The Modern Natural Science Picture of the World

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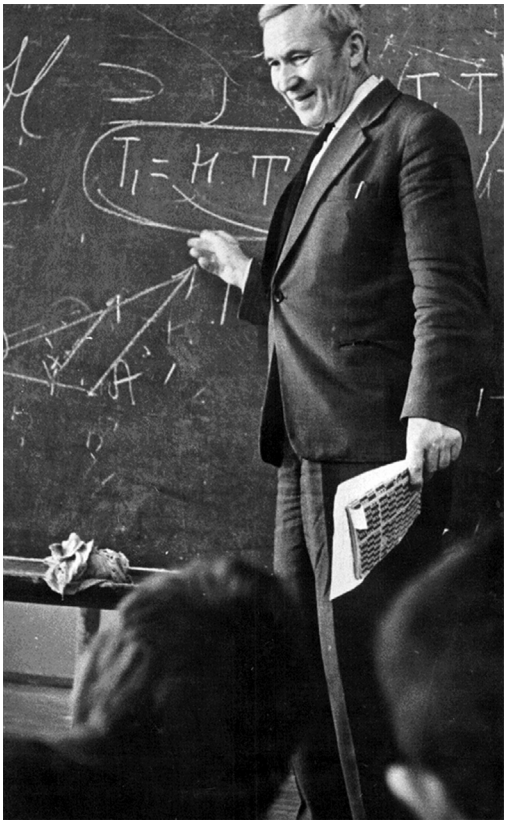
This book is dedicated to the memory
of the Great Scientist and Teacher
Andrei Nikolaevich Kolmogorov
(25.04.1903–20.10.1987)



Giants thanks to which we see the scientific picture of the World “from the height of bird flight”.

Kolmogorov – Poincaré – Gauss – Euler – Newton: only five such lives separate us from the sources of our science.

Academician V.I. Arnold

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Part III: Living Systems

PREAMBLE

We are not given to predict
How our word will respond ...
Fyodor Tyutchev

The achievements of the natural sciences over the past decades are so great that the very attempt to realize them today has become a difficult cognitive problem. Increasing differentiation is an obvious fact of modern science. Modern science has set itself the task of finding and developing common fundamental principles of scientific knowledge. Solving such a problem is by no means trivial. The search for a single foundation of natural science has long ceased to be the lot of philosophers alone. Today scientists from various fields such as physics, chemistry, biology, mathematics, etc., have been attached to its resolution.

Hence the desire of the authors of this course to lead the reader to the breadth of views on the problems of natural science corresponding to today. Unfortunately, traditional standards of education, especially in the humanitarian fields, do not allow the comprehension of the modern achievements of the science of nature.

Michael Faraday, who first organized public scientific readings for unprepared listeners, came to the conclusion that a truly instructive lecture can never be popular, but a really popular lecture will never achieve real instruction. In this book we will try to partly refute this point of view of the great scientist.

Separate ideas of the course are taken from the works of Vladimir Arnold, Paul Davies, Pavel Florensky, Alexander Markov, Boris Mednikov, Yuval Ne'eman, and Ilya Prigogine. We have included fragments of these works in the book, only slightly *mutatis mutandis*, not changing their meaning.

The authors remember the famous Gödel theorem on the incompleteness of an axiomatic description. Applied to our case, it boils down to the following statement. There is no such finite axiom system within which all problems can be described. Nevertheless, we consciously, where possible, axiomatized the presentation of the material. This approach, according to the authors, is in keeping with the idea of the book. In addition, it is possible to say *multa paucis*.

One or another concept becomes understandable to a person or even obvious a priori, if the ratio of the parameters characterizing it, K_i to the values of L_i corresponding to life experience becomes of the order of or less than unity (K_i/L_i <1). In some cases, this ratio can be satisfied by constant repetition, leading to habit. The incomprehensible becomes clear when it becomes habitual. However, one should not forget that, although *Repetitio est mater studiorum* – repetition is the mother of learning, it is the enemy of creativity. Here it is appropriate to quote Ovid: "Repetition is the mother of learning and the shelter of donkeys (the consolation of fools)".

