The Secret of Geniality

Robert DJIDJIAN[*]

Khachatur Abovian Armenian State Pedagogical University

Instead of abstract

This is the last part of the book THE SECRET OF GENIALITY (Yerevan, Armenia, Noyan Tapan Printing House, 2002) written by our colleague Robert Djidjian. We published this book not only because we all must know the philosophical research and creation (in our domain of epistemology and philosophy of science and technology) from a wider geographic area than that provided by the established fashion in virtue of both extra–scientific reasons and a yet obsolete manner to communicate and value the research; but also because the book as such is living, challenging and very instructive.

The title of the book is suggestive enough to make us to focus on an old problem: the dialectic of the insight, of the discovery – its psychology moving between flashes of intuitions and knowledge stored in memory – and its logic of composition of knowledge from hypotheses to their demonstration and verification. The realm of science is most conducive to the understanding of this dialectic and the constitution of the ideas which are the proofs of what is the most certain for humans: the "world 3", as Popper called the kingdom of human results of their intellection, and though transient and perishable in both their uniqueness and cosmic fate, the only certain proof of the reason to be of *homo sapiens* in the frame of multiversal existence. Therefore, the power to create is the secret of the human geniality, and how to create science is a main part of this secret.

This last part of the book is that of the Appendix the author added especially in order to highlight the methodology of the scientific discovery and the dialectical principles

[*]Graduated in Physics, later in Philosophy; Ph.D., Professor of Epistemology at the Department of Philosophy and Logic named after Academician Georg Brutian at the Armenian State Pedagogical University after Khachatur Abovian, Yerevan.

of both knowledge and the world. Highlighting the big problems or theories as "mysteries" and elucidating them by revealing the contradictions that lead to new theories and prefigures not only a new basis of understanding but also new problems makes the philosophy of science to appear here exciting as in the research of a detective. The clear explanation of concepts, the unexpected links between domains and between theories of different domains, the impeccable logic of inferences, the sense of humour and the integrative approach where the history of ideas formation is crossed by the red thread of the methodological goal make the reading of – not only this part but – the entire book a useful and enjoyable event for anyone. The book is a tool in the intellectual development so necessary nowadays.

Ana Bazac

Contents

Case 1. The mystery of demonstrative knowledge

"demonstrative knowledge is derived ***from necessary principles****."*

Aristotle

Science as such began by Aristotle. Yet Aristotle succeeded to present his teaching of natural phenomena in such a demonstrative way that for almost two millennia educated mankind was completely convinced in the truth of its principles and laws. How could can it happen? If one is ready to be satisfied by a simple answer to this mystery then the answer may sound as follows. Aristotle showed that things could not be other way.

In actuality, the situation with the demonstrative knowledge of causes was markedly complicated. The scientific way of thinking emerged along with the attempts of rational understanding of the world. A rational explanation of natural phenomena presumes, first of all, the idea of "total causality" which demands to find out for each object and phenomenon its causes. Scientific causality, which explains events of the world accounting them to their natural causes, first became a dominant tendency by the Greeks. Aristotle expressed the Greek obsession with rational explanation of natural phenomena in his conception of scientific knowledge as of the general knowledge of causes.

Aristotle's greatest work *Metaphysica* begins with the sentence, "all men by nature desire to know". Differentiating theoretical and empiric levels of knowledge, science and art in terms of his day, Aristotle insisted that both of them grow up strongly supported by experience. It seemed to him even that experience was "almost the same as science and art." When experience brings us some general understanding of a group of similar kind of objects, we reach the empiric level of knowledge. For instance, we can find out by experience that some medicine has been helpful for callias, Socrates and various other individuals. Then the empiric art of curing will recommend using this medicine in the similar cases of diseases. We arrive to the theoretical level of knowledge, which is the science, when we succeed to reveal the causes of the phenomenon under investigation. For instance, by establishing that the given medicine does good to persons of a certain constitution (phlegmatic and bilious patients in Aristotle's example). "we say we know each thing only when we think we recognize its first cause," concluded Aristotle. (*Metaphysica* A3, 983 a25)

Science made by the Greeks its first steps only. Quite mysteriously, educated people of that time believed they possess a *demonstrative knowledge* of nature and even of the heavens. This conviction was formed, at large, under the influence of Aristotle's works where all basic problems of natural philosophy got their rigorous solutions. Moreover, Aristotle grounded theoretically that scientific knowledge is demonstrative.

To prove a statement, one needs premises. But these premises require a proof too. Yet the process of proving cannot go to infinity. *The most basic premises, the primary truths cannot be proved.* They should be admitted as the basic principles or axioms of a scientific theory. Aristotle explained that the demonstrative power of scientific knowledge is based on the set of primary principles and axioms. In any scientific theory, axioms provide the most fundamental and most general knowledge.

But where from got axioms their demonstrative power, what can guarantee their truthfulness? Aristotle's answer was definite. The only way of attaining a demonstrative axiom was *induction.* Real causes of natural phenomena are acting everywhere and every time and involve all particular cases. So they can be expressed only through general statements. The only way to reveal general properties is induction. The starting point of our experience is the knowledge of individual cases. Processing this kind of information through induction, we get the first level of general knowledge. By successive generalizations we reveal more and more essential causes and eventually reach the most fundamental causes – the principles of the existing world.

But the devotion to abstract discussion made philosophers unobservant of the facts and too ready to dogmatize on the basis of a few observations. Speculative thinkers usually try to force natural phenomena into the framework of their own views. "Lack of experience diminishes our power of taking a comprehensive view of the admitted facts," pointed out Aristotle. Hence those who dwell in intimate association with nature and its phenomena grow more and more able to formulate the principles of their theories.

Modern readers will be surprised at Aristotle's conviction that observation and induction may provide a firm bases for demonstrative theoretical knowledge. In the language of the present time science the term induction is understood as the source of generalizations grounded on the study of a number of particular cases. But the term "induction" in Aristotle's theory of proof is understood as complete induction based on the study of *all* instances. Of course, generalizations through complete induction provide necessary and demonstrative knowledge. So principles and axioms, if acquired by complete induction, could really serve the corner stone of any theory.

But how can one use complete induction to explore natural phenomena? A mathematician can easily consider the complete set of types of triangles (rectangular, acute–angled and obtuse–angled) and study each one of them separately, eventually generalizing the results of inquiry through complete induction. Unfortunately, this scheme of research fails with natural phenomena since each one single phenomenon of nature can be different from the rest and require its specific examination. So Aristotle should realize that building theories of natural phenomena one could never be absolutely sure in his primary principles and axioms. Aristotle himself had mentioned that frequent observations of the same natural phenomena only "elucidate" the way to an axiom.

But there is another Aristotelian characteristic of scientific knowledge that makes his conception more acceptable to us. I mean the interpretation of scientific knowledge as of a necessary truth or rather of knowledge of necessary things and their interrelations. In *Analytica posteriora* Aristotle insisted that "scientific knowledge is commensurately universal and proceeds by necessary connections", and that which is necessary cannot be otherwise. Of course, such an understanding of scientific knowledge limits it to the field of necessary relations and objects. "So though there are things which are true and real and yet can be otherwise, scientific knowledge clearly does not concern them," admitted Aristotle.

Why is the interpretation of scientific knowledge as of knowledge of necessary things so close to the heart of the modern reader? The reason is that we all are brought up by classical science and therefore we all have a *deterministic* vision of the world. Though we cannot be sure that any building block of the universe is necessary by its nature, nevertheless we are convinced that all basic laws of nature are acting necessarily and unceasingly.

But we can learn the necessary things and their interrelations only through observation. So how can one be sure that a law of nature revealed by series of the present time observations will always and everywhere demonstrate its power and never fail? Judging from the way Aristotle handled numerous problems of natural philosophy, the effective method of revealing necessary interrelations was the theoretical proof that things could not be any other way. We suppose ourselves to possess scientific knowledge of a thing when we think we know the cause on which the fact depends and that the fact could not be other than it is. (*Analytica Posteriora* I1, 71 b10)

Case 2. The mystery of Aristotle's heritage

"for many centuries educated people called him respectfully teacher."

W. F. Asmus

The dimension of Aristotle's scientific heritage is one of the most striking mysteries of the whole history of human culture. Ancient science was composed of several separate components like physics and mathematics, astronomy and cosmology, philosophy and logic, geography and biology, conceptions of human mental and bodily health, theories of human society (including social, political and economical sciences), etc. Normally, each one of these sciences should have been worked out by a number of investigators. But the real history of science is definitely different. And this because of Aristotle. He created almost all sciences of the ancient world. His theories were so complete and in such harmony with people's experience that over two millennia they provided the educated mankind convincing answers to all arising questions and problems.

Aristotle's scientific heritage was so significant for the educated mankind that many generations referred him simply the teacher. Up to the last decades of the Middle Ages, to be a scholar meant to learn and comment works of Aristotle. Many of his works are read with interest even today. Literature on Aristotle involves thousands of authors. Aristotle built his theory of deductive inferences with such a rigorous proof that, in the eighteenth century, Immanuel Kant regarded Aristotelian syllogistics as an example of absolute truth that will never be surpassed by any new theory.

To realize the colossal dimensions of Aristotle's genius, let us just list his many works that were directly involved in forming the scientific world picture of the epoch.

Physica treatises, which presented the fundamental principles and theoretical considerations regarding change and motion in nature (*physis* in old Greek).

Meteorologica the explanation of the scope of phenomena of the sublunary world.

De Caelo the conception of the super–lunar world, its main problem being the dynamics of celestial spheres.

Metaphysica treatises on the first philosophy which presented the teaching of the essence of the existing world and a scrupulous analysis of fundamental philosophical categories.

Analytica Priora the famous theory of syllogistics, presenting the first theory of deductive inferences.

Analytica Posteriora the theory of knowledge, proof, and definition.

Topica the theory of dialectical reasoning, including the methodology of inquiry and scientific investigation.

The only possibility to tackle with the mystery of the enormous dimension of Aristotle's genius is to question the authenticity of works ascribed to him. Especially if one takes into account the medieval tradition of writing tractates under the name of Aristotle or Plato.

One of Aristotle's most significant contributions to science was his grandiose scientific picture of the world. Like many of his predecessors, he accepted that the sphere of the fixed stars was the outermost boundary of the universe. This boundary was evident to each one who ever looked at the night sky. Considering the fabric of the heavens, aristotle set forth two difficult, but extremely important questions. First, what is the source of the eternal motion in the universe?

The answer of Aristotle was clear. All material things of sublunary world are composed of four basic elements – earth, water, air, and fire. So the motion of each object comes from the natural motion of the elements present in its composition.

But then Aristotle asked the second cardinal question. Since the universe is eternal, why did not material things reach their natural destinations, which, in turn, would bring to the total stoppage of all the motion in the sublunary world?

The immediate cause, according to Aristotle, was the "reciprocal transformation" of the elements into each other. But there should be also the primary cause. In Aristotle's model of the universe there was place only for one single possible answer. That is, the motion of the sublunary world is supported by the impact of the motion of the heavenly spheres. In *Meteorologica* Aristotle directly stated that the revolution of the heavenly spheres is the primary cause of motion in the sublunary world.

The problem might appear solved. But not for Aristotle. Suppose, the sphere of the moon brings into motion the adjoining mass of air that in turn transmit their motion to the lower strata, then to water, earth and eventually to all objects of the sublunary world. But if a celestial sphere brings into motion air or anything else, then some other mover must bring the celestial sphere itself into motion. In the case of the moon, this mover could be the sphere of the sun. In its turn, it could be kept moving by the motion of the sphere of some other heavenly body, until we reach the outmost sphere of the fixed stars. Consequently following this line of thought, one should necessarily accept the existence of some ultimate mover, the so–called first mover, which had to keep in motion the outermost celestial sphere of the fixed stars.

Judging strictly, the necessity to introduce the extremely strange concept of the first mover should force Aristotle to revise the principles of his physics. The basic principles of his natural philosophy were in complete harmony with the everyday experience of the ancient Greek society. Aristotle himself demanded from the explorers to deny conceptions that do not agree with observational data. But what could be less compatible with everyday experience then the idea of the first mover presumed to keep in motion all the objects of the universe while being itself motionless and bodiless?

Theory is something that shall be surpassed. Yet each author of a fundamental theory may repeat after Horace, "*Non omnis moriar*" (I shall not all die). Though many basic Aristotelian conceptions are of significant interest even today, there is practically nothing inherited by Newtonian physics from Aristotle's natural philosophy. Many writers mention with apparent satisfaction that Galileo's telescope and Newton's mechanics had destroyed the system and basic principles of the Aristotelian physics.

Quite surprisingly, some ideas of Aristotle's physics, rigorously rejected by classical physics, reemerged in Einstein's general theory of relativity. Both Aristotle and Einstein denied the substantial conception of space and time as of universal containers of material objects and physical events. Aristotle developed the "relational" conception according to which time and space (or "place" in Aristotle's terminology) were characteristics of relations of the objects and processes of the physical world. Place could be viewed as the boundary of the containing body at which it is in contact with the contained body. It was quite evident that the earth was in water and this in air, and air in ether, and ether in the heaven. "But we cannot go on and say that the heaven is in anything else," noticed Aristotle. So one should suppose that no body contained the heaven. Which meant that the heaven as a whole was not in any place. It is quite clear that Einstein would fully agree with Aristotle's conclusion that "there is no place or void or time outside the heaven." (*De Caelo* I9, 279 a13.)

The most striking case of similarity of Aristotle and Einstein world views is, surely, the point that both great physicists admitted *the existence of the maximal speed of motion* in the physical world. Though Aristotle did not state this principle explicitly, it directly follows from his model of the universe. Aristotle was aware of the huge distance between the Earth and the stars. He stressed that the sphere of the Earth is negligibly small compared to that of the circumference of the universe. On the other hand, the sphere of the fixed stars possessed the fastest rotation in the universe since the first mover was situated immediately contacting with it. Thus one should realize that the speed of the orbital motion of the fixed stars must necessarily be the maximal speed of motion in the universe.

Another striking point provides Aristotle's mental experiment designed to prove that the Earth should have originated as a spherical body. Imagine the Earth coming–to–be from the initial chaos, as the old natural philosophers (the "physiologists") were used to tell. The particles of earth would emerge out of the initial chaotic mixture of elements and proceed according to nature to the place of their destination – the center of the universe. The bigger parts of mass of the emerging earth would "push forward" the lesser parts until all the parts of the earth particles get situated symmetrically around the center, forming thus the spherical body of the Earth.

In one of the recent studies of Aristotle's heritage, H. Scholz summed up his impression of *Analytica* as follows: "we hope for a reader who will salute a truly classical work, to which even the clever men of today may look up with awe and reverence." These wards can be justly extended to Aristotle's whole scientific heritage.

Case 3. The mystery of revolutions of orbs

"he saw his completed work at his Last breath upon the day that he died."

Bishop Giese

The lifework of Nicolas Copernicus *De revolutionibus orbium coelestium* ("On the revolutions of the heavenly spheres") presented a revolutionary theory of the heavenly world. It proved that the motion of the sun on the sky as well as the motion of all heavenly bodies was just an illusion. The real motion behind these apparent motions was declared the motion of the Earth itself.

How could people of those days believe in such a fantastic conception that demanded to put in motion the huge mass of the earth? Did the *revolutions* suggest some strong arguments to propagate this extraordinary world–view? What had driven Copernicus himself to believe in this strange conception? And for what reason did Copernicus delay the publication of his great creation for long years though his friends pressed him constantly to publish his valuable work?

As it is usual with great discoveries, we can only guess what arguments Copernicus did drive to build a radically new system of the world. But one factor seems quite evident. The new system of the world had an indisputable advantage of clear simplicity.

Copernicus' great work belongs first and foremost to astronomy. In the huge volume of the *De revolutionibus* non–mathematical considerations are discussed only in the first book. The main preoccupation of its author was to carry on calculations of the positions of the heavenly bodies. So it sounds quite convincing that at the start of his research copernicus could be attracted by the simplicity of astronomical calculations that the new system of the world should afford. How much attractive should seem to copernicus his system of the planets uniformly rotating in concentric circles round the sun compared to the Ptolemaic system of deferents, epicycles, eccentrics and equants.

Unfortunately, challenged by the task to make astronomical calculations at least as correct as those of Ptolemy, Copernicus had eventually to use 46 celestial spheres to fit his calculations with astronomical observations, a number quite comparable with the set of spheres used by Ptolemy.

