THE SECRET OF GENIALITY (III)

Robert DJIDJIAN[1]

djidjianrobert@aspu.am

INSTEAD OF ABSTRACT

We continue to publish, in a series, the book THE SECRET OF GENIALITY (Yerevan, Armenia, Noyan Tapan Printing House, 2002) by our colleague Robert Djidjian, 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 age question: the dialectic of the insight, of the discovery, its psychology moving between flashes of intuitions and cognizance 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, creation is the secret of the human geniality, and how to create science is a main part of this secret.

(Ana Bazac)

Step 7. THE LAW OF INTERMEDIATE SOLUTIONS

"If I have seen further it is by
standing on the shoulders of Giants".

Isaac Newton

The greatest discoveries of geniuses of science are really marvelous. Wonderful and incredible they are. The ways leading to them appear unconceivable and mysterious. And all that because *we miss or forget the intermediate steps through which the great discoveries had been achieved*.

It is like with David Copperfield's fabulous tricks. They impress us as incredible miracles until we learn the complex apparatus behind them. The preparatory steps of great discoveries are so important for the proper understanding of their mechanism that I would like to suggest a special law concerning these steps. I call it the law of intermediate solutions. It proves that *all great discoveries had been made with the help of intermediate solutions.*

I will prove this important law empirically, bringing the evidence of the history of natural sciences. History shows clearly that theoretical conceptions were formulated and developed by efforts of successive generations of scientists. Every great discoverer might repeat about his predecessors Robert Burton's phrase, "I light my candle from their torches." Historians of science had truly noticed that the thought of each age is the foundation of that which follows.

Once again we begin with the Copernican revolution.

Astronomy took its rise from the tradition of watching the night sky. These observations eventually brought to the discovery of the five planets observable by the naked eye. Then cam the epoch of astronomical records and predictions. In regard of the history of human understanding of

[1] 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.

the universe, the discovery of the retrograde motion of the planets by the astronomers of Babylon was of extreme significance.

That was the initial factual material. The rational theory of the fabrics of the Heavens began with the formulation by ancient Greek natural philosophers of the fundamental conception that circular rotation is an ideal motion that can be continued eternally. Accordingly, heavenly bodies were supposed to move uniformly on circular orbits. In fact, the Heavens itself forced this conception on ancient thinkers. For long centuries mankind had observed the uniform and unchangeable rotation of myriad of stars. Was not it an absolute proof that heavenly bodies did move eternally and uniformly? And could anyone imagine any other type of motion to be eternal?

Plato used the principle of eternity of circular motion to build a model of the universe, with the Earth at its center and the planets and the Sun rotating in circles round it. But he was well aware of the main difficulty of the geocentric model of the universe – that of the retrograde motion of the planets. Plato urged his pupils and followers to overcome the difficulty with the help of some combination of uniform circular rotations.

Eudoxos brilliantly solved this enormous difficulty. He described the motion of each planet with the help of four uniformly rotating spheres. Later on, Herakleides of Pontos and Appolonios developed further the conception of Eudoxos suggesting the system of deferents and epicycles. The large deferent circle had its center the Earth. The center of the smaller epicycle circle steadily moved along the deferent. Arranging appropriate radii and speeds of these two motions, one could get any observed loop track of a planet.

Aristotle put a physical sense in the geometrical construction of Eudoxos. As we have discussed above, one of the main principles of his physics was a statement evident to anyone of his contemporaries: Each thing that is in motion necessarily is brought into motion by something else. We have learned already that this principle brought to the conclusion that there should be a source of the eternal motion in the world – the First Mover. According to Aristotle, the First Mover kept in eternal motion the outmost sphere of the fixed stars and through this sphere transmitted motion also to the spheres of the planets, to the Sun and the Moon, and eventually to the objects of the sublunary world.[2]

Surprisingly, Ptolemy and many other astronomers had little interest in the physics and mechanics of the heavens. Their aim was to build geometrical constructions that would enable them to calculate positions of heavenly bodies in satisfactory accordance with astronomical records. Ptolemy's great authority was based on brilliant calculations of his fundamental work – the famous *Almagest*. Actually, he built each time a special construction of epicycles, eccentrics and equants to calculate every type of deviation of the planetary motion from the uniform circular rotation. These constructions were so specified for each case that on could never combine them in one coherent model of the universe. In the result, there remained no physical sense in the Ptolemaic geometrical models of the motions of the heavenly bodies.