The inclusion of art in the book seemed to us important for the following reason. This is due to the concept of the law of nature. The fact is that this concept was formed only within the framework of the European civilization. In the pictures of the world of some other civilizations, the concept of the laws of nature was simply absent. Consequently, this concept requires justification, which philosophy historically claimed, and at present it is becoming the subject of science itself. However, man's knowledge of the world occurs not only through science or philosophy, but also through art. Therefore, the idea of the laws of nature is reflected in art.

It is necessary to know, respect and appreciate philosophy and art. In the 18th century, the head of the Prussian Department of Education, Baron von Tsedlitz (Immanuel Kant dedicated his "Critique of Pure Reason" to him) inspired students: "After completing the science course, you will have to be a doctor, judge, lawyer, etc., only a few hours a day, but you will be a man for the whole day".

In conclusion of the preamble, we consider it necessary to explain why science is popularized. Currently, there is an increased separation between fundamental science and the mass consciousness. This gap is particularly noticeable in the natural sciences. The deeper scientists penetrate the secrets of nature, the more distorted their discoveries are in the media. As a result, an inadequate scientific picture of the world is being formed in the public consciousness. This trend may lead to the fact that society finally ceases to understand what scientists are doing and why they are needed.

Many people's lack of modern scientific knowledge at least at the elementary level is not at all harmless. Many of the most important decisions in society are endorsed through democratic procedures. In this case, everyone has the right to vote, regardless of their level of education.

People have a natural need to understand natural processes. In this regard, scientists are waiting for answers to key questions about the structure of the universe. It is assumed that these answers should be simple and straightforward. Of course, people would like the understanding of these answers not to require excessive intellectual effort. However, the

world is much more complex than many would like to think. Therefore, in order for the modern scientific picture of the world to penetrate the mass consciousness, targeted systematic efforts are needed.

Recently, an outstanding philologist Andrey Zaliznyak at the award ceremony of the Solzhenitsyn Literary Prize drew attention to the following important circumstance. Nowadays, unfortunately, two old, banal ideas have gone out of fashion. First, truth exists, and the goal of science is to find it. Secondly, in any matter under discussion, a professional is in the normal case more correct than an amateur. These are confronted today by new, much more fashionable positions. The first point is that there is no truth, but a multitude of opinions. The second clause states that no one's opinion weighs more than someone else's. Therefore, popularization in the modern world is a public duty and a necessary means of civilization's self-preservation.

The idea of this book came from Prof. Yu.P. Khapachev as a result of the creation of an original training course for the humanitarian specialties of Kabardino-Balkarian State University, first read by the authors in the mid-1990s. Since then, a number of fundamental results have been obtained in the field of natural sciences. The most interesting are given in the book offered to the reader. This book generally follows our publications (Khapachev at al. 1997; Khapachev, Dyshekov, and Oranova 2013; Khapachev at al. 2017; Khapachev at al. 2018).

The translation into English and the general editing of the book were carried out by Prof. Yu.P. Khapachev and Prof. A.A. Dyshekov. Statements by Russian authors used as epigraphs were also translated by them. This translation, of course, is not poetic, but most importantly, it does not lose the meaning of the original.

Thanks.

The authors are grateful to Prof. B. Karamurzov and PhD. A. Tashilov for encouraging the publication of this book.

LIST OF ABBREVIATIONS

ALS	artificial living system
ANS	autonomic nervous system
BFB	biological feedback
CAR	compensatory-adaptive reaction
CMB	cosmic microwave background
CNS	central neural system
CR	conditioned reflex
DNA	deoxyribonucleic acid
fMRI	functional magnetic resonance imaging
GTR	general theory of relativity
GUT	grand unified theories
HNA	higher nervous activity
KAM	Kolmogorov – Arnold – Moser theory
mOFC	medial orbito-frontal cortex
mRNA	messenger RNA
mtDNA	mitochondrial DNA
mtEve	mitochondrial Eve
PNS	peripherical nervous system
RNA	ribonucleic acid
SFWU	structural functional working units
STR	special theory of relativity
TD	thermodynamic
TS	transition state
UCR	unconditioned reflex
WB	“Weisman barrier”

INTRODUCTION

Oh, how many wonderful discoveries to us
Prepares an enlightened spirit
And experience, the son of difficult mistakes,
And genius, paradoxes friend,
And the chance, God is the inventor.
Alexander Pushkin

Natural and humanitarian culture. Beauty

Let's face what is at first glance a trivial question. What is culture? Despite the seemingly obvious answer to this question, there are many interpretations of this concept. We confine ourselves to the most obvious sign of culture. Culture refers to everything that relates to the results of human activity. These results can have a direct material character (material culture), as well as be fixed on various material carriers (books, notes, etc.) without having a material embodiment (non-material culture).