For some historians of science, the most probable driving motif of Copernicus' revolutionary program seemed his dissatisfaction with Ptolemaic system as far as it could not be viewed as a consistent physical picture of the world. In actuality, Ptolemy's system provided only an effective instrument for precise astronomical calculations. If the Ptolemaic teaching were considered as pretending to suggest a system of the world, the impression could be only extremely negative. In fact, the geometric construction designed to present the motion of a given planet was completely independent from the constructions designed for other planets. Copernicus expressed his dismay with Ptolemy's approach quite vigorously. "It is as though, in his pictures, an artist were to bring together hands, feet, head and other limbs from quite different models, each part being admirably drawn itself, but without any common relation to a single body: since they would in no way match one another, the result would be a monster rather than a man," wrote Copernicus sarcastically.

By contrast to Ptolemy's geometrical constructions, Copernicus' model of the planets rotating round the sun should be first of all conceived as the *system of the world.* Copernicus could hardly avoid believing that the heliocentric system provides a possibility to build a consistent cosmological and astronomical model of the universe. In the preface of the *De revolutionibus* he emphasized that in his system, "the orders and magnitudes of all planets and spheres, nay the heavens themselves, become so bound together nothing in any part thereof could be moved from its place without producing confusion of all other parts and the universe as a whole".

Yet, discussing the classical arguments against a moving Earth, Copernicus introduced but little new ideas compared to those suggested earlier by medieval scholars Nicolas of Oresme and Nicolas of Cusa. In fact, Copernicus was on the defensive and could suggest only some possible explanations to apparent contradictions following from his heliocentric hypothesis. Most convincingly sounded his explanation of the illusion of the motion of the sun and the heavens: "It is like what Aeneas said in Virgil's *Aeneid* (III, 72): "we sail out of the harbor, and the land and the cities retire." When a ship floats along on a calm sea, all external things appear to the sailors to be affected by a motion which is really the motion of the ship, while they themselves seem to be at rest with everything which is with them on the ship. Doubtless, in the case of the motion of the Earth, it could happen similarly that the whole universe was thought to rotate."

But, strictly judging, one should admit that Copernicus had neither a decisive argument objecting the Ptolemaic system nor a convincing proof of his own heliocentric alternative. Actually, neither the spirit of the physical science of his day nor the level of the available means of astronomical observations did afford a possibility to accomplish these two tasks. One could to point out only the weaknesses of the old conception and the potential advantages of the new approach.

Continuing the critical line of argumentation, adherents of the heliocentric system could concentrate the attention of scientific community on the following strange feature of Ptolemy's system. The sun was not supposed to have any bearing on the motion of the planets. Yet the observable motion of each planet contained a component accurately equal to the period of the annual rotation of the sun. One should admit that such a precise coincidence in the movements of all planets, without single exception or any slight deviation, was unlikely to be a matter of accidence. At least, it demanded a profound study and explanation. On the other hand, such a precise regularity was a necessary conclusion in Copernicus' system since all the planets were observed from the Earth orbiting the sun just with this period of one year.

Unfortunately, there arose some specific complications. *De revolutionibus* relied upon astronomical tables available by those days. But these tables contained many inaccurate observational data, which caused immense trouble to tackle them. To publish the new system with lesser accuracy than that of Ptolemy would mean for Copernicus accepting his own defeat.

It will remain an unsolved mystery whether Copernicus really meant to rebuild radically the human vision of the world. Was Copernicus actually a rebel of scientific thought, as some writers like to present him? His life and work provide little ground for such an assumption. The later thirty peaceful years of his life he was the canon of the Frauenburg cathedral. Angus Armitage noticed about Copernicus' personality: "in his own age he must have passed for an exceptionally favorable specimen of the priesthood". Would a rebel keep his revolutionary work locked up for thirty years making some insignificant corrections in it at the very rare occasions? Copernicus never showed signs of stiff determination to come out publicly with his revolutionary system of the world. The constant pressure of his friends to publish his monumental manuscript, of which there was always much talking in scientific circles, had little effect. The first sketch of his conception, the *little commentary*, Copernicus never sent to publication but rather gave its handwritten copies to his closest friends only. The publication of the short summary of the great manuscript in 1540 was due solely to the personal initiative of Joachim Rheticus, a young german scholar. Copernicus agreed to publish the manuscript of the *De revolutionibus* already being fatally ill, just a few months before he completely lost all the ability of accomplishing any activity. The publication of the historic manuscript was carried on under the supervision of Copernicus' friend Andrew Osiander.

Far from being a rebel, Copernicus was apparently worried by the perspective of severe criticism from clerical circles. He had consulted on this issue with Osiander who wisely advised to present the *De revolutionibus* as a system of purely astronomical calculations. Judging from Copernicus' cautious behavior in regard of publication of his manuscript, it looks probable that he could agree with Osiander. But all writers like to blame Osiander for the short second preface *concerning the hypothesis of this work* where the task of Copernicus' book was defined as that of developing merely a new instrument for astronomical calculations. This tactical step of Osiander significantly neutralized the potential ideological critique of clergy, both Catholic and Protestant. But the second *preface* markedly weakened the revolutionary claim of Copernicus' work.

Case 4. Hypotheses non fingo

> *"fortunate Newton, happy childhood of science!"*
>
> Albert Einstein

By his intellectual capacities, Isaac Newton was probably the first scientist meeting the qualities required from the modern time theoretician. Newton was apprehensive in his research of the essence of physical phenomena, inventive in his interpretations of mysteries of nature, excellent in using mathematics, brave in building theoretical systems of natural science.

As his great predecessor Aristotle, Newton was convinced that science provides certain knowledge of nature. Both great geniuses had been led to this deep conviction by their unique ability to find out such convincing solutions of fundamental problems of natural science that their theories appeared to many generations clear samples of absolute truth.

By its historic impact, Newton's service to natural science is equal to that of great Aristotle's. "His law of gravitation", wrote sir Edmund Whittaker, "regarded then and now as the greatest of all scientific discoveries, was held to be ultimate and unassailable, the typical law according to which all other laws must be fashioned."

Today there can be no doubt that *all laws of nature are revealed with the help of the method of hypotheses.* Even the most profound laws of nature that seem to us absolutely certain and unshakable first emerge as hypotheses and some day should undergo certain corrections and generalizations under the pressure of new empiric data.

Then how it happened that one of the most gifted natural philosophers in all the history of science, Isaac Newton, rejected uncompromisingly the value of scientific hypotheses declaring his firm position, "*Hypotheses non fingo*" (I frame no hypotheses)?

There might be the impression that the general rejection of the method of hypotheses had serious reason in the framework of the *Principia* where every statement was strictly and rigorously proved. But Newton confirmed his position also in the *Opticks*. Here he stated the central principle of his methodology: "the main business of natural philosophy is to argue from phenomena without feigning hypotheses". In the last pages of the *Opticks* this position is also declared directly: "hypotheses are not to be regarded in experimental philosophy".

The mystery of Newton's negative attitude is underlined by the certain fact that just the last part of the *Opticks* contains a variety of hypothetical assumptions unprecedented by their number, range and significance in the entire history of physical science. These hypotheses covered an enormously wide range of subjects like the nature of light, the atomic structure of substance and causes of gravitation, mechanisms of heat transmission and the conservation of motion in the universe, cohesion of bodies and the nature of chemical forces, the action of light rays on solid bodies and formation of visual images, etc., etc.

Newton's real attitude to hypotheses reveals itself in his deliberations concerning the nature of light. Newton suggested his corpuscular conception of light in the third book of the *Opticks* as an apparent hypothetical assumption: "are not the rays of light very small bodies emitted from shining substances? For such bodies will pass through uniform mediums in right lines without bending into the shadow, which is the nature of the rays of light."

The interesting point in this text is the argument that rays of light do not bend into the shadow. This argument indicates how seriously did Newton consider the *alternative wave conception of light*. It shows also that by that time Newton had not yet observed the phenomena of the diffraction of light. In these circumstances, it was quite natural to prefer the corpuscular conception, the general idea of which in this or another form was discussed already by ancient natural philosophers.

The striking thing is how inventive was Newton using the corpuscular conception. Trying to explain observations of the colors of thin plates, Newton introduced the extraordinary idea of "fits" of *easy reflection and easy transmission*. Deliberating upon the nature of his hypothetical "fits", Newton found nothing better but to view them as caused by *vibrations of ether*. Many reviewers of the Opticks thought that both the ideas, those of vibrations and of ether, were incompatible with Newton's fundamental principles. The first of them was in obvious contradiction with the *corpuscular conception of light*, while the second meant a definite retreat from the basic conception of the *action at distance*.

In reality, Newton just followed his main *methodological principle to draw causes from the phenomena and to be free from preconceived ideas*. Vibrations were the only possible cause able to produce the observed periodical stripes in the colors of the thin plates. So Newton should have no hesitation to use this idea though it apparently belonged to the domain of the rival wave conception.

Newton presumed the same ethereal medium when hot bodies communicate their heat to contiguous cold ones and when light communicates heat to bodies that absorb its rays (query 17 of the *Opticks*).

But what could be the nature of this mysterious medium? There was no other way but to suppose that ether, like air, *should be composed of particles*, which endeavor to recede from one another and are exceedingly smaller than those of air, or even of those of light. These properties seemed necessary in view of the fact of the regular motion of the planets and comets in space. "The exceeding smallness of particles," explained Newton, "may contribute to the greatness of the force by which those particles may recede from one another, and thereby make that medium exceedingly more rare and elastic than air, and by consequence exceedingly less able to resist the motion of projectiles, and exceedingly more able to press upon gross bodies, by endeavouring to expend itself."

Newton could not resist the temptation to suggest that ether might be accounted also for the action of electric and magnetic forces though the factual knowledge of these forces was minimal by his day. Moreover, Newton, who earlier rejected to consider the nature of gravity, bravely assumed in the *Opticks* that just a subtle ethereal medium could be accounted for the gravitational attraction. "If the elastic force of this medium be exceeding great, it may suffice to impel bodies from the denser parts of the medium towards the rarer, with all that power which we call gravity," suggested Newton his brave hypothesis.

This apparent contradiction of wide use of hypotheses with the general declaration "*Hypotheses non fingo*" can be eased in a degree if we take into account the main principle of Newton's *inductive methodology according to which scientific research should advance by progressive step by step generalizations.* In the light of inductive methodology, one had to reveal immediate causes of the phenomena under research but *not to jump to speculative hypotheses.* Yet this argument, though significant and helpful, is not sufficient for a complete resolution of the mysterious contradiction. For Newton clearly realized that his suggestions concerning the nature of light were far from being certain solutions of problems under discussion. He had to admit that in regard of the number of unresolved problems he had proposed "only some queries, in order to a farther search to be made by others". Summing up his discussion of the problems to be solved, Newton wrote in the final page of the *Opticks*, "in this third book i have only begun the analysis of what remains to be discovered about light and its effects upon the frame of nature, hinting several things about it, and leaving the hints to be examined and improved by the farther experiments and observations." By these words, Newton actually admitted that his "hints" were *working hypotheses*, which should be "examined and improved" by further experimental and theoretical research – a program perfectly in line with the method of hypotheses.

Newton's thinking could not avoid hypotheses since his mind was preoccupied by most cardinal questions regarding the material world. Here is the short list of questions from the *Opticks* that Newton would like to find an answer: "what is there in places almost empty of matter, and whence is it that nature doth nothing in vain; and whence arises all that order and beauty which we see in the world? To what end are comets, and whence is it that planets move all one and the same manner of ways in orbs very excentrick; and what hinders the fixed stars from falling upon one another?" By the day of the great physicist, any answer to this kind question should be a speculative hypothesis.

Case 5. So close to solving all mysteries

"matters that vexed the minds of ancient seers, Now are seen in reason's light..."

Edmund Halley

By the end of the nineteenth century physicists believed they had already succeeded to explain all the unlimited variety of natural phenomena. The mysterious point of their tremendous achievement was that all the completely different fields of natural phenomena were given purely *mechanical* explanation. Factually, all complex and divergent phenomena had been reduced to simple, if not primitive, *mechanical models.*

From the days of Democritus and Plato, natural philosophy sought the eternal basis of the ever–changing material world. Democritus suggested this eternal basis were atoms; Plato believed the real world was the world of ideas; Aristotle proved this basis was matter presented in the form of the interchanging four elements and transformed by forms. To Newton the physical world consisted of inert masses and forces of interaction. With the discovery of the *law of conservation and conversion of energy*, science introduced a *new eternal feature* of realty. In all the unlimited variety of changes occurring in nature, one thing remained unchangeable – the total energy. So it became a new paradigm of scientific thought to reveal in all natural occurrences the conversion of some form of energy into other forms, strictly retaining the amount of the total energy.

Besides theoretical mechanics, the nineteenth century classical science developed two fundamental theories that had essential bearing on the general world picture. I mean the theory of *electromagnetism* and that of *thermodynamics*. Electric and magnetic phenomena are so essential for our understanding of nature that the development of electromagnetic theory was a very significant contribution to the scientific world picture. Besides the laws of electromagnetic phenomena, the new theory introduced into physical science the idea of the *field* that later became one of the most fundamental conceptions of physical science.

Thermodynamic approach started by the discovery of the quantitative relation existing between *heat* and *work*. Soon the laws of thermodynamics were formulated as the most fundamental laws of nature. Thermodynamics proved that all forms of energy eventually transform into thermal energy. And this final form of energy should be distributed uniformly all over the universe. Since the universe is practically infinite while the number of hot stars is quite limited, the process of establishing of the thermal balance in the macrocosm should mainly result in the total cooling down of all the stars all over the meta–galaxy. So the main philosophical conclusion from the laws of thermodynamics was the dull picture of the "cold death" of the universe.

The world picture drawn by classical science appeared extremely distressing. The *heliocentric* world picture was the first hard blow to the self–esteem of humanity so well used to the idea of being the center of all things. The situation became downright unbearable when astrophysicists proved by the end of the nineteenth century that the sun itself was just a medium size star lost among billions of stars of the galaxy. Then it was revealed that the galaxy itself was one of the innumerable "isles" of stars in the limitless universe. So what importance could have the mankind drifting on a tiny particle undetectable in the infinite dimensions of the universe?

The only consolation for the mankind was the discovery that all the heavenly bodies were composed of the *same substance* as our earthly world. Being aware of colossal distances to nearest galaxies which even the light beam had to travel for hundreds years, one should conclude that the mankind will never know anything definite about the composition of stars and processes going on there. But a simple discovery radically changed the situation. Gustav Kirchhof and Bunsen revealed in 1860s that the spectra of the *beams of light* contained essential *information* about substances that had emitted them. It was soon proved experimentally that stars are composed only of elements, which are well known on the Earth. Only the typical substance of many stars, helium, was first discovered in the spectrum of the sun, and only afterwards on the Earth.

Already by the end of the eighteenth century, light was understood as a special type of wave propagation. But even the wave conception of light was interpreted in the frame of mechanistic approach. It was quite evident that waves need a medium to be propagated. Physicists readily accepted that there should necessarily exist a special kind of medium – the luminiferous *ether*.

The mechanistic vision of the world was so natural for the nineteenth century scientists that even Michael Faraday elaborated his physical conceptions in complete accord with mechanistic approach. Though it was Faraday who first proposed the idea of physical field, the corner stone of the twentieth century non–classical world picture, *his understanding of the field was rather mechanistic itself*. According to his conception, forces of magnetic field were acting along the special kind of tubes which filled space around magnetic poles. Moreover, Clerk Maxwell, who built the physico–mathematical theory of electromagnetic phenomena, preferred to interpret the essential points of his own theory with the help of various mechanical models.

By the end of the nineteenth century, lord Kelvin, then the president of the Royal Society of London and the most prominent scientist of those days, was eager to declare that science succeeded to explain all the secrets of nature. There remained, in lord Kelvin's words, only two small "clouds" on the sky of natural science – the *distribution of energy in the radiation spectra and the speed of light in the moving substances*. But just these two small clouds started the tremendous thunderstorm that shook fiercely the very foundations of classical science.

Besides these two particular phenomena that nature had designed to help scientists to get a deeper understanding of its laws there were at least two basic questions that troubled the mind of an adherent of classical physics. The first was the traditional question of the nature of *gravitational attraction*. The second troubling question arose in regard of the new basic component of physical world picture, the ether.

Newton was very cautious tackling the question of the nature of gravity. Finally he concluded that one should be satisfied by realizing the existence of the law of universal gravitation. "and to us it is enough," admitted the great physicist, "that gravity does really exist, and acts according to the laws which we have explained, and abundantly serves to account for all the motions of the celestial bodies." This modest approach appeared to be fully justified. Apart from Albert Einstein's radical conception, that tended to unify the gravitating masses, energy and space in one physical *continuum*, scientists did not succeed to suggest any satisfactory solution up to the present time.