Except of Copernicus, no astronomer ever reproached great Ptolemy for the lack of physical sense in his geometrical constructions. If Copernicus succeeded to demonstrate that the geocentric system was an erroneous conception, but could provide with the help of his alternative heliocentric system only less accurate calculations, many astronomers would still prefer Ptolemic better calculations to Copernicus' true model. Perhaps, Copernicus himself would prefer to build more accurate astronomical tables rather than to be involved in disputes around his new conception of the Heavens. Anyway, for long thirty years Copernicus did not bring forth his fundamental work *On the*

[2] Aristotle, *Physica* VIII 10, 267 b 9.

Revolutions until the last month of his life. And even this late publication was due to the strong insistence of his friends.

There came the year 1543. With the publication of the *Revolutions* started the new epoch of human understanding of the world. Myriad of stars stopped their rotation around the Earth. The dwelling of the mankind lost its sacred standing at the center of the universe. The Earth was brought down to be an ordinary planet, the third planet of the solar system. Yet astronomers did not hurry to change their traditional world outlook. Almost a century after the publication of the new system of the world, few astronomers did accept the heliocentric conception.

Things changed dramatically with the publication of Galileo's telescopic observations. Nevertheless, Isaac Newton had to discover his law of universal gravity to give the final proof to the heliocentric hypothesis. This, in turn, would be very hard to accomplish if Johannes Kepler had not discovered the kinematic laws of the motion of the planets. And Kepler would not have the opportunity to undertake his exploration without night-to-night observations of the position of Mars that had been carried on continuously in Tycho Brahe's observatory for many years.

Finishing thus with the intermediate steps of Copernican revolution, let us now revue the intermediate solutions that eventually brought to the second great scientific revolution – the Newtonian mechanics.

Aristotle's physics had its heel of Achilles. I mean the problem of the motion of projectiles, for instance, the motion of a stone released from a sling. To explain this kind of motion, scholars of Medieval Europe assumed the action of an "incorporeal power", or "impetus". Buridan thought that the action of impetus continued until interrupted by an outside interference or resistance. Benedetti was first to emphasize that the stone released from a sling continued its motion by a straight line. Eventually Galileo concluded that, in general, bodies would maintain their motion if external interference were removed – a statement which contains the main idea of the first law of Newton's mechanics.

Analyzing further the motion of a stone kept in rotation by a sling, Christian Huygens found out that the acceleration of the stone was directly proportional to the square of its velocity, and inversely proportional to the radius of the circle. Huygens concluded that the force, which prevents the stone from flying away, was also proportional to this amount of acceleration. In fact, Huygens presumed that the acting force was proportional to the acceleration it caused to a moving body. And that was the essence of the second law of Newtonian mechanics.

Newton's predecessors and contemporaries had found many intermediate solutions also in regard of the law of universal gravitation. Borelli suggested that the force, which kept the Earth and the planets of the solar system on their orbits, was the attraction exerted by the Sun. Huygens demonstrated that if planets were moving by circular orbits, the force of attraction would be inverse-square of the radii of orbits.

To the same conclusion came also Robert Hooke. He attempted also to show that the Earth must travel on an elliptical orbit being attracted by the Sun. Hooke eventually suggested the hypothesis of the universal gravitation though did not succeed in proving it. I think the above-mentioned rich variety of intermediate solutions fully justifies Newton's remark in his letter to Robert Hooke that I used as an epigraph to the present chapter. Indeed, Newton could see much further and build the synthetic system of the new mechanics due to the gigantic work made by his great predecessors.[3]

[3] Newton's words in the epigraph of this chapter were written in his letter to Robert Hooke on February 5, 1675. By these words he appreciated the contribution of Descartes and Hooke to natural science. (*The Correspondence of Isaac Newton*, vol.1. Cambridge, Cambridge University Press, 1959, p.416.) Unfortunately, Newton never admitted publicly

Now let us turn to another revolutionary discovery. Charles Darwin's teaching is usually mentioned as "the theory of evolution" though it was neither the first nor the final theory of evolution. Undoubtedly, *The Origin of Species* contains the main principles of the modern theory of evolution and draws a convincing picture of the evolution of animal world. But the idea of evolution had a history of long centuries, and the conception of natural selection could hardly be convincingly proved without the help of new genetic theory.