In this book we mainly consider conceptual issues of fundamental science which naturally relate to the sphere of non-material culture. Ideas permeate not only the field of scientific knowledge, but also art as the most important part of humanitarian culture. One of the main concepts that unite the two types of culture is beauty. We will not try to give a definition of this concept but simply give a few examples from various fields of art and science. At the same time, we hope that the reader understands that art is fundamentally subjective in its essence, and the examples we cite cannot be an absolute example of beauty for all people. On the other hand, science claims to be objective knowledge, and therefore the beauty in it is absolute.

Beauty in Humanitarian Culture

Painting and Sculpture

Sandro Botticelli: Spring, The Birth of Venus. Uffizi, Florence, Italy.

Leonardo da Vinci: The Last Supper, Convent of Sta. Maria delle Grazie, Milan, Italy.

Raphael: The School of Athens, in the Apostolic Palace in the Vatican. Madonna Sixtina. Dresden Gallery, Dresden, Germany.

Michelangelo: Pietà, in St. Peter's Basilica in the Vatican. The Creation of Adam, Last Judgement, in the Apostolic Palace in the Vatican.

Andrei Rublev: Trinity, Christ the Redeemer. Tretyakov Gallery, Moscow, Russia.

Reproductions of these works are available on the Internet.

The task of painting is not to duplicate reality, but to give the most profound comprehension of its material and its meaning. The artist comprehends this meaning directly contacting reality. He gets used to this reality. Therefore, painting is, or wants to be the truth of life. This truth of life does not replace life, but only symbolically reflects it in the deepest reality.

In 1919 Florensky wrote an article “Reverse perspective” (Florensky 1999). This article is devoted to understanding the phenomenon of the way in which images take up space on a plane. Florensky examines the iconographic canon and compares it with examples of world art. He points to the regularity of the periodic return of artists to the reverse perspective and abandonment of it. This was due to the spirit of the times and historical circumstances which influenced one or another worldview of the artist.

People who first examine Orthodox icons from the XIV and XV centuries, and partly from the XVI century, are struck by unexpected promising relationships. These paradoxical relations contradict the rules of linear perspective from the point of view of which they are the gross illiteracy of the drawing. However, after a while, icons with a large perspective violation for artistic perception turn out to be more attractive than those that more closely match the perspective textbook. These violations of the rules of perspective are so persistent and so systematic that involuntarily the thought arises about the non-randomness of these violations. Thus, there is a special system of image and perception of reality, on the icons depicted.

Is perspective really, always and everywhere, to be seen as an absolute prerequisite of artistic truthfulness? Or is it one of the possible schemes of visualization, corresponding not to the worldview as a whole, but only to one of the possible interpretations of the world. And this is connected with quite a certain life feeling and life understanding.

Florensky reports referring to Vitruvius. Around about 470 BC, Aeschylus staged his tragedies in Athens, and Agafarh made the scenery and wrote a treatise about it, “Commentarius”. It is on this occasion that Anaxagoras and Democritus had the opportunity to consider this very subject (writing scenery) scientifically.

Florensky analyzes the work of the geniuses of the Renaissance and classic perspectivism. He notes their deliberate violation of the direct perspective rules of The Last Supper as Leonardo has the task of removing the spatial distinction between that world, the gospel, and this, the everyday. The fresco presents a stage setting. In this scene the laws of Kant, space and Newtonian mechanics reign. But if it were only thus, there would be no supper. And Leonardo commemorates the special value of the committed violation of the uniqueness of scale. A simple measurement will show that the room barely has a double human height, with a triple width. Thus, the room does not correspond to the number of people in it, or the greatness of the event. However, the ceiling does not seem oppressive, and the smallness of the room gives the picture a dramatic richness and fullness. Unnoticed, but surely, the master resorted to a perspective violation and applied different units of measurement to the actors and to the room. He reduced the size of the room, though differently in different directions. Thus, he glorified people and gave the humble farewell dinner the significance of a world-historical event at, moreover, the center of history. The unity of perspective is broken, the duality of the Renaissance soul has manifested itself, but on the other hand, the picture has become aesthetically convincing.