Possibly, already the nineteenth century scientists had to realize that the *question* of the nature of gravity *is not correct in its essence*. I mean the status of the concept of gravity. The law of universal gravitation was the most basic law of classical physics. Demanding to answer the question of its nature, one should realize that this answer is *possible only on the basis of a new, more fundamental theory*. And this was possible only if one could suggest a *law more basic and more general* than the law of the universal gravitation. In actuality, up to Einstein's attempts to develop general relativity, all scientists were completely satisfied by the Newtonian law. So any deliberation on the nature of gravity in the frame of classical physics was principally incorrect. It was like demanding to define gravity with the help of a more basic concept. But already Aristotle explained that *the basic concepts of a theory could not be subjected to definitions.* Their essence is revealed in *corresponding laws, principles, and axioms.* Newton's law of gravity was one of the most fundamental laws of classical physics. Asking for additional explanation of its nature in the frame of classical physics was as incorrect as asking for a definition of the concept of gravity.

A basic concept of a theory may be defined only in the frame of the more general theory. The question of the nature of gravity may be correct only in the frame of the more general physical theory like Einstein's general relativity. But the time of the more general theory had yet to come.

At first sight, the above argument seems applicable also regarding the nature of the ether, the medium of classical electromagnetic theory. But here the situation got significantly complicated. By the end of the nineteenth century it was realized that ether had to have a set of extremely strange properties. It had to be weightless, frictionless, undetectable, pervading all matter and space, etc. To believe in the existence of a substance with such an unbelievable set of properties was something very close to a kind of superstition.

Case **6. The mystery of the origin of species**

> *"the origin and its author have a history which runs silently and mysteriously through twenty years of ill health, lone effort, and corroding doubt."*
>
> Loren Eiseley

There is a great mystery concerning Charles Darwin's celebrated creation, the theory of evolution. In later life, Darwin claimed that he came to the idea of the evolution through natural selection already in 1838. But the fact is that up to 1858 none of Darwin's published works contained any slight attempt to prove or just to discuss the idea of evolution. But how could it happen that during long twenty years Darwin did not publish a single sentence on his great discovery until Alfred Wallace sent him his paper that suggested the principle of natural selection?

This mysterious gap between the time of the alleged discovery of the principle of natural selection and the publication of Darwin's *Origin of Species* caught the attention of many writers. "The sources of such long continued mental effort," mentioned Loren Eiseley, "are not always easy to discern, and it is unlikely that Darwin himself preserved to the end of his life clear memories of all his multiform activity during the years when he was engaged upon his book."

In actuality, there was a serious factor that almost *excluded* for Darwin the possibility to discover natural selection. This factor was Darwin's unlimited devotion to the alternative principle of *inherited effects of use and disuse of parts* and his strong belief in *the direct action of physical conditions.*

All over the pages of *The Origin of Species* proving the decisive role of natural selection, Darwin persistently mentioned also the role of use and disuse of parts. Concluding his celebrated work, Darwin wrote that the modification of species "has been effected chiefly through natural selection of numerous successive, slight favourable variations; *aided in an important manner by the inherited effects of the use and disuse of parts*; and in an important manner, that is in relation to adaptive structures, whether past or present, *by the direct action of external conditions*, and by variations which seem to us in our ignorance to arise spontaneously."

To be understood clearly, Darwin emphasized that the latter two forms of variation lead to permanent modification of the structure of organisms "independently of natural selection". It is true that *The Origin of Species* is mostly a demonstration of the *unlimited capacities of the principle of natural selection in explaining general features and peculiarities of the evolution of species.* Yet, in almost each of these demonstrations, Darwin persistently added that natural selection can or should be helped by the mechanism of *use and disuse of parts.*

These strong bonds with the hypothesis of evolutionary importance of use and disuse of parts and direct action of external conditions almost push us to a crucial assumption. *Namely, that in Darwin's manuscripts of his first attempts of developing the theory of species, just the principles of use and disuse of parts and action of external conditions were initially presumed as the mechanism of the variation of species.* While the principle of natural selection appears to be a later insight, most probably conceived only after receiving the memoir of Wallace.

We have already mentioned how uncompromisingly scientists did defend their important ideas and hypotheses, clinging to them even when opposed by strongly contradicting facts and rigorous theoretical objections. By contrast to this universal rule, Darwin was never strong and incisive in defending the principle of natural selection.

In 1867, Fleeming Jenkin, an erudite Scotish engineer, strongly criticized Darwin's theory. He mentioned that a favorable new character possessed by one or a few rare mutants, which Darwin considered the initial step of evolution, would soon be swamped out of existence in any population group in which it occurred. Jenkin's calculations proved that a new favorable character could survive only if it emerged simultaneously throughout the majority of the population. Loren Eiseley stressed that Jenkin's challenge could be answered only by genetic theory of inheritance, yet unknown in the day of Darwin. Nevertheless, Darwin too readily admitted that the principle of natural selection was insufficient to build the theory of evolution. Under the pressure of critique, in the later editions of the Origin of Species the principle of natural selection was supported by the idea of use and disuse of parts and direct action of conditions.

In *The Descent of Man* (1871) Darwin directly admitted his retreat from his earlier view of the principle of natural selection as of leading motif of his theory of evolution. In that most characteristic volume of his theory of evolution, Darwin wrote that he "attributed too much to the action of natural selection".

Darwin's favorable principles of use and disuse of parts and action of conditions are apparently non–Darwinian if natural selection is understood as the corner stone of Darwinism. The assumption of the inheritance of variations emerging through use of parts and action of external conditions is diametrically opposite to the ideology of natural selection. Factually, Darwin's principles of use and disuse are incompatible with natural selection. The latter selects and accumulates favorable variations among a mass of fortuitous, chaotic modifications. While Darwin's principles of use and disuse of parts and action of conditions deal from the start with favorable variations.

How could the increased use of a particular part of an organism bring finally to the emergence of a new variety with a given favorable character? It could happen if and only if the increased use of that part would modify the organism in a favorable manner. In that case, the inheritance of such modifications through successive generations could be accounted for the emergence of a new variety with the given particular feature.

Darwin believed that variability was generally related to the conditions of life to which each species has been exposed during several successive generations. He tried to show that "*changed conditions act in two ways*, directly on the whole organization or on certain parts alone, and indirectly through the reproductive system". "The direct action of conditions of life produce well directed favorable modifications that cannot be evaluated as being fortuitous or chaotic. The principle of use and disuse of parts presumes same kind modifications too. But assuming initial favorable variations, one would have no need of natural selection to deal with them. So, any biologist who accepted the principle of use and disuse of parts and direct action of conditions would hardly need natural selection. This implies the crucial conclusion that biologists with such vision of variation of species least of all would be inclined to discover the principle of natural selection.

Thus we come to the following final conclusion. Preparing and elaborating during long years his manuscript on the problem of species in the light of the principle of use and disuse of parts and action of conditions of life, Darwin neither did need the principle of natural selection nor had any chance to discover this principle. Darwin's non–Darwinian principles were not just an occasional misjudgment of an inexperienced investigator. On the contrary, they emerged from Darwin's vast experience in regard of the problem of species and his excessive studies of variation under domestication. Darwin was strongly convinced that *under domestication there was more variability and more monstrosities than under nature*. This conviction he advocated in many occasions in the Origin and even after its publication. Such a hypothetical feature of variability, or "fact" in Darwin's opinion, could be accounted only to the action of change of conditions.

Case 7. Did Max Planck discover quanta of energy?

> *"with his quantum hypothesis he dethroned classical physics."*
>
> Albert Einstein

The answer to the paradoxical question suggested in the headline of this section depends on its context. Planck did discover quanta of energy if we consider the way his work influenced the development of atomic physics. But if Planck's conception is approached rigorously just as a work of theoretical physics, the conclusion must be that it did not provide a correct proof of the quantum nature of energy.

In the last decade of the nineteenth century, the failure of classical electromagnetic theory to treat satisfactorily the experimental data concerning *short wave radiation* puzzled many theoreticians. Later the situation was labeled as "ultraviolet catastrophe", the term "violet" pointing out the short boundary of optical radiation. Planck approached the problem of short wave radiation from the point of view of *statistical physics*, namely using the conception of *entropy*. At first sight, Planck's approach may seem absolutely strange since electromagnetic radiation was understood as a specimen of *continuity*, while the statistical physics is applicable only to *discrete* systems.

In actuality, Planck's statistical approach applied quite normally to the building of the theory of heat radiation. Radiating bodies are complex systems of atoms. So the problem was not just of the *radiation* of atoms but also that of the radiation of *atoms*. Since radiating objects are usually huge complexes of atoms, heat radiation could be adequately described by the means of statistical physics.

Anyhow, the study of the statistical model did not produce significant results. Planck was forced to tackle the problem from another side, that of thermodynamics. In this field he felt himself quite confident since during many years he had profoundly analyzed the laws of thermodynamics.

The intensive research of the problem made it necessary to realize the essential role of the *universal constants of the laws of radiation*. They were two. The first was the well–known *Boltzmann's constant*. The significance of the second universal constant appeared more complex. It represented the *product of energy and time*, that physicist called *action*. So the second constant could be viewed upon as the elementary quantity of action or, using the Latin term, the *quantum* of action. Similar considerations could bring Max Planck to the idea of *quanta of action*, from which there was a short distance to the hypothesis of the *quanta of energy*.

Of course the suggestion that heat radiation is composed of *discontinuous* quanta or atoms of energy was absolutely incompatible with the principles of classical physics. Yet to consider energy in terms of quanta, as a *transitional* means for reaching the real basis of the nature of heat radiation, could seem quite admissible. Especially: if we take into account that all the research was carried on in the light of statistical physics and thermodynamics where scientists were used to deal with discontinuous entities, that is, atoms and molecules. This way or another, Planck suggested his revolutionary hypothesis of *quantum structure of energy of radiation*.

In the history of revolutionary conceptions, it is the first step that counts. The first, and most decisive, confirmation of quantum conception came from Albert Einstein's investigations. In his Nobel lecture, Max Planck clearly admitted that the acceptance of quantum conception was due not to the experimental proof of the law of energy distribution or to the theoretical derivation of that law. It should rather be attributed to the restless forward trusting work of those research workers who used the quantum conception to help them in their own investigation.

Einstein's discovery of *photons of light* is traditionally viewed as a direct application of Planck's theory of quanta of energy to the phenomenon of absorption of light. Such an interpretation is natural and has an evident logic. But in that case what was the greatness of the discovery of photons? By that time, it was already well known that light is a particular case of *electromagnetic radiation*. So light unavoidably should be understood as *composed of quanta* too. The revolutionary essence of Einstein's discovery can be revealed only taking into account historical realities and scientific paradigms at the start of the century and, what is no less important, Einstein's personal attitude to Plank's quantum conception.

But first, what was wrong with Planck's approach to the problem of radiation? By analogy with Boltzmann's approach to molecular statistical mechanics, Planck considered radiation as a chaotic gas under the natural presumption that in each state of energy there could be only one particle. In the case of such statistics, later labeled Fermi–Dirac statistics, the conclusion of discrete quantum structure of radiation appears completely justified. But already in the early 1870s J. Willard Gibbs developed a definitive theory of *statistical equilibrium*. In 1901 he presented a rigorous and most general theory of statistical thermodynamics where, in particular, he considered the option of an entirely different statistics of particles that could occupy the same state of energy in unrestricted numbers. The conception of this statistics was in 1924 independently rediscovered by Bose and developed further by Einstein. In the frame of Bose–Einstein statistics, the "ultra–violet catastrophe" resolved without introducing the assumption of quanta of energy.

But even in 1905 Albert Einstein would not agree that his conception of photons is a direct application of the idea of energy quanta to particular physical phenomena like that of photoelectric effect. His 1905 famous paper clearly pointed out what was the source of the idea to introduce the conception on quanta of light. "Indeed, it seems to me", explained Einstein, "that the observations of black–body radiation, photoluminescence, production of cathode rays by ultraviolet light, and other related phenomena associated with the emission or transformation of light appear more readily understood if one assumes that the *energy of light is discontinuously distributed in space*. According to the assumption considered here, in the propagation of a light ray emitted from a point source, the energy is not distributed continuously over ever–increasing volumes of space, but consists of a finite number of energy quanta localized at points of space that move without dividing, and can be absorbed or generated only as complete units."

Einstein quite clearly stated here that he was driven to his hypothesis by the inability of the classical conception to deal with the newly discovered phenomena of the *interaction of light with the ponderable matter* like those of the phenomena of production of cathode rays by ultraviolet light.

Now let us consider the matter in more detail. The 1905 paper on quanta of light began with a general *methodological* remark regarding energy radiation: "a profound formal difference exists between the theoretical concepts that physicists have formed about gases and other ponderable bodies, and Maxwell's theory of electromagnetic processes in so–called empty space… according to Maxwell's theory, energy is considered to be a continuous spatial function for all purely electromagnetic phenomena, hence also for light, whereas according to the present views of physicists, the energy of a ponderable body should be represented as a sum over the atoms and electrons. The energy of a ponderable body cannot be broken up into arbitrarily many, arbitrarily small parts, but according to Maxwell's theory (or, more generally, according to any wave theory) the energy of light ray emitted from a point source continuously spreads out over an ever–increasing volume."

In this introductory remark two points should be underlined. First, the idea of *discontinuity* is introduced in opposition to the classical conception of continuous energy emission. And second, in regard of the *discontinuous structure of ponderable bodies and their energy*, Planck's quantum conception is not mentioned in general. Both these specific features come out more clearly and strongly in the succeeding two paragraphs of the paper. Of course, the wave theory of light, which operates with continuous spatial function, has proved itself superbly in describing purely optical phenomena and will probably never be replaced by another theory. But the things seem radically different when the phenomena of the radiation of light are considered. The young author of the paper was convinced that the classical theory of light "leads to contradictions when applied to the phenomena of emission and transformation of light".

And here comes the principal argument: "indeed, it seems to me", insisted Einstein, "that the observations of 'black–body' radiation", photoluminescence, production of cathode rays by ultraviolet light, and other related phenomena associated with the emission or transformation of light appear more readily understood if one assumes that the energy of light is discontinuously distributed in space. According to the assumption considered here, in the propagation of a light ray emitted from a point source, the energy is not distributed continuously over ever–increasing volumes of space, but consists of a finite number of energy quanta localized at points of space that move without dividing, and can be absorbed or generated only as complete units."

Most surprisingly, the new quantum conception of Planck is not mentioned again though it had a direct and most important bearing on the issue. But such a position had its definite ground. The context of the introductory arguments of the 1905 paper shows that for Albert Einstein, by that time, the real ground for suggesting the conception of spatially localized energy quanta was not Planck's hypothesis. Einstein was driven to his hypothesis by the *inability of the classical conception to deal with the newly discovered phenomena of the interaction of light with the ponderable matter like that of the phenomena* of production of cathode rays by ultraviolet light.

Case 8. The mystery of Schrödinger waves

"the idea of your work springs from true genius."

Einstein to Schrödinger

Schrödinger wave function is the most effective instrument of theoretical atomic physics. The idea of wave properties of electrons and, in general, of duality of matter and waves came forth in 1923 in Louis de Broglie's doctoral theses. Actually, Louis de Broglie proposed not only the general idea of wave–particle duality, but also mentioned that in the light of the new conception it could be natural to assume that electrons vibrate inside the atom in the form of spatial standing waves. If he had been more mathematically gifted, he would soon develop the wave mechanic theory of atom. But this last task accomplished Erwin Schrödinger.

The source of the startling conception of wave–particle duality was apparently Einstein's discovery of photons. In 1905, Albert Einstein proved that light was composed of particles the energy of which depended on the frequency of the corresponding light wave $E = h\nu$. In his turn, de Broglie suggested that each particle of matter should demonstrate wave properties, the length of the wave λ being inverse proportional to the product of the mass and speed of the particle $\lambda = h/mv$. There is such a striking similarity between the above–mentioned formulas and ideas that it seems very probable that some kind of analogy with Einstein's conception should help de Broglie in his great insight.

Though I did not find a direct confirmation of my assumption in the works of de Broglie, there are plenty of indirect ones. For instance, I would like to quote the following passage from *The Revolution in Physics*: "and it was desirable to establish this association so that the general rule expressing the connection between the wave and the corpuscle would, when applied to the photon, yield the well–known and well–verified relations *established by Einstein* expressing the association of photons and light waves."

Over a decade after his discovery, Louis de Broglie told of two other factors that led him to the conception of wave–particle duality. First, "a purely corpuscular" theory sounded to him unsatisfactory since it was unable to answer what frequency should have photons. "on the one hand", wrote louis de broglie, "the quantum theory of light cannot be considered satisfactory, since it defines the energy of light–corpuscle by the equation $W = h\nu$, containing the frequency. Now a purely corpuscular theory contains nothing that enables us to define a frequency; for this reason alone, therefore, we are compelled, in the case of light, to introduce the idea of a corpuscle and that of periodicity simultaneously."