Darwin himself mentioned in the short historical introduction of the *Origin* that Aristotle was quite aware of the role of natural selection and spontaneous mutations in the evolution of the living world. Aristotle's ideas were never developed further. Up to eighteenth century, the common belief was that all forms of life appeared on the Earth in one act of Creation. This view appeared almost necessary if one believed in the *Bible* and accepted the classification of species by Linnaeus. The eighteenth century educated people firmly believed in the Linnaean principle "There are no new species".

But just the eighteenth century produced a generation of great innovators. In 1749, the Comte de Buffon published his *Natural History*, a fascinating study of the living world. Through its volumes were scattered many important evolutionary statements. Buffon declared that all animals came from the same origin. The new forms of life came to existence through improvement and degeneration, by variations of individuals and struggle for existence. Jean Baptiste Lamarck, apparently under influence of Buffon, created a quite convincing conception of evolution. Its main idea was completely logical. Changing environment produces changes in the behavior of an organism. New behavior brings to more intensive use of some organs and disuse of others. Physical and biological changes that an individual acquires through use and disuse are inherited by next generations.

Baron George Cuvier made the next important intermediate step. Cuvier created comparative anatomy, which appeared to be the only empiric means for evolutionary studies of the living species as well as of their relations to the extinct ones. In Loren Eiseley's words, Cuvier "opened the doorway of the past".

When Cuvier succeeded to show that many fossils contained in geological layers belong to extinct species it brought the final proof to the idea of the evolution of species. The theoretical interpretation of this factual statement might be different, and many of them had been wrong (as the conception of catastrophism proposed by Cuvie himself). But after Cuvie, no one could question the *fact* of the evolution of organic life on the Earth.

By the beginning of the nineteenth century, every component of Darwin's theory had been at hand for the synthesis of the new conception.[4] And when it was presented in the *Origin of Species*, the impression was immense. Yet many educated people learned about the theory of evolution not directly from Darwin's voluminous work, but rather from the abridged presentations of the theory in many popular publications. So there was a wide spread doubt and suspicion if Darwinian

the significance of Hooke's contribution to physical science. "Hooke was a genius," pointed out Robert Burton, "that is only now being recognized as it should have been, long since." (Robert K. Merton, *On the Shoulders of Giants.* New York, The Free Press, 1965, p.12.)

[4] Loren Eiseley's historical study convincingly proves a paradoxical conclusion that Darwin could develop the theory of evolution without undertaking the voyage on the *Beagle* for the search of new observational data. Everything lay ready in the works of Darwin's numerous predecessors. "One can point out," wrote Eiseley, "that every idea Darwin developed was lying fallow in England before he sailed. One can show that sufficient data had been accumulated to enable man of great insight to have demonstrated the fact of evolution and the theory of natural selection by sheer deduction in a well-equipped library." (Loren Eiseley, *Darwin's Century: Evolution and the Men Who Discovered It* (1958), Anchor, 1961, p. 148.)

principles were sufficient to explain all the perfection and richness of the living world. Even today you can meet people who have serious difficulties to believe that chance variations could bring to such complex and intricate structures as living organisms and their complex organs. It seemed almost impossible that such specific organ as the eye could be a result of the accumulation of chance mutations.

And just here proved itself Darwin's genius. Darwin brilliantly demonstrated on the space of two pages how could the eye originate through several intermediate stages, beginning with the cells reacting to the rays of sun and through organisms with spots of their skins sensitive to the sunlight.[5] A chance occurrence of the eye is really an improbable phenomenon, but just natural selection was the mechanism for generating an exceedingly high degree of improbability. As Julian Huxley had mentioned, natural selection converts random accident and blind chance into purposeful design and organized pattern.

