.

In 15th – 16th centuries Chinese suanpan through Korean peninsula reached Japan where it has been transformed in a

[7] **Xu Yue** (185-227), Chinese astronomer and mathematician. He wrote several books, of which only Shushu jiyi ("Memoir on the Methods of Numbering")

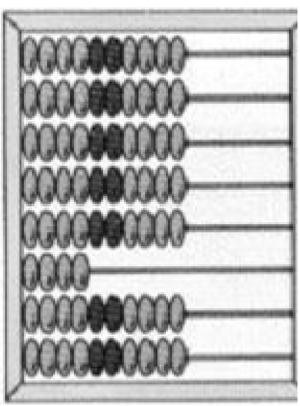
Japanese abacus – soroban. As one can see a soroban differs from its "Chinese relative".

Moving stones by two fingers (thumb and index finger), Japanese calculates with the help of soroban fantastically fast. It is interesting that in Japan schoolchildren are taught to calculate with a soroban even today: psychologists believe that it helps to develop students creative abilities.



Russian version of abacus is called "stchioty" that means "calculations". At the beginning this tool was called "wooden calculations" due to construction: it was a wooden box resembling a box for chess with drown strings, on which there were threaded plum or cherry stones.

This original tool has been transformed into "stchioty", which can be found even now at small shops in remote rural areas of Russia and Ukraine. Those "Russian abacuses" appears so late (at the end of XI century) that to use five stones instead of 10 would be a real anachronism. However, in other way, it was a direct follower of an abacus. Thus, let us glorify ancient Babylonians!



It is interesting to notice that approximately in X century, a tool analogous to abacus has appeared at Aztecs. The only difference was in numerating system and they use dry corn seeds instead of stones…

2. FIRST TOOLS FOR COMPUTATIONS

> Around the world there are many difficult things, but there is nothing harder than four arithmetic actions.
>
> **The Venerable Bede** [8]

2.1. A little bit about logarithm

> I have always tried, to the extent allowed my strength and ability, to get rid of difficulties and boredom of computation, which usually very discouraged many people from the study of mathematics.
>
> ***John Napier***

Abacus is convenient for summation and extraction. However, multiplication and dividing also are widely used in everyday activity. However, multiplication large numbers (especially several of them) "by hand" is rather unpleasant process.

Almost half millennium ago, John Napier invented logarithm tables which made our life much easier.

The word "logarithm" is formed by two Greek words *logos* (can be translated in this context as "relation") and *arithmos* (means "number"). Napier himself called logarithms as "artificial numbers" (*numeri artificialis*) in contrast to "natural numbers" (*numeri naturalis*).

The idea of logarithm is simple and transparent (as most of genius ideas!). Let us begin with a simple example. First compile a table of integer powers of number 2.

Power	0	1	2	3	4	5	6	7	8	9	10
Presentation	2^0	2^1	2^2	2^3	2^4	2^5	2^6	2^7	2^8	2^9	2^{10}
Число	1	2	4	8	16	32	64	128	256	512	1024

[8] **The Venerable Bede** (673 – 735), British Benedictine monk well known as an author and scholar. His most famous work "*Historia ecclesiastica gentis Anglorum*" ("*The Ecclesiastical History of the British People*") gained him the title "The father of British history".

John Napier

(1550-1617)

Scottish theologian, mathematician, astronomer and astrologist. As most of scientists of his time, he was universal scientist of extremely wide profile. He was also a talented engineer: invented a number of machines for agriculture, water pumps for irrigation, and some military devices (armored car, aqualung, rocket, etc.), partially repeated some Leonardo da Vinci inventions that were not known to him.

He also invented tablets for determining major Christian festivals; tablets to help in the calculation of the movement of the sun, the times of sunrise and sunset for any given day of the year; tablets to perform calculations to determine the motions of the planets; tablets to aid the novice in composing music and creating melodies.

Assume that we would like to multiply 16 by 32.

$$16 \times 32 = 2^4 \times 2^5 = 2^{(4+5)} = 2^9.$$

Instead of direct calculations, we can find the result in the table for power equal to 9: this is 512. (Of course, for this purpose we should have a table calculated in advance.)

Well, it is clear with 2 and integer powers. However, we know that any number A can be presented as any positive B in some power. Let us take, for example, B=5. Then A_1=7 can be written in the form $A_1 = 7 = 5^x$, where $x = 1.209$. (Indeed, $5^{1.209} = 6.9993 \approx 7$.) Now let $A_2 = 9$. This number can be written as $A_2 = 9 = 5^y$, where y=1.366. (One could check using, for instance, standard program *Excel*: $5^{1.366} = 9.0114 \approx 9$.)

So, how to find product $C = A_1 \times A_2$?

$$C = 5^{1.209} \times 5^{1.366} = 5^{(1.209+1.366)} = 5^{(1.209+1.366)} = 5^{2.575}.$$

Using same *Excel*, we find

$$5^{2.575} = 63.0376 \approx 63.$$

So what? You may ask: Why to use these complex transformations if I have *Excel*? And you are right! However Napier did not have a computer with *Excel*! So, he took number *B* that is called base of logarithm and showed how to multiply numbers, using their presentation as basis in corresponding power. For such calculations, he had calculated tables and gave a possibility to use summation instead of multiplication!

Napier introduced the so-called "natural"(or "Napier's") logarithms that have number «*e*» as the basis.

Deserving Napier's successor became Oxford Professor Henry Briggs[9]. He was literally astonished when he knew about an excellent Napier's idea. He went to Scotland to express his respect to Napier and to discuss with him some ways of the further development of the method.

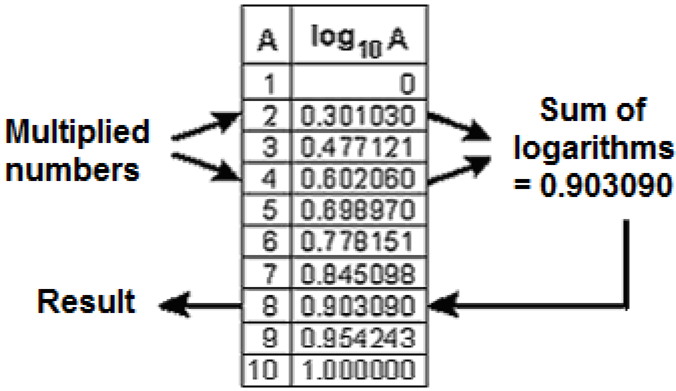
It is almost obvious that he suggested decimal basis for logarithms that significantly improved the Napier's method. Coming back to London, Briggs began to compile the table of decimal logarithms. Napier himself was unable to participate in this work…

This work was interrupted only once when Briggs by Napier's request prepared English translation of Napier's book "*Description of Miraculous Logarithmical Tables*" ("*Mirifici Logarithmorum Canonis Descriptio"*).

Due to Henry Briggs efforts famous Napier's tractate has been published 20 years after Napier had compiled his first tables of logarithms. This book had a tremendous influence on calculating mathematics. This idea was widely used centuries until appearance of mechanical and then electronic computational devices.

Having completed this publication in 1616, Briggs continued to prepare his tables of decimal logarithms. An example of calculation with the use of Brigg's table of decimal logarithms is shown below.

[9] **Henry Briggs** (1561 - 1630). British mathematician notable for changing Napier's logarithms into common decimal (Briggesian) logarithms in 1617.



In the summer of the same year Briggs came to Scotland to show Napier the first result. Briggs promised Napier to complete calculations in several months and come again to show the final results to his mentor. However, he was late: John Napier died...

2.2. Napier's rods

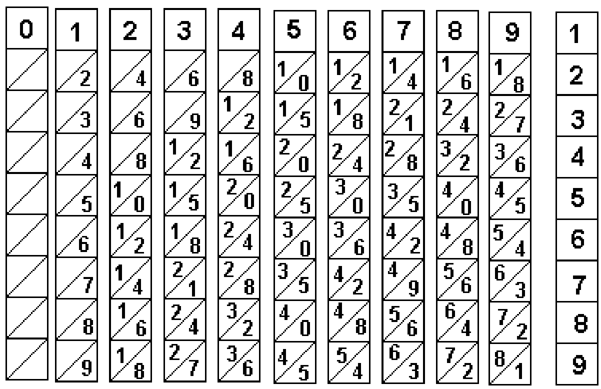
In parallel to developing logarithms, John Napier had been working on a simple calculating tool that was later called as "Napier's rods". Napier himself estimated this work so high that when he felt that his health declined significantly, he ordered to publish his book "Rabdology" before mentioned above "Description", though namely this book made his name in the history of mathematics. "Rabdology" had been published in Edinburgh, the capital of Scotland in the same year when its author died.

Napier gave the definition of "rabdology" in the widen title of the book: "Rabdology, or two books on calculations with the help of sticks". (Greek word ϱαβδοσ means "rod, and λογοσ means "word".) In the preface to the book, he wrote that he had developed a special method for those who preferred calculations with "natural numbers" rather that with logarithms.

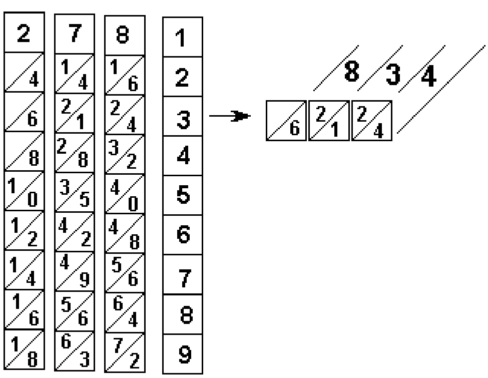
These rods invented by Napier allowed multiply, divide and even extract roots. "Rabdology" has been translated in France, Italy and Holland. Napier's rods were widely used, and long time they shadowed the main Napier's scientific achievement – logarithms...

However, the book has been translated into English only in 1667…

"Napier's rods were done from wood or ivory and had approximately such form:



There are 10 rods with numbers from 0 to 9 in the top cells and an additional rod with numbers from 1 to 9. Each rod contains cells with product of the "number of rod" and corresponding number of the additional rod. For instance, the 5th rod in its 5th cell (level of 5 for the additional rod) has number 20, which is the product 4×5. Numbers in the cells are written is a special form: the upper part contains tens and the lower part contains units.



The use of the Napier's rods best of all could be explained on a numerical example. Let us multiply 278 by 3 (see figure below). Take rods for numbers 2, 7 and 8 and one supplementary rod. Rods put together as it shown on the figure. Look at the row with number 3 of the supplementary rod.

How to get the result? In the 3rd cell of the 1st rod we have 6 that actually corresponds 600 (you get it after multiplying 200 by 3). Then we take the 3rd cell of the 2nd rod: we see in this cell number 21. Since the 2nd column corresponds to tens, 21 actually corresponds to 210. Take 6 from the bottom of the cell of the first rod and add it to 2 from the upper part of the cell of the 2nd rod. It gives 800. (This procedure is depicted in the right side of the figure.)

Analogous procedures are applied to other rods.

2.3. The slide rule

Several decades after Napier's death, a mechanical analog computer was invented – the slide rule that often nicknamed a "slipstick". It consists of at least two finely divided scales (rules): a fixed outer pair and a movable inner one, with a sliding window called the cursor. This tool is used primarily for multiplication and division, and raise to the power. Actually, first slide rulers were just improved and modernized Napier's sticks.

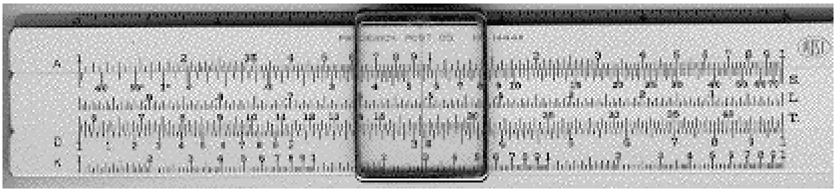
In 1620 in London Edmund Gunter[10] made a straight logarithmic scale and performs multiplication and division on it with the use of a set of dividers. In a sense it was the first prototype of slide ruler.

In about 1622 William Oughtred, an Anglican minister (today recognized as the inventor of the slide rule) places two such scales side by side and slides them to read the distance relationships, thus multiplying and dividing directly. He also develops a circular slide rule. In 1632 in London one of Oughtred's pupils published a book about a slide ruler of his teacher.

In 1675 Sir Isaac Newton solves cubic equations using three parallel logarithmic scales and makes the first suggestion toward the use of the cursor, though this idea was implemented only about hundred years later.

[10] **Edmund Gunter** (1581-1626), British mathematician.

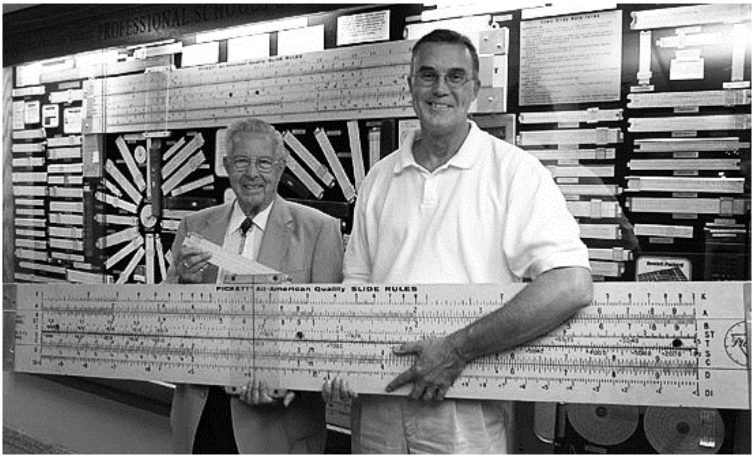
By 1790 James Watt[11] had modifying slide rules to improve their accuracy and usefulness. His so-called “Sotho slide ruler” had accuracy about 3 decimals after comma. It construction almost coincided with those slide rulers that were used by our grandparents and grand-grand parents.



Early in the 19th century the first slide rules came into use in the United States: Ex-president Thomas Jefferson recognized their advantages in his chemistry work, which includes the discovery of oxygen.

For more accurate calculations, in 1870 in Germany two giants of the slide rulers were made.

However, now all of them are exhibits in museums of science history.



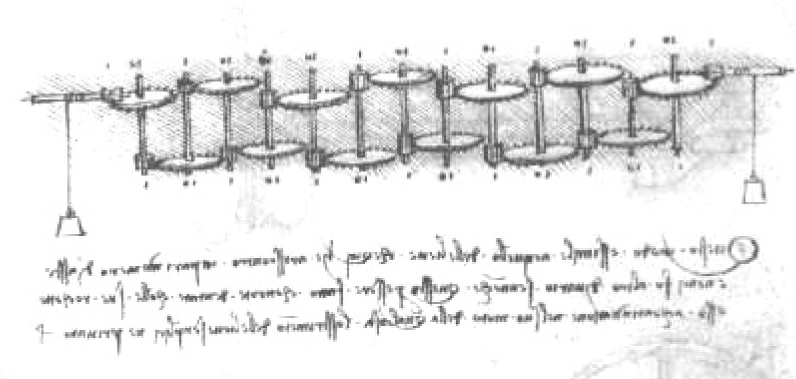
[11] **James Watt** (1736-1819), Scottish inventor and engineer whose steam engine played a significant role in the so-called Industrial Revolution.

3. COMPUTER ERECTUS

However practical needs of scientific and engineering calculations and especially accounting led to developing computational machines rather than computational "hand" tools. The era of mechanical computational machines has been begun.

3.1. Leonardo da Vinci

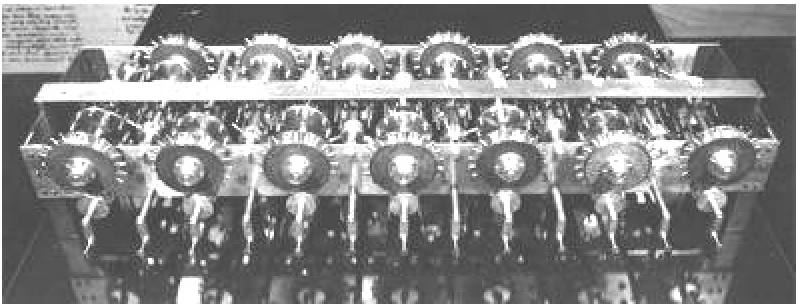
In the middle of the last century an amazing discovery was made by American researchers working in Madrid in the National Library of Spain. They had stumbled upon two unknown manuscripts of Leonardo da Vinci[12] know as the "Codex Madrid". Among multiple schemes and drawings there was a sketch of 13-position arithmetic machine with rack-wheels, each of which had tooth gearings. As one can see, Leonardo used weights for moving wheels (in the manner of old wall clocks of the time of our grand-parents.)



As it is known Leonardo relatively rare realized his projects, though he was inexhaustible source of new and extremely original ideas.

[12] **Leonardo da Vinci** (1452 –1519), great Italian universal scientist, inventor and artist. For more details, see XXX.

Basing on the presented draft, IBM[13] engineer have built a replica of the machine. This machine assumed to use weights to move its shafts as our grand-grandparents used in their wall-clocks.



This operating replica was displayed in the IBM exhibition and later was displayed at schools, offices, labs, museums and galleries.

3.2. Wilhelm Schickard

Wilhelm Schickard, having been teaching biblical languages at the University of Tübingen, was an extraordinary astronomer. He kept a correspondence with Johann Kepler[14] and some other European scientists. Kepler noticed his out of the common mathematical abilities and advised him to study mathematics. Schickard took the advice and soon reached a significant success in the area. In 1631 he became a professor of the same university.

In their correspondence, Schickard and Kepler came to the conclusion: methods of astronomical calculations should be

[13] **IBM** (abbreviation for International Business Machines Corporation) is a multinational computer technology and consulting corporation. It was established in 1911 and was named C-T-R (Computing-Tabulating-Recording).