But where could de Broglie meet "a pure corpuscular theory"? Einstein's photon theory was a theory of corpuscles of *light*, and as such it should have initially the information concerning the frequency of light. The second source, mentioned by de Broglie, was the quantum model of the atom. "on the other hand", continued de Broglie his argument, "determination of the stable motion of electrons in atom introduces integers: and up to this point the only phenomena involving integers in physics were those of interference and of normal forms of vibration. This fact suggested to me the idea that electrons too could not be regarded simply as corpuscles, but the periodicity must be assigned to them also."

As an abstract possibility, de Broglie's argument sounds quite convincing. But if this kind of reasoning had brought him to the conception of wave–particle duality, than de Broglie should have come to the theory of electrons vibrating in atom. But that could happen only at the next stage of building the wave mechanics, namely, by applying it to the problems of atomic radiation.

On the surface, Schrödinger wave approach was an attempt to build atomic physics on the basis of classical mechanics. But in essence, it assumed an extremely radical, a really "crazy" idea. A free electron outside the atom felt itself, at large, as a particle. But getting inside the atom and becoming its structural part, the electron should be transformed into a pure wave of electric substance.

The philosophical difficulties of the wave approach should be very disturbing. But they were significantly stifled due to immense success of wave mechanics as of an extremely productive instrument of theoretical calculations. All the parameters of atomic world were easily described with the help of *wave function*. It was unanimously accepted soon that the three conceptions of atomic physics – Schrödinger wave mechanics, Heisenberg matrix system, and Dirac operator approach – were equivalent systems of the newly born quantum mechanics.

What regards the philosophical difficulty of the transformation of electrons within the atom into waves of electric substance, Max Born overcame it with the help of his *probabilistic* interpretation. According to this conception, the wave function described not the actual position of electrons inside the atom but rather the probability of finding an electron in different points of space inside the atom. The wave function became a universal means for the description and calculation of all physical parameters in the atomic world. But the idyllic picture of complete incorporation of wave mechanics into the framework of probabilistic conception of quantum physics, in fact, contained a number of serious problems.

Niels Bohr and his colleagues and followers strongly believed that probability was built in at the very foundation of the micro–world. They denied that quantum mechanics was unable to give a deterministic description of atomic world just because of lack of knowledge about the processes going on there at the sub–atomic level of physical interactions. Probability *was regarded a necessary feature of each sub–atomic event*, independent of the number of interacting particles or conditions of interactions.

Was there a firm empiric ground for such generalization? The answer to this question can be both positive and negative depending on its aspect. The positive answer is grounded on the brilliant experiments carried on by Davison and Germer that proved that a beam of electrons passing through a crystal produces a diffraction picture. This discovery confirmed de Broglie hypothesis and forced physicists to admit that science should *reject the classical belief that particles and waves belong to different domains of physical reality.*

But the answer to the above question should be negative if one takes into account that experiments on electron diffraction proved wave properties of electrons but not their probabilistic nature. Wave properties could be interpreted as supporting the standpoint of classical mechanics as well. Niels Bohr, Max Born, and other adherents of the Copenhagen school insisted on the probability as the essential feature of atomic events but apparently underestimated the wave properties of atomic particles. Born denied electron standing waves, but he readily used the wave function. Yet, on the macro level, one could not show any difference between the standing wave of an electron in the atom and the sum of positions of an atomic electron described by the wave function. In both cases, a macro–observer would have the same picture of a cloud of electric charge inside the atom in the form of standing wave.

In one point Schrödinger and Heisenberg held the same orthodox view. They both denied believing in trajectories of electrons inside the atom. I am not going to insist that electron's inside the atom move on separate trajectories in the classical sense of the term. But I would like to point out that Schrödinger and Heisenberg rejection of the reality of electron trajectories did not follow from a deeper insight into the physics of the micro–world. In actuality, neither wave mechanics nor matrix system had sufficient means to describe electron's motion along its orbit. If for some reason Schrödinger and Heisenberg found admissible to consider the orbital motion of atomic electrons, they would not be able to describe it by the means of their theories.

Returning to the problem of the equivalence of matrix approach and wave mechanics. If Schrödinger had abandoned his far going claim of reducing all micro–world to material waves, he could easily sustain the principle of wave–particle duality in his system. But there is no comprehensible place for the fundamental principle of wave–particle duality in Heisenberg's matrix version. There is no slightest possibility to speak of waves in the Heisenberg version of quantum mechanics. So one cannot talk seriously of the equivalence of the main systems of quantum theory. Perhaps, it is time to realize that they are *partial theories*, which are able to describe the atomic world only combining their efforts. But in this case one should realize the necessity to develop a really fundamental theory of atomic physics.

Case 9. Einstein refuting relativity?

"probably every theory will some day experience its 'no'"

Albert Einstein

It is really a mystery, how could Albert Einstein develop the conception of the absolute basis of the physical world – that of the notion of entity of space, energy, gravitational masses, and fields. Did not this absolute basis of existence refute the conception of total relativity proved by Einstein's special and general theories of relativity? The special theory of relativity is usually praised for the deeper understanding of space and time. Einstein proved that all inertial frames of reference were equivalent. That meant that there is no absolute space, no absolute time, and no absolute motion. Soon the conception of world ether was also abandoned since it implicitly presumed the presence of absolute space.

But did it mean that the relativistic correction of classical mechanics was logically necessary? In retrospect, many contemporary physicists are ready to suppose that Michelson's experiment was quite sufficient for Einstein to proceed with his cardinal reconstruction of classical mechanics. Several other writers go even further and insist that Einstein derived the whole conception of relativity just out of his own head having no information concerning relevant empiric data.

In actuality, the historic process that eventually brought to the formation of relativistic mechanics began with the difficulties of classical electromagnetic theory to describe the motion of fast moving electrons. Then problems came with the speed of light when experiments proved that it was independent of the speed of the hypothetical ether (Fizeau, 1851) as well as of the speed of the source of light (Michelson, 1881 and 1887).

The negative conclusions of the special theory of relativity concerning absolute space and motion sounded very convincing and categorical. It was quite easy to accept that there was no absolute motion. So, one had to accept that motion could be only relative. It appeared also completely clear that there was no absolute space.

But what did the theory say positive regarding the essence of space? When Minkowski presented relativistic mechanics in terms of four–dimensional continuum, the educated public was soon informed of new revolution in understanding the essence of space and time. It was declared that modern mechanics rejected the old belief of space and time as of independent characteristics of the physical world. Since space and time coordinates of events were presented by Minkowski as components of the unified space–time continuum, writers on the theory of relativity convinced their readers they should stop making difference between space and time.

It is really surprising how easily the adherents of the new belief succeeded to forget that *space coordinates served to describe distance and extension* while time described a very different thing – *change and motion*. If one day a young driver learns that car engine, wheels, chassis, seats, etc. are just separate parts of car, would it mean that the engine should lose for him its special statue? Why should any newly discovered property or interrelation of space and time coordinates change their essentially different standings as of fundamental characteristics of the physical world? No new discovery can change the fact that the concept of space emerged as an abstraction of extension of physical bodies and distances between them. Likewise, the concept of time had been formed as an abstraction of duration and succession of events.

Of course, one never could imagine in classical mechanics that there existed any link between space coordinates and time. It was really strange that the length of a rod or the pace of a clock might depend on the speed of the frame of reference. The relativity of simultaneity of events, proved by Einstein, and the invariance of the space–time interval, introduced by Minkowski, required long consideration and much effort to be properly understood.

For Einstein the invariance of a physical law was the most necessary indicator of its claim to be a true description of reality. So it seems quite possible that Einstein would accept the absolute character of space–time intervals since it is an invariant characteristic of physical events independent of the speed of motion of the reference system. This argument may be supported by Einstein's remark in *Mein Weltbild*: "the four–dimensional space of the special theory of relativity is just as rigid and absolute as Newton's space."

Apparently, the special theory of relativity had not any new answer to the most fundamental philosophical question of science, "what is space?" What would be Einstein's answer if he were asked "what would remain there if all material objects, charges and fields were removed from the universe?" Even after the discovery of relativistic mechanics, but before the creation of the general theory of relativity, Einstein, most probably, would agree with the answer given by classical physics: "there would remain empty space." Following Minkowski's terminology, one could give a slightly different answer: "there would remain empty space–time continuum." But the difference between this answer and that of classical mechanics is not essential.

The space component of four–dimensional continuum is the good old Euclidean space. In classical physics, space was understood to be the universal receptacle of all the objects of the physical world. Similarly, the four–dimensional continuum of special relativity functioned as the universal container of all physical events.

The problem of the essence of space became the central issue of the general theory of relativity. Here Einstein's genius demonstrated its immense dimensions. Even the greatest minds of scientific thought, after they had made a revolutionary discovery and advanced science into a new epoch, *still remained themselves in the framework of general paradigms of their epoch*. The special theory of relativity opened a new chapter in the history of physics. Its revolutionary insight into laws of mechanical motion radically changed scientific conceptions of mass and energy and provided new understanding of the essence of relativity and invariance, and so on.

The only scientist who tried to think of a post–Einsteinian world was Einstein himself. His general theory of relativity is the most daring theory ever developed by human mind. Following Einstein's thought, physicists and all educated people observed in amazement the astonishing picture of the universe as a whole.

Einstein's equations of the general theory of relativity and their solutions described a stable universe. According to this model of the universe, it had finite space. Yet due to the curvature of space, this finite world had no boundary. In Einstein's model of the universe, the curvature of space served to describe the motion of gravitating masses. Space–field entity became a kind of specific substance. Its properties, including the distribution of its curvature, were determined by gravitating masses. In its turn, space–field continuum determined the trajectories of motion of gravitating masses, stars and other heavenly bodies. I would like to stress here that space of the general relativity appeared to be a unique entity, a real frame that determined the distribution and motion of all objects in the universe. Thus, space by Einstein became the absolute basis of existence.

This impression of substantiality became even stronger in relativistic cosmology. Models of expending universe proved that space not only determined the motion of gravitating bodies but also carried with it all existing bodies and made them to run away from each other due to its self–extension. Considered as the most basic carrier of all existing material objects, space appeared much like a special kind of substance.

To sum up. Space of classical physics was a passive container of heavenly bodies and all existing material objects. It has no other function and never demonstrated its independent existence as of a substance or of anything else. Space of the theory of general relativity became the real basis of the physical world, the absolute determiner of the motion of all gravitating masses. As it is often the case with the development of ideas in the history of human ideology, the extreme extension of a conception brings to its opposite. *Extending the principle of relativity to all frames of reference, Einstein found the absolute.*

Einstein's relativistic mechanics is as immortal as is its predecessor, Newton's mechanics. Any future development of theoretical mechanics can bring only to certain corrections of relativistic mechanics. With the general theory of relativity there is no such guarantee. All depends on the real nature of gravitation. One cannot exclude today that gravitation may appear to be some unique, non–field–theoretical phenomenon.

Case **10. The mystery of Michelson experiment**

"the principle of relativity was proved in a particularly incisive manner by Michelson's famous experiment"

Albert Einstein

It is widely accepted today that Michelson's experiments denied the existence of the world ether and rejected the conception of the absolute space and time of classical mechanics. Surprisingly enough, the great physicists of the early part of the twentieth century, even discussing Einstein's conception of relativity, regarded mainly Fizeau experiment and hardly ever took into account the results of Michelson's experiments.

Absolute space and absolute motion are usually thought as symbols of classical mechanics. In actuality, Newton stated quite clearly that only relative motion reveals itself in mechanical appearances. Absolute space was rather a philosophical concept necessary to think of the very possibility of mechanical motion.

But in the year 1818 Arago pointed out that the index of refraction of any given substance should depend on the ratio of its velocity of absolute motion to that of the speed of light. When the experiment did not succeed in determining the absolute motion, a hypothesis was suggested that the light might be partially "dragged" by the moving substance. In 1851, Fizeau designed an experiment to test this hypothesis. He measured the speed of light along a tube with water flowing in it. The result of the experiment was positive. The velocity of light slightly changed in the moving water. In 1895 Lorentz presented a satisfactory explanation of Fizeau experiment still assuming absolute space and ethereal medium.

But in the classical electromagnetic theory there remained the problem of the nil result of Michelson's experiment of 1881 that was confirmed by the more refined

Michelson–Morley experiment of 1887. The nil result of these experiments proved that the speed of light is constant in all directions and independent of the motion of the source of light.

To explain this experimental fact, Fitzgerald suggested in 1892 one of the most unusual physical hypotheses. He showed that one could explain Michelson–Morley experiment if it was assumed that moving bodies contract along the direction of their motion. In 1904, Lorentz introduced special rules of transformation of space–time coordinates and deduced Fitzgerald contraction as a necessary conclusion from his general principles.

To Lorentz and all other physicists of that epoch the absolute factors were space and ether. The speed of light only seemed constant due to the relativistic contraction. In 1905, Einstein came forward with his revolutionary revision of this classical viewpoint. He introduced a new absolute – the speed of light. Postulating the speed of light as a physical constant, Einstein deduced the Lorentz rules of transformation and all basic relativistic effects, including the effect of relativistic contraction earlier designed to explain the nil result of Michelson experiment. Einstein's revolutionary approach abolished the absolute space and the ethereal medium.

Thus we have the clear picture of the *chain of ideas that brought eventually to formation of relativistic mechanics*: Michelson experiment – Fitzgerald contraction – Lorentz transformation – Einstein relativity.

In essence, if properly understood, Michelson's experimental proof of the independence of the speed of light from the speed of its source necessarily implied a crucial conclusion that there was neither absolute motion nor absolute space. Michelson experiments could be understood only with the help of Lorentz transformations. They, in turn, should sooner or later bring to the necessary corrections of classical mechanics. Einstein was the scientist who performed this great reconstruction and created relativistic mechanics. But to this day, historians of science cannot resolve the puzzle whether Einstein had the information on Michelson's historic experiment prior to creating his revolutionary theory. Einstein's contradicting answers to the question made the situation completely unsolvable.

One may think that there is an objective factor that can make the positive answer more likely. This is the fact that in 1907 Michelson was awarded Nobel Prize for physics. Could Einstein miss information about the experiments of such a highly appraised investigator?

Unfortunately, this line of argumentation comes out to be absolutely unproductive. First, Michelson got his Nobel prize not for his famous experiment. According to the formulation of the Nobel committee, Michelson was awarded "for his optical precision instruments and the spectroscopic and metrological investigations carried out with their aid". In his greeting word, president of the Royal Swedish Academy of Sciences, K. A. Mörner, made a special notice of the American scientist's fascinating instrument. "Your interferometer," praised K. A. Mörner, "has rendered it possible to obtain a non–metrical standard of length, possessed of a degree of accuracy never hitherto attained." And no single word on the historic experiment carried out with the help of this instrument! And what is not less startling, Michelson himself did not mention his greatest achievement in his Nobel lecture! Michelson's report in the *Nobel lectures* is followed by his short biography. Here, at last we find a clear statement of the exceptional importance of Michelson's experiment: "Michelson performed early measurements of the velocity of light with amazing delicacy and in 1881 he invented his interferometer for the purpose of discovering the effect of the Earth's motion on the observed velocity. In cooperation with Professor E. W. Morley, and using the interferometer, it was shown that light travels at a constant speed in all inertial systems of reference." But this biography was composed by the editor sixty years after Michelson's Nobel lecture.

The above strange facts can normally mean one thing: by the year 1907 neither the Nobel committee nor Michelson himself did realize the significance of his experiment on the speed of light. Moreover, I am going to bring in another fact which proves that the physicists of that time had been unaware of the historic importance of Michelson's experiment.

In 1911, shortly after the first Solvay Congress, Albert Einstein was invited to give lecture on the theory of relativity at the meeting of the Zurich Society of the researchers of nature. Quite surprisingly, during this lecture Einstein did not mention the Michelson experiment, even when he stated the constancy of the speed of light. Many prominent professors of physics participated in the discussions. Only one of them spoke in passing about the Michelson experiment and that only in connection with the Lorentz–Fitzgerald contraction.

We have to conclude that at the start of the century the physics community was unaware of the exceptional importance of Michelson's experiment. So it could hardly play a notable role in the formation of Einstein's conception of relativity. For instance, in the above–mentioned lecture Einstein derived the principle of the constancy of the speed of light as a consequence from Lorentz' assumption of resting ether, but not from Michelson's experiment.

Possibly, the physicists did not pay deserved attention to Michelson experiment due to the dominant position of the concept of ether in those days. Fizeau experiment was immediately intended to investigate the relation of ether and moving bodies, while the relation of Michelson experiment to ether was not so much evident.