Darwin himself did not stress in a general form the important role of intermediate species in the process of evolution. To me, the mechanism of intermediate steps appears the most basic point of evolutionary theory. Evolution is not just a continuous accumulation of infinitesimal variations. It is rather a step by step change through the intermediate forms, the accumulation of variations being only the mechanism leading to each of these qualitative stages. The final stage of this step by step evolution – the species with some radically new organ or behavioral property – is an organic form that has a dominant advantage compared to the challenging species. Just this dominant advantage provides the evolutionary stability of new species.

Let us now review the intermediate stages in the formation of another great achievement of the nineteenth century science – the electromagnetic field theory. One of the most effective means of modern science is the experimental method. The science of electromagnetic phenomena came to existence directly by implication of various experiments. At first stages of its development, the new science did its consecutive steps by the following scheme. A chance observation during an experiment revealed an unusual phenomenon; then it was immediately labeled by a special term and given some preliminary explanation, usually not so much true; the further experimental research brought to light the real essence of the new phenomenon.

The first book on electromagnetic phenomena was published by William Gilbert in 1600. The title of the book was *On the Magnet and Magnetic Bodies, and on that Great Magnet the Earth.* It presented the results of long 17 years of experiments with natural magnets and static electricity.

By the end of the eighteenth century Charles Augustin Coulomb formulated the law of electrostatic interaction almost identical by its structure to the law of universal gravitation.

The real advance in the study of electromagnetic phenomena began only after the invention of the stable source of electric current. All began with Luigi Galvani's chance discovery of electric effects in the chains containing different metals. Soon Alessandro Volta understood the essence of Galvani's discovery. He succeeded to build by the beginning of the nineteenth century the first sources of stable electric current – the Voltaic pile and electric battery. Already two decades later, Simon Ohm established the law of direct electric current.

The first scientist who discovered that electric and magnetic phenomena are interconnected was Hans Christian Örsted. In 1820, during a lecture on the hitting of the conductors of electric current, Örsted observed the action of the electric current on a magnetic needle that accidentally had been left nearby.

It is hard to believe, but this single fact appeared sufficient for Andre-Marie Ampere to develop the first theory of electrodynamics. He proved that all magneto-static phenomena could be

[5] Charles Darwin, *The Origin of Species by Means of Natural Selection,* p.144.

explained with the help of electric current flowing in circles. Ampere actually “abolished” magnetism. Magnetic phenomena were reduced to properties of the systems of circular currents.

Naturally, some physicists thought there might be a symmetrical relation, namely, magnets were supposed to be able to produce electric current. Possibly, if Ampere’s discovery were given more appropriate wording, the expectations of physicists would be more realistic. Electric current is a stream transmitting electric charge. So Ampere should state that the *flow*, or the *motion*, of electric charge could produce magnetic field. In that case, it might be expected that the *motion* of magnets, the change of magnetic field, in its turn, could produce electric current, too. All that, of course, I understood *post factum*, already knowing Faraday’s discovery. Faraday himself was guided only by his deep conviction that there must be a unity of all forces of nature, first of all, the unity of the closest “relatives” – the electric and magnetic fields.

Michael Faraday was, undoubtedly, one of the greatest geniuses of physical science. Nevertheless, he did not inquire the secrets of nature in complete isolation. Faraday’s investigations were strongly motivated by the general atmosphere of the expectation of great discoveries in the field of electricity and magnetism. Many scientists conceived the unity of these fields. One should first mention among them Örsted and Ampere, the most prominent figures in the field of electricity of their day. During his first trip to the Continent, young Michael Faraday attended in Rome the experiments of Morichini who tried, among other original things**,** to magnetize needles with the help of Sun rays.

Anyhow, it took Faraday more than ten years of systematic experimentation to discover that electric current could be produced by the change of the flow of magnetic fields. Earlier he proved that magnetic field could rotate a circuit with electric current. These discoveries eventually brought to the formation of the modern electromagnetic technology. Faraday built himself the first electric motor and the first electric generator.