It is known what a magnificent impression the architecture makes in the "Athenian School" of Raphael. If you characterize these arches, then you want to compare them, for example, with the Cathedral of St. Peter in Rome or the Moscow Cathedral of Christ the Savior. It seems that the arches are equal in height to the church. However, measurement shows that the height of the columns is slightly more than twice the height of the figures. So the whole building, apparently so magnificent, would be very insignificant if it were actually built. Raphael's method in this case is also very simple. He accepted two points of view, located on two horizons from the top point of view, the floor is drawn and the whole group of faces, from the bottom drawn arches and in general the entire upper part of the picture. If the figures of people had a common vanishing point with the lines of the ceiling, then the heads of people in the depths of the picture would have dropped below and would have been closed off by the people standing in front. This would damage the picture. The vanishing point of the ceiling lines is in the right hand of the central figure (Aristotle) who holds a book in his left hand and points to the right with his right hand. To conceal this promising violation, Raphael placed the actors in the depths of the picture and disguised the lines of the floor to the horizon.

As in many other paintings Raphael balances two principles, perspective and reverse. This corresponds to the peaceful coexistence of two worlds,

two spaces. It is just as if the veil of another world has unfolded silently before us, and our eyes see not a scene, not an illusion in this world, but a real, though not invading, different reality. Raphael gives a hint of such a spatial property in the Madonna Sixtina with its separated curtains.

There is a balance of the two principles of spatiality in “Apostle Paul's Conversion” by Michelangelo. But there is a completely different spatiality in his “Last Judgment”. The fresco represents a certain slope: the higher a point in the picture, the further from the viewer is the point that it depicts. Consequently, as the gaze is raised, the eye will see smaller and smaller figures, due to the perspective reduction. This is evident from the fact that the lower figures block the upper ones. But, the size of the figures increases as they rise on the fresco, i.e., as they move away from the viewer.

Such is the property of that spiritual space. Within it, the farther away something is, the greater it is, and the closer, the smaller it is. This is the reverse perspective. Having understood it, and, moreover, so consistently carried it out, we begin to feel its complete incommensurability with the space of the fresco. We are not drawn into this space. On the contrary, it pushes us. Although visible, it is transcendent to us, thinking according to Kant and Euclid. Michelangelo who lived in the Baroque was, however, not in the past, not in the future of the Middle Ages. He was a contemporary and not at all contemporary to Leonardo.

Architecture

Church of the Protection of the Theotokos on the Nerl. Vladimir Region, Russia. Architect unknown.

The Tempietto within a narrow courtyard. Rome, Italy. Architect Donato Bramante.

Taj Mahal. Agra, Uttar Pradesh, India. Ustad Ahmad Lahauri. Persian architect, student of Sinan, he is often called the main creator of the architectural image of the monument.

Music

Johann Sebastian Bach: Toccata and Fugue in d minor.
Wolfgang Amadeus Mozart: Symphony No. 40.
Sergey Rachmaninoff: Prelude in g minor, Op. 23.

Poetry

William Shakespeare
Sonnet 117
Accuse me thus: that I have scanted all
Wherein I should your great deserts repay,
Forgot upon your dearest love to call,
Whereto all bonds do tie me day by day;
That I have frequent been with unknown minds
And given to time your own dear-purchased right
That I have hoisted sail to all the winds
Which should transport me farthest from your sight.
Book both my wilfulness and errors down
And on just proof surmise accumulate;
Bring me within the level of your frown,
But shoot not at me in your waken'd hate;
Since my appeal says I did strive to prove
The constancy and virtue of your love.

John Donne
The Anniversary
All kings, and all their favourites,
All glory of honours, beauties, wits,
The sun itself, which makes time, as they pass,
Is elder by a year now than it was
When thou and I first one another saw.
All other things to their destruction draw,
Only our love hath no decay;
This no to-morrow hath, nor yesterday;
Running it never runs from us away,
But truly keeps his first, last, everlasting day.