Perhaps the most decisive clue regarding the role of Michelson's experiments in Einstein's deliberations on relativity is contained in the introductory section of 1905 celebrated paper. Here Einstein first pointed out the widely known examples of asymmetries of Maxwell's electrodynamics in regard of the motion of a conductor relative to electric and magnetic fields. Then came the decisive sentence. "examples of this sort," wrote Albert Einstein, "together with the unsuccessful *attempts to detect a motion of the Earth* relative to the light medium, *led to the conjecture* that not only the phenomena of mechanics but also those of electrodynamics have no properties that correspond to the concept of absolute rest". In this sentence two points that I marked by italics are of cardinal importance. First, the phrase about the "unsuccessful attempts to detect a motion of the Earth relative to the light medium" may be attributed only to the Michelson's experiments. Second, Einstein assessed the negative results of these experimental attempts as helping only to *conjecture* the principle of relativity.

So the mystery of the role of Michelson's experiments in the formation of Einstein's theory of relativity may be more adequately understood taking into account the above–discussed circumstances. Writing his famous 1905 paper, Einstein was well aware of the negative results of Michelson's experiments but assessed them only as helping to conjecture but not to prove the principle of relativity.

Historians of physics sometimes discuss also if Einstein, preparing his 1905 paper on statistical physics, had any information concerning the so–called Brownian motion. The problem apparently arose from the denial of such knowledge in *autobiographical notes*. This passage goes on as follows, "in the midst of this i discovered that, according to atomistic theory, there would have to be a movement of suspended microscopic particles open to observation, without knowing that observations concerning the brownian motion were already long familiar".

The truth is that writing his autobiography in 1947 Einstein did not remember that his 1905 paper contained a direct reference to the Brownian motion.

Case **11. The mystery of infinity**

> *"in regard of infinity, to rely on mere thinking is absurd."*
>
> Aristotle

Aristotle suggested the following strict definition of infinity: "a quantity is infinite if it is such that we can always take a part outside what has been already taken. On the other hand, what has nothing outside is complete and whole." For instance, the infinite is not the biggest number, but rather the *potential to be bigger of any given big number*, the ability to get beyond any given finite number and thus always to have "something outside it". This classical notion of infinity, called potential infinity, is a generalization of the properties of mathematical series like that of the series of natural numbers.

In spite of the completely clear meaning of the concept of potential infinity, human mind always felt unsurpassable difficulty to imagine infinity. It could not be other way. For we imagine something as actually existing while *by its definition and essence infinity is only a potential*.

Kant demonstrated clearly what an enormous difficulty we have to face trying to apply the mathematical category of infinity to such a unique object as the universe as a whole. These difficulties were clearly outlined in the so–called first antinomy of the famous *Critique of Pure Reason*. Kant's antinomy consists of two parts. The thesis proves that the universe is finite, since it cannot be infinite. The *antithesis* proves the opposite statement that the universe is infinite since it cannot be finite. Let us have a closer look at Kant's argumentation.

The thesis is formulated as follows: "the world has a beginning in time, and is also limited as regards space." Naturally, the proof of the *thesis* consists of two parts since the thesis speaks of two essentially different characteristics of the universe, namely its space and time. The proof of the temporal argument may be presented as follows: "if we assume that the world has no beginning in time, then up to every given moment, there has passed away in the world an infinite series of successive states of things. Now the infinity of a series consists in the fact that it can never be completed. It thus follows that it is impossible for an infinite series to have passed away, and therefore the world necessarily has a beginning."

This proof sounds quite convincingly. The only point that leaves room for a critical analysis is the first sentence of the proof. Here from the assumption (a) "the world has no beginning in time" a conclusion is derived that (c) "up to every given moment, there has passed away in the world an infinite series of successive states of things." But in this conclusion (c), in actuality, are joined together two sentences: (c_1) "in the world, up to every given moment, the series of the successive states in the past is infinite", and (c_2) "this series is completed (since it has passed away)".

But it is impossible for the sentences c_1 and c_2 to be together logical consequences of the assumption a. If it follows from a that the series of the successive states in the past is infinite (c_1), then this same series cannot be completed. And if one admits that it follows from the assumption a that the series of the successive states in the past is completed (c_2), then this series cannot be infinite. This contradiction makes meaningless all the following argumentation of Kant's proof. So we have to conclude that Kant's proof of the first part of his antinomy could not go further of its first sentence.

The second (spatial) part of Kant's proof of the *thesis* of the first antinomy concerns the extension of the universe. It is not difficult to show that in this case too, Kant's proof cannot be continued after its very fist sentence. Let us examine in detail the proof of the second part of Kant's thesis: "the world is limited as regards space."

Since Kant proves his thesis by the refutation of a contradicting proposition, he had to begin with the following assumption: "the world is not limited as regards its spatial extension."

(1) Instead, Kant begins with a self–contradicting assumption: "the world is an infinite given whole of co–existing things." But in actuality, the predicates "infinite" and "given as a whole" (=completed) are incompatible. Any sentence, containing a joint assertion of these two predicates is a contradiction in terms. Since Kant proves his thesis by the refutation of a contradicting proposition, he had to begin with the following assumption: "the world is not limited as regards its spatial extension." Then he could draw from this statement the following conclusions:
(2) "the world space is not completed."
(3) "the world space can be continued limitless."
(4) "the world space is infinite."

But having the assumption (1) and drawing from it sentences (2)–(4), one is forbidden to continue by a contradicting assertion "the world is an infinite *given whole* of co–existing things". This means an evident failure in Kant's proof of the spatial part of the thesis of his antinomy.

Let us now examine the proof of the *antithesis* of Kant's first antinomy. Kant formulated the *antithesis* of the first antinomy as follows: "the world has no beginning, and no limits in space; it is infinite as regards both time and space." Again we have two distinct parts, one temporal and the other spatial. And again, Kant proves each one of them by refuting the contradicting proposition. The temporal part of the antithesis can be proved as follows. *Antithesis*: the world has no beginning.

Proof: let us assume that it has a beginning in time. Then there must have been a preceding time in which the world was not. Since the world is the totality of all existing things, there could nothing exist in the time preceding the beginning of the world. But this means that the world had to begin out of nothing, which is impossible.

Indeed, this laconic proof is rigorous and strong. The only possible objection may be suggested taking into account modern conceptions of relativistic cosmology. The teaching of the expending universe brought to light a theoretical possibility of a "tight "model in which the universe and time begin together. This is believed to be very helpful in avoiding the unpleasant question what was the state of the universe before the start of the big bang.

To evaluate this alternative, we have to concentrate attention on the concept of the "beginning". Kant rightly mentioned that the beginning of an object assumes "a preceding time when the object did not exist". Explicating further the concept of beginning, we must mention also that it assumes also two additional points. Firstly, "the object must change from non–existence to existence." Secondly, and just this point comes to be the most important factor in the analysis of the alternative of the "tight "model, "any thing arises from something else." But this "something else" cannot be presented by "nothingness" (an empty world) as well as it cannot be also the world itself.

Now we are ready for the critical analysis of the alternative of the "tight" model. The essence of this approach is expressed by the statement "the world and time have begun together at the moment $t = 0$." But to begin means arising from something different. So there should exist something prior to the world, which would necessarily require the existence of time. This would unavoidably raise the question of the beginning of this *something existing prior to the world*, which would bring to the assumption of the new something, new beginning and so on *ad infinitum*. As we see, the "tight" model of the universe and time beginning together cannot change the conclusion that the world cannot have a beginning.

Now we can sum up the analysis of the temporal part of Kant's antinomy. The thesis "the world has a beginning in time" has not any convincing proof, while there is a strong proof for the antithesis "the world has no beginning in time."So we have to accept that the world has no beginning. A conception advocated by Aristotle and assumed in Einstein's model of the universe.

Let us turn to the last proof, which concerns the spatial part of the antithesis of Kant's antinomy. *Antithesis*: the world has no limits in space.

Proof: let us assume the opposite that the world in space is finite. It would follow then that there is empty space beyond the world. But empty space is impossible. Though apparently clear and strong, in fact, this version of the proof is self–contradicting. Its starts arguing on the basis of the absolute space and then rejects own conclusion from the position of the relational conception of space. But these two conceptions of space are completely incompatible and exclude one another. So, one has to admit that the proof of the spatial part of the *antithesis* is, in fact, a failure. But earlier we have seen that there is no proof also for the spatial part of the *thesis* of the first antinomy. So we must conclude that either the thesis "the world is finite in space" or the antithesis "the world is infinite as regards space" have no consistent proof.

Case 12. The mystery of singularity

"humanity should not seek knowledge exceeding its capacities."

Aristotle

Great explorers of secrets of nature have an obsessive dream to explain the universe as a whole. And not only to draw its present picture but also to reveal its genesis from the very beginning whatever it were. Considering the problem of the universe as a whole, Isaac Newton was aware that there would be a problem with the infinite space uniformly filled with stars. The masses of innumerable stars should create gravitational fields that would produce resultant infinite tension at any point of space. Yet it was realized that the background gravitating masses of the infinite number of stars of the uniform universe would act on any given star from all sides thus compensating each other's force of attraction.

The problem of the universe as a whole became a cardinal issue of modern physics due to the relativistic cosmological models. In 1917, following the principles of his theory of gravitation, Einstein suggested an attractive model of a finite but unbounded universe. The startling conclusion of Einstein's theory was that huge gravitating masses changed the "normal" space, which had Euclidean geometry, into Riemannian space with positive curvature. Because of the positive curvature of space, the finite universe should have no boundary.

Einstein's beautiful model underwent a disastrous change in 1922. Alexander Friedmann, mathematics professor from Soviet Russia, proved that Einstein's cosmological equation had a non stable solution. Friedmann's purely mathematical consideration led, in actuality, to the speculative assumption of an incredible physical phenomenon of self–extension (or self–contraction) of space.

Friedmann's two papers on non–stable solutions of the cosmological equation passed almost unnoticed by the community of theoreticians. Much greater was the impact of the 1927 paper of Georges Lemaitre, a young Belgian priest who demonstrated a genuine devotion to cosmology rather than to theology. Lemaitre independently found out the non–stable solutions of the Einstein equation with a zero cosmological constant. But unlike Friedmann, he, from the very start, considered the model of the expanding universe as a theory explaining the coming to be of the physical world.

Lemaitre put emphasis on the past of the universe. If the assumption of self–expansion was true there followed a very unordinary conclusion. The expansion of space should have its beginning in time. Moreover, "at the beginning" all the matter of the universe should be pressed together in one singular point. Lemaitre introduced the idea of the "primeval atom", the sphere of very negligible size that had to contain all the matter of Einstein's finite world. Lemaitre himself was very glad to prove scientifically the biblical thesis of the beginning of the world. Modern writers prefer to speak of "singularity", while for the general public they use the picturesque term big bang. The term "singularity" actually sounds better, since the singular state of the universe can refer not only to the moment of the self–expansion of space but also to the super–dense state of all the matter of the universe pressed together in the negligibly small volume of the "primeval atom". Later on, it was proved that in the conception of general relativity the assumption of self–expansion of space inevitably brings to the conclusion of a singularity at the origin of the universe.

As soon as it was realized, that Hubble's empiric law of the red shift in the spectra of all remote galaxies might be well interpreted as the evidence of the self–expansion of space, physicists almost unanimously accepted the models of the expanding universe. And this: in spite of the apparently absurd conclusions following from the physical interpretations of the state of singularity adherent to all finite models of the universe.

Finite cosmological models bring inevitably to the conclusion that the expansion of the universe must stop at a definite moment, depending on the density of the cosmic matter. And then a really horrible thing should happen. The universe must begin contracting into a new singularity. All the matter of the universe should be pressed back into one single point. The most distressing thing is that after this catastrophic contraction of the universe, no new expansion would follow.

Adherents of this conception are so excited with their unchallenged success in predicting the so called back ground radiation that they think of their theories as of the final truth that precisely pictures the present, the past, and the future of the material world. They quite seriously discuss and calculate physical parameters of the universe up to the point of 10^{--10} seconds after the "beginning".

What does make adherents of the conception of the expending universe so sure in their extraordinary assumption? The basis of the conception of the expending universe is the fact, the absolutely certain fact that there is a significant red shift in the spectra of all remote galaxies. This empiric observation becomes a dominant cosmological factor as soon as physicists admit that the only possibility to explain the red shift is to account it to the Doppler effect: which assumes that galaxies are running away from us, some of them at speeds close to the speed of light. From the moment the red shift is admitted being a Doppler shift, we are necessarily bound to the picture of the expending world of galaxies.

Only a very fundamental controversy can bring a shadow of uncertainty in the ranks and files of adherents of the big bang models. Such a fundamental feature of the world of galaxies is already well known though its damaging effect upon the conception of the expending universe is not fully realized yet.

This extremely important feature of the macrocosm is the fact of cosmogonical activity of the nuclei of galaxies. I mean the discovery of the enormous eruptions of matter and radiation from the nuclei of many galaxies. These eruptions prove that there is an unimaginable huge density of matter and energy at the nuclei of galaxies. While the main problem of the models of expanding universe is to bring together into stars and galaxies the initial substance of the "primeval atom" that should have been driven away all over space from the moment the big bang had started.

I would like to emphasize this controversy. On the one hand, we have the *fact* of enormous density of energy and matter at the heart of galaxies, in their nuclei. On the other hand, we have a *hypothetical* conception of the big bang, which provides the least favorable condition for the formation of galaxies and leaves almost no place for the extraordinary huge density of matter and energy in galactic nuclei. Again, the *fact* is the enormous star density end energetic activity of the nuclei of galaxies. The *hypothesis* of the self–expending space makes such an enormous density and activity the least probable phenomenon.

In my following objection to the hypothesis of self–expansion of space I will prove that this hypothesis, in fact, does not achieve its main goal. Namely, *the self–expansion of space is unable to explain Hubble's law.*

Let us ask a paradoxical question, "would the expansion of space bring in an increase of the distances between galaxies?" Indeed, to measure any physical distance, one should do it with the help of some measuring rod. If space expends, the measuring rod will extend accurately the same way as any other distance. So the value of the distance between any two given galaxies as the ratio of the distance between them to the length of a measuring stick would always remain the same, if even space were expending.

This argument holds in behalf of all physical processes related to spatial distances. Any law of nature refers not to space as such, but rather to the distance related to a measuring rod. So no law of nature would change its influence on physical bodies and processes if space were extending. No physical phenomenon or measurement would be able to reveal the expansion of the universe. This argument was clearly formulated by W. K. Clifford and Delbauf and supported by P.W. Bridgman and Henry Poincaré.

But if we accept this conclusion that the expansion of space can bring no change in the phenomena of the universe, it will make groundless all the models of the expending *universe. The expansion of space cannot cause any red shift of radiation. Distances between all physical bodies, including galaxies, will always remain the same since if space expends k times, the measuring stick extends precisely k times too. But if distances do not change, there would be no Doppler shift and no red shift of the light of remote galaxies.*

Case 13. The mystery of virtual particles

"the whole fifty years of conscious brooding have not brought me nearer to the answer to the question, "What are light quanta?"

Albert Einstein

The idea of *field* necessarily becomes the central issue of discussions when scientists try to answer what is the nature of the electric force or, in general, of any other force of physical interaction. Albert Einstein was deeply convinced in the most fundamental place of physical fields in the structure of the material world. Yet, just Einstein's scheme of the interaction of the electron with electromagnetic radiation brought eventually to the factual elimination of the classical concept of field. If electromagnetic energy was emitted and absorbed by means of special particles, photons, there remained no use of the concept of field in regard of radiation. Moreover, the exchange of photons could be supposed to be the real mechanism of interaction of electric charges. Such an approach would eventually lead to complete elimination of the concept of field from the theory of electromagnetic phenomena.

On the other hand, Bohr's theory of atom emphasized the fact that electrons do not radiate electromagnetic energy moving on their stable orbits in atom. This fact challenged the most profound principle of classical field theory according to which charged bodies moving with acceleration had to radiate electromagnetic waves. Another mystery of atomic radiation concerned its frequency. It did not coincide with the frequency of rotation of electrons in atom.

In spite of the above–mentioned insurmountable difficulties, the leading paradigm of the early part twentieth century physics remained the notion of field. By that time, physicists had already faced serious troubles with the luminiferous ether as the carrier of electromagnetic radiation. But it was soon realized that one could silently ignore all uncomfortable questions substituting the troublesome term *ether* by the term *field*. Even the non–classical quantum physics and relativistic mechanics continued to work along the conception of field interaction. Moreover, the modern quantum electrodynamics, which actually introduced the idea of the *interaction by* *means of virtual particles*instead that of the interaction by a field media, is still called quantum *field* theory.

In the frame of classical field conception, physicists thought it quite admissible to postulate that electric charge was the "inborn" ability of matter to produce in the surrounding space a field of forces. On the other hand, quantum physics actually told that the atom is a material structure able to transform the energy of heat into photons of electromagnetic radiation. Is it not possible to extend this mechanism on the process of creation of electrostatic field by an electric charge? Does not, for instance, an electron create his electrostatic field by the way of some transformation of its inner energy?