[14] **Johannes Kepler** (1571-1630), German mathematician and astronomer, discoverer of the laws of planetary motion. He was a key figure in the 17th century astronomical revolution.

improved. It inspired Schickard to begin designing his machine that he had completed in 1623, which he called a "Calculating Clock". Some brave historians even consider this year as the beginning of computer history.

Schickard's machine, as we can understand from some saved letters (no model comes to our days), could perform basic arithmetic operations based on the traditional decimal system.

Wilhelm Schickard

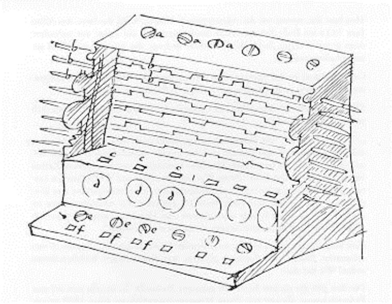
(1592 – 1636)

German mathematician and astronomer. His research was broad and included astronomy, mathematics and surveying. He invented many machines such as one for calculating astronomical dates and one for Hebrew grammar. He also created the first Planetarium that demonstrated position of Nebular bodies in Copernicus model of the Solar System. He made significant advances in mapmaking, producing maps which were far more accurate than those which were previously available at the time. His most important invention is the first automatic mechanical calculator.

In 1617 Schickard began corresponding with Johann Kepler. He realized difficulties that stood before the astronomer and decided to improve calculation methodology. In his letters to Kepler, he explained the application of his "Calculating Clock" to the computation of astronomical tables. Schickard described his machine as follows:

> *What you have done by calculation I have just tried to do by way of mechanics. I have I have constructed a machine which automatically reckons together the given numbers in a moment, adding, subtracting, multiplying and dividing...*

The next letter to Kepler in 1624 contains sketches of the machine.



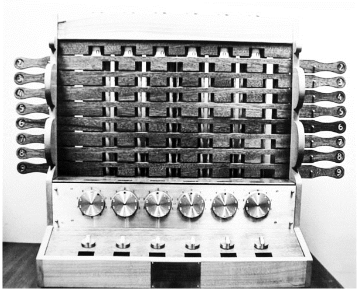
Unfortunately, the only machine made by Schickard was lost in a fire that happened in the mechanic's shop when he assembled the second machine.

In his letter after the fire, Schickard wrote to Kepler: "… I am writing you to alleviate my heart, because I am so depressed that I cannot make a new machine in a short time…"

No records exist of the events that Schickard practically used his calculator for real calculation...

Schickard and all members of his family died of cholera pandemic in Europe. All papers concerning the machine had been lost during the Thirty Years War (1618 –1648). However, in the 1957, scholars found a copy of draft of unknown computing device.

Then it was found that original is kept in Kepler's archive that was stored in St Petersburg's Observatory in Russia. As it was found this was a part of Schickard's letter to Kepler where he described his machine. Using this sketch, engineers of the Tubingen University had reconstructed the Schickard's "Calculating clock".



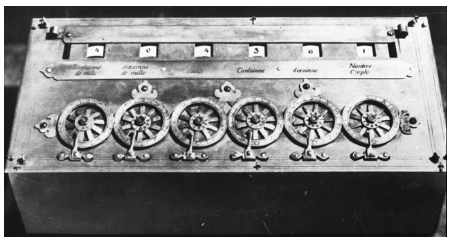
Frankly speaking, a replica is a bit enigmatic: how one could re-create a tool, having such fuzzy and unclear drawing? It is like to reconstruct an engine construction by an inaccurate sketch of an airplane fuselage…

3.3. Blaise Pascal

First operating mechanical calculator was built by famous French mathematician Blaise Pascal[15], when he was only 18-year old. This mechanical calculator "Pascaline", called alternatively the «Pascal's Wheel", was produced, distributed and practically used.

It seems to me that to argue Pascal's priority in the very first calculator invention is unreasonable. What like was Schickard machine nobody knows and never will know. With the same success one can consider Leonardo as the first creator of mechanical calculator. But it was only idea… How many ideas flying always around us! Nevertheless, we give priority invention to those who realized an ephemeral idea into a working system!

What inspired young Pascal to create first operating computing machine?



Blaise's father, Etienne Pascal, was a tax collector for Upper Normandy. His work needed a lot of calculations, and his son decided to make his father's work easier. Blaise had designed his machine in 1642 and in 1645 it was ready for production. "Pascalina", resembled a mechanical calculator, which were actively used in Europe and America in the 1940-s. It could add and extract any six-position decimal numbers fast and without errors.

With "Pascalina", there was a problem due to the contemporary French currency[16]: it was similar to the Imperial pounds ("livres"), shillings ("sols") and pence ("deniers"): there were

[15] **Blaise Pascal** (1623-1662), great French mathematician and physicist.

[16] The livre was established by Charles the Great, or Carolus Magnus, (742-814) who was King of the Franks. It was a unit of account equal to one pound of silver. It was subdivided into 20 sols, each of 12 deniers. The word livre came from the Latin word libra, a Roman unit of weight. This division is also seen in the old British pound sterling, which was divided into 20 shillings, each divided into 12 pence. The system remained in France until 1799 (but in Great Britain Imperial system was in use until 1971!).

20 sols in a livre and 12 deniers in a sol. So, “Pascalines” came in both decimal and non-decimal varieties, both of which exist in museums today.

The calculator had metal wheel dials, with the digit 0 through 9 displayed around the circumference of each wheel. When a gear with ten teeth made one rotation (tens) a second gear shift one tooth until that gear rotated ten times (hundreds) that shifts another gear (thousands) etc. This principle is still used in pumps of petrol stations, and electricity meters. The results of calculations in special windows at the top of the calculator.

The Pascaline worked like a clock and only performed addition. Multiplication was performed as multiple summations. The initial prototype of the Pascaline had only a few dials, whilst later production variants had eight dials, the latter being able to deal with numbers up to 99,999,999.

Later Pascal wrote that the idea of the adder appeared when he read about ancient Greek geometers who constructed angles with unbelievable accuracy[17].

Believing that his son’s invention could be extremely profitable, Etienne Pascal invested huge money in production of the machines: in the very first year several tens of machines had been produced. However, Pascalines met “intellectual Luddites[18]”: against Pascal’s invention were clerks who were afraid of losing their job as well as employers who preferred to use a cheep labor instead of buying relatively expensive calculating tools.

Pascaline invention and production certainly puts Pascal on the position of inventor a mechanical calculator. Factually, it was the first operating calculating machine in the world because nobody saw or used previous machines, including Schickard’ machine.

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[17] In more details see about this in Part XXX of Volume 1.

[18] The **Luddites** were a social movement of British textile production in the early nineteenth century who protested (often by destroying sewing machines) against the changes produced by the Industrial Revolution, which they felt threatened their livelihood. Since then, the term Luddite has been used to describe anyone opposed to technological progress and technological change

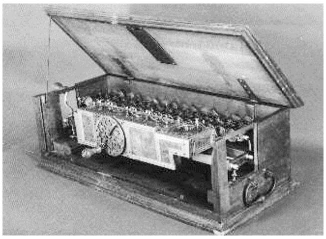
The description of the Schickard's machine actually proves nothing: much earlier Leonardo described his calculating machine that was never realized (unfortunately, as many other inventions of the genius).

The Pascal's method of connected gears became a basis for most of mechanical computing machines during next three centuries.

3.4. Gottfried Leibniz

In the middle of the 17th century Gottfried Leibniz[19] met Dutch mathematician and astronomer Christiaan Huygens[20] (who, by the way, invented a prototype of modern anchor clocks. After that meeting Leibniz who performed himself huge astronomical computations began to think about creating a tool that could make easier such calculations. He wrote:

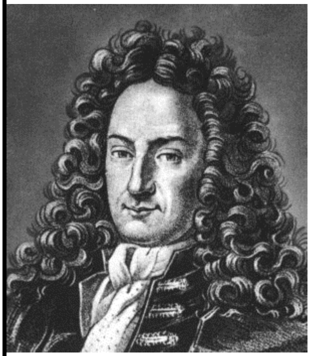
> *"For it is unworthy of excellent men to lose hours like slaves in the labor of calculation which could safely be relegated to anyone else if machines were used".*



Being not only a great mathematician but also an excellent engineer, Leibniz designed in 1673 his own mechanical computing machine based on "Pascalina" principles. However, he introduced many improvements into the construction.

[19] **Gottfried Wilhelm Leibniz** (1646-1716), great German mathematician.

[20] **Christiaan Huygens** (1629-1695), outstanding Dutch mathematician, astronomer and physicist.



Gottfried Wilhelm von Leibniz

(1646–1716)

German philosopher, physicist, and mathematician. Being 15-year old, he entered in Leipzig University and graduated in 4 years. He was a Fellow of Royal Society; founded Brandenburg Scientific Society that later became Berlin Academy of Sciences, which first President he became. He wrote on philosophy, science, mathematics, theology, history, and comparative philology, even writing verse.

He developed calculus independently of Newton. He also introduced binary numerical system that is so useful in computer sciences.

The calculator could make four arithmetic operations, add, subtract, multiply, and divide. He called his machine the Stepped Reckoner, because it was based on a new mechanical feature, the stepped drum or Leibniz Wheel. It was a cylinder with nine bar-shaped teeth of different lengths, which increased in equal steps around the drum. This brilliant concept has been used in many later calculators. When the first wooden prototype of the Stepped Reckoner was constructed Leibniz was able to show it to the Royal Society in London. Although the model did not work properly, the Society members were impressed and asked him to create a proper working model. A new version was completed in 1674.

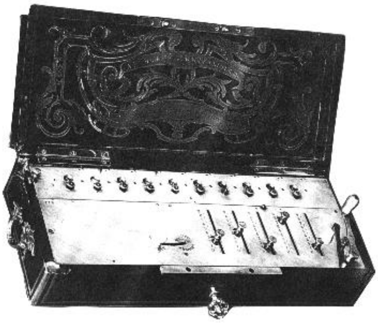
However, the first model needed substantial improvements that took 20 years more: Leibniz completed his construction only in 1694.

A few Leibniz calculators survived. One of them is in the Hanover State Library; another model is in the German Museum in Munich. It is known that one Leibniz's machine has been gifted by Leibniz to the Russian Tsar, Peter the Great, who invited Leibniz to help to arrange the Sanct-Petersburg Academy of Sciences.

In the 20th century a number of replicas of the Leibniz calculator have been built, one of them by IBM.

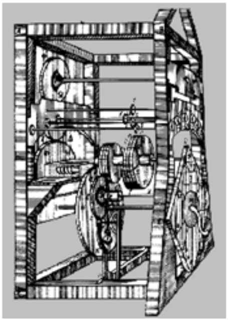
3.5. Giovanni Poleni

In 1709 in Padua it was published the book by Giovanni Poleni[21] "*Something about barometers, thermometers and arithmetic machine*" (*Miscellanea: de barometris et thermometris de machina quadem arithmetica*), where the author gave a description of his arithmetic machine. Main components of the machine were wooden and they moved due to the attached weights (Notice that Leonardo's work could be known for him.)



By legend, when Poleni had known about existence of the Pascal's machine, he had destroyed his own machine.

3.6. Thomas De Colmar



The honor of first establishing the manufacture of calculating machines as an industry goes to Charles Thomas de Colmar[22]. His nickname "Colmar" comes from the name of a small town Colmar (in province Alsace) where he was from. He was a founder and director of two insurance companies with poetic names "Phoenix" and "Soleil' ("Sun"). He decided to fire a number of clerks by inventing a machine which could perform calculations faster and more reliable.

[21] **Giovanni Poleni** (1683 - 1761), Italian mathematician, physicist, architect and engineer.

[22] **Charles Xavier Thomas de Colmar** (1785–1870), French engineer and mathematician.

Basing on Leibniz's calculating machine, he invented his own machine, which could perform four arithmetic operations. In 1820 he patented his machine called "an arithmometer" (from two Greek words «arithmos» («number») and «metreo» («to measure»). Next decades he introduced important changes that improved ease of operation and reliability of the device, while they did not disturb its main mechanism.

Thomas de Colmar began industrial production of his arithmometers. During the first year he produced 15 machines and next years the production was about hundred machines, among which about half were sold abroad. This type of calculating machined has been continued about 90 years.

This machine performed multiplication of two 8-decimal numbers during ¼ of minute, dividing a 6-decimal number took about half a minute. Not too bad for that time!

3.7. Pafnuty Chebyshov

Outstanding Russian mathematician and mechanist Pafnuty Chebyshov was an author of classical discoveries in the number theory and probability theory. In the number theory he is known for solving the problem that intrigued mathematicians since ancient time: he found an asymptotical law of simple numbers distribution. In the probability Chebyshov proved the fundamental result – he proved the so-called Law of large numbers.

However, not many know that one of the greatest Russian mathematicians was as well a perfect engineer-inventor.

A model of steam engine with Chebyshov's regulator was demonstrated at Moscow Polytechnic Exhibition in 1872 and then at the World Exhibitions in 1873 and 1876. In 1876 at the 5th Session of "French Association of Sciences Promotion" Chebyshov made a report on the theme "Summing machine with continuous movement". A model of the arithmometer made by Chebyshov is now at the Museum of Petersburg History.

Pafnuty Lvovich Chebyshov

(1821–1894)

After graduation from Moscow University, he defended dissertation in 1846 dissertation "Elementary Analysis of the Probability Theory and since then he had been a professor of the university.

He is often referred as a father of the Theory of mechanisms.

Chebyshov's works made him name in Russia as well as abroad. He was a member of St. Petersburg, Paris, Berlin and Bologna Academies of Sciences and a corresponding-member of the Sweden Academy of Sciences and London Royal Society.

In 1878 he made a new model of summating machine and gifted it to Paris Museum of Art and Craft. In three years Chebyshov sent to the museum additional device for multiplication and dividing. Since there were no publications about the invention, a few specialists knew about existence of Chebyshov's machine.

In B 1882 at 11th Session of "French Association of Sciences Promotion", he presented a report "About new calculating machine".

In 1893 at the International Industrial Exhibition in Chicago there were some interesting mechanical devices from Russia: a "walking machine" that imitated animal, moving armchair, a boat with mechanical oars, etc. However, the most attention of visitors was attracted to calculator that fast and correctly performed four arithmetical operations…

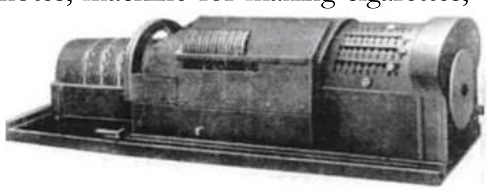
The most surprising was the fact that all these mechanisms were created by the same man – Pafnuty Chebyshov. Not in vain he was called "a father of the theory of mechanisms"!

Chebyshov's arithmometer was 10-decimal summating machine with continuous transmission to the next position: neighboring wheels moved to the next position with the help of a planetary gearing. It was absolutely new approach. Actually, Chebyshov did not try to make his machine more convenient for users – he searched new paths in constructing mechanical devices. By the way, such kind of summation you could observe at gas stations.

In semi-automatic calculators, one should multiply numbers sequentially with moving carriage step by step. In Chebyshov's calculator entire multiplier was installed once and after one should only rotate a handle of the machine. It is clear that if one uses electric engine for rotation, the Chebyshov's arithmometer could make calculation automatically. Thus, this arithmometer actually is a prototype of automatic mechanical calculating machines.

3.8. Willgodt Odhner

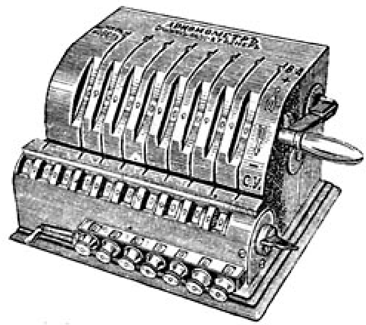
Willgodt Odhner[23] was well known inventor: he invented machine for numerating banknotes, machine for making cigarettes, mechanical box for voting, tourniquet, etc. in 1874 created an adding machine which was widely used then all over the world.



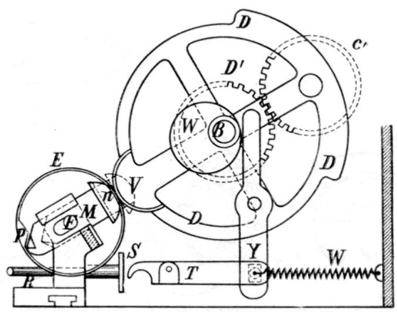
However, Odhner became a worldwide famous due to his arithmometers. The first Odhner's machine was produced in St. Petersburg, Russia. Odhner wrote: "I had a chance to improve Thomas' machine and came to the conviction that there should be simpler way to solve the problem of mechanical calculations".

[23] **Willgodt Theophil Odhner** (1846-1905), Swedish engineer-mechanic. Since 1970 working in St. Petersburs, Russia.

The main Odhner's idea was in replacing Leibniz's stepped drum by a wheel with varying number of gears (the so-called "Odhner's wheel")).



Odhner established in St. Petersburg (Russia) a factory producing his machine. As he wrote in his memoirs: "I had a chance to improve Tomas' machine and was convinced that there is a possibility to solve the problem of mechanical calculations faster and in more reasonable way".



At the beginning, a few Odhner's machines were made at the factory "Ludwig Nobel" belonged to a Swedish owner. The only machine of that series is kept now in Moscow at the Polytechnic Museum.

Several years Odhner continued to improve his invention, arranged a small factory and tried to produce his machines. However, a patent of his invention belonged to Swedish company… Only in 1890 Odhner got a patent of his own invention!