Two graves must hide thine and my corse;
If one might, death were no divorce.
Alas ! as well as other princes, we
– Who prince enough in one another be –
Must leave at last in death these eyes and ears,
Oft fed with true oaths, and with sweet salt tears;
But souls where nothing dwells but love
– All other thoughts being inmates – then shall prove
This or a love increasèd there above,
When bodies to their graves, souls from their graves remove.

And then we shall be thoroughly blest;
But now no more than all the rest.
Here upon earth we're kings, and none but we

Can be such kings, nor of such subjects be.
Who is so safe as we? where none can do
Treason to us, except one of us two.
True and false fears let us refrain,
Let us love nobly, and live, and add again
Years and years unto years, till we attain
To write threescore; this is the second of our reign.

Rudyard Kipling
If
If you can keep your head when all about you
Are losing theirs and blaming it on you,
If you can trust yourself when all men doubt you,
But make allowance for their doubting too;
If you can wait and not be tired by waiting,
Or being lied about, don't deal in lies,
Or being hated, don't give way to hating,
And yet don't look too good, nor talk too wise:

If you can dream – and not make dreams your master;
If you can think – and not make thoughts your aim;
If you can meet with Triumph and Disaster
And treat those two impostors just the same;
If you can bear to hear the truth you've spoken
Twisted by knaves to make a trap for fools,
Or watch the things you gave your life to, broken,
And stoop and build'em up with worn-out tools:

If you can make one heap of all your winnings
And risk it on one turn of pitch-and-toss,
And lose, and start again at your beginnings
And never breathe a word about your loss;
If you can force your heart and nerve and sinew
To serve your turn long after they are gone,
And so hold on when there is nothing in you
Except the Will which says to them: "Hold on!"

If you can talk with crowds and keep your virtue,
Or walk with Kings – nor lose the common touch,
If neither foes nor loving friends can hurt you,
If all men count with you, but none too much;
If you can fill the unforgiving minute
With sixty seconds' worth of distance run,
Yours is the Earth and everything that's in it,
And – which is more – you'll be a Man, my son!

Some British people say that one who knows these lines of Kipling is capable of bringing the future closer. Who knows, maybe they are right?

The Servant When He Reigneth

For three things the earth is disquieted,
and for four which it cannot bear.
For a servant when he reigneth,
and a fool when he is filled with meat;
for an odious woman when she is married,
and an handmaid that is heir to her mistress.
PROV. XXX. 21-22-23.

Three things make earth unquiet
And four she cannot brook
The godly Agur counted them
And put them in a book –
Those Four Tremendous Curses
With which mankind is cursed;
But a Servant when He Reigneth
Old Agur entered first.
An Handmaid that is Mistress
We need not call upon.
A Fool when he is full of Meat
Will fall asleep anon.
An Odious Woman Married
May bear a babe and mend;
But a Servant when He Reigneth
Is Confusion to the end.

His feet are swift to tumult,
His hands are slow to toil,
His ears are deaf to reason,
His lips are loud in broil.
He knows no use for power
Except to show his might.
He gives no heed to judgment
Unless it prove him right.

Because he served a master
Before his Kingship came,
And hid in all disaster
Behind his master's name,
So, when his Folly opens
The unnecessary hells,
A Servant when He Reigneth

Throws the blame on someone else.

His vows are lightly spoken,
His faith is hard to bind,
His trust is easy broken,
He fears his fellow-kind.
The nearest mob will move him
To break the pledge he gave –
Oh, a Servant when he Reigneth
Is more than ever slave!

Johann Wolfgang Goethe
O'er all the hill-tops
Is quiet now,
In all the tree-tops
Hearest thou
Hardly a breath;
The birds are asleep in the trees:
Wait; soon like these
Thou too shalt rest.

Translated by Henry Wadsworth Longfellow

This poem is a diamond of German poetry. The translation into Russian was by the great Russian poet Mikhail Lermontov. In turn, this translation is considered a brilliant example of Russian poetry.

Beauty in mathematics

> The mathematician plays a game in which he himself invents the rules while the physicist plays a game in which the rules are provided by nature, but as time goes on it becomes increasingly evident that the rules which the mathematician finds interesting are the same as those which nature has chosen.