The discovery of quanta of radiation and of photon structure of light made unavoidable the question, "what is the carrier of the field interaction?" Or "by what means does an electric charge create its field of force?" The quantum mechanical theory of atomic radiation brought to light several additional questions: "how do electrons absorb photons?" and "how do atomic electrons produce photons while they radiate electromagnetic energy?"

In the framework of atomic physics, all these questions could be considered abstract speculations. But the nuclear physics made it unavoidable to realize the profound significance of the phenomenon of *birth of particles in nuclear interactions*. Subsequent intensive studies of interactions of high–energy particles revealed that the birth and transformation of elementary particles was a predominant way of behavior and interaction at the very basis of the structure of substance.

By the mid–twentieth century, quantum field models of Dirac, Fermi, and Yukawa provided a completely satisfactory picture of the atom and atomic nucleus. Atoms and their radiation were described in detail by the force of electromagnetic interaction, the *photon being its force–carrying particle*. The properties of atomic nuclei were well explained by pi meson model of strong interaction of protons and neutrons. The process of beta decay was accounted to the force of weak interaction that required introducing one more elementary particle, *neutrino*, in addition to the well–established electron, photon, proton and neutron.

If only physicists could stop here their unceasing quest of research of nature. What a clear and beautiful picture of the world would have the physical science. But physicists had no chance to enjoy their achievements. By the end of 1960s, there were discovered over 200 new elementary particles, which demonstrated numerous strange properties and unexpected transformations. The predominant part of new particles had been observed in experiments with electrons and protons accelerated to high energies up to several billions electron volts. To study high–energy interactions, physicists bombarded with charged particles of accelerator beams tiny targets made of different substances. Soon observations showed that the main feature of high–energy interactions was the birth of a number of particles. The birth of new kinds of particles went on with such an explosive intensity, and the newborn particles behaved themselves in such unordinary ways that there the impression arose among physicists: the time had come for a new revolution in the foundations of physics. But still many theoreticians *believed they could manage to deal with all new particles and their extravagant properties in the framework of the quantum field theory.* Rather unexpectedly, this conservative position came out to be the winner.

Theoreticians first undertook the task of building a classification table for elementary particles like that of periodical system of chemical elements. The most successful one was Murray Gell–Mann's "eightfold" table. It grouped elementary particles into octets. The table provided effective means to reveal the mass relations among all barions and mesons. The significance of the new conception for the world of the elementary particles was so obvious that already in 1969 Gell–Mann received the Nobel Prize for physics.

The next step was the search of new "ultimate" building blocks for this complex world of elementary particles. The intensive efforts of a number of theoreticians, among which the central role belonged again to Murray Gell–Mann, brought eventually to the formation of the *quark theory.* In1963, Gell–Mann showed that all barions and mesons could be built of three quarks only. Physicists thought they had found the last building block of nature. Quarks seemed to be the real "atoms", the principally indivisible particles of matter since the force binding quarks together appeared to increase when one tried to bring them apart.

Of course, there was a stumbling block too. Quarks had to have fractional charge that of 1/3 and 2/3 of the charge of the electron. There was no slightest evidence of fractional charge in the huge body of observational data. Nevertheless, Friedmann, Kendall and Taylor verified experimentally the reality of quarks. Their work was awarded the 1990 Nobel Prize for physics.

Contemporary physicists are almost unanimous in accepting the quantum theoretical picture of an elementary particle.

Surrounded by a frothing cloud of virtual particles that, in Feynman's words, all the time are "popping in and out of existence." But is it not absurd to believing in entities that have to keep on their shoulders the entire physical world by constantly coming into existence and vanishing? Really, why are field carrier particles of quantum electrodynamics called "virtual"? Just because they cannot function as real normal particles.

Consider proton–neutron interaction. Hear we deal with a short–ranged strong force. To build the quantum field of such kind a force, physicists have to assume that the proton–neutron interaction is carried on by exchanging special field particles having a significant mass of rest. Namely, protons and neutrons, having the mass of rest about 1800 me, are presumed to interact by sending and absorbing pi mesons that have mass of rest about 270 me. The law of conservation of energy clearly forbids processes in which low energy protons and neutrons could produce pi mesons. That means that *protons and neutrons cannot interact inside the atomic nucleus by exchanging actually existing mesons.*

But never mind such a trifle. Let us say that pi mesons, so much necessary to quantum field theory, exist *virtually* when we deal with the process of strong interaction. The term "virtual" helps to reason about the processes of exchanging pi mesons as if these field carrier particles actually existed. Actually *non–existing field carrier particles are presented as a special form of physical existence* (or rather non–existence) *called virtual particles.* And then, getting used to descriptions of physical interactions in terms of virtual particles, physicists speak about virtual particles as of really existing ones. Surely, physicists would hardly agree with such a trick if they learned about it in some other branch of science.

Case 14. The mystery of Goedel's theorem

"Gödel's reasoning skirts so close to and yet misses a paradox."

Stephen Kleene

Kurt Gödel is one of the greatest logicians from the time of Aristotle. His proof of the completeness of the calculus of predicates is one of the most significant results of the modern meta–logic. And the famous 1931 paper on the incompleteness of formalized arithmetic is evaluated as the greatest single piece of work in the history of mathematical logic. "Kurt Gödel's achievement in modern logic," declared John von Neumann, "is singular and monumental – indeed it is more than a monument, it is a landmark which will remain visible far in space and time".

The advantage of the axiomatic presentation of a theory is widely accepted. As a rule, axioms of a theory are chosen from the most clear and evident statements of the given field of research. On the other hand, a good theoretician is just unable to make a mistake in his logical deductions. So there is little chance to refute an axiomatic theory or even question its particular statements. If the axiomatic method is so ideal and strong, why do logicians and mathematicians undertake the task of formalization of axiomatic theories? What is the goal of the method of formalization?

The idea of formalization emerged as a remedy against paradoxes that had been revealed in the very foundations of mathematics. By the early twentieth century, some prominent mathematicians, having a natural interest to philosophical foundations of their science, became really upset by the emergence of paradoxes in the theory of sets, the very last basis of mathematics.

David Hilbert, the most prominent authority of the mathematics of his day, believed that paradoxes arise due to the use of the everyday language. Any term or concept of everyday language has, as a rule, several meanings, some of them significantly different from each other. There is always a chance that one and the same term could be used in different meanings during the same proof bringing thus to contradictory conclusions. So Hilbert suggested that mathematicians should avoid using everyday language in their proofs. This should be achieved through the formalization of mathematical theories.

To formalize an axiomatic theory means to present it as a symbolic calculus. This can be done as follows. First, one builds the corresponding formal language. It can be done substituting the terms and concepts of a given axiomatic theory by a set of symbols, which compose the "alphabet" of the formal language. Then one defines the concept of the "well–formed" formula. When a formal language gets some interpretation, the well–formed formulas correspond to those symbolic expressions that have a sense in the non–formal language.

After the formal language is built the axioms of the formalized theory are introduced as its initial formulas. Then one has to formulate the last structural component of the formalized theory – its rules of inference. Only with the help of the rules of inference one is allowed to draw new formulas (theorems) from the initial formulas, the axioms and definitions.

Now, the question is whether the method of formalization can prevent the appearance of paradoxes in mathematics and in science in general? The pro–argument is quite evident. From the day of Aristotle, scientists realized that the main ground feeding the paradoxes is the lack of rigorousness and precision in the language we use. It seems very probable that using a formal language one can eliminate the main source of paradoxes in mathematics, too.

On the other hand, any formal calculus is a translation of a respective axiomatic theory into the given formal language. By this translation a term is just substituted by a corresponding symbol, usually a letter of the Latin alphabet. If a given paradox follows from the use of a term, say "space", in its different meanings, then the respective "bad" statements can creep into the formal proof, too.

By the term *Gödel's theorem* writers usually mean the main theorem of *Gödel's* famous 1931 paper "on formally undecidable propositions of *Principia Mathematica* and related systems". In modern presentations the address of the theorem is more concrete – the formal system s of the axiomatic set theory or the theory of numbers. For instance, Stephen Kleene formulates Gödel's theorem as follows: "if the number–theoretic formal system is consistent, then it is (simply) incomplete, with $aq(q)$ as an undecidable formula".

Why is so important this $aq(q)$ formula? If a formula is undecidable, it means that neither this formula nor its negation is provable in the formalized system. But according to the law of the excluded third, the assertion of this formula or of its negation necessarily must be true. Thus, presenting an undecidable formula one factually proves the incompleteness of the corresponding formal system.

So all our attention must be directed to this formula $aq(q)$, which for its importance I will call Gödel's formula.

What does assert Gödel's formula? In its essence, Gödel's formula a asserts its own unprovability. One cannot miss how close is such a statement to the *liar* paradox. Yet it does not lead to a logical contradiction since Gödel built the formula a with the help of the predicate "to be a proof" and did not use the characteristics "true" or "false". By its construction, all the content of Gödel's formula is as follows, (1) A means that A is unprovable.

It is absolutely clear that such a formula does not belong to the field of mathematical knowledge. It can belong only to the domain of the *theory of proof* or metatheory, sometimes called *metamathematics*. Then how could Gödel's formula be related to the completeness of the number theory, and generally to mathematics?

There is serious ground for it. Gödel built his formula using the means of the formalized number theory. Logicians believe that building his formula Gödel made metamathematics a branch of number theory. In actuality, this evaluation needs a correction very significant for the task of the adequate understanding of the meaning of Gödel's theorem.

In the ordinary elementary number theory, one cannot build Gödel's formula. This theory uses only one predicate (equality), usually denoted by "=". To build Gödel's formula, one must introduce the predicate $W(x, n)$ that means that x is a proof of n, when interpreted metatheoretically. So the system in which Gödel's formula can be built and of which Gödel's theorem does speak, is an extension of the formal system of the number theory. Gödel's undecidable formula is a formula only in that extended theory, but not in the system of the formalized number theory. That means that Gödel's theorem proves the incompleteness of Gödel's extended theory, but not of the formalized number theory.

Moreover, even the introduction of the predicate w is not enough to build Gödel's formula. One must also use a special kind of enumeration of the introduced metatheoretical means. But here Gödel's proof confronts a serious drawback. For some mysterious reason, analysts of Gödel's proof do not see the apparent fact that Gödel's numbering is ambiguous. Each one of Gödel's numbers designates two completely different objects, namely, a natural number and, *at the same time*, a metatheoretical predicate. Just this ambiguity, *strictly forbidden by the most fundamental law of identity*, provides the possibility of building Gödel's formula with its characteristic apparent strictness.

In fact, Gödel's proof had a cardinal specificity. It can be carried on only with the help of a self–referential formula. But *using self–referential statements one violates the basic logical law of identity.* In Gödel's proof, A denotes simultaneously the proposition A and the statement "A is unprovable". This means that *building mathematics and proving theorems with the help of self–referential statements one gets results based on a plain logical fallacy.* Would any mathematician agree to prove a fascinating theorem or build a profound theory allowing a logical fault, be it only just in one single point of the undertaken theoretical construction? No serious mathematician would do it. For in mathematical sciences revealing a single logical fault in a mathematical conception necessarily leads to its complete rejection, unless this error is corrected.

To sum up. Using Gödel's numbering means to break the law of identity. If one has difficulties to accept this disturbing fact, he must realize at least that Gödel's proof reveals the *incompleteness of his formalization of metalogic* rather than that of formalized arithmetic.

Case **15. A method to resolve paradoxes**

"he said true things, but called them by wrong names."

Robert Browning

The mysterious ways of great discoveries remind the hidden apparatus of magnificent shows of modern magicians. Both are fascinating and wondrous, yet, in the both cases, one suspects that huge hidden structures have been put into action to produce the final performance.

Paradoxes of science are much more challenging for the self–respect of scientists as are the striking card tricks that magicians perform, so to say, "barehanded" just in front of the spectator. How can one hope to overcome their mystery if there is, apparently, no possibility of using an implicit assumption or a hidden string?

On the other hand, philosophers had long ago recognized that Aristotle possessed a universal method for the solution of the most complicated problems. This notorious method was the *rigorous explication of the meanings of main notion* involved in the problem under discussion.

Aristotle brilliantly used the method of explication to solve all the *aporias* known to the ancient men of learning. I would like to begin my discussion with Melissus' famous *aporia*. Probably Melissus was the first thinker to query what was there supposed to be beyond the boundary of the universe. "If one succeeds to reach the celestial sphere," asked Melissus, "and from there throws his javelin out of the universe, where then that javelin will come down?"

Aristotle's solution of this paradox is one of the most amazing achievements of human thought. As it was usual for Aristotle, he found the solution through the *detailed analysis of the most basic concept related to the problem.* In the case of Melissus' question, the basic notion was the concept of space. Considering the main aspects of the problem, Aristotle developed the relational conception of space. Space appeared to be not a separate entity but a relation of material objects, namely, the boundary surface between the given body and the one that contained it. And since the universe embraced all existing material objects, it should be concluded that, out of the universe, there was no space and no place for the Melissus' javelin.

In the day of Aristotle, the notion "paradox" was not yet consciously realized. All difficult problems, including paradoxes, were *questions to be answered.* So "real" paradoxes of the type suggested by Zeno were considered "usual" *aporias* demanding a solution rather than resolution.

Paradoxes got their specific status of irresolvable contradiction due mainly to Immanuel Kant. In the wide sens of the term, any well argued statement that comes into apparent contradiction with well–established theories, or just with common sense, may be called paradox. In the strict sense, we face a paradox when one presents a sufficiently rigorous proof both to a statement and its negation. Thus a paradox contains, explicitly or implicitly, two contradictory statements both claiming to be true, in direct violation of the most fundamental law of human thought – the law of contradiction.

I am going now to prove that *Aristotle's method of explication of notions is the universal method for resolving paradoxes.* My proof is empirical, or rather "practical". I am going to resolve all paradoxes, known to this moment, by explication and correction of a relevant term or notion. In this regard, I would like to remind you that in the above discussions I have resolved Kant's paradox of infinity and Gödel's theorem just by the explication of main notions (see cases 11 and 14 of this Appendix). I gave the solution of the famous *liar* paradox using the same approach in my recent book *Twenty Rules for Talented Thinking*. In the present section I will show the effectiveness of the same method by resolving Zeno's aporias – the most challenging paradoxes in the long history of human culture.

Let us begin with the relatively simple case of Zeno's aporia called *the arrow*. Zeno's argument may be presented as follows. "Consider a flying arrow. Observing it at any instance of its flight, we have to admit that at this instance of time the arrow is at a definite place. Then, at any instance of its flight the arrow stands still".

Let us concentrate our attention upon the main concept of the argument – the flight of the arrow, or more generally, the notion of mechanical motion. If we use an explicit definition of mechanical motion, then it will be easy to show that observing a body during an instance, one cannot decide does that body move or not. That means that Zeno's argument in *the arrow* contains a logical error of the type *non sequitur* ("does not follow"). Really, we can admit that "now", at the given instance, the arrow is in a definite point of space. But from this statement it does not follow that at that instance of time the arrow does not move. To be able to find out does a body move or not, one must observe it during a *time interval of a non–zero duration*.

The argument of Zeno's another paradox, called *dichotomy*, is as follows. "To pass a given distance, one has first to traverse its half. But to do it, one has to traverse the half of this half, and so on *ad infinitum*".

According to the widely accepted interpretation, *dichotomy* proves that mechanical motion is not possible since it cannot be started. But what does in actuality the argument of *dichotomy* show? Only one thing: any distance can be infinitely divided into its halves, then halves of halves, and so on. But does the divisibility of the distance and space present any obstacle for motion? On the contrary, the space continuum was usually regarded as an optimal condition for mechanical motion. So, Zeno's dichotomical division of the distance a body has to traverse, in fact, has no bearing on its motion, in general, or the possibility of starting this motion, in particular.

Zeno's most popular paradox is called *Achilles and the tortoise*. Suppose, Achilles is at point a and the tortoise at point b, some distance ahead of Achilles. To catch up with the tortoise, Achilles has first to reach the point b. But by that time, the tortoise would already move to a new position c ahead of b. While Achilles moves from b to c, the tortoise will appear at a new point d. And so on *ad infinitum*.

Some modern writers reject Zeno's proof in the *Achilles and the tortoise* the following way. They admit that Zeno succeeded to prove that Achilles' advance could be presented as an infinite series of decreasing distances. But building this series did not mean that Achilles would never catch up with the tortoise.

In general, this objection is correct. To say "never", Zeno had to prove that his infinite series composed an infinite distance. But modern learned persons know well that Zeno's series is a fast decreasing geometrical progression. So summing up members of Zeno's series, one gets a finite total distance.