In 1892 he built two more factories in Germany. Since then, Odhner began industrial production of his machines. Thousands such machines were sold all over the World.

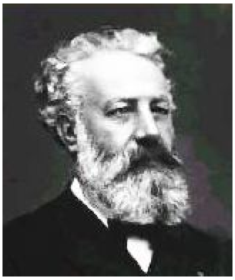
After 1917 Bolsheviks' revolution in Russia, Odhner production was moved to Sweden. Total production has exceeded 1 million units.

Early Odhner's arithmometers are now on exhibits of the Polytechnic Museum of Moscow (Russia), the Smithsonian National Museum of American History and Technology

(Washington, D.C. USA), and the Swedish National Museum of Science and Technology in Stockholm.

3.9. Jules Verne and computers

What a relation could fiction-novelist Jules Verne could have to computers? The same that he has to flying apparatuses heavier than air or to submarines! He predicted with an astonishing clairvoyant's ability – yes, not in a pure scientific form but in a form of scientific fiction – predicted spaceflights («*All Around the Moon*", "*From the Earth to the Moon*", "*The Moon-Voyage*", and submarines ("*The Mysterious Island, Twenty Thousand Leagues Under the Sea*"), and helicopters ("*Robur the Conqueror*"), and airplanes ("*Master of the World*"), and other interesting future inventions of the mankind.



Jules Gabriel Verne

(1828 - 1905)

Famous French fiction novel writer who actually was Father of the scientific fictions. He wrote about 70 novels (including not finished), 20 stories, 30 plays and even several pure scientific works.

Is it possible that this brilliant Fantast (definitely with a capital "F"!) missed electronic computers? It is absolutely impossible!

Indeed, until recent time nothing was known about Jules Verne's interest in electronic computers. However, almost hundred years after his death, interesting facts have been found.

It was in 1863 when Jules Verne just started his writer's carrier, he brought his second futurological novel "*The City of the Future*" ("*La Ville du Futur*"). The novel had been inclined and somehow lost in the author's archives. It was found only in the middle of 1980-s and later was published under the title "*Paris of the 20th century*".

The novel describes events of 1960 (remember, it was written in early 1860-s). Probably, a plot of the novel is not too intriguing though the author paid a great attention to various technical and technological miracles. He described an interior of one of the Parisian banks where there were enigmatic calculating machines.

Below are some citations (in abbreviated form):

> *"Michel was led to a large hall where he saw unusually constructed equipment, whose purpose he understood not momentarily. They were calculating machines.*
>
> *Since Pascal who invented something reminding these machines, that seemed at the time a real miracle, we moved significantly forward. Bank "Casmadage" possessed real masterpieces: the calculating machines reminded giant pianos. Using a keyboard, one can instantaneously calculate resulting sums, amount of change, fractions, and complex percents for any period and with any interests. These machines were incomparable with something else... "*

Of course, even brave Jules Verne's brain could not foresee all possibilities of modern computers. However, he was the first who fingered on a real principal possibility to substitute a man by a computer. He wrote:

> *"Michel was wonder: why an accounter still as not displaced by a calculating machine? "*

In 1889 Jules Verne had published a short story "*In the 29th century*" where he described a day of the life an American chronicler in 2889. It seems (by absence of readers' and critics' reaction) that the story was not interesting at that time: who cares about something that might happen in a millennium?

> *"Thirty scientists were working at calculating machines. One of them was absorbed with solution of 95th power; others played with formulae with algebraic infinity and 24-dimension space like children of elementary school solve simplest problems using four main arithmetic*

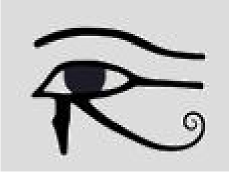
operations... Bennet intending to check accounts for the current day went to his office. He should check everyday balance of a multimillion company. With the help of electric calculating machine he director had performed his problem very fast. "

Indeed, such fore vision seems to us naïve… However, who of living futurologists will risk predicting what will be in thousand years?

4. COMPUTER SAPIENS

> We are approaching to the time when for mathematicians it will be left only composing of equations, solving of which will provide machines.
>
> ***Sergei Vavilov*[24]**

4.1. Who was the first?



Modern computers use binary numeral system. This system is rather special and, probably, it was a reason that it appeared on the historical scene so late.

However, one can trace some roots of the binary numerical system into ancient time.

The ancient Egyptians had the so-called Eye of Horus[25], a symbol of protection and royal power from deities.

In the Ancient Egyptian measurement system, the Eye of Horus defined an Old Kingdom rounded off number one: 1 = 1/2

[24] **Sergey Ivanovich Vavilov** (1891-1951), Soviet physicist, the President of the USSR Academy of Sciences. Head of the Lebedev Institute of Physics, a chief editor of the Great Soviet Encyclopedia,

[25] **Horus** is one of the most ancient deities of the Ancient Egyptian religion, who is represented as a man with a falcon's head. His name is connected to the sky and kingship.

+ 1/4 + 1/8 + 1/16 + 1/32 + 1/64. Of course, if you wish, you could find a "binary numerical system" here, though it is rather a genius guess of ancient people about a simplest geometrical set!

It is said that the ancient Indian mathematician Pingala[26] presented the first known description of a binary numeral system in 5th century BC, written in Hindu numerals.

So often people who desperately try to find something have found exactly what they wish to find by wrong interpretation of the found facts! If one spend some time and try to learn more about Pingala, then he finds actually that he dealt with quite different things: he wrote about prosody[27] Moreover, he did not possessed a concept of zero at all! Positional use of zero dates from later centuries and would have been known to Halayudha[28] but not to Pingala.

Pingala used short and long syllables (that some interpret as "0" and "1"). However, four short syllables (corresponding to binary "0000") in Pingala's system represented the number one, not zero.

Actually, there is an ancient Chinese manuscript "Book of Changes"[29] that is traditionally attributed to the mythical Fu Xi[30], who is seen as an early culture hero, one of the earliest legendary rulers of China. By legend, 8 trigrams[31] revealed to him supernaturally.

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26 **Pingala** (the 5th century BC), an ancient Indian mathematician.

27 **Prosody** in linguistics means the study of rhythm, intonation, and related attributes in speech. In poetry it is the study of poetic meter.

28 **Halayudha** (the 10th century), Indian mathematician who wrote a commentary on Pingala's "*Chandas Shastra*", containing a clear description of Pascal's triangle (called "*meru-prastaara*").

29 The "***Book of Changes***" (in Chinese "*I Ching*" or "*Yì Jīng*") is the oldest of the Chinese manuscripts, accepted as a canonic for Confucianism, an ancient Chinese ethical and philosophical system.

30**Fu Xi** , or **Fu Hsi** (traditional dates 2800-2737 BCE) was the first of the mythical Three Sovereigns of ancient China. He is a culture hero reputed to be the inventor of writing, fishing, and trapping.

31 A **trigram** (also referred as "*Bagua*"), is a philosophical concept in ancient China means a various set of three symbols.

First, what does it mean "trigram"? Trigrams are ordered triplets of any kind of token. For instance, AAA, ABB, BAB, BBA, AAB, ABA, BAA AND BBB are all possible trigrams for letter A and B. Trigrams for numbers 4 and 7 are 444, 447, 474, 744, 477,747, 774 and 777.

In ancient China there were all possible triplets of two symbols: one long and two short lines. (By the way, similar sets of binary combinations have also been used in traditional African divination systems as well as in medieval Western cultures. Hardly anybody will think that there is some mathematical meaning in these cases!))

Let us consider eight Chinese trigrams.

Chinese names	Qian	Dui	Li	Zhen	Xun	Kan	Gen	Kun
Chinese "binary notation"	☷	☶	☵	☴	☳	☲	☱	☰
Binary numerical system	000	001	010	011	100	101	110	111
Corresponding decimal numbers	0	1	2	3	4	5	6	7
Symbolical meaning	Earth	Mountain	Water	Wind	Heaven	Lake	Fire	Thunder
Animals	cow	dog	pig	fowl	dragon	pheasant	sheep	horse
Family relations	mother	3rd son	2nd son	1st daughter	1st son	2nd daughter	3rd daughter	father

Do these codes resemble binary numbers? Yes, they do… However, it seems to me that these signs are just special hieroglyphs that use two basis elements – a long line and two short lines. That's all! Nevertheless, these signs are ordered as binary numbers: 0, 1, 2, … up to 7. Is it casual coincidence or intentional system?

If the Chinese "binary system" exists, then numbers – as one can assume – were used for ordering objects in the table above.

Let us say that objects are ordered in increasing of their "importance" from 1 to 8 (or more exactly, from 0 to 7). Let us introduce for convenience of the future analysis a conditional sign of preference "←". Then we can write the following chain of objects' relations:

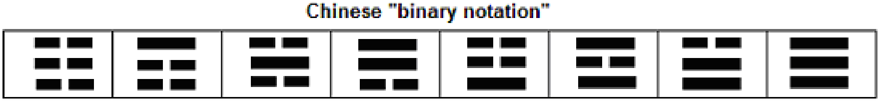
earth←mountain water←wind heaven←lake←fire←thunder.

It is difficult to explain, why *water* is "more important" than *mountain* but "less important» than *wind*. Let us consider the next chain:

cow←dog←pig←fowl←dragon←pheasant←sheep←horse.

Why *pheasant* is "more important" than *dragon* but "less important" than *sheep*? (By the way, how a dragon appeared among those domestic animals?) Who knows? It depends, probably, on people's culture (customs, mythology, prejudices, etc.)…

Chinese "binary notation"



Family relations

mother	3rd son	2nd son	1st daughter	1st son	2nd daughter	3rd daughter	father

However, let us take family relations where everything is clear. From these trigrams, one can make a conclusion that

mother←3^{rd} son←2^{nd} son←1^{st} daughter←1^{st} son

←2^{nd} daughter←3^{rd} daughter← father.

It is obvious that something is wrong… Okay, a father of the Oriental family was (and is) a main figure in the family. But why the 3^{rd} daughter is more important than the 1^{st} son? Unbelievable, isn't it? You could continue this analysis yourself and find other contradictions to a common sense.

Now let us be more attentive looking at the trigrams: of course, a long line means male attribute and two short lines means female attribute. Who is the most important woman in a family? Surely, a mother, so she has only female signs. Analogously, a father has only male signs. Sons have male sign and actually two female signs are not more than a "background" – each trigram should have three symbols in total. A position of male sign for sons shows their order (from the down to the up). The same we have for daughters.

You also could observe a kind of axes symmetry: 1st and 8th, 2nd and 7th, 3rd and 6th, finally, 4th and 5th trigrams are "inverse mirror" reflections of each other! It means that in each mentioned pair, one trigram can be obtained from another by changing 0 for 1 and 1 for 0! In addition, it is easy to notice that from the left to the right (from "mother side") there are inclining "female steps" and from the right to the left (from "father side") there are inclining "male steps".

Thus, maybe there is no enigmatic "Chinese binary numerical system"! Just a hieroglyphic notation constructed by some regular way?

However, look: if you add 2 and 3 in "Chinese form" you will get 5! Don't hurry! Any trigram – this

☺☺☺, ☺☺☻, ☺☻☺, ☺☻☻,☻☺☺, ☻☺☻, ☻☻☺, ☻☻☻

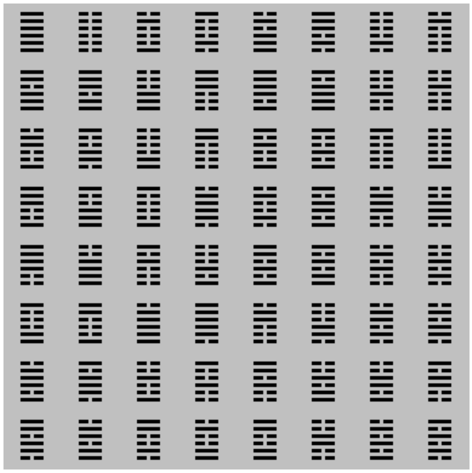
or that

♣♣♣, ♣♣♥, ♣♥♣, ♣♥♥, ♥♣♣, ♥♣♥, ♥♥♣, ♥♥♥

will possess binary numbers property as soon as you artificially replace on sign for 1 and another one – for 0. In other words, if you will play with zeros and ones you definitely get something reminding binary numbers, however it does not mean that you are working with binary numerical system!

Nevertheless, the ordering of trigrams is very much intriguing…

"*Yì Jīng*" contains also hexagrams[32] that could be interpreted as the decimal sequence from 0 to 63. This is known as King Wen[33] sequence. This set has the following form.



In decimal numbers this table looks like the following:

(Following ancient Chinese, we start with 1 and finish with 64, since they don't know zero.)

02	23	08	20	16	35	45	12
15	52	39	53	62	56	31	33
07	04	29	59	40	64	47	06
46	18	48	57	32	50	28	44
24	27	03	42	51	21	17	25
36	22	63	37	55	30	49	13
19	41	60	61	54	38	58	10
11	26	05	09	34	14	43	01

Of course, it was rather enigmatic order. Nobody could understand how such a square with hexagrams was built. An elegant method of generation of hexagrams was developed by Shao Yong[34] in the 11th century.

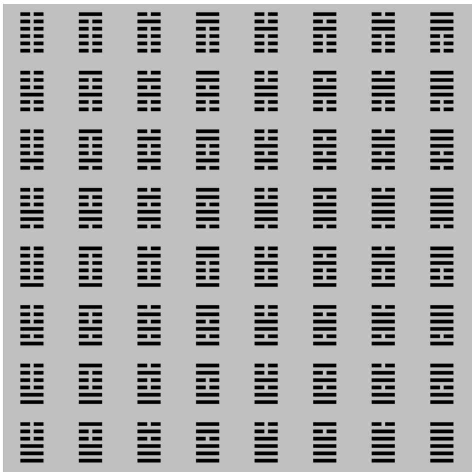
That genius mathematician built hexagrams in a systematic order and arranges them due to his

[32] A **hexagram** is any of the sixty-four sets of solid and broken lines. Each hexagram consists of two trigrams. Remark: a six-pointed geometric star figure is also called a hexagram.

[33] **King Wen** (1099–1050 BC) was the founder of the later Zhou Dynasty in ancient China.

[34] **Shao Yong**, courtesy name **Yaofu** (1011-1077), Chinese scholar, philosopher, cosmologist, poet and historian.

algorithm of generating in binary order! Let us look at the so-called the Shao Yong Square.

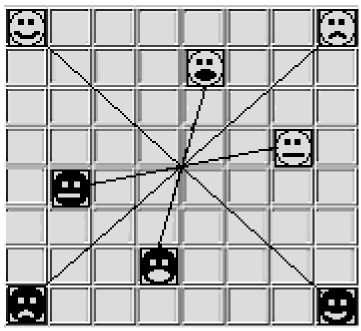


What can we see? Let us divide each hexagram into upper and lower parts, each of which corresponds to respective trigram. The first "column" consists of two trigrams, each of which above is denoted as 0. So, the total first hexagram is 0. To get the second hexagram, we keep the lower trigram and put on the top the next trigram that corresponds to 1. Reading the "binary number" from down to up, we get 01. The in the third hexagram we put next trigram, corresponding 2 and get finally the number 02, and so on. So we get numbers from 0 to 63, i.e. all numbers up to 2^6.

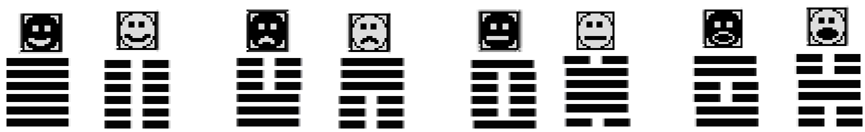
So, corresponding decimal numbers in the Shao Yong square are

01	02	03	04	05	06	07	08
09	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

Such an amazing structure of the Shao Yong square is due to the algorithm that Shao Yong had chosen for constructing the table. This table has one wonderful property: all numbers have center symmetry! Take, for instance, the following pairs of the Shao Yong square that are "inverse mirror" reflections. Let us mark some of them.



Below you could see the same pairs in detailed form.



Probably this property of a square table of binary numbers made the Shao Yong square even more enigmatic for people.

4.2. About the binary system and its creator

The modern binary number system was fully documented by Gottfried Leibniz in the 17th century. He wrote a manuscript named "*De progressione dyadica*" that was published in 1679 under the title "*Explication de l'Arithmétique Binaire*". In 1701 the Jesuit Joachim Bouvet, who served as a missioner in China many years, wrote to Leibniz a letter enclosing a copy of the Shao Yong square.

Nobody knows how Leibniz reacted on this letter, however he probably saw that there is no mathematics at all: there was invention of some special way of objects numerating.

By the way, notice that any complete set of trigrams, for instance like this

☺☺☺, ☺☺☻, ☺☻☺, ☺☻☻,☻☺☺, ☻☺☻, ☻☻☺, ☻☻☻

or like that

♣ ♣ ♣, ♣ ♣ ♥, ♣ ♥ ♣, ♣ ♥ ♥, ♥ ♣ ♣, ♥ ♣ ♥, ♥ ♥ ♣, ♥ ♥ ♥

possess all attributes of binary numbers from 0 to 7 if one symbol is substituted by 1, and another is substituted by 0. In other words, there is a resemblance but do these hieroglyphs have become numbers?

Gottfried Wilhelm von Leibniz

(1646–1716)

German philosopher, physicist, and mathematician. He wrote on philosophy, science, mathematics, theology, history, and comparative philology, even writing verse. He was self-taught in mathematics, but nonetheless developed calculus independently of Newton. Although he published his results slightly after Newton, his notation was by far superior (including the integral sign and derivative), and is in use today.