Since Faraday was not good in mathematics, he never tried to formulate quantitative laws of electrodynamics. The complete theory of electrodynamics was developed by James Clerk Maxwell in the second half of the nineteenth century. Maxwell came to the conclusion that changing electric and magnetic fields must induce each other producing electromagnetic radiation. When he calculated the speed of this radiation, it came out that it was very close to the speed or light. Did not it mean that light itself was an electromagnetic radiation? By the end of the century, Heinrich Hertz confirmed Maxwell’s both predictions experimentally.

Though the general theory of electrodynamics was triumphant by the end of the nineteenth century, even its founders could not guess what was the substance of electric charge. The first answer came with J. J. Thomson’s discovery of the electron in 1898.

This discovery was the important link for the transition from the classical macrophysics to the new science of atomic physics. First significant steps in this direction made Lord Kelvin and J. J. Thomson.[6] A number of transitional solutions on the way to the quantum mechanical theory of the atomic world emerged from the ideas of Rutherford, Planck, Einstein, Bohr and De Broglie.

Finally, let us consider the formation of the theory of relativity. In his lecture indirectly related to his Nobel Prize award, Albert Einstein mentioned two major factors having essential

[6] I would like to bring in A. D’Abro’s account of Lord Kelvin’s first intermediate step in developing the model of atom: “The first atomic model was devised by Lord Kelvin. At the time he was pursuing his investigations, the most conspicuous property credited to atoms was their stability; and the main purpose of Kelvin’s model was to account for this stability. Now, the theoretical investigations of Helmholtz in hydrodynamics had established the peculiar stability of vortex motions, and so Kelvin availed himself of this discovery and assumed that an atom was a vortex in the ether… “ (A. D’Abro, *The Rise of the New Physics. Its mathematical and physical theories.* New York, Dover Publications, 1951 (first edition 1931), p.473.)

bearing on the formation of his theory of relativity, namely, the problem of preferred states of motion and the necessity to use only strictly defined theoretical notions. Yet, in the same lecture Einstein admitted, "The special theory of relativity is an adaptation of physical principles to Maxwell-Lorentz electrodynamics".[7]

A. D'Abro who could closely observe the formation of the theory of relativity illuminated the role of Lorentz works as an intermediate solution to the final creation of Einstein's theory. "The progress of science is gradual, " pointed out D'Abro, "and before revolutionary changes are accepted, attempts are usually made to interpret the facts at our disposal in terms of those classical notions which have proved their worth in other situations. Lorentz accordingly viewed his transformation as purely formal and as having no bearing on the space and time of physics. Then a year later, Einstein adopted the more revolutionary course, contending that the Lorentz transformation expressed the relations between physical space and time. This departure marked the start of the special theory of relativity."[8]

Let us sum up. All great discoveries had been made through intermediate stages. Ideas breed ideas. With the help of intermediate ideas scientists come to greater insights.

It is not difficult to see that this principle fact of the history of science is in good accordance with the analytic-synthetic conception of the logic of creative problem solving.

To solve a difficult research problem one has, first of all, to simplify it, to build its approximate models. The solutions of these simplified models are important intermediate stages of scientific investigations, in general, and of great discoveries, in particular. The second group of intermediate solutions is formed by the sub-problems to which investigators reduce their research problems. The third typical group of intermediate solutions comes out of preliminary hypothetical solutions the correction and improvement of which bring to the final solution of the problem.

If we fail to realize the role of intermediate solutions, many discoveries would appear to us unexplainable and irrational. Especially in the case of Isaac Newton who insisted in his later life that all his great discoveries in mathematics, optics, mechanics, and theory of planetary motion were made in the so-called "plague years" of 1665-1666. This wonder could happen only with the help of divinity since Newton began reading first serious scientific works on mathematics and natural science in 1664 only. Naturally, writers who believed the correctness of the reminiscences of the aging sage about these events, which presumably took place many decades ago and were not fixed in any of Newton's dated manuscript, had no choice but call the years 1665-1666 *anni mirabiles* ("the years of wonder"). And their entire life these writers had to struggle with another mystery too. What was the reason that Newton published his discoveries of *anni mirabiles* only twenty and even thirty years later?