So wrote one of the founders of quantum mechanics, the Nobel laureate Paul Dirac in 1939. The beauty of mathematics is the ability to see the true essence of things. Perhaps this refers to any beauty. First of all, it should be noted that beauty is associated with taste. It is better not to argue about tastes, but we believe that taste can sometimes be developed through education. Secondly, beauty can be external (form) and internal (meaning). There is a lot of beauty of both types in mathematics. The second type of beauty is deeper and inaccessible not only to people with a liberal arts

education but also to representatives of other sciences. Let us give a few examples that, we think, are available to everyone.

1. Geometers of Ancient Greece achieved much, but they could not calculate the volume of the ball. Brilliant Archimedes derived a formula, applying the idea of weighing!

2. In Euclid's book "Elements", a method for constructing regular figures is described: a triangle, a square, a pentagon, a fifteen-square and all polygons obtained by doubling the number of sides (using only a divider and a ruler). After a thousand years, it was proved that it is impossible to construct correct 7- and 9-gons (with the same tools). There was no consideration about building 11- and 13-gons. Mathematicians believed that other regular polygons could not be built. However, the 19-year-old Gauss, using imaginary numbers, found a way to construct a regular 17-gon.

3. Take an arbitrary triangle; draw trisectrices of angles (i.e. rays that divide the angles into three equal parts). Mark the points of intersection of three pairs of trisectrices leaning toward the sides. It turns out that these three points form an equilateral triangle (Morley's theorem). The proof of this theorem by means of elementary mathematics is not easy. The French mathematician Alain Connes found a very short and beautiful proof of Morley's theorem using imaginary numbers.

The sum of the corners of the triangle

However, the very concept of beauty is not limited to the visual aspect. There are beautiful poems, beautiful music, beautiful relationships, beautiful reasoning, and beautiful mathematical constructions.

Beauty in mathematics is a fine line between simplicity and complexity, naturalness and unusualness, a riddle and its solution. Beauty is what allows us to see more than we saw a moment ago. Beauty surprises us.

Apparently, the category of beauty in mathematics first appeared in ancient Greece with the advent of geometry.

Of course, intellectual pleasure in solving geometric problems is valuable in itself. But we believe that the aesthetic side also matters. In fact, what else can explain the desire to study abstract drawings made up of straight lines, line segments and circles?

Put yourself in the place of ancient geometers. The practical significance of most of your research will become clear only after many centuries. And now you just draw triangles in the sand and discover an amazing regularity: whatever triangle you build, the sum of its internal corners always makes a straight angle.

You feel that this cannot be an accident. There must be some reason, some explanation. But in the picture, there is not. This fact does not give you peace; you constantly think about it. Finally, perhaps almost randomly, intuitively, you add a new stroke to a drawing with a triangle. You draw a line passing through one of its vertices parallel to the opposite side.

Look at the picture (Fig. a), reason (logic turns on) and understand. The three angles are equal to the angles of your triangle, which together form a straight angle. Here they are, in front of you!

Now it is clear that nothing else could be. The fact, that a few minutes ago still seemed an unsolved mystery, has become a strictly proven fact. As a result, an amazing and wonderful meaning was revealed to your mental gaze due to intuition and logic.

You look at your drawing, which consists of only a few line segments, and you understand that this is one of the most beautiful pictures in your life.

This is what mathematical beauty looks like.

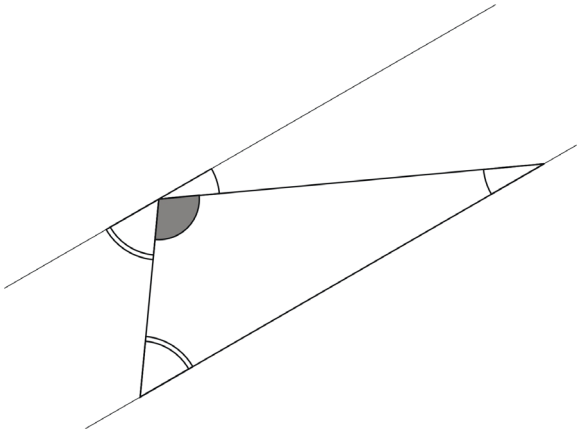

Fig. a.
With an additional straight line, it becomes clear that the sum of the angles of the triangle is equal to two right angles

Part of not less than a whole. The set of a power continuum

On line segments of different lengths are the same number of points. To verify this, it is enough to arrange the points in pairs (that is, in a pair of one point from one line segment, and the second from the other). Here is an illustration of how to do it (Fig. b). Each dotted line intersects each line segment, here are the intersection points and formed pairs.