Leibniz wrote about binary calculations: "These operations are so easy that we shall never have to guess or apply trial and error, as we must do in ordinary division".

What was it – genius intuition or admiration of a new mathematical discovery? Anyway, the discovery binary mathematics made a real revolution in mathematics and opened the door for developing computers.

However, it is important to notice that Leibniz did not recommend using binary calculations for calculations "by hand".

Leibniz himself took a great interest in binary system. He even saw some mystique sense in it: for instance, binary 7, that is 111, was interpreted as Trinity and at the same time he connected this number with 7 days of God's creation of the Universe…

In his practical judgments he was much more pragmatic: values 1 and 0 he corresponded to answers "yes" or "no" that was an anticipation of what later became algebra of logic.

Nevertheless, it is interesting now to consider what does it mean "a binary system"? (Those who know the subject, we recommend to go to the next Section.)

"Normal people" counting from 1 to up, after 9 write 10 and again count from 1 to 9 up to the second ten (20). "A stupid computer" can count only up to two: as soon as you add 1 to 1, a computer considers it as a jump to the next position! It is more convenient for a computer because at the same time it can get advantage in the speed of easy calculations, convenience of information transfer, etc.

For demonstration of contrast and resemblance between various numerical systems, let us compile the following table.

Basis 10	**Basis 2**	**Basis 3**	**...**	**Basis 5**	**...**
1	1	1	...	1	...
2	10	2	...	2	...
3	11	10	...	3	...
4	100	11	...	4	...
5	101	12	...	10	...
6	110	100	...	11	...
7	111	101	...	12	...
8	1000	102	...	13	...
9	1001	110	...	14	...
10	1010	111	...	20	...
11	1011	200	...	21	...
12	1100	201	...	22	...
13	1101	202	...	23	...
14	1110	210	...	24	...
15	1111	211	...	30	...
16	10000	212	...	31	...
17	10001	220	...	32	...
...	...	...	...	...	...

This table could be easily continued. Now let us consider only "jumps" to the next position.

Decimal number	Power of 2	Binary number
32	2^5	100000
64	2^6	1000000
128	2^7	10000000
256	2^8	100000000
512	2^9	1000000000
1024	2^{10}	10000000000
...	...	...

Thus, the number of zeros in a binary presentation is equal to the power of 2.

The numbers in binary system seem bulky but it is only because you don't use to operate with them. Leibniz was the first who had seen calculating convenience of the binary system. (How simple is everything in genius minds!)

Let us consider summation. In each position of a binary number there are only the following situations: 0+0 = 0, 1+0 = 1, 1+1 = 10. For instance, add 5 to 10, that in a binary system are 101 and 1010. Let us use a rule that we were taught in the 1st grade of an elementary school.

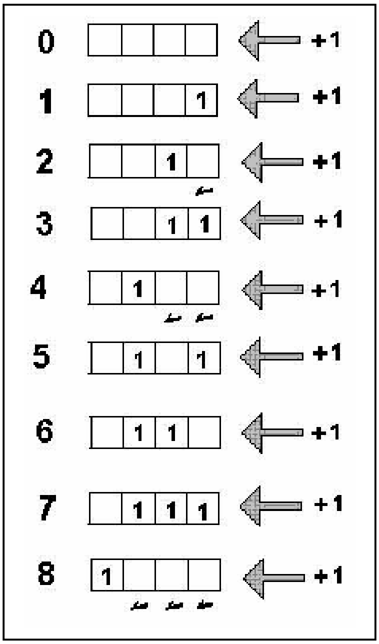
$$\begin{array}{r} 101 \\ +\ 1010 \\ \hline 1111 \end{array} \;.$$

In table of powers of 2, we find that this binary number corresponds to decimal 15. Now let us take "more difficult" problem: add 1 to 7.

$$111 + 1 \rightarrow 11(1+1) \rightarrow 1(1+1)0 \rightarrow (1+1)00 \rightarrow 1000.$$

(Here conditional recording (1+1) means that 1 is added to the corresponding binary position.) In result, we have binary number 1000, corresponding to decimal 8.

Sometimes one uses the rule of the so-called "killing unit."



Consider a series of cells, in each of which there could be 1 or 0. (In case when there is 0, we will say that "a cell is empty".) If a cell is empty and a unit "comes in", it stays at the cell. If a cell is already "occupied", entering unit "kills" its "host" and move to the next cell, until finds an empty cell. The same process repeats with a new unit entering the very right cell.

This procedure is illustrated by the figure on the left. ("Killed" units are depicted lying under a corresponding cell.)

Notice that multiplication is also performed in an elegant way. Let us multiply binary 110 (decimal 6) by 101 (decimal 5). Let us multiply it "in column", as we were taught in elementary school:

$$
\begin{array}{r}
\times\; 110 \\
101 \\
\hline
110 \\
000 \\
110 \\
\hline
11110
\end{array}
$$

So, one gets 11110. Let us check, what this binary equal to. For this use the table of powers of 2:

Binary position in the resulting number	1	1	1	1	0
Decimal values	16	8	4	2	0
Decimal values corresponding binary number	16	8	4	2	0

Thus, binary 100011 corresponds to decimal 16+8+4+2+0=30.

For comparison, let us multiply now 101 by 111.

```
  101
 x111
------
  101
 101
101
------
100011
```

The result is 100011 (decimal 35). In this case, a new binary position appears (2^5).

So, now you are armed up to you tooth with binary arithmetic!

4.3. Binary system has its own Googol!

In computer science a binary unit has its own name – “bit” (abbreviation for **bi**nary digi**t**). For computer operation, it was convenient to introduce 8-position block called “byte”. Each byte can transfer $2^8 = 256$ various binary codes.

Naturally, the binary system has its own “monster numbers” as it is in the decimal system. Below there is a table with “binary relatives of Googol” introduced by International Electrotechnical Commission.

Measurement in bits					
Decimal basis			**Binary basis**		
Name	**Symbol**	**Power**	**Name**	**Symbol**	**Power**
kilobit	Kb	10^3	**kibibit**	KiB	2^{10}
megabit	Mb	10^6	**mebibit**	MiB	2^{20}
gigabit	Gb	10^9	**gibibit**	GiB	2^{30}
terabit	Tb	10^{12}	**tebibit**	TiB	2^{40}
petabit	Pb	10^{15}	**pebibit**	PiB	2^{50}
exabit	Eb	10^{18}	**exbibit**	EiB	2^{60}
zettabit	Zb	10^{21}	**zebibit**	ZiB	2^{70}
yottabit	Yb	10^{24}	**yobibit**	YiB	2^{80}

Measurement on bytes					
Decimal basis			**Binary basis**		
Name	**Symbol**	**Power**	**Name**	**Symbol**	**Power**
kilobyte	KB	10^3	**kibibyte**	KiB	2^{10}
megabit	MB	10^6	**mebibyte**	MiB	2^{20}
gigabyte	GB	10^9	**gibibyte**	GiB	2^{30}
terabyte	TB	10^{12}	**tebibyte**	TiB	2^{40}
petabyte	PB	10^{15}	**pebibyte**	PiB	2^{50}
exabyte	EB	10^{18}	**exbibyte**	EiB	2^{60}
zettabyte	ZB	10^{21}	**zebibyte**	ZiB	2^{70}
yottabyte	YB	10^{24}	**yobibyte**	YiB	2^{80}

Do not forget that one byte equals 1024 bit! Here you can see relations between decimal and binary values:

$$KB = 1024^1 = 1.024 \cdot 10^3 \text{ bit}$$

$$MB = 1024^2 \approx 1.049 \cdot 10^6 \text{ bit}$$

$$GB = 1024^3 \approx 1.074 \cdot 10^9 \text{ bit}$$

$$TB = 1024^4 \approx 1.100 \cdot 10^{12} \text{ bit}$$

$$PB = 1024^5 \approx 1.126 \cdot 10^{15} \text{ bit}$$

$$EB = 1024^6 \approx 1.153 \cdot 10^{18} \text{ bit}$$

$$ZB = 1024^7 \approx 1.181 \cdot 10^{21} \text{ bit}$$

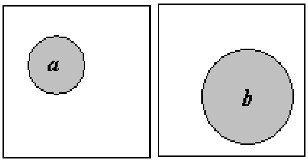
$$YB = 1024^8 \approx 1.209 \cdot 10^{24} \text{ bit}$$

So, how do you like yobibyte? Not much worse than Google!

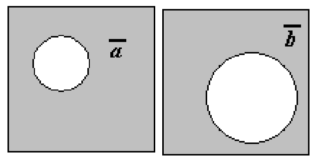
4.4. Nevertheless, how computer can logically think?

It appeared that binary numbers are convenient not only in sense of arithmetic. Even Leibniz related concepts of “yes” and “no” with “1” and “0”.

George Boole[35] introduced a logical statement that considered only two responses: TRUE and FALSE corresponding to them 1 and 0, respectively. On the basis of this concept he built algebra of logic that now is called Boolean algebra. Working with 1 and 0, Boole actually dealt with concepts.

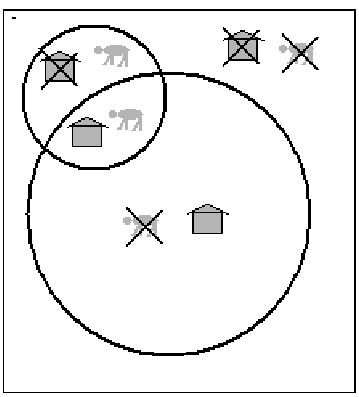


A classical example given by Boole himself is an example with "horned sheep", which is traveling from one textbook to another. Let $a = 1$ means "horned" and $b = 1$ means "sheep"; then $a = 0$ means "hornless" and $b = 0$ means "non-sheep". Let us denote "all possible statements" as a conditional square, and each statement a and b as some areas inside that square:



Even with all our respect to George Boole and his bright example, let us use more simple notifications.

It is clear that from here follows that "complementary" statements "not *a*" and "not *b*" are also defined. In algebra of logic, such statements are denoted by a bar over the corresponding symbol, i.e. in our case we have $\bar{a}$ and $\bar{b}$, respectively:



Indeed, if "*a*" corresponds to TRUE then "not *a*", i.e. rejection of *a*, means FALSE. At the same time TRUE and FALSE exhausted all possible outcomes for "a". (A computer cannot respond: "I don't know".)

Notice that for logical functions of this class one can use the law of so called double rejection that in a verbal form sounds approximately as follows:

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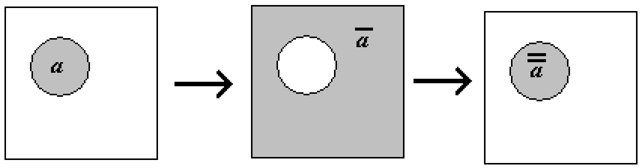
[35] **George Boole** (1815-1864), British mathematician and philosopher working in Ireland. ***For more details, see Chapter 5, "Pantheon".***

FALSE is not Not-a-TRUE but Not Not-a-TRUE is TRUE. In other words, if I am cheating telling you that I am cheating, that means that indeed I am telling you a truth. In formal terms it looks like the following: $a = \bar{\bar{a}}$.



Boole introduced further operations over logic statements and showed that there were the same laws that there were in algebra, i.e. such statements could be added and multiplied!

Thus, the space of

The Boolean algebra uses the following logic functions.

1. **Logic "OR"** (logic addition, or disjunction).

Notation: $y = a \vee b$.

The table of values of function "OR" with an illustration on "horned" and "sheep" is given below.

a	***b***	***y***	**Explanation**
0	0	0	Either hornless, or non-sheep, for instance, elephant, crocodile, even you, my reader ☺. In other words, everybody except horned sheep.
0	1	1	Either hornless, or sheep, i.e. everybody except horned non-sheep. So, you, my reader, do not belong to this category!
1	0	1	Either horned, or non-sheep, i.e. everybody except hornless sheep. You, my reader, are definitely here!
1	1	1	Either horned, or sheep. Otherwise, it is there is no home-less non-sheep. .Again you are here, my reader.

This table could be easily explained with the help of the so-called Venn[36] diagram.

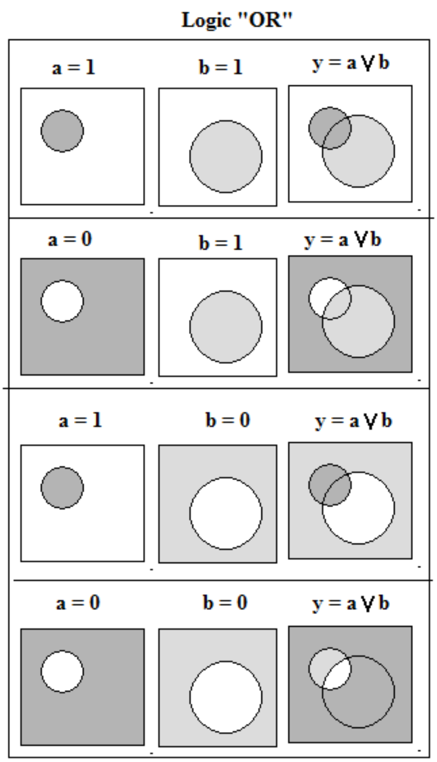
[36] **John Venn** (1834-1923), British logician and philosopher, who is famous for conceiving the Venn diagrams, which are used in many fields, including set theory, probability, logic, statistics, and computer science.

It can be seen that the last picture (y) is formed by overlapping of two transparent films each of which has a shadowed area: as the result, we see the resulting shadowed area. In other words, if "something" is overlapped with "nothing", we are seeing "something".

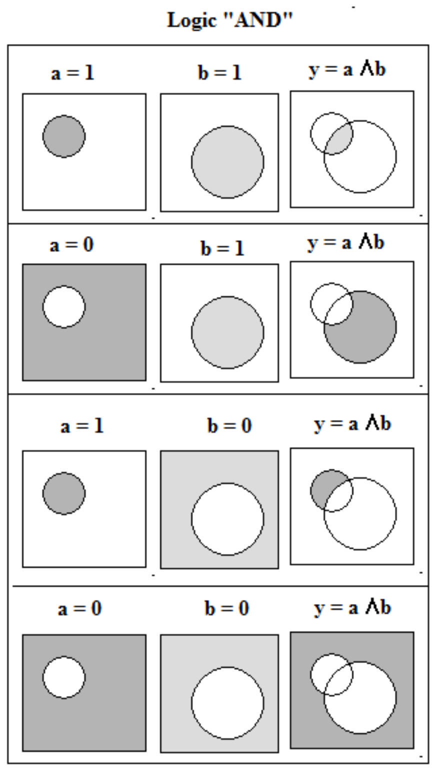
2. **Logic "AND"** (logical multiplication, or conjunction).

Notation: $y = a \wedge b$.

We avoid further verbal explanations of the situations and will use only Venn diagrams. Venn diagrams for these cases are presented below. Part A presents Venn diagrams for function "OR" and part B does for function "AND".



(A)



(B)

3. **"Peirce[37] arrow"** is the logical NOR operator or joint denial. It is a Boolean logic operator which produces a result that is the inverse of logical OR. In other words, it means "not *a*, not *b*".

Notation:

$y = \overline{a \vee b}$, or $y = a \downarrow b$.

The Venn diagram is below.

4. **The "Sheffer[38] stroke"** (**NAND** operation: "not and").

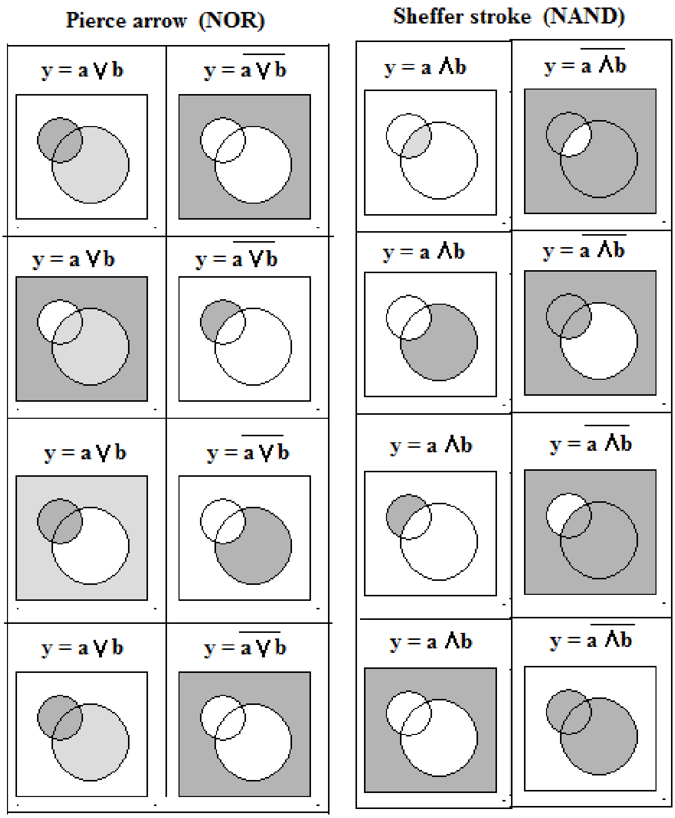
Notation:

$y = \overline{a \wedge b}$ or $a \uparrow b$

Venn diagrams for these cases are:

[37] **Charles Sanders Peirce** (1839-1914), American philosopher and mathematician. He demonstrated that any logical operation can be expressed in terms of logical NOR that has been named after his.

[38] **Henry Maurice Sheffer** (1882-1964), American mathematician.