But this kind of objection ignores the historic background. In day of Zeno, no one could imagine that a sum of infinite number of quantities could bring to a resultant finite amount (in the case of this *aporia* – a finite distance). So, for ancient readers, presenting the distance as an infinite series meant that one could never travel it.

If Zeno kept in mind, that Achilles for certain would catch up with the tortoise in a finite time interval, then he could conceive that he had made a great mathematical discovery. *In fact, Zeno had proved that there existed such infinite series that the sum of their members gives a finite amount.*

Now a concluding general remark. Many methodologists begin to panic foreseeing an unavoidable crisis in science when a paradox arises in some field of research. By contrast, the men of science steadily continue their investigations being convinced that someone will soon make things clear with the source of the paradox. The common sense of scientists appears in this case completely justified. One should not panic confronting a paradox. *Any paradox is an indicator that the progress of science and advance of human understanding have arrived at a higher level requiring more strict and accurate use of relevant concepts and notions.*

Case **16. Absurd conceptions and crazy ideas**

"... nor do we know how ignorant we are."

Charles Darwin

It is really a great mystery that scientists can suggest absurd conceptions. But it is even a greater mystery that the scientific community and educated wide circles could accept an absurd conception as a respectful and true theory.

Quite naturally, present day learned people look at ideas and conceptions of the past in amusement and disbelief. But it should be remembered that we observe ideas of the past epochs from the height of the science of the present time often forgetting historical realities that formed the scientific conceptions of the past days.

Evaluating any scientific conception of a past epoch as absurdity, we must first of all take into account the common sense and basic scientific principles of that time. Let us observe examples of scientific conceptions that held an important position in the natural science of the past but should be evaluated as absurdities even from the viewpoint of the common sense of their time.

Though there is no limit for my appreciation of Aristotle's great genius, even his brave conception of the *first mover* appears belonging to the province of absurd conceptions. Aristotle proved that the first mover was the source of eternal motion of the heavens and all material objects of the sublunary world. For many thinkers already this statement could sound rather strange. But the concept of the first mover appeared beyond reasonable judgment when Aristotle proved additionally that the first mover should be unmoved and unchangeable and had no extension in space. Such an object could not be material since it had no extension and consequently could not be perceived by senses. Thus we come to a concept of an object unconceivable from the point of view of the common sense of the ancient society. No one had ever experienced a motion of material object caused by a non–material, invisible body.

Another example of influential concept that apparently should be evaluated as belonging to the domain of absurd notions is the assumption of the self–expansion of space. This idea is in contradiction with the most fundamental principle of natural science – that of the principle of determinism. In the deterministic world any change (any effect) must have its cause (its acting agent). The self–expansion of space denies the principle of determinism since it has no cause. The big bang of the universe is not caused by any physical agent. It is an unconditioned and "unprovoked" self–expansion and as such is irrational if not absurd.

Of course, judging a theoretical conception one must bear in mind that the characteristic "absurd" is relative. We find a conception absurd if it is completely incompatible with the present day common sense or with the fundamental principles of natural science. So, in our evaluations we must be very careful since common sense itself evolves with the progress of the scientific picture of the world.

Modern scientific thought had encountered such a variety of absolutely new domains of reality that explorers, to be able to deal with them, were forced to try completely new approaches, or in Niels Bohr's words, make use of definitely "crazy" ideas. But crazy ideas look out so much like the absurd ones. Many crazy ideas eventually finish their life by landing into absurd conclusions.

Any hypothetical explanation, even seemingly absurd, is better than none. In actuality, the only thing the theoreticians are really interested in is that of being able to carry on correct quantitative descriptions of phenomena under research. And once the job of correct description is done, all other points seem superficial. At least, scientists are convinced that it is a matter of time to overcome all other obstacles. This is the way by which emerge beliefs in realities that do not exist. So, *the appearance of absurd conceptions is rather unavoidable in the perspective of the development of sci-*

entific knowledge. Likewise, the acceptance of an absurd conception by the scientific community of its day is, in a sense, a normal behavior too.

Scientists know well that nature never unveils its mysteries easily. Each level of knowledge of nature is achieved through hard and slow step by step advancement. A scientist never comes to the final and complete knowledge of some basic feature of natural phenomena. *Each level of knowledge is incomplete, partial, and sometimes simply wrong*. Just the latter case often results in absurd conclusions.

The revelation of an absurd conclusion or/and of an apparent contradiction in the framework of a fundamental theory is a clear sign that something is wrong with its basic principles. If colleagues reveal just some minor inconsistencies in a theory of a scientist, he would not even react to it. Men of learning find minor discrepancies quite a normal thing in the process of the development of their conceptions.

Principles and laws of natural science grow from the empiric data and its interpretation. The interesting thing is that wrong principles of a natural theory of the past are due, as a rule, not to the fantasy or imagination of a scientist, but rather are related to a "natural" interpretation of certain well–established facts. I put the term natural in commas to emphasize that this interpretation had been natural just for its time. The appearance of an absurd conclusion signals scientific community that some of the most obvious assumptions as well as some interpretations of empiric experience of the epoch are false.

But how can one differentiate absurd conceptions from the crazy ideas, the latter understood as ideas that bring with them revolutionary changes to natural sciences? It is quite a common place in *methodology of science* that *great ideas are at first conceived as absurdities*. A revolutionary idea is accepted as a serious scientific conception and then admitted as a new icon in the temple of science only by the *power of its striking success in explaining the most serious difficulties*.

The difference between crazy ideas, including those that later appeared to be a fantasy, and absurd conceptions, involving those ones that are yet accepted by scientific community, is as follows. *Crazy ideas are radically new principles designed to solve profound difficulties in a given fundamental theory. Absurd conceptions are necessary conclusions from the principles of a given theory signaling a basic crisis in its foundations*.

Crazy ideas are rather *paradoxical* than absurd. When even in apparent contradiction with common sense and established scientific principles, crazy ideas contain these principles implicitly as some particular or limited cases. *Absurd ideas have no prospective of improving their incompatibility with facts*. I would like to bring in here some illustrations.

Aristotle's striking statement that beyond the heavenly sphere there was no material object and no space meant a basic solution of the problem of space and time. Copernicus, substituting by a hypothetical motion of the Earth the "obvious" motion of the sun, moon and all innumerable stars, factually suggested a new approach which had to free astronomers from the haunting mystery of the retrograde motion of the planets. Planck–Einstein conception of quanta of energy and photons of light resolved the "ultraviolet" crisis in the theory of radiation and found explanation for the absolutely strange laws of photoelectric phenomena. Einstein's principles $c = const$ and $E = mc^2$, together with Lorentz transformation, were intended to build the new system of physical science.

These crazy ideas struggled by and by to the statue of fundamental physical principle providing solutions to insurmountable difficulties of the natural science of their day. By contrast, absurd conceptions were necessary conclusions from the principles of a corresponding fundamental theory.

The conception of the singularity at the "beginning" of the universe followed from the assumption of self–expansion of space. The impossible set of properties of caloric and ether were preconditioned by the mechanistic interpretation of heat and electromagnetic field. This list can be continued but not completed. Each epoch has to face its own absurdities. But one should not consider them merely historic curiosities. Already William Whewell had mentioned that failures of science help to disclose important clues of the scientific way of thinking.

Case **17. The true destination of science**

"we are always struggling from the relative to the absolute."

Max Planck

It is really strange or rather mysterious that in all historic epochs people smiled at scientific teachings of the past but felt genuine respect in regard of theories of their own day.

Why do people smile at the science of the past, but take for granted that the knowledge of their day is certainly the final truth? The crucial factor is the *discovery of the principally new empiric facts and experimental data*. New theoretical conceptions, being developed on the ground of the newly discovered observational and empiric data, appear in good agreement with the main body of the available factual knowledge. For this reason, the theoretical teachings of the new epoch make the impression of completely certain scientific knowledge based on well–known facts and experimentally proved conceptions. By contrast, the theoretical conceptions of the past seem apparently contradicting to well–established facts and principles. Not knowing or forgetting the historical background of old conceptions, modern readers wonder what primitive and contradicting ideas preoccupied the minds of the best thinkers of the past.

The great german philosopher Immanuel Kant was deeply convinced that Newton's mechanics was a sample of absolute truth. But at the same time he realized that human knowledge grows on the empiric bases. Unlike abstract–analytical laws of logic and mathematics, the principles of mechanics were synthetic statements based on empiric data. So Kant found himself confronting an unsurpassable question: "how can the human mind with its limited empiric experience suggest absolutely true general laws?" For modern time educated people this question does not sound much disturbing since there is hardly any principle of natural science that we are ready to declare as an instance of absolute truth. But if we admit for a moment the existence of absolutely true general statements in natural science, we would feel how difficult it would be for Kant to resolve the problem. To do justice to Kant, one must admit that he found the only possible answer. Human mind should posses several *a priori* principles of cognition initially built into its structure. All human knowledge is construed in accordance with these *a priori foundations*. That is the reason that human mind perceives them as being absolutely true even realizing the limited nature of own experience. For instance, we all are absolutely sure that all natural phenomena have their causes since the principle of causality is an inborn paradigm of our judgment.

In regard of Kant's theory we have made the serious reservation that modern educated man can hardly consider any general statement of natural science as an instance of absolutely true knowledge. Nevertheless, Kant's conception of *a priori* has a close bearing to our way of thinking as well as to the thinking of any other epoch. All the knowledge, which a person uses uncritically, is *a priori* to his mind and consciousness. Paradigms of science when used uncritically function as a priori knowledge of a whole epoch. A basic paradigm of science is *a priori*, strictly in Kantian sense, if for some historic reasons there are no grounds to question its validity. But again, it will be strictly *a priori* only for the epoch that considers this paradigm an unshakable principle.

Modern natural science reduces all physical objects and phenomena to *elements, structures*, and *forces*. A theory is appraised as an important achievement as long as it succeeds to deduce significant features and properties of the object under research from the assumed hypothetical elements and forces. But the scope of empiric data constantly grows through continuous observations and new experiments. Each theory in the field of natural sciences must be ready to face some day a radically new empiric fact able to force significant changes in the original theory.

Einstein's revolutionary conception of relativity followed by the quantum mechanical revolution manifested the hypothetical nature of the most fundamental scientific theories. Under the impact of the theory of relativity and quantum mechanics it was realized that one should adopt a highly critical attitude towards those theories which he admires most.

The emergence of special and general relativity, quantum mechanics and theory of elementary particles made clear that *even the most fundamental and well proved theories can undergo a revolutionary rebuilding.* Nothing appeared sacrosanct to scientists. Laws and principles that for long centuries had been appreciated to be unshakable pillars of the entire scientific world picture were suddenly rejected and substituted by some extremely strange postulates. A philosopher noticed that truth became stranger than fiction, since fiction has to make sense.

Scientists of our time are, at large, "progressive relativists". They realize that a scientific theory can be evaluated only as a "relative truth" since it is hardly in position to embrace all available data, not speaking of the ability to predict principally new phenomena. On the other hand, they never panic confronting new empiric data apparently incompatible with their theories. Scientists are sure that improving their views and assumptions they will eventually overcome present difficulties thus achieving more and more adequate picture of reality. Einstein believed in the existence of the "ideal of knowledge" and agreed to call this ideal limit to which science continually approaches by the philosophical term "objective truth."

But Einstein's revolutionary theories spread the impression that the principle of relativity held in regard of scientific knowledge, too. Even the most fundamental principles of the past could not stand the critique of the present day science. So one should be *ready to meet contradictory facts in regard of the most authoritative modern theories* when they will undergo the scrutiny of the science of the nearest future. Modern age is, in a sense, entirely opposite to the mode of thinking of the Greeks. Bright speculations are pushed to the background by crude empiric facts. "It is the spirit of the age," remarked Gore Vidal, "to believe that any fact, however suspect, is superior to any imaginative exercise, no matter how true."

Theories and principles of natural science, changing each other in succession, often drew entirely different, even contradicting pictures of reality. Methodologists extrapolated these kind facts of the history of science and proved that, in general, there was no theoretical conception that could be evaluated as representing the real truth. In the light of such philosophy, theoretical conceptions appeared to be just useful conventions that enabled scientists to discuss, interpret, and systematize empiric data. *Extreme conventionalism denied any general tendency and logic in the historic path* *of scientific conceptions and theories.*

To do justice to relativism and conventionalism, one should admit that these conceptions were not far away from the truth. But conventionalism needs an essential correction. First, scientific theories, if even being conventional, have to satisfy the strong balancing demand of empiric verification. It is immensely difficult to work out even a mere conventional conception when it is controlled by stubborn empiric facts. Second, even if we agree that the progress of science is a chain of conventions, we must realize that this chain is directed by experience, mainly by principally new empiric data. New empiric data are often so specific, so incompatible with current conceptions that they require radical changes in the whole theory. So, *scientific progress is directed by experience toward more and more adequate conceptions.*

The advance of science is achieved through *deeper understanding of basic principles and more exact definition of fundamental concepts directed by the discovery of radically new empiric data.*

The contemporary conception of scientific progress is laconically expressed in Albert Einstein's following remark concerning the problems of modern science and their solutions: "our knowledge is now wider and more profound than that of the physicist of the nineteenth century, but so are doubts and difficulties."

Generations of scientists, in Einstein's words, seek solutions of mysteries in the book of nature. But no one can be sure that "the great mystery story" has a final solution. Science just keeps constantly moving to deeper understanding of reality through the chain of relatively true conceptions. "The absolute represents an ideal goal which is always ahead of us and which we can never reach," wrote Max Planck.

Case **18. Einstein – Darwin striking parallels**

"as long as science lasts their story will be remembered."

Loren Eiseley

Though Loren Eiseley's wrote about a group of prominent English biologists, his beautiful sentence could be perfectly applied in the case of the heroes of this chapter, Einstein and Darwin, too. I have revealed the secret of geniality deliberating for long years over the startling phenomenon of Albert Einstein's life in science. And only recently I have observed how many striking common features were there in the intellectual capacities and ways of thinking of the two greatest geniuses of modern science.

In the above discussions I have mentioned a number of these parallels. The most striking moment concerning these great revolutionaries of science is that they both were completely ignored by their teachers and never gave a slightest hint of their extremely bright future. It is quite surprising also that both prominent scientists in their early life hated compulsory learning and had more or less serious difficulties in mathematics. Yet both were extremely ambitious in regard of their destination in science. History completely justifies their inner conviction. The revolutionary essence of the theory of evolution through natural selection and the radical principles of relativistic mechanics will demonstrate their historic significance more and more convincingly.

My clarification of the phenomenon of geniality is partly theoretical, based on the analytic–synthetic conception of the logic of creative thinking, and partly empiric, oriented on biographies of famous scientists. No surprise, both Einstein and Darwin possessed qualities that I revealed as the main factors of geniality, involving that of having big ambition.

My evaluation of the both prominent scientists Einstein and Darwin as of ambitious persons may sound strange enough to many readers. So I would like to remind that in the context of the problem of geniality, ambitiousness is regarded as an inner conviction of being able to make great scientific discoveries.

Of course, even people not so much close to science know well what a simple and unpretentious person was Albert Einstein. This point of his character got its expression in many humorous stories told traditionally about Einstein. Darwin was a very amiable person, too. From his early life, there was something in Darwin's personality that made him sympathetic to his young friends and even to many grown–ups.

Yet Darwin spoke directly about his ambition of becoming a prominent scientist in his *autobiography*. As far as I know, Einstein never confessed having great ambitions in early years of his life. But what it had been if not a great ambition when a sixteen years old youngster makes a sketch of the theory of ether under the title "on the investigation of the state of the ether in magnetic field"? The author of the sketch was the young Albert Einstein.

Few people were aware of young Einstein's great ambition. To his friendly circle he appeared a very lovely, but not much serious and markedly lazy young man, always ready for a daylong walk to nearby mountains, striving for friendly talks, especially if they pertained to fundamentals and newest achievements of physical science. But in Einstein's approach to the subjects he had to learn and theories he readily discussed with his friends and colleagues as well as in his attitude to his teachers and senior colleagues there were definite signs that he was not as simple as he might appear at the surface. It was eventually assented at the Zurich Polytechnic that Einstein was, in his own words, "a curious bird" with certain ambitions and a deep conviction he knew more than his elders and betters.

One person was mostly trusted Einstein's far–reaching plans of building completely new theoretical conceptions. This person was Mileva Marič, Einstein's first serious romance. Letters to Mileva Marič help us to realize with certainty the general direction of the development of Einstein's thoughts that eventually brought him to his epochal discoveries.

The most rare, almost improbable thing one can believe of a famous scientist is the assumption that he was not in command of exceptionally strong and vividly demonstrated intellectual capacities. Is not it quite clear that one can make a great discovery only with the help of an extremely powerful intellect?