Similarly, there are as many points on a line segment as on a straight line, and even on the whole plane. In a more general form, it turns out that a part is not always smaller than a whole. Moreover, the part (in a certain sense) is equal to the whole!

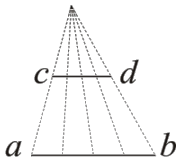

Fig. b.
The figure shows that there are as many points on the line segment as on the straight line

That which does not seem obvious or even impossible is realized. The impossible is thus possible. Here is an example of how the "Impossible is possible." Take a round target with infinitely many points on it, so the probability of hitting any of them is zero. Now let's shoot an arrow, it will hit some point. Let me remind you that this point was no better and no worse than all the others, with a zero probability of hitting it. That event happened, the probability of which was zero.

Fractals

The word beautiful is associated primarily with something visually pleasing, pleasing to our eyes, like a painting in a museum. There is such beauty in mathematics. Some mathematical objects allow a representation in the form of images, sometimes very pleasing to the eye.

The beauty of this example is understood by the humanities. How it turns out mathematically is not so easy to understand even for many techies. It is noteworthy in fractals that from a small mathematical formula it turns out to be an incredibly complex and sophisticated piece, the like of which we would rather get used to seeing in nature or in art.

The most beautiful formula

Two numbers: π and e. These numbers are everywhere; you can find and read a bunch of different facts about these numbers. It is simply impossible for an unprepared person to comprehend which of the facts is the cause, and which the result and where it all comes from. The most surprising is the connection of these numbers. If, nevertheless, you understand where π and

e come from, when you see the Euler identity, in which there are five fundamental constants of mathematics π, *e*, 0, 1 and *i*, a sense of admiration encompasses you, if not your own mind, then the minds of other people.

Here it is:

$$\exp(i\pi)+1=0.$$

In this formula the number $e = 2.718281828...$, or the base of the natural logarithm, i is the imaginary unit, the number $\pi = 3.141592653...$ the ratio of the circumference to the length of its diameter, 1 is the unit, the neutral element in the multiplication operation, 0 – zero, the neutral element of the operation of addition. Truly brevity is the sister of talent, if there is one, of course.

Unfortunately, or fortunately in mathematics and theoretical physics, not everything is always simple. Therefore, we must remember the following words of Paul Dirac:

> A theory with mathematical beauty is more likely to be correct than an ugly one that fits some experimental data. God is a mathematician of a very high order, and He used very advanced mathematics in constructing the universe.

PART I:

THE WORLD AS A PHYSICAL SYSTEM

CHAPTER 1

DISCOURSE AND INTUITION. CRITERION OF EVIDENCE. THE PROBLEM OF SCIENTIFIC AXIOMATICS

Vita brevis, ars longa, occasio praeceps,
experientia fallax, iudicium difficile.
Hippocrates

Let's start with the concretization of our topic. To do this, we should at least briefly dwell on the terminology that we will use. This is extremely important, because it is the terminology that specifies in some cases the subject of the research itself.

Recall that in the introduction we talked about natural and humanitarian cultures. In our book, we will talk further mainly about the first one. The language of science is created on a mathematical basis. However, our book is intended primarily for people who do not professionally own the mathematical apparatus. Therefore, we will deliberately avoid the presentation of excessive mathematization giving only a minimum of publicly available formulas.

In natural science the way of thinking, first of all, is logical, rational, and discursive. However, and it is very important to clarify from the very beginning, the construction of science is impossible without a kind of irrational thinking – intuition.

It is intuition that makes it possible to express a previously unknown statement as a hypothesis, which can then either be confirmed or disproved. What is intuition? For our purposes, it suffices to mention the most obvious feature of this concept. Intuition is a direct guessing of the result. Note here that the result may be false.

For example, at some stage of the knowledge of mankind, it seemed intuitively obvious that the Sun revolves around the Earth. In fact, even our distant ancestors observed the visible movement of the Sun across the sky. Now we know that the true picture is just the opposite.