(C) (D)

We have to add that English mathematician Augustus de Morgan introduced two more rules that now bear his name:

$$\overline{a \wedge b} = \bar{a} \vee \bar{b} \text{ и } \overline{a \vee b} = \bar{a} \wedge \bar{b}\,.$$

Both these rules can be rewritten with the use of the rule of “double rejection” as

$$a \vee b = \overline{\bar{a} \wedge \bar{b}} \text{ и } a \wedge b = \overline{\bar{a} \vee \bar{b}}\,.$$

Augustus de Morgan

(1806 - 1871)

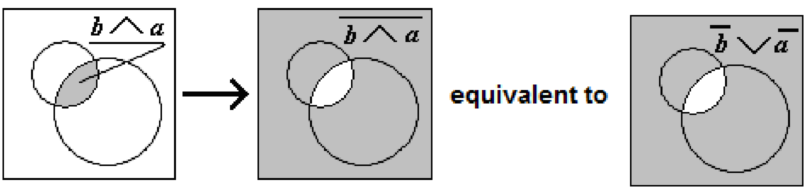
Scottish mathematician and logistic. He was born to a colonel who served in India. He was graduated from Cambridge University. He was a professor at London University.

Morgan was the first president of London Mathematical Society.

He developed his ideas in algebra of logic independently on George Boole and published them in 1847.

Well known logic laws are named after him (de Morgan's Rules).

These rules are easily understood from the corresponding Venn diagrams:



$$a \vee b = \overline{\overline{a} \wedge \overline{b}} \text{ и } a \wedge b = \overline{\overline{a} \vee \overline{b}}.$$

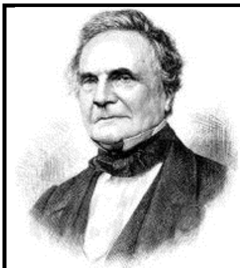
What for we drew all these squares and circles? Just to demonstrate that with the help of those simple operations one can describe entire logical part of our thinking! It is difficult to believe, is not it?

Now Boole's ideas are used in all modern computers. His ideas Boole published first time in 1847 in paper "*Mathematical Analysis of Logic*" and in 7 years developed them in an extended treatise "*An Investigation of the Laws of Thought, on Which are Founded the Mathematical Theories of Logic and Probabilities*".

4.5. From calculating machine to analyzing machine

In 1830-s English mathematician professor of Cambridge University Charles Babbage tried to build a universale computing device – "Analytical Machine" that could perform calculation without a human participation. Except such a machine could save expensive human labor, it saved from multiple errors which were inevitable due to boring and tiresome calculation process.

That machine for information processes Babbage imagined as some kind of analogy to the Jacquard[39] loom machine in sense of controlling by punch cards. By the way, Jacquard's looms left without job thousands and thousands of handicraft textile workers.



Charles Babbage

(1791- 1871)

English mathematician, inventor of the first computing machine.

In 1864 he wrote: "T=It takes probably half a century before the people will realize that it is impossible to live without the machines which 1 will have left after me".

He was a Fellow of London Royal Society and St. Petersburg Academy of Sciences (Russia).

Babbage understood that punch cards (at the time) were a perfect method of controlling the computational process. In addition, he suggested making storage for input, output and current data (now we call it "computer memory"). He intended also to supply his machine with a kind of a printer for presentation of results of computations.

[39] **Joseph Marie Jacquard** (1752-1834), French inventor of a mechanical loom. The Jacquard loom was the first machine to use punch cards to control a sequence of operations.

In complete correspondence with his time, Babbage assumed to have a steam engine as an energy source for his machine.

Babbage had not built his machine– from one side, it was to ahead of his time, from another side, and it was too complicated from mechanical construction viewpoint. Nevertheless, Babbage entered the history of computers due to tons of original ideas and constructive solutions of various problems.

First of all, Babbage clamed that it was possible to build a mechanical machine that could be able performing of sequence of dependent computations, which could be programmed by an operator. In addition, different sets of "controlling" punch cards could permit the machine performing various tasks.

He mentioned that his machine could make non-arithmetical operations if input data would be presented in numerical form. (That completely coincides with George Boole concepts.)

As a matter of fact, during attempts to realize Babbage machine the concepts of programming appeared. In this connection we should mention an outstanding role of talented mathematician Ada Lovelace[40], the daughter of the great English poet George Byron[41].

Unfortunately in 1842 Babbage's project had been closed due to over expenses and multiple delays of various deadlines.

* * *

In 1991 English scientists and engineers have built Babbage's mechanical machine using detailed drawings and descriptions. It was not fast (arithmetical operation took about 2-3 minutes) though performed everything that Babbage described.

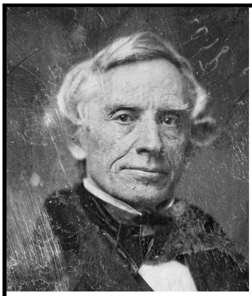
[40] **Augusta Ada King**, **Countess of Lovelace**, born **Augusta Ada Byron** (1815-1852), mainly known for having written a description of Charles Babbage's analytical engine. She is also known as the "first programmer". ***For more details see Part 7 of this volume***.

[41] **George Gordon Byron**, known as **Lord Byron** (1788-1824), great British poet, a leading figure of romantism in literature.

4.6. First relay computers

As it often happened, a serious discovery begins with a funny experiment that a professor of one of New Jersey colleges, Joseph Henry[42] demonstrated to his students. He took a small horseshow-like piece of iron with a wire winded round it and attached to a source of constant electric flow. In the middle he installed am iron rod that could move around its center of weight. When he, standing in a distance, turn on a switch, one end of the rod stick to the horseshoe and another one hit a miniature bell. In such a way an idea of an electric relay has been born.

This invention by American physicist made a real revolution in communication engineering. This idea was put into the basis of the first telegraph – "Morse apparatus" that has been invented by Samuel Morse[43] with Joseph Henry.



Samuel Finley Breese Morse

(1791-1872)

American inventor and painter.

His most known invention was electro-magnetic writing telegraph and "code Morse" that was used in telegraphy over 100 years.

The Henry's idea occurred to be very fruitful: in 1937 (almost a century after Henry's discovery) a scientist of Bell

[42] **Joseph Henry** (1797 - 1878), one of the outstanding American physicists. He discovered electromagnetic phenomenon of self-inductance. He served as the first Secretary of the Smithsonian Institution. During his lifetime, he was considered one of the greatest American scientists since Benjamin Franklin.

[43] **Samuel Finley Breese Morse** (1791-1872), American painter of portraits and historic scenes, the creator of a single wire telegraph system, and co-inventor of the Morse Code that was in the use over hundred years.

Telephone Laboratories[44] George Stibitz[45] at home, literally "on his knees" made a simple device on a battery that could add two binary numbers. In two years, he began to develop with one of his colleagues "Complex Number Computer (CNC) that at the time has a name "Model-1". A working prototype has been completed in 6 months: it could multiply and divide complex numbers; though after a slight modification it began to perform addition and subtraction. "Model-1" had about 450 two-pole relays and 10 multi-pole relay that were used for storage of intermediate results and input data.

The machine could make approximately on multiplication in a minute.

In September of 1940 in Hanover (New Hampshire) several hundreds miles from Bell Labs, there was a meeting of American Mathematical Society. Stibitz presented report about CNC and during the presentation sent input data by teletype for test problem to CNC and in several minutes got result by the same teletype.состоялось собрание Американского математического общества. That demonstration impressed the audience which included such outstanding scientists as John von Neumann[46], Norbert Winner[47], and Richard Courant[48].

It was a beginning of a new era – era of telecommunication.

In 1943 Stibitz developed a specialized machine "Relay Interpolator" for performing computations for controlling anti-aircraft guns. In contrast with the previous machine that one was

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[44] **Bell Laboratories** (also known as Bell Labs) were formerly known as AT&T Bell Laboratories and Bell Telephone Laboratories. Now they are a part of the research and development organization of Alcatel-Lucent.

[45] **George Robert Stibitz** (1904–1995), American mathematician who invented one of the first electro-mechanical binary adding machines. He is internationally recognized as a father of the modern digital computer.

[46] **John von Neumann** (1903-1957), outstanding American mathematicians.

[47] **Norbert Wiener** (1894-1964), American theoretical and applied mathematician, a pioneer in the study of stochastic processes. He also has founded cybernetics as a scientific direction.

[48] **Richard Courant** (1888-1972), American mathematician of German origin.

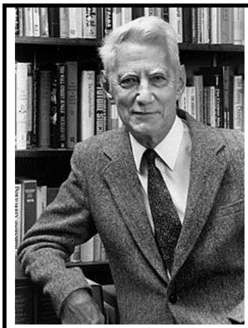
programmable controlled one tough performed only additions and subtractions.

This model had a long life – until 1961, being used for solving various engineering and scientific problems.

Bell Labs has been continuing to develop new models of relay machines up to 1949, when it was obvious that such machines cannot compete with their electronic rivals...

* * *

Interesting fundamental results in analysis and synthesis of relay and switching schemes and networks have been obtained by Claude Shannon. In particular, he gave the theory of design of reliable relay two-pole networks with unreliable relays.



Claude Elwood Shannon

(1916-2001)

American electrical engineer and mathematician, who is often been called "the father of information theory".

Shannon is famous for having founded information theory and both digital computer and digital circuit design theory when he was21 years-old by way of a master's thesis published in 1937. It has been claimed that this was the most important master's thesis of all time.

In 1948 he published his fundamental work “Mathematical Theory of Communication”. Next year he published “Communication Theory of Secrecy Systems” with mathematical foundation of cryptography.

5. EPOCH OF ELECTRONIC COMPUTERS

We are coming to that utopian time when mathematicians will compile equations that will be perfectly solved by computing machines.

Sergey Vavilov[49]

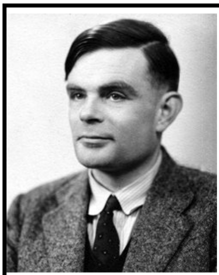
5.1. Turing machine

In 1900 at the 1900 at the Second International Congress of Mathematicians in Paris, outstanding German mathematician David Hilbert presented his historical lecture, where he posed his famous "23 questions" – main mathematical problems that were waiting for solutions in the forthcoming century. Of these, the second was that of proving the consistency of arithmetic.

In 1936, Alan Turing recently having been graduated from Cambridge University, formulated a universal arithmetic-based formal language in the form of an imaginary machine (later named "*Turing machine*") and proved that such a machine would be capable of performing any conceivable mathematical problem if it were representable as an algorithm. His paper "*On Computable Numbers, with an Application to the Entscheidungsproblem*" with his new results made him Worldwide famous.

Universal Turing Machine (UTM) was assumed to get input data in binary form (in accordance with some alphabet), to perform operations depending on the current state of the machine that could be changed after the operations. In other words, Turing was first who suggested storing programs within the computer's memory and the machine could itself change its own program. Factually, it means that any universal machine could be programmed for solving any specific problem.

[49] **Sergey Ivanovich Vavilov** (1891-1951), Soviet physicist, the President of the USSR Academy of Sciences from 1945 until his death.



Alan Matheson Turing

(1912 - 1954)

English mathematician, logician, and cryptographer. Turing is often considered to be the father of modern computer science. He provided an influential formalization of the concept of the algorithm and computation with the Turing machine.
During the Second World War, Turing was working at the Britain's Code-Breaking Centre where he devised a number of techniques for breaking German ciphers.
In 1947 he participated in one of the first computers design.
In 1952 he was arrested for homosexuality that at the time was considered as a crime. He lost his clearance, was blamed in media, and in two years committed suicide being completely psychically broken.
Posthumous recognition: the Association for Computing Machinery in 1966 established the Turing Award for technical contributions to computer science.

In last 1940-s, at the National Physical Laboratory located near London one of the most original computers based on electronic lamps began to operate.

During the Second World War, Chair of the Mathematical Department of the Laboratory John Womersley[50] had been sent to Harvard and Pennsylvania Universities where he during three months learned about a new computer – ENIAC.

Backing home, Womersley began to gather a team for designing a new computer that he decided to name ACE (brief for "*Automatic Computing Engine*"). Alan Turing was asked to head the project and took the proposal willingly because it gave him a possibility to realize "in metal" his idea of universal computer.

[50] **John Womersley** (1907—1958), British mathematician.

More than computing ability of the machine, Turing was interested in its "intellectual abilities".

In 1950 in a journal with symbolical name "*Mind*" h publish a small paper "*Computing Machinery and Intelligence*" that was immediately translated in many countries. Factually it was the very first paper in a new scientific branch – the so-called theory of artificial intellect.

Doubtlessly, an artificial intellect is amazing! However, without a natural intellect it is impossible to create an artificial one…

More than that: it is even impossible to understand what it means "artificial intellect"... ☺.

For checking "intellectual abilities" of a computer, Turing suggested to arrange an imitational game" that later got the name "*Turing's test*". During this game, "examiner" assumed to ask by teletype questions that were simultaneously sent to a computer and a man. Questions were asked on a "natural language". In some time both respondents simultaneously sent their responses to the "examiner". (It was done for avoiding guess who sent the answer: at that time a computer was significantly slow in comparison with a man.)

If "examiner" could not distinguish human behavior from computer one, than a conclusion was that a computer possessed the same abilities as a man.

The idea of such a test was hinted by a salon game in which a company in a room tried to guess by sending notes and getting written responses who is in another room – a man or a woman?

Turing was convinced that computers finally would pass the test. He claimed that up to 2000 computers could chit "examiners" in 30% of tests. However, this Turing prognosis still is not right:

there is no such a program now. Every year there is a competition between "speaking programs" and a most human-like is awarded by the Loebner[51] Prize.

Turing wrote: “We can hope that computers sooner or later could compete with people in all intellectual spheres of human activity. However, what type of machine is the most preferable? Even this question remains unclear”.

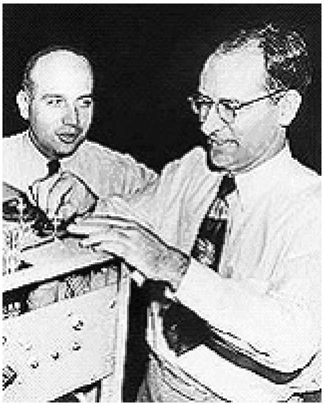
Loebner established the Loebner prize in 1990. He pledged to give $100,000 and a solid gold medal to the first programmer able to write a program whose communicative behavior can fool humans into thinking that the program is human. The competition is repeated annually.

5.2. Eckert and Mauchly

Just before the World War II professor of one of the Philadelphia colleges John Mauchly[52] was involved in research concerning statistical analysis of daily changing of ions density in atmosphere. It forced him to deal with a huge volume of statistical data. And, probably, it is not in vain one says that “a leisure is an engine of the progress”! Mauchly came to a thought of creating an electronic device able to perform needed data inferences and remember the final results. He designed several simple experimental counters using neon lamps and confirmed correctness of his ideas.

[51] **Hugh Loebner** (b. 1942), American inventor, established Loebner Prize in $100.000 for the best program imitating a human communication.

[52] **John William Mauchly** (1907-1980), American physicist who, along with Eckert, designed the first general purpose electronic digital computer, as well as the first commercial computer made in the United States.



At that time Pentagon, being concern with inevitability of the war with Nazi Germany, arranged in Pennsylvania University 10-week preparation courses for young physicists and mathematicians for operating with military electronic equipment. In 1941 the courses director asked Mauchly to delegate some his student for participation. The director found in the list of candidates' names … the name of professor Mauchly who, being inspired by his ideas, decided to get some extra knowledge in electronics!

The instructor of the courses was a talented 22-year old engineer, John Eckert[53] who was known as the best university's specialist in electronic. In spite of a significant difference in age between the instructor and his student, they soon became friends that lasted afterwards years and years.

Completing the courses, Mauchly stayed to teach in Pennsylvania University and participated with Eckert in several military projects. One of those projects dealt with preparation and correction of ballistic tables that needed a huge volume of calculations that practically could not be done by hand. Mauchly shared his ideas about electronic computing machine with Eckert.

During the discussion, Eckert be quick to understand literally instantaneously Mauchly's **John Mauchly (on the right)** theoretical ideas and concluded that the **and John Eckert**. Contemporary state of electronic technology permitted to create such a calculating machine. As a result, in 1942 they wrote a proposal about design a universal computational machine that was "successfully" lost in the bureaucratic system.

[53] **John Adam Presper "Pres" Eckert Jr.** (1919-1995), American electrical engineer and computer pioneer. With Mauchly he invented the first general-purpose electronic digital computer, and designed the first commercial computer in the U.S. In 1982 the Institute of Electrical and Electronic Engineers (IEEE) named him "The Engineer of the Century".

However, it was seen by many specialists, and later one of them mentioned about its existence to a military client who asked Mauchly and Eckert to restore the proposal.

Finally, the so-called "Project PX" was placed with Eckert as chief engineer and Mauchly as principal consultant. The contract was signed in 1943 with the University of Pennsylvania's Moore School of Electrical Engineering. Construction began in June 1944, with final assembly in the fall of 1945. Almost 50 engineers and technicians (with a number of workers) had been working over the project.

Then electronic machine ENIAC was designed and built to calculate artillery firing tables for the U.S. Army's Ballistic Research Laboratory.

ENIAC, short for Electronic Numerical Integrator And Computer, was the first general-purpose electronic computer. Precisely, it was the first high-speed, purely electronic digital computer capable of being reprogrammed to solve a full range of computing problems, since earlier machines had been built with some of these properties.

Almost 50 engineers and technicians (not counting numerous workers) during 3.5 years had been working over the project.

Initial cost of the project was $50.000 that was a substantial sum of money at the time. Step-by-step development of the project and quality of results led to increase of financing. In the beginning of 1946 it was unveiled that total expenses had reached almost $500,000.

Mauchly decided to make the machine on the decimal system basis, though it led to increase of the lamp number. He argued that "the machine should be understandable for users". Of course, in retrospective view, such a position hardly could be seemed correct. However, Mauchly and Eckert were pioneers! (It is the time to mention that Eckert was not agreeing with his elder companion and suggested to use the decimal system though with binary coding.)