Yet biographers of both famous scientists are unanimous in their evidence that neither of them demonstrated outstanding intellectual capacities as a school pupils and even as university students.

Ronald Clark stated in his fundamental study of Einstein's life and time, "nothing in Einstein's early history suggests dormant genius." At his early teens, Albert made rather an impression of being a common child. People perceived him as being slightly backward and rather introspective.

Charles Darwin, at the early years of his life was even regarded having intellectual capacities lower of the standard ones. "...I believe that I was considered by all masters and by my father as a very ordinary boy, rather below the common standard in intellect," admitted Darwin in his *Autobiography.*

Here I would like to mention one particular feature common to both my heroes. They both disliked making references. Of course, references do not play any significant part in the history of great discoveries. But they are necessary conditions for adequate understanding and plausible discussion of a newborn idea. From the day of Aristotle, good references were considered as being insistently demanded from a serious scientific investigation. Men of learning know Zeno's famous paradoxes just due to Aristotle's references. Correct references play a special role in revealing the concise history of the development of scientific conceptions.

Being indifferent to making references, my heroes did not pay much attention to their predecessors. As it was mentioned above, historians of science cannot find a convincing answer to the question whether Albert Einstein had knowledge of Michelson's experiments by the time he developed his conception of relativity. Einstein's famous 1905 paper on relativity did not contain any reference of the works of his predecessors and did not mention ideas of his prominent forerunners Hendrick Lorentz and Henri Poincaré.

Likewise, the first edition of Darwin's voluminous *The Origin of Species* did not contain practically any plausible references. Charles Darwin never admitted the influence of Lamarck's conception on the formation of his evolutionary viewpoint. Loren Eiseley mentioned Darwin's "cavalier rejection of his distinguished forerunner". In the vast volume of *The Origin*, Alfred Wallace's discovery of the principle of natural selection was mentioned only once, and that only in the introduction. No surprise that the reading public believed Darwin drew his evolutionary conception directly from his studies of the living world. Loren Eiseley was forced to admit that "the still widespread notion that Darwin drew all his ideas from pure field observation has been furthered perhaps by Darwin's own seeming indifference to the history of the ideas with which he worked."

The indifference of my great geniuses to references is partly eplained by the fact that only their bright names remained in the history of science. History had made its decisive choice. Speaking of relativity, scientists remember only Albert Einstein. Considering evolution, people keep in mind only the name of Charles Darwin.

The differences between any two persons are practically unlimited. Nevertheless, I would like to mention two of them. Darwin's understanding of the logic of research was limited to orthodox Baconian inductive methodology. He was sure that discoveries were made through systematic collection of the necessary amount of observational data. He proudly mentioned in his *Autobiography*, "I worked on true Baconian principles and without any theory collected facts on a wholesale scale." Quite contrary to Darwin's inductive approach, Einstein gave preference to the inventiveness of thought and creative imagination. "For the creation of a theory," explained his standpoint Einstein, "the mere collection of recorded phenomena never suffices – there must always be added a free invention of the human mind that attacks the heart of the matter." These "free inventions of the human mind" were, of course, *hypotheses oriented on empiric data* and needing experimental confirmation. But many writers still believe that Einstein theories were pure products of a mighty intellect.

Charles Darwin took everything too seriously, especially his family life and continuous illnesses. Einstein liked to speak of everything, including his striking geniality and unprecedented fame, with a good portion of humor. Here is an example of his light–hearted attitude. "With fame", wrote Einstein, "I become more and more stupid, which, of course, is a very common phenomenon. There is far too great a disproportion between what one is and what others think one is, or at least what they say they think one is. But one has to take it all with good humor."

Case 19. Building artificial intellect

"nature could offer his children only primitive laws of thought."

Anonymous

In the mid–twentieth century cybernetics there was a sincere conviction that if one builds a sufficiently complex neuron system it would automatically model human intelligence. This romantic air of immediate success faded away very soon. Scientists had to admit that to model human intelligence one has to understand first of all the *logic of creative reasoning*. Eventually it came out that the most productive line of modeling human thinking was that of revealing the algorithms of solving problems in particular fields of human activity. This approach brought to creation of several types of so called "expert systems", among which I cannot avoid mentioning the *systems of medical diagnosis* and the *chess–game programs*.

This remarkable success should help to realize a simple truth that the general theory of artificial intellect must be based on the complete theory of problem solving. And as such a theory, of course, I would recommend my analytic–synthetic conception.

According to my analytic–synthetic approach, one may build the firm basis of the theory of artificial intellect revealing the *system of precise steps of problem analysis*. The second pillar of the strategy of building artificial intellect must be the teaching of the *methods of idea generation*. Here the main principle is that all solutions of problems are synthesized by *analogy with the solution of some similar problem*.

In actuality, the field of similar prototypes covers an unlimited range of problems. The most similar problems are almost identical with the problem under investigation. In this case one applies direct analogies. Extending the search of prototypes one comes to problems and objects so different from the problem under investigation that only inordinate imagination may assume there any similarity. These type analogies produce most original ideas some of which sound strange and crazy not only metaphorically.

Analysis prepares synthesis by analogy. Yet only clever people use right analogies. The field of possible analogies is unlimited. An analogy may never guarantee a correct solution. Since only a very limited number of prototypes lead to more or less satisfactory solutions, all the vast field of possible analogies are useless. Moreover, many of them are absurd and may serve only for one goal – to reveal the stupidity of the person that used it.

So, how should one choose the direction leading to right prototypes? Natural phenomena, living organisms and technical devices are normally classified according to their essential features and properties. So thinking of a given object, one first of all considers the most closely related objects in a corresponding list of natural classification.

But solving research problems or designing new devices one has to deal with different aspects and features of related objects. In research and design, as well as in any other field of investigation, just the *question formulated in the problem* under discussion determines the cross section by which the given object should be considered. The question of the problem directs also the search for prototypes and analogies.

For instance, studying the patterns of social behavior we find features similar with human social organization mostly in the tribes of primates. But when one deals with transplantation of organs it comes out quite unexpectedly that the closest species to humans are pigs.

The indicators of similitude are relative and dependent on the aspect of identification of the objects under consideration. The model of an object is usually suggested using some characteristic features essential in its relations and interactions.

In general, the strategy of searching *clever analogies* and good prototypes is as follows. Carrying on the analysis, the investigator reveals those features of the objects involved in the given problem that are related to the question of the problem. Taking into account these features, the investigator chooses the direction of the search for relevant prototypes. In the case of easy problems, the prototypes are very close to the initial problem and they bring to direct analogies. But if the problem is difficult, one is happy to find any prototype and does not much think if the analogy is remote enough or original.

Let us call *indicators* those features of the problem under research that one uses to reveal its precise type. Knowing the set of indicators, one can easily determine the type of the problem and its prototypes. This, in its turn, provides the ways by which the solution of the problem may be synthesized. This is the way to clever analogies.

Now let us turn to the weakest point of modern systems modeling human thinking. Even the best of them lack a basic ability – the ability to *understand* simplest information. Moreover, developing smart cybernetic systems, people are completely indifferent whether their creation would demonstrate any level of human understanding or not. And what is even more discouraging, this approach has good reason. The main goal of developing a computerized smart system is to suggest consumers a product that will satisfy their demands. In this practical approach, it does not matter at all if an efficient cybernetic device is deprived of the ability of understanding. The situation will change only if one presents a computerized device more efficient of competing systems due to its ability of understanding.

Thus one has to admit that the problem of computerized systems provided with the ability of understanding has undeniable theoretical significance. One should bear in mind also that people would never agree that a cybernetic device does really think unless it has the ability of understanding.

To make a bit closer the coming of computers capable of understanding information, let us examine what does a computer need to have this ability.

In general, the kind of understanding a computer needs is that of understanding the information it has got and stored in its memory. *Information is expressed and exists in the form of propositions.* Any information coming to the input of a computerized system may be presented as a chain of propositions. A complex proposition, in its turn, is built of simple propositions. The most simple proposition is the singular judgment "a has the property p" or symbolically $P(a)$. So the most simple task is to understand singular judgments of the type P(a).

What abilities should one provide a computer to make it able to understand the simplest information $p(a)$?

Aristotle had revealed that all notions of natural language belong to ten categories that in turn may be reduced to three most basic ones denoting *objects, properties*, and *relations*. Almost to the same conception came modern mathematical logic. Developing a symbolic language appropriate to mathematical reasoning logicians found out that the most adequate formal language is that of the calculus of predicates. Here any simple proposition is expressed with the help of symbols denoting objects and relations, properties being considered as a particular case of relations.

In short, all information may be reduced to objects, properties, and relations. This is the principle statement that programmers should introduce into computer's mind, I mean, into computer's memory. All the terms (symbols) in the memory of a computer should be divided into these three basic classes of objects, properties, and relations.

Then to understand a simple proposition $P(a)$, the computer must just identify its components with those the computer has in its memory and activate the information relevant to these components.

Thus the task of understanding by a computer the information it is supplied is in essence resolved. For complex propositions may be understood with the help of simple propositions of which they are built. And to understand a portion of information means to understand propositions contained in it.

There remains the practical problem of *standard presentation* of propositions of natural languages. Sentences used in the practice of communications often have structures significantly differing from the standards of the language of predicates. But even standard structures may lead to misunderstanding due to the ambiguity of the terms used in natural languages. A closely related difficulty is presented by idioms. To overcome these obstacles, one has to reveal and explicate syntactical, morphological, and contextual indicators sufficient for standard and unambiguous presentation of sentences.

Though any given theory may be considered as a set of sentences, the task of understanding a theory has its specificity. The core of a theory is contained in the *set of its basic principles and laws.* To reach a proper understanding of a theory, one should be able to deduce from its basic principles all general conclusions and particular laws. In other words, one can prove his adequate understanding of a theory by successfully applying it for the solution of general and particular problems.

The proper understanding of a problem under investigation is achieved, first of all, by its analysis. Testing suggested ideas of solutions we come to a deeper understanding of the given problem.

All the above factors are united in one final criterion. Namely, smart and understanding people suggest only clever analogies.

Case **20. The law of new scale of events**

"no one is warranted in extending principles beyond the boundaries of experience."

Ernst Mach

Different scales of reality have principally different laws.

Albert Einstein, most probably, was the first scientist to realize this law. At least, many interpreters of the special theory of relativity had mentioned that Einstein's revolutionary rebuilding of classical mechanics was conditioned by the necessity to involve into the framework of the theory the motion of objects travelling at the speeds close to the speed of light. Einstein himself, undertaking the task of building the theory of the universe as a whole, did not hesitate to introduce the force of cosmic repulsion, a hypothetical type of interaction of which there was no single evidence.

"No oath too binding for lover," said Sophocles. The founders of atomic physics Niels Bohr and Werner Heisenberg were ready to abandon the newly born quantum mechanics in the name of a more striking scientific revolution they felt in the air of their day. Niels Bohr once announced even that the fundamental law of conservation of energy might appear not necessary on the level of individual subatomic events. He repeatedly tried to revise the laws of conservation when physicists started to investigate a completely *new scale of physical phenomena*, that of atomic nuclei and nuclear forces.

Werner Heisenberg considered the possibility of the discrete, "quantized" structure of space to build the theory of interactions of high–energy elementary particles.

The law of the new scale of events is not specifically belonging to physical sciences. It should be considered as a *universal law covering all natural sciences.* Charles Darwin succeeded to explain the most improbable thing – the appearance of the ability of vision of animals through chance mutations – just by demonstrating the enormous evolutionary role of the big scale of time. Antony Leeuwenhoek discovered the secretive world of microorganisms when he got the opportunity to observe living cells through the microscope he built himself. The long and detailed research of the structure of the nuclei of the living cells revealed the DNA code of life itself.

Nevertheless, the law of the scale of events most vividly demonstrates itself in physical sciences. The study of atomic world revealed that even the conception of space–time motion of bodies loses its meaning on this level. Though quantum physics still assumes a kind of structure of atomic electron shells when it has to deal with atomic radiation.

On the level of atomic nucleus, even the concept of structure is hardly applicable. The *concept of structure presumes that there are separate elements having inner energy or mass of rest much bigger than that of the energy binding them with other elements of the system.* The heavy atomic nuclei do not satisfy this demand. Quite definitely, there is no ground at all to speak of inner structure at the scale of elementary particles since, in this case, the binding energy of presumed structural elements is comparable with the total energy of a particle under consideration.

Modern classical astrophysics tries to explain galactic evolution using only well known forces of physical interaction. But the newly revealed dimensions of eruption of energy and ejection of substance in the nuclei of galaxies are so enormous that one can hardly hope to handle them with the help of known forces. The only resort of astrophysicists is to adjust black holes to these purposes. But I can mention two major characteristics of the world of galaxies that make the hypothesis of cosmogonical activity of black holes practically improbable.

First, all galaxies eventually evolve and continue to exist as elliptical galaxies. This means that elliptical galaxies contain mainly old stars. According to comprehensive theories, black holes emerge at the last stage of evolution of stars. These two circumstances should have resulted in numerous events of accretion of the starry substance of elliptical galaxies by black holes accompanied by their huge radiation. But this, apparently, is not the case. In short, if the black hole were the finishing phase of certain type stars, then they would disrupt the matter of all galaxies giving no opportunity for the formation of elliptical galaxies.

There should be surprises also in the field of evolution of galaxies. Carefully examining pictures of galaxies in the *Hubble atlas* one can notice that all bright spots on these pictures are due to the superposition off faint multiple arms of galaxies. Keeping this conclusion in mind, it is not difficult to reveal that all structural elements of bared spiral galaxies – their nuclei, arms, and even bars – are visible just resulting from the superposition of their multiple arms. Further study shows that almost all barred galaxies have more or less developed disks of multiple arms. The dynamics of the tracks of multiple arms strongly suggests that the substance of multiple arms slowly slides down from the surface of the bars.

On the other hand, all spiral galaxies demonstrate quite developed disks of multiple arms. All these details of the structure of galaxies bring to the conclusion that barred galaxies evolve into corresponding type normal spiral galaxies by dissolving their bar–structure into a disk of multiple arms.

But it is almost unanimously accepted that normal spiral galaxies evolve into elliptical ones. So we come to an important conclusion that the evolution of galaxies takes its beginning by the phase of barred galaxies. In its turn, a barred galaxy emerges in the process of dissolving of its initial barred structure into a disk of multiple arms. This all means that all galaxies emerge from initial barred structures composed of dark substance of dust and cool gas.

But all the substance of the universe is contained in galaxies. Thus we come to an extraordinary picture of the cosmic evolution: the universe of galaxies took its start from innumerable bar–like structures composed of dust and gas. And these dust–gas bar–like structures unavoidably presume the existence of some unknown forces of nature since they rotate like rigid bodies.

I have above mentioned the huge effect of the big scale of time in evolution of life. Friedmann–Lemaitre assumption that the scale factor in Einstein's cosmological equation changes with cosmic time brought to the awful picture of the universe that should eventually contract into singularity. The extraordinary assumption of self–expansion of space has its positive role, too. Now *any physical constant may be considered as being time–dependent*. In his later years, Paul Dirac examined implications of the assumption of world constants being the function of time.

Consider one simple case, namely, that the world constant c is increasing with time. Then the older is a photon, the lesser should be its frequency. Accordingly, more remote is a galaxy, more significant should be the red shift of the spectrum of its radiation. Thus we explain the Hubble law of red shift. It makes unnecessary the assumption of the self–expansion of space and saves the universe from the Friedmann contraction into singularity.

Editor's note

Robert Djidjian claims, in the 14th section, about Gödel's theorem:

> *"In the ordinary elementary number theory, one cannot build Gödel's formula. ... the system in which Gödel's formula can be built and of which Gödel's theorem does speak, is an extension of the formal system of the number theory. Gödel's undecidable formula is a formula only in that extended theory, but not in the system of the formalized number theory. That means that Gödel's theorem proves the incompleteness of Gödel's extended theory, but not of the formalized number theory."*

But, as far as we know, Gödel's incompleteness theorems proves that the theory of Peano's arithmetic – not "elementary number theory" – if consistent, then is incomplete, i.e., there are first-order logic sentences true in the model of Peano's arithmetic but are not a consequence of the first-order logic axiomatization. Hence, Peano's arithmetic is an example of an undecidable theory. Indeed, in the ordinary elementary number Gödel's theorem does not work because it was developed in a more complex mathematical theory (which is not *metamathematics*), the Peano's arithmetic, which Robert Djidjian does not discuss. Consequently is hard to accept the concluding sentence of Robert Djidjian:

> *"If one has difficulties to accept this disturbing fact, he must realize at least that Gödel's proof reveals the* incompleteness of his formalization *of metalogic rather than that of formalized arithmetic."*

because the proof provided by Kurt Gödel is developed in Peano's arithmetic not in "his formalization".