The second example will seem to you less believable. Nevertheless, we will give it right now, postponing the explanation to the corresponding

chapter. Consider a “global” task. Suppose we are standing on the platform of a train station in London and are looking at the roof of a train going to Paris. On the roof of the “London-Paris” train runs Professor Moriarty (Fig. 1-1).

Fig. 1-1.
Professor Moriarty runs on the roof of the train

The London-Paris train is moving at a speed of v_T. Prof. Moriarty’s speed on the train is v_M. Calculate the speed of Prof. Moriarty relative to the London railway station. You will say that this is a primitive task from the course of school physics, and it all depends on which way Prof. Moriarty is running. If in the direction of the train, then $V = v_T + v_M$, if against the movement of the train, then $V = v_T – v_M$. Simple, but absolutely wrong!

Now we will not explain why these simple formulas of school physics are wrong. And this is despite the fact that they give in our everyday life a result that perfectly matches the experiment. The point here, of course, is not in the personality of the great criminal, Professor Moriarty. It turns out that a good, even very good coincidence with an experiment does not mean more truth.

It is reasonable to remind ourselves why this or that concept becomes understandable to a person or even intuitively obvious as it were, *a priori*. This happens if the ratio of the parameter characterizing the concept K to the value L corresponding to life experience becomes of the order of or less than unity K/L <1. Otherwise, the concept seems absurd to us or at least incomprehensible. The following examples can explain what has been said.

While a person was thinking of usual distances, i.e. about meters or kilometers, the idea of the sphericity of the Earth caused considerable difficulties. Recall that the radius of the Earth is about 6400 km. Meanwhile, it is known that even at the turn of the III-II centuries BC in Egypt, the Alexandrian scientist Eratosthenes of Cyrene (276–194 BC) rather accurately measured the Earth's radius from the difference on a shadow deviation in Alexandria and Luxor on the day of the summer solstice. Interestingly, Christopher Columbus had a significantly underestimated value of the Earth’s radius. That is why he hoped to go around the globe and sail to India so quickly. As we see, sometimes a mistake leads to discoveries.

Another example is the incorrectness of the above discussed speed formula. The problem is that our usual speed does not exceed 10^3 m/s even for a rocket. This is significantly less than the speed of light $c = 3 \cdot 10^8$ m/s.

The last characteristic example is connected with the seeming paradox of the laws of the microworld. The problem here is that our natural pace of life is determined by a pulse rate of about 60 beats per minute, i.e. 1 Hz. This value is at least 16 orders of magnitude less than the "world" of atomic frequencies (10^{16} Hz for optical radiation and 10^{19} Hz for *X*-rays and gamma radiations).

We now turn to the axioms of science. We consider the axioms of science to be the criteria of the scientific worldview that separate it from art and religion.

Axiom 1. *Sine ira et studio*; which means: without anger and addiction. In a broader sense, this means the following. To comprehend the scientific truth, do not have a preconceived opinion and question everything.

It is clear that this axiom separates scientific thinking from religious, reconstructive-prophetic thinking. For example, the doubt that the sum of the angles of a triangle is always 180°, led to the creation of a fundamentally new branch of mathematics – non-Euclidean geometry (Figs. 1-2 and 1-3). It is remarkable that one of these geometries has found an application in the description of the world in the general theory of relativity, which we will discuss later. This is Riemann's geometry.

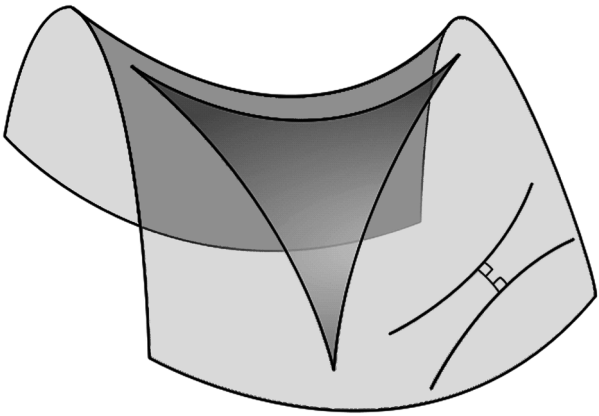

Fig. 1-2.
Hyperbolic geometry. The sum of the angles of the triangle is less than 180°