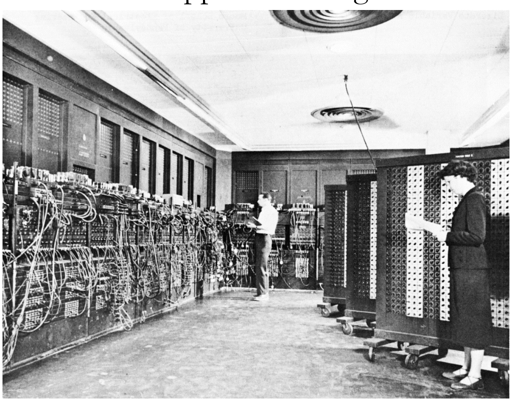
The first electronic machine was a terribly clumsy construction from the today's point of view. It was about two and a halve meters height, about a meter in the depth, and about 30 (!) meters length. Its weight was about 30 tons[54]. There were over 20 thousand electronic lamps and thousands and thousands of other electronic components. It consumed about 150 KWatt of energy, i.e. equally to a plant of a middle range!

ENIAC

The machine could perform about 5000 summation and about 350 multiplications of 10-digital numbers per second.

Pentagon's clients were satisfied: ENIAC performed the computation of 60-second ballistic trajectory during 30 seconds! The Bell's relay machine did it in 400 times longer.

The main engineering problem for designers as well as for users of ENIAC was reliability: electronic lamps failed too frequently. The mean time between failures was less than six hours... To increase reliability, lamps were tested in advance, using the "burning out" procedure, and they were operating in under loading regime. Besides, it was discovered that the lion share of failures had happened during turn in and turn off processes, so it was decided o keep the machine in on regime constantly. (Rather costly due to energy expenditure!) Nevertheless, all these measures led to20-fold increase of the mean time between failures.



[54] In the beginning of this century, a "chip" of size of half a square millimeter was equivalent to the electronic mammoth of ENIAC!

5.3. Appearance John von Neumann on the scene

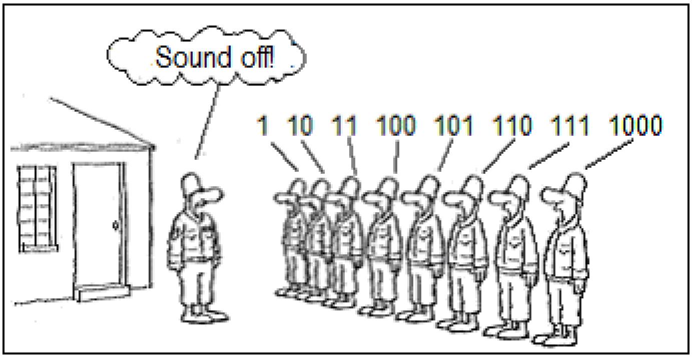
In 1953 John von Neumann was directed to join the Eckert-Mauchly research group. As usual, he actively began to participate in all spheres of the project, new ideas poured from him like from a horn of plenty.

John von Neumann
(1903 – 1957)

Outstanding American scientist of Hungarian origin who is generally regarded as one of the foremost mathematicians of the 20th century.
He made major contributions to a vast range of fields in mathematics and physics.
He was a member of the Manhattan Project where worked out key steps in the nuclear physics involved in thermonuclear reactions.
Architecture of the first two generation of computers was called "Neumann's architecture".
For more details, see Chapter 5 of PANTHEON at the end of this book.

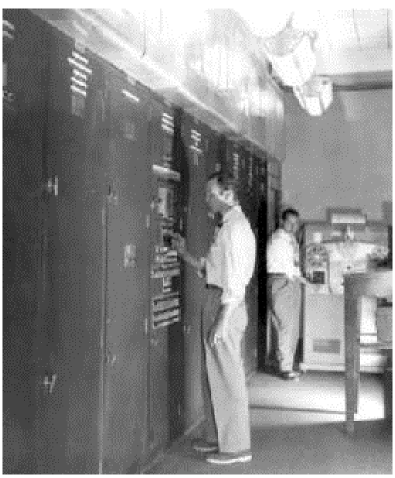
Very important Neumann's approach was modification of the programming process (that he actually suggested long before, in 1947). This new method not only makes programming easier but also permitted to improve the testing procedure of various computer's parts.

He also concluded that decimal arithmetic used in ENIAC is rather ineffective and suggested to change it for binary. Thus, a fantastic Gottfried Leibniz's foresight concerning potentialities of binary system became a reality only two and a half centuries later!



About a year after joining the Eckert-Mauchly group, Neumann wrote a 101-page "*First Draft of a Report on the EDVAC*" (commonly shortened to "*First Draft*»), where he summarized plans for the next project – computer named EDVAC (abbreviation for *Electronic Discrete Variable Automatic Computer*). The report, authored solely by von Neumann, mentioned that the EDVAC was intended to be the first stored program computer. To be correct, one should mention that this idea first was formulated by Eckert and Mauchly at the early stage of ENIAC project.

Besides, one should remember that as early as in 1936 Alan Turing described his hypothetic universal machine with inner memory. Hardly Eckert and Mauchly, as well as Neumann – being highest level specialists in the area – were not familiar with that classic work! (And if **EDVAC.**



you would like to give a priority for computer memory invention, do not forget that Ada Lovelace-Byron wrote about it in her "Notes" in 19th century! Though, to be correct, we should say that these "Notes" were found in archives only relatively recently.)

A Pentagon military representative, attending the Neumann's presentation, send a copies of the "*First Draft*" to a number of scientists in the USA and Great Brittan, who dealt with military projects. Thus, this Neumann's report was the first work on digital electronic computers being known to wide circle of scientists.

Doubtlessly, the report attracted attention of audience due to high scientific reputation of its author. Since then, computers were considered as extremely important objects for studying and developing. Due to the Neumann's authorship even now computers sometimes are called "von Neumann's machine"…

Looking at the furor created by the "First Draft", Eckert and Mauchly were furious: they had no right to publish their results due to secrecy of the subject and suddenly the same Pentagon permitted to do it to a person who entered the project literally yesterday evening!

Quarrel concerning the author's rights on ENIAC and EDVAC had begun… Naturally, such a process could not lead to something positive: as the result the effective working group had been collapsed… John Eckert and John Mauchly broke with John Neumann: probably, to have three Johns at the same project was too much!

5.4. Eckert and Mauchly destiny

John Eckert and John Mauchly decided to design a universal computer that could solve except pure scientific and engineering problem some every day's routine tasks.

With financial support of John Eckert's father, they started the first computer company, the Eckert-Mauchly Computer Corporation (EMCC), and pioneered fundamental computer concepts including the stored program, subroutines, and programming languages. They got from the National Bureau of Standards a modest grant for research that led finally to design a new computer – UNIVAC (brief for ***Univ****ersal* ***A****utomatic* ***C****omputer*).

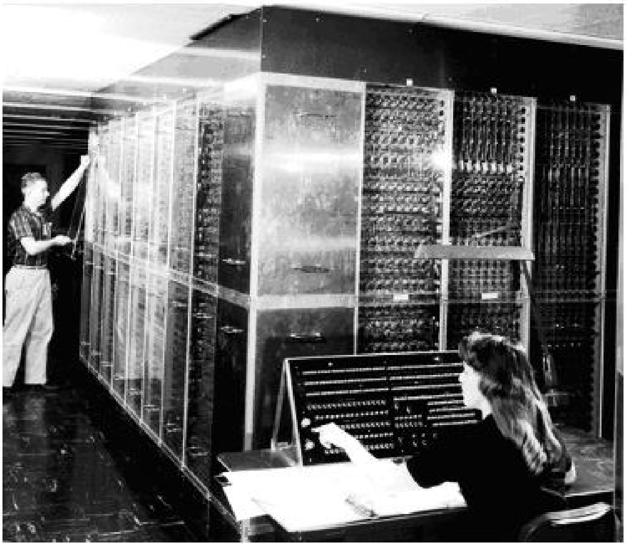
UNIVAC

However, they did not make a marketing research or estimate a profitability of the project. Besides, many computer experts (unfortunately, including John Neumann) were skeptical about their project. Of course, there was a kind of a "technical jealousy". Anyway, the project was not too successful from financial viewpoint.

5.5. John von Neumann continue his research

The role of John Neumann in designing of the first computers cannot be overestimated. Working on the EDVAC project, he developed its detailed logic structure, where structural units were not physical components but the so-called "ideal computational units". This new methodology permitted to separate design of a logical scheme from technical hardware design. It was an important step forward. In addition, he suggested a lot of new pure engineering solutions.

After the Eckert-Mauchly group collapse, Neumann was invited to the Institute for Advanced Study at Princeton. He was one of the few originally appointed to a group collectively referred to as the "demi-gods". Here he participated in new computers design. One of them Neumann witty named MANIAC (brief for *Mathematical Analyzer, Numerator, Integrator and Computer*).



MANIAC

In particular, it was Neumann's invention to use cathode ray tubes as memory units instead of delay lines. This innovation was met by engineers with a high level of skepticism, however, very soon experiments proved rightness of the Neumann's suggestion.

This idea had been realized I the next project. For the huge input into this project, colleagues named a new computer JOHNIAC after Neumann. JOHNIAC permitted to perform important and labor consuming calculations needed for hydrogen bomb design. Probably then the total volume of calculations was larger that all done by all previous calculating machines ever.

6. FURTHER DEVELOPMENT

6.1. First time-sharing system.

In 1950 in Massachusetts Institute of Technology (MIT) the Committee on Machine Methods of Computation has been established. Professor Philip Morse[55] from the Department of Physics was named chairman. He recommended that the special Computation Center to be built on the territory of the Institute. In 1957 Phillip Morse became the first Director of the Computation Center.

On the basis of MIT Computation Center was built the New England Regional Computing Center (NERCC). All of this computer access activity was performed under the general direction of Dr. Philip Morse. In the beginning, there were 20 member institutions involved in the NERCC. The first project of this Center was New England Regional Computer Project (NERCP). It was a beginning of building a network, in which it was envisioned that a user at one place would be connected to a program at another institution.

In 1963, the Laboratory began Project MAC (for Multiple Access Computer and Machine-Aided Cognition). Within the frame of this project there has been developed the Compatible Time-Sharing System (CTSS), the first timeshared system in the World. The author of this book was lucky to visit in 1966 MIT as a personal guest of Philip Morse. Philip Morse demonstrated him MAC system, which at the time had about 60 remote terminals at some R&D institutes of New England and mostly in labs of MIT. Later on the basis of this project, there was established MIT Computer Science and Artificial Intelligence Laboratory.

[55] **Philip McCord Morse**, (1903 - 1985) was an American physicist, administrator and pioneer of operations research – powerful branch of modern applied mathematics. He was the Founder and first Director of the MIT Computation Center.

6.2. Computer networks

Probably, one of the greatest scientific and technological jump in human history has been done in last century. First, it was invention of radio, then almost half a century afterwards, TV broke into life of billions of people. However, in some sense, it was a "one way road": some centers distributed And at last, in the end of the last century the World has been caught by a "computer web". A computer network is a set of interconnected computers that facilitate communications among users and allows users to share resources.

The Advanced Research Projects Agency (ARPA) started in the end of 1960s designing of the Advanced Research Projects Agency Network (ARPANET) for the United States Department of Defense. It was the first computer network in the world. Development of the network began in 1969, based on designs developed during the 1960s.

Computer networks are usually classified as local area network (LAN), wide area network (WAN), metropolitan area network (MAN), personal area network (PAN), and others, depending on their scale, scope and purpose. A Global Area Network (GAN) is a network used for supporting mobile communications across an arbitrary number of wireless LANs, satellite coverage areas, etc. The key challenge in mobile communications is handing off the user communications from one local coverage area to the next.

Apogee of the computer penetrating into human life is the Internet that cardinally change mankind life: people began to communicate and exchange information without borders and across huge distances. The Internet is a global system of interconnected governmental, academic, corporate, public, and private computer networks.

Exchange by emails replaces for millions of people regular post mail. Appearance of Skype leads to simple way of video-telephone comunication.

Of course, the Internet did not appear from nowhere. Its predecessors were the ARPANET and CERNET – European network created by the European Organization for Nuclear Research (CERN). The Internet is the communications backbone underlying the World Wide Web (WWW). creation. In 1971 Ray Tomlinson created what was to become the standard Internet e-mail address format, using the @ sign to separate user names from host names.[44]

6.3. Google

Google Inc. is a multinational public corporation founded by Larry Page and Sergey Brin, often dubbed the "Google Guys". The company was established in September 1998, when they were attending Stanford University as Ph.D. candidates. Google runs over one million servers in data centers around the world, and processes over one billion search requests. The company has about 25 thousand employees. Profit of this company is over 5 billion dollars.

"Google Guys" – Larry & Sergei.

Sergey M. Brin (b. 1973)

&

Lawrence Page (b.1973)

are American computer scientists and Internet entrepreneurs, co-founders of Google. As of 2012, personal wealth of each of them is about $20 billion.

Both of them earned their Ph.D in computer science at Stanford University. Sergei Brin and Larry Page, shared dormitory room and became friends. They suspended their PhD studies and in 1998 founded Google, Inc. The company started located in a rented garage.

They applied Brin's data mining system to build a superior search engine. Larry Page invented the so-called PageRank, which became the foundation of Google's search ranking algorithm.

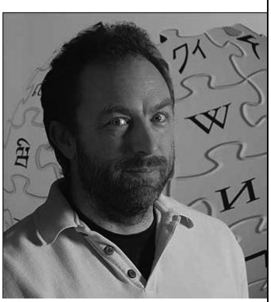
Ninety-nine percent of Google's revenue is derived from its advertising programs.

6.4. Wikipedia

Wikipedia is a web-based multilingual encyclopedia project supported by the non-profit Wikimedia Foundation. Its 17 million articles have been written collaboratively by volunteers around the world. Wikipedia was launched in 2001 by Jimmy Wales and Larry Sanger and has become the largest and most popular general reference work on the Internet, having almost half billion readers.

The name *Wikipedia* was coined by Larry Sanger is formed with the using two words: the Hawaiian word "*wiki*", meaning "quick", and "encyclopaedia" that is formed, in turn, from

two Proto-Greek language words "ἐγκύκλιος" (*enkyklios*), meaning "circular" or "general", and "παιδεία" (*paideia*), meaning "education, or rearing of a child".



Jimmy Donal "Jimbo" Wales (b. 1966).

American Internet entrepreneur best known as a founder and promoter of the online non-profit encyclopedia Wikipedia, which he launched in 2001, with Larry Sanger and others.
His role in creating Wikipedia, which has become the world's largest encyclopedia, prompted *Time* magazine to name him in its 2006 list of the world's most influential people.

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Lawrence Mark "Larry" Sanger
(b. 1968)

American philosopher, co-founder of Wikipedia.

Sanger left Wikipedia in 2002, and has since been critical of the project. In 2007 he launched Citizendium, first envisioned as a fork of Wikipedia. Citizendium represents an effort to create a credible and free-access encyclopedia.[22] Sanger had aimed to bring more accountability to the Internet encyclopedia model.

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Though the English Wikipedia reached three million articles in August 2009, its growth appeared to have flattened off around early 2007: in the middle of 2007, about 2,200 articles were added daily to the encyclopedia; as of the middle of 2009, that average is 1,300.

PANTHEON

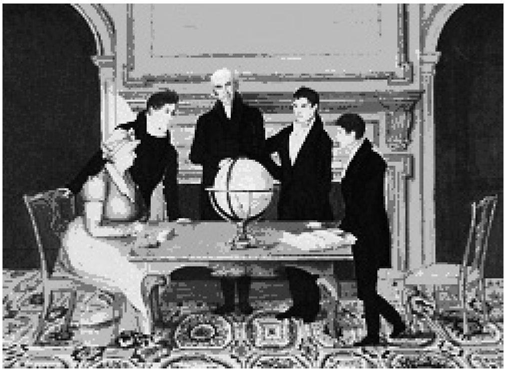
Samuel Finley Breese Morse

(1791-1872)

American painter of portraits and historic scenes.

He was the creator of a single wire telegraph system. He also was a co-inventor of the Morse code widely used during more than a century.

Samuel Morse was born in Charlestown, just outside of Boston, Massachusetts. He was the son of Jedidiah Morse, a pastor who was a famous man at that time: he was well known for his geography as Noah Webster, a friend of the family, was known for his dictionaries.



As a youth, Samuel studied at Phillips Academy before going on to Yale College at the age of fourteen. He went to the college to study religious philosophy and mathematics. However, Morse's initial interest was art and he studied under

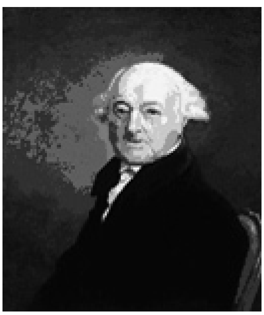
Washington Allston[56], a famous painter. Simultaneously he listened to lectures the then newly-developing subject of electricity and its applications, something that he found fascinating. To support himself, he painted portraits of people for money.

After college, to the discomfort of his conservative parents, Samuel directed his enthusiasm especially to painting. In 1810 he left with his mentor, Allston, on a trip to England, where he gained admittance to the Royal Academy of Art.

After getting a good education and practice in painting, Morse left England in 1815 and began his full time career as an American painter.

Next ten years mark significant growth in Morse's paintings as he sought to capture the true essence of America's culture and life.

After settling in New York City in 1825, he became one of the most respected painters of his time.



Morse also worked on inventing useful tools. His first innovation was a marble-cutting machine that was capable of carving in three dimensions. However, when he attempted to patent his idea, he discovered that it was already covered by a patent issued in 1820. Despite this, he was not disappointed and continued working on various new ideas.

He had the honor of painting former Federalist President John Adams[57] (see picture on the left).

Morse felt a great degree of honor of painting the Marquis de Lafayette[58], leading supporter of the American Revolution. The

[56] **Washington Allston** (1779-1843), American poet and influential painter. He pioneered America's Romantic movement of landscape painting.
[57] **John Adams, Jr.** (1735-1826), the 2nd President of the United States (1797–1801). He also served as America's first Vice President (1789–1797). He was defeated for re-election by Thomas Jefferson.

developing friendship between Morse and Lafayette affected the artist upon returning to New York City.

Morse was warmly sociable and has a soul of a natural leader. He was a founder and the first president of the National Academy of Design. He even attempted to become mayor of New York or a Congressman, but was defeated in both campaigns.

Morse once more was in Europe in 1830-1832 for improving his painting skills. He traveled in Italy, Switzerland and France. He thought about an interesting project: to paint miniature copies of some 38 of the Louvre's famous paintings on a single canvas (about 2 by 3 meters), which he entitled "The Gallery of the Louvre". He planned to complete this painting when he returned home to Massachusetts.

However, on his way back from Europe, Morse heard a conversation about the newly discovered electromagnet and conceived of the idea of an electric telegraph. He mistakenly thought that the idea of such a telegraph was new, thus helping to give him the impetus to push the idea forward. Morse developed the concept of a single wire telegraph, and ”The Gallery of the Louvre" was set aside. It is said that he was devising his telegraph code even before the ship docked.

By 1835 he had his first telegraph model working in the New York University building where he taught art. Being poor, Morse used in his model such crude materials as an old artist's canvas stretcher to hold it, a home-made battery and an old clock-work to move the paper on which dots and dashes were to be recorded.

In 1837 Morse acquired two partners to help him develop his telegraph. One of them was Leonard Gale, a quiet professor of chemistry at New York University who was a personal friend of Joseph Henry. He advised Morse, who thought that a telegraphic signal could be carried only over a few hundred yards of wire, how

[58] **Marie-Joseph-Paul-Yves-Roch-Gilbert du Motier, Lafayette** (1757-1834), French military officer and former aristocrat who participated in both the American and French revolutions.

to increase voltage. It allowed Morse's telegraph soon to be able to send a message through ten miles of wire. Another partner was a young enthusiast, Alfred Vail, a modest young man who had excellent skills, insights and … money! Since then Morse's telegraph now began to be developed very rapidly.

With the aid of his new partners, Morse applied for a patent for his new telegraph in 1837, which he described as including a dot and dash code to represent numbers, a dictionary to turn the numbers into words.

From this moment, Morse quit discouraged with his art career, was giving nearly all his time to the telegraph.

In 1837, Morse claimed invention of a new communication system known as the telegraph. The device transmitted electrical impulses in a special manner that could be interpreted as numbers or alphabetic characters. For this purpose, he invented the so-called "Morse Code": series of short and long pulses on the telegraph for ciphering alphabetic and numeric characters.

In 1838, Morse made the first public demonstration of the telegraph system in Philadelphia, Pennsylvania. At the exhibition of his telegraph, Morse transmitted ten words per minute. This time he decided to use dot-dash code directly for letters instead of using his number-word dictionary. After some improvements, the Morse code became standard throughout the world.

During the next few years Morse exhibited his telegraph before scientists and businessmen. He made presentation at some committees of US Congress, hoping to find the funds to give his telegraph a large-scale test. He met considerable skepticism that any message could really be sent from city to city over wire.

Morse made a trip to Washington, D.C., in 1842, stringing wires between two committee rooms at the House of Representatives in the Capitol, and sent messages back and forth – and this there was a success! Some people believed him, and a bill was finally proposed allocating $30,000 towards building an experimental line.

Morse set up the first inter-city electromagnetic telegraph line in the world on May 24, 1844. During this test , he sent from the Capitol building in Washington a Biblical quotation as the first formal message on the line to Baltimore, a message that revealed his own sense of wonder that God had chosen him to reveal the use of electricity to man: "What Hath God Wrought!"

In 1845 the Magnetic Telegraph Company was formed in order to radiate telegraph lines from New York City towards Philadelphia, Boston and Buffalo.

After twelve years in which most Americans had ignored his efforts to develop a telegraph, Morse had quickly become an American hero.

By 1846 private companies, using Morse's patent, had built telegraph lines from Washington reaching to Boston and Buffalo, and were pushing further.

In the 1850s, Morse became well known due to his defending position of slavery. In his treatise "*An Argument on the Ethical Position of Slavery*", he wrote:

> *My creed on the subject of slavery is short. Slavery per se is not sin. It is a social condition ordained from the beginning of the world for the wisest purposes, benevolent and disciplinary, by Divine Wisdom. The mere holding of slaves, therefore, is a condition having per se nothing of moral character in it, any more than the being a parent, or employer, or ruler.*

The Morse telegraphic apparatus was officially adopted as the standard for European telegraphy in 1851 (excluding Great Britain who used their own model). There was a widespread recognition and in 1858 Morse was awarded the sum of 400,000 French francs (equivalent to about $80,000 at the time) by the governments of France, Austria, Belgium, the Netherlands, Piedmont, Russia, Sweden, Tuscany and Turkey, each of which contributed a share according to the number of Morse instruments in use in each country.

There was still no such recognition in the USA. This remained the case until 1871, when a bronze statue of Samuel Morse was unveiled in Central Park, New York City.

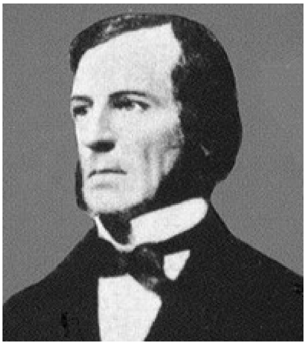
By 1847, with enough money from the telegraph, Morse was at last able to bring his scattered family together in his country house that he bought with one hundred acres of land just outside of Poughkeepsie and named it Locust Grove.

In 1848, 57-year old Morse married a second time to a poor cousin of only 26 years who was considerably deaf and dumb. Morse explained that he chose her in part because she would be dependent on him. Morse's family grew with several more children.

In his later years, Morse became famous in his country and abroad. He was wealthy and generous in giving funds to colleges and scientific societies and to poor artists.

He died of pneumonia in New York City at the age of 80 and was buried in Greenwood Cemetery in Brooklyn.

George Boole
(1815 – 1864)



Pure mathematics was discovered by Boole, in a work which he called "The laws of thought"

Bertrand Russell[59]

British mathematician and philosopher who created Boolean algebra that is one of the bases of modern-day computer science. Boolean algebra was rediscovered by Claude Shannon about 75 years after Boole's death.

George Boole was the first professor of mathematics of then Queen's College in Cork (now University College Cork), Ireland.

He is one of the founders of mathematical logic.

George Boole was born in Lincoln[60], a small city in Eastern England. George's father, John Boole had a cobbler's shop but his business was not too successful, probably, because his main interest was mathematics and its applications. One of the most his attraction was constructing of telescopes. On the window of his shop there was an announcement: "Everybody who wishes to observe with a reverence before our God, the fruits of his creation, I invite to visit me and to look at the universe through my telescope". His family was not well off because John Boole did not

[59] **Bertrand Arthur William Russell** (1872-1970), British philosopher, historian, logician, mathematician. He was a prominent anti-war activist, championing free trade between nations and anti-imperialism. He also co-authored "*Principia Mathematica*», an attempt to ground mathematics on the laws of Logic.
[60] **Lincoln** is a cathedral city and county town of Lincolnshire, England. (In 2000 population was about 100.000.)

devote the energy to developing his business in the way he might have done.

George was the first child and he was born after his parents had been married for nine years. They had almost given up hope of having children, so George appearance was an occasion for great rejoicing. Since George was christened the day after he was born, one make a conclusion that he was a weak child and his parents feared he might not live. George birth was a good sign: over the next five years the Booles had three further children.

George first attended a kindergarten-kind school in Lincoln for children of tradesmen when he was less than two years old. After a year he was transferred to a commercial school, where he remained until he was seven years old. When he was seven George attended a primary school where his interests turned to languages and his father arranged that he receive instruction in Latin from a local bookseller.

Having learnt Latin from a tutor, George went on to teach himself Greek. By the age of 14 he had become so skilled in Greek that he translated an ancient poem about the mythological Greek hero Meleager[61]. John Boole was so proud of his son translation that he had it published. However the talent was such that a local schoolmaster disputed that any 14 year old could have written with such depth. The schoolmaster even wrote to the newspaper that this publication is a pure fabrication…

By this time George was attending the Commercial Academy in Lincoln. This school did not provide a good education but it was all his parents could afford. However, George spent his time for self-education: he taught himself French and German and studied for himself academic subjects that a commercial school did not cover.

He had a phenomenal memory. He wrote in his late years: "My brain is made in a special way: any facts I had known reflected in my mind as a well organized pictures".

61 **Meleager** was a hero of the Greek mythology who was one of the Argonauts.

George Boole did not study for an academic degree, nevertheless, from the age of 16 he was an assistant school teacher. This was rather forced on him: his father had ruined his business and George found himself having to support financially his parents and his siblings.

He continued his self-education in mathematics seriously, though he was later to realize that he had almost wasted five years in trying to teach himself the subject instead of having a skilled teacher. In 1833 he moved to a new teaching position in Liverpool but he only remained there for six months before he opened his own school in Lincoln although he was only 19 years old.

School textbooks depressed him very much by its primitivity. Being not educated too much, he began to study extremely strong works like Newton's "*Philosophiæ Naturalis Principia Mathematica*", Laplace's " Celestial Mechanics" and Lagrange's "Analytical Mechanics". (Take into account that Laplace and Lagrange were read in original.).At the same time he continued to write lyrics (mostly religious contents). For instance, this is a part of his "*The Third Sonnet*"

When the great Maker, on creation bent

Thee from thy brethren chose and framed by thee

The world to sense revealed, yet left it free,

To those whose intellectual gaze intent

Beyond the veil phenomenal is sent,

Space diverse systems manifold to see

Revealed by thought alone; was it that we,

In whose mysterious spirits thus are blent

Finite of sense and infinite of thought,

Should feel how vast how little us our store –

As you excelling arch with orbs deep fraught

To the light wave that dies along the shore –

Till from our weakness and our strength may rise

One worships unto Him the only wise?

George Boole loved poetry in such a way that he wrote letters to his friends in verses. However, poetry was not the main subject for a young teacher.

In 1838 he was invited to take over the school in Waddington[62] which he accepted. His parents, brothers and sister moved to Waddington and together they ran the school. At this time Boole was studying the works of Laplace and Lagrange, making notes which would later be the basis for his first mathematics paper.

In the summer of 1840 he had opened a school in Lincoln and again the whole family had moved with him.

Without any hope for success in 1839 he sent to Cambridge Mathematical Journal" his first paper "*Researches on the Theory of Analytical Transformations*". The novelty and originality of thinking impressed the editor of the journal so much that a paper of absolutely unknown author had been published in the forthcoming issue. Moreover, the editor wrote a letter of admiration to the author…

Boole began publishing regularly in the Cambridge Mathematical Journal. (In total 22 Boole's papers were published in the journal.)

In 1842 Boole had begun to correspond with De Morgan soon he sent him for comments his paper "*On a general method of analysis applying algebraic methods to the solution of differential equations*" that was published in the Transactions of the Royal Society. Two years later Boole received the Society's Royal Golden Medal - his mathematical work was beginning to bring him fame.

At this time Boole began his works in mathematical logic. Drafts of the beginning of algebra logic were written in 1846. In half a year, in 1847 Boole published a thin brochure "*The mathematical analysis of logic, being an essay towards a calculus of deductive reasoning*", that is considered as the beginning of the algebra that later was named "Boolean". This work was actively supported by

[62] **Waddington** – a smaller town close to Lincoln.

Augustus De Morgan who became an enthusiastic supporter of George Boole's idea.

The accuracy of the dates is important because in the same 1847 independently from Boole De Morgan came to the same idea of logic algebra.

De Morgan highly estimated the Boole's approach. Moreover, with the De Morgan's support, in 1849 Boole was appointed to the chair of mathematics at Queen's College of Ireland in Cork. In his reference letter De Morgan wrote:

> I can speak confidently to the fact of his being not only well-versed in the highest branches of mathematics, but possessed of original power for their extension which gives him a very respectable rank among their English cultivators of this day.

Being the first Professor of Mathematics at the College, he taught there for the rest of his life, gaining a reputation as an outstanding and dedicated teacher.

In two years, Boole was elected as Dean of Science, a role he carried out alertly. By this time he had already met Mary Everest who was a niece of famous explorer Sir George Everest[63], who was the professor of Greek at the College and had friendship relations with George Boole.

George met Mary first in 1850 when Mary visited her uncle in Cork. Boole began to give Mary informal mathematics lessons on the differential calculus. At this time he was 37 years old while Mary was only 20. In 1855 Mary's father died leaving her without means of support and Boole proposed marriage. Their marriage was happy with five daughters.

Mary was a very devoted wife and referred to her husband as to a great mathematician even before he was widely recognized.

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63 **Sir George Everest** (1790-1866), British geographer and Surveyor-General of India from 1830 to 1843. The highest mountain on Earth was named after him – Mount Everest (originally called Chomolungma or Qomolangma (in Tibetan) or Sagarmatha (in Nepali).

Though sometimes she showed some tyrannical form of it: once she saw that George wrote lyrics; she took off a sheet of paper with the text and threw it into the fire with the words that George should not spend his time for such negligible things as poetry.

George Boole most important work "*An investigation into the Laws of Thought, on Which are founded the Mathematical Theories of Logic and Probabilities*" Boole published in 1854. Boole reduced logic in a new way to a simple algebra, making logic a mathematical science. He pointed out the analogy between algebraic and logical symbols and began the algebra of logic that now is called Boolean algebra. Boole himself understood the importance of the new direction in mathematics. In one of his letters he wrote:

> *I am now about to set seriously to work upon preparing for the press an account of my theory of Logic and Probabilities which in its present state I look upon as the most valuable if not the only valuable contribution that I have made or am likely to make to Science and the thing by which I would desire if at all to be remembered hereafter...*

Boole also worked on differential equations ("*Treatise on Differential Equations*", 1859), the calculus of finite differences ("*Treatise on the Calculus of Finite Differences*", 1860), and general methods in probability. He also was one of the first who investigated the basic properties of numbers, for instance the distributive property.

George Boole was widely recognized: he received honorary degrees from the universities of Dublin and Oxford and was elected a Fellow of the London Royal Society.

His work was highly evaluated by De Morgan who said:-

> Boole's system of logic is but one of many proofs of genius and patience combined. ... That the symbolic processes of algebra, invented as tools of numerical calculation, should be competent to express every act of thought, and to furnish the grammar and dictionary of an all-containing system of logic, would not have been believed until it was proved.

Boolean algebra has wide applications in telephone switching and the design of modern computers. Boole's work has to be seen as a fundamental step in today's computer revolution.

George Boole died when he was only 50myears old…

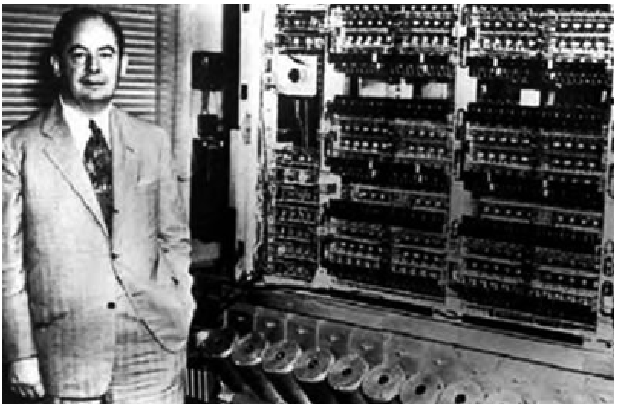
Mary survived George on 52 years. After his death she wrote several works where she propagated ideas of her husband.

All five daughters of George and Mary were out of the common personalities. Alice was a talented mathematician, honorary doctor of Groningen University. Lucy was the first British woman-professor in Chemistry. The most famous was the youngest daughter – Ethel Lilian Voynich[64], who was a famous writer of her time and afterwards.

[64] **Ethel Lilian Voynich** (1864-1960), novelist and musician, and a supporter of several revolutionary causes. She was married to Wilfred Michael Voynich, Polish revolutionary escaped from Siberian drudgery in Russia. Ethel is most famous for her outstanding novel "*The Gadfly*", first published in 1897 in the United States.

John von Neumann

(1903 – 1957)



If people think that don't think that mathematics is really simple, it means that they don't realize how complex is life.

John von Neumann

Outstanding American scientist who is generally regarded as one of the foremost mathematicians of the 20th century.

He made major contributions to a vast range of fields including mathematics, physics, mechanics, computer science, as well as many other mathematical fields.

John von Neumann was born in Budapest, Hungary. His father, Max Neumann, was a lawyer who worked in a bank.

János, nicknamed "Jancsi" (similar to "Johnny"), was an extraordinary prodigy. At the age of only six, he was able to divide two 8-digit numbers in his head.

He had an extraordinary memory: at the same age of six, he was able to exchange jokes with his father in classical Greek. The Neumann family sometimes entertained guests with demonstrations of Johnny's ability to memorize phone books. A guest would selected a page of the phone book at random, then the boy read the page over, then handed the book back to the guest and answered any question put to him (who has what number, recite names, addresses, and numbers in order, etc.).

He was very curious boy and most of all he was interested in mathematics: at age of eight he already understood beginnings of calculus…

His parents hired teachers when Johnny was small and when he was eight years old he entered the German speaking Lutheran Gymnasium in Budapest, one of the best local school. His mathematics teacher quickly recognized von Neumann's genius and special tuition was put on for him. Moreover, he introduced a young boy to a group of professional Budapest mathematicians. It influenced on a boy very much: he published his first paper "On root location of some minimum polynomials" as early as at 18 years old.

In 1913, his father was rewarded with ennoblement for his service to the Austro-Hungarian empire, therefore Janos full name changed to Johann von Neumann (in German).

Graduating from the gymnasium, Johan von Neumann entered the University of Budapest to study mathematics and simultaneously the University of Zurich, Switzerland to study chemistry at the behest of his father, who wanted his son to invest his time in a more profitable business than mathematics.

He spent almost all his time in Zurich coming to Budapest only for exams. Nevertheless,

While in Zurich he continued his interest in mathematics, despite studying chemistry, and interacted with Weyl[65] and Pólya[66] who were both at Zurich. He even took over one of Weyl's courses when he was absent from Zurich for a time. Pólya wrote: "Johnny

[65] **Hermann Klaus Hugo Weyl** (1885-1955), German mathematician who spent his working life in Zurich, Switzerland and then Princeton. His research has had major significance for theoretical physics as well as pure disciplines including number theory. He was one of the most influential mathematicians of the twentieth century

[66] **George Pólya** (1887-1985), Hungarian mathematician. He worked on a great variety of mathematical topics, including series, number theory, combinatorics, and probability.

was the only student I was ever afraid of. If in the course of a lecture I stated an unsolved problem, the chances were he'd come to me as soon as the lecture was over, with the complete solution in a few scribbles on a slip of paper".

In 1925 he achieved outstanding results in the mathematics examinations at the University of Budapest despite not attending any courses and almost simultaneously earned his diploma in chemical engineering from the Technische Hochschule in Zurich.

Von Neumann published his first paper at the age of 18: that paper was hardly a printed page long and contained excellent result. By age 25 he had published 10 major papers. He quickly gained a reputation in set theory, algebra, and quantum mechanics.

He lectured as an assistant professor at Berlin University, then at Hamburg University and also held a Rockefeller Fellowship to enable him to undertake postdoctoral studies at the University of Göttingen.

At the University of Göttingen at the moment were gathered all stars of mathematics and physicists (in alphabetic order for not discriminating anybody): Niels Bohr[67], Max Born[68], , David Hilbert[69], Felix Klein[70], Hendrich Lorentz[71], Herman Minkovski[72],

[67] **Niels Henrik David Bohr** (1885-1962), Danish physicist who made fundamental contributions to understanding atomic structure and quantum mechanics, for which he received the Nobel Prize in 1922. He was also part of the team of physicists working on the Manhattan Project.

[68] **Max Born** (1882-1970), German physicist and mathematician. Emigrated to the USA before the World War II. He won the Nobel Prize in Physics.

[69] **David Hilbert** (1862-1943), German mathematician, recognized as one of the most influential and universal mathematicians of the XIX and early XX centuries.

[70] **Felix Christian Klein** (1849-1925), German mathematician, known for his work in group theory, function theory, non-Euclidean geometry, and on the connections between geometry and group theory.

[71] **Hendrik Antoon Lorentz** (1853-1928), outstanding Dutch physicist. He received the 1902 Nobel Prize in Physics.

[72] **Hermann Minkowski** (1864-1909), Lithuanian mathematician, who created and developed the geometry of numbers and who used geometrical methods to solve difficult problems in number theory, mathematical physics, and the theory of relativity.

Max Plank[73], Henri Poincare[74], Karl Runge[75], Hermann Weyl and others....

Any university in the World had such constellation of scientific stars ever!

In 1930 von Neumann emigrated to the United States. Here von Neumann anglicized Johann to John, keeping the Austrian-aristocratic surname of von Neumann.

Von Neumann was invited to Princeton, New Jersey in 1930, and was one of four people selected for the first faculty of the Institute for Advanced Study (two of the others were Albert Einstein and Kurt Gödel[76]), where he was a mathematics professor from its formation in 1933 until his death.

It was said many anecdotes about Neumann (as, probably, about anybody of his caliber), especially about his hazardous manner of driving.

Once he reported about one of his many car accidents as follows: "I was proceeding down the road. Suddenly one of the trees from my right stepped in my path".

73 **Max Karl Ernst Ludwig Planck** (1858- 1947), German physicist. He is considered to be the founder of quantum theory.

74 **Jules Henri Poincaré** (1854 - 1912), one of France's greatest mathematicians and theoretical physicists, and a philosopher of science. Poincaré is often described as a polymath, and in mathematics as The Last Universalist excelled in all fields of the discipline.

75 **Carl David Tolmé Runge** (1856 -1927), German mathematician, physicist, and spectroscopist. Co-developer of the Runge-Kutta method in numerical analysis.

76 **Kurt Gödel** (1906-1978), Austrian American mathematician and philosopher. He proved fundamental results about axiomatic systems.

In 1937 he became a US citizen and already in 1938 American Mathematical Society awarded him a prestigious prize for his work in analysis.

During the war, von Neumann served as a consultant to the armed forces, participating in several projects where his expertise in hydrodynamics, ballistics, meteorology, game theory, and statistics, was of great use. These projects led him to consider the use of mechanical calculator invented by Howard Aiken[77]. His correspondence in 1944 shows his interest with the work of not only Aiken but also the electromechanical relay computers of George Stibitz.

One more anecdote about von Neumann's brilliant mathematical capabilities.
Once someone posed the "fly and the train" problem to von Neumann.
Remind you the problem: a train is moving from *A* to *B* with a constant speed of 100 mph. The distance between *A* and *B* equals 100 miles. Simultaneously, from *B* a fly starting to fly with a speed of 200 mph. Reaching the train, the fly flied back to the station located at B. Reaching the station it flies back to the train, and so on. The question is: How many miles the fly covers until the train reached the station?
The solution is extremely simple: the train spends exactly an hour to reach the station and all this time the fly is flying forth and back with 200 mph, so it make 200 miles way!
Quickly von Neumann came up with the answer. Being asked, how he got the answer, he said: "Simple, I summed the series!"

[77] **Howard Hathaway Aiken** (1900-1973),a pioneer in computing, who constructed an electro-mechanical computing device that was originally called the Automatic Sequence Controlled Calculator (ASCC) and later renamed Harvard Mark I.

By the latter years of World War II von Neumann was playing the part of an executive management consultant, serving on several national committees, applying his amazing ability to rapidly see through problems to their solutions. Through this means he was also a conduit between groups of scientists who were otherwise shielded from each other by the requirements of secrecy. He brought together the needs of the Los Alamos National Laboratory (and the Manhattan Project) with the capabilities of firstly the engineers at the Moore School of Electrical Engineering who were building the ENIAC[78].

In 1944 he was directed to the group developing the computer as a consultant in mathematical problems. Two years later, when the design had been completed, he wrote and issued the report entitled "First Draft of a Report on the EDVAC". Since von Neumann was a widely known scientist all ideas were prescribed to him, even the computer infrastructure which is now known as the "von Neumann Architecture". For the sake of justice, it is necessary to mention that main ideas belonged to two project leaders – Eckert and Mauchly.

John von Neumann came back to the Institute for Advanced Study and worked on his own project on building the IAS [79]machine. (Postwar von Neumann concentrated on the development of the IAS computer and its copies around the world.)

Here Neumann participated in design of new computers, partially, a machine for which he gave a joking name MANIAC (abbreviation for Mathematical Analyzer, Numerator, Integrator and Computer).

In the 1950's von Neumann was employed as a consultant to IBM to review proposed and ongoing advanced technology projects. It is interesting that he was confronted with the FORTRAN concept, asking: "Why would you want more than

[78] **ENIAC**, short for Electronic Numerical Integrator And Computer. The first large-scale, electronic, digital computer designed and built to calculate artillery firing tables for the U.S. Army.

[79] **IAS** was the first electronic digital computer built by the Institute for Advanced Study (IAS), Princeton, USA.

machine language?" When he found that one of the assistants took time out to build an assembler, he angrily said that it was a waste of a valuable scientific computing instrument to use it to do clerical work.

* * *

Von Neumann was diagnosed with bone cancer in 1957, possibly caused by exposure to radioactivity while observing A-bomb tests in the Pacific or in later work on nuclear weapons at Los Alamos, New Mexico. (Fellow nuclear pioneer Enrico Fermi[80] had died of stomach cancer in 1954.)

Several surgeries did not help and being awarded by American President Eisenhower[81] in person, he took the Presidential Medal of Freedom – one of the highest civilian awards – sitting in a wheelchair…

In the same year the Atomic Energy Commission awarded him with the Enrico Fermi Prize for his works in creation of modern computers.

Last days von Neumann spent in a hospital where at the beginning he continued to work in spite of unbearable pain. However, the cancer had spread very fast and reached to his brain, inhibiting mental ability.

He died on February 8, 1957.in a hospital.

He was only 53 years old…

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[80] **Enrico Fermi** (1901-1954), Italian physicist most noted for his work on the development of the first nuclear reactor. He was awarded the Nobel Prize in Physics in 1938..After receiving the Nobel Prize in Stockholm, he with his wife and children emigrated to New York, running from the fascist regime in Italy.

[81] **Dwight David Eisenhower** (1890-1969), the 34th President of the United States (1953–1961). During the Second World War, he served as Supreme Commander of the Allied forces in Europe.

* * *

John von Neumann was one of the greatest polymaths of all time, managed to have profound impact on mathematics, quantum theory, economics, computer science, neurology, and other fields.

He wrote 150 published papers in his life; 60 in pure mathematics, 20 in physics, and 60 in applied mathematics.

John von Neumann was an honor professor of many European and American universities and a member of several Academies of Sciences..

The Institute of IEEE[82] is annually awarded John von Neumann Medal "for outstanding achievements in computer-related science and technology."

The professional society of Hungarian computer scientists, Neumann János Számítógéptudományi Társaság, is named after John von Neumann. It also is awarded its medal for achievements in achievements in computer science.

[82] **Institute of Electrical and Electronics Engineers** (USA), the world's leading professional association for the advancement of technology.

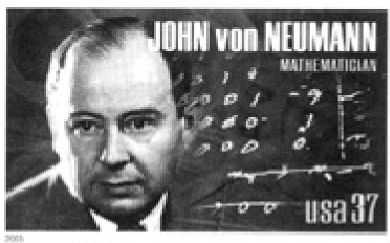
The John von Neumann Theory Prize of the Institute for Operations Research and the Management Sciences (INFORMS, previously TIMS-ORSA) is awarded annually to an individual (or group) who have made fundamental and sustained contributions to theory in operations research and the management sciences.

The John von Neumann Lecture is given annually at the Society for Industrial and Applied Mathematics (SIAM) by a researcher who has contributed to applied mathematics, and the chosen lecturer is also awarded a monetary prize.

The John von Neumann Computing Center in Princeton, New Jersey was named in his honor.

A crater on the Moon is named after John von Neumann.

Hungary and the United States – two countries to whom John (Janos) von Neumann belongs – issued postage stamps commemorating von Neumann.



Philip McCord Morse

(1903 - 1985)

American physicist, administrator and pioneer of operations research – new scientific direction formed during in World War II. He is considered to be the father of operations research in the United States.

Philip Morse graduated from the Case School of Applied Science (Cleveland, Ohio) in 1926 with a B.S. in physics. He earned his Ph.D. in physics from Princeton University in 1929. In his dissertation he proposed the Morse potential function for diatomic molecules which is used to interpret vibrational spectra. After defending his dissertation, he has been granted an International Fellowship and visited University of Munich (Germany) for the postgraduate study and research. Upon return to the United States, he joined the faculty of MIT.

Morse made many contributions to the development of operations research (OR). Early in 1942 he organized the Anti-Submarine Warfare Operations Research Group (ASWORG), later ORG, for the U.S. Navy. Philip Morse co-authored with George Kimball[83] *Methods of Operations Research*, the first OR textbook on OR, on their mutual work for Navy. The book has been published

[83] **George Elbert Kimball** (1906 –1967) . American professor of quantum chemistry, and a pioneer of operations research algorithms during World War II. Kimball was one of the first persons recruited by Morse to ASWORG, and within the year he became Morse's Deputy Director

in 1951, and was based on a classified report, which was later released for general publication.

In 1949 Philip Morse was named the first Research Director of the Weapons Systems Evaluation Group (WSEG), an organization founded to conduct studies for the Joint Chiefs of Staff, where he served a year and a half before returning to MIT. In 1956 he launched Operations Research Center at MIT and in 1968 he was awarding the first Ph.D. in OR in the United States.

He was a member of a National Research Council committee dedicated to bringing OR into civilian life, and was a founder of the Operations Research Society of America (ORSA) in 1952. He served as president of the American Physical Society, president of the Acoustical Society of America (ASA), and board chair of the American Institute of Physics.

In 1946, he was a recipient of the Medal for Merit from the U.S. President for his work during the war.

Morse had a distinguished career in physics. In 1973 the ASA awarded him the Gold Medal, its highest award.

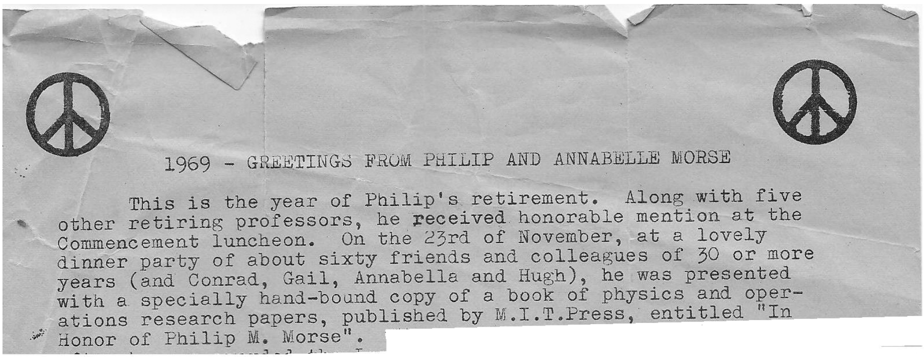
He received ORSA's Lanchester Prize in 1968 for the book "*Queues, Inventories, and Maintenance* and *Library Effectiveness*".

Morse gave the opening address at the 1957 organizing meeting of the International Federation of Operational Research Societies (IFORS). Actually, he was a real founder of this International Federation.

He had definite administrative talents: was co-founder the MIT Acoustics Laboratory, was first director of the Brookhaven National Laboratory, founder and first director of the MIT

Computation Center, and board member of the RAND Corporation and the Institute for Defense Analyses.

The author of this book was invited by Philip Morse to visit the Computer Center at MIT in 1966. After this during years there was a brief correspondence between us. Belof is a fragment of the Phil's letter sent him to Moscow.



1969 - GREETINGS FROM PHILIP AND ANNABELLE MORSE

This is the year of Philip's retirement. Along with five other retiring professors, he received honorable mention at the Commencement luncheon. On the 23rd of November, at a lovely dinner party of about sixty friends and colleagues of 30 or more years (and Conrad, Gail, Annabella and Hugh), he was presented with a specially hand-bound copy of a book of physics and operations research papers, published by M.I.T.Press, entitled "In Honor of Philip M. Morse".

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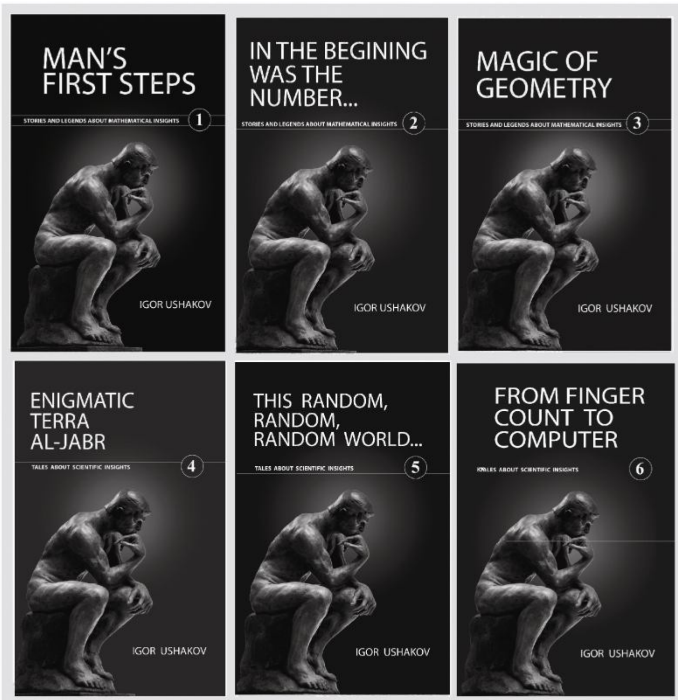
You can buy the following my books of series "Legends and Stories about mathematical Insights" in English:



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Professor Igor Ushakov, Doctor of Sciences. He led R&D departments at industrial companies and Academy of Sciences of the former USSR. Simultaneously, was a Chair of department at the famous Moscow Institute of Physics and Technology. Throughout his career he had the pleasure of acting as the Scientific Advisor for over 50 Ph.D. students, nine of which became Full Professors.

In 1989 Dr. Ushakov came to the United States as a distinguished visiting professor to George Washington University (Washington, D.C.), later worked at Qualcomm and was a consultant to Hughes Network Systems, ManTech and other US companies..

The author has published roughly 30 scientific monographs in English, Russian, Bulgarian, Czechoslovakian, and German.

In addition to scientific writings, the author has published several book of prose, poems and lyrics (in Russian).