Ideas emerge mainly by reading and talking. This simple principle solves all the mysteries of "delayed publications" and *anni mirabiles.* Developing his system of the world Newton apparently got the assistance of the intermediate solutions presented in Hooke's hypothesis. Many useful ideas of optics one could find in Huygens' publications. The Leibnitz-Newton controversy concerning the discovery of differential calculus reflects another case of an important intermediate solution.

Some philosophically reasoning writers believe that it is impossible to imagine the Newtonian revolution without the background of medieval philosophy and Aristotelian teachings. For instance, Richard Westfall insists that Newton had "to reciprocate the prior history of the

---

[7]Albert Einstein, *Fundamental Ideas and Problems of the Theory of Relativity*. – In: *Nobel Lectures. Physics*, vol.1. Amsterdam, Elsevier Publishing Company, 1967, p.p.482-484.

[8] A. D'Abro, *The Rise of the New Physics. Its mathematical and physical theories*. New York, Dover Publications, 1951(first edition 1931), p.79.

scientific revolution and have his own private rebellion against the orthodoxy established around him". But as we have seen above, reading the works of his contemporaries and talking to them would quite suffice Newton's enormous genius to proceed with his great theories.

Step 8. ON SEEING CENTURIES AHEAD

"*The years teach much*
***which the days never know.*"**

Ralf Emerson

Like children dreaming of beautiful fairytales, educated grown-ups are inclined to believe in the magical intellectual power of the geniuses of science. Indeed, it seems quite impossible that without this magical power there could emerge the wonder of amazing theories, which impress wide public even more irresistibly when their principles and conclusions appear totally incomprehensible.

After the publication of Einstein's *Autobiographical Notes* many writers on science and creativity set out to prove that geniuses of science are able to coin fundamental theories "just out of their own brain", never seeking help or guidance of empiric data and experimentation.

This conviction arose partly due to Einstein's account of the way he had developed *the special theory of relativity*. A casual remark of the great genius made the impression that the starting point of his deliberations upon the problem of radiation was the paradox he had revealed at the age of sixteen. The paradox concerned a hypothetical observer travelling at the speed of light. Such a traveler should observe a beam of light "as a spatially oscillating electromagnetic field at rest", which was impossible both empirically and theoretically.

This paradox contained the "germ" of the special relativity. "Today everyone knows, of course," mentioned Einstein, "that all attempts to clarify this paradox satisfactorily were condemned to failure as long as the axiom of the absolute character of time, viz., of simultaneity, unrecognizably was anchored in the unconscious. Clearly to recognize this axiom and its arbitrary character really implies already the solution of the problem." The last sentence apparently made reference to Einstein's 1905 famous paper in which he developed his theory through a careful analysis of the concept of simultaneity.

But how could one come to this unusual way of building a fundamental physical theory? Einstein's answer was entirely clear: "The type of critical reasoning which was required for the discovery of this central point was decisively furthered, in my case, especially by the reading of David Hume's and Ernst Mach's philosophical writings".[9]

At first glance, this scheme of discovery clearly confirms the popular view that this great scientific result, *the conception of special relativity*, was achieved through "pure thinking". It had begun with the mental experiment of a sixteen years old inquisitive youngster and was finalized by another mental experiment, which revealed the essence of simultaneity with the help of critical reasoning learned from the great skeptics David Hume and Ernst Mach.

If we want to understand the position of the great scientist adequately, we must avoid judging from isolated statements. In general, Einstein underlined in many his writings the important role of empiric data and the necessity to develop theoretical conceptions in agreement with them. In

[9] Albert Einstein, *Autobiographical Notes.* – In: *Albert Einstein*: *Philosopher-Scientist*, vol.1. La Salle, Ill., The Open Court Publishing Co., 1970, p. 51.

the same *Autobiographical Notes* it is firmly stated that the study of the problem of relativity was started on the basis of empiric data and experimental facts. "By and by I despaired," recalled Einstein, "of the possibility of discovering the true laws by means of constructive efforts based on known facts."[10] Here Einstein clearly notes that he started his attempts to solve the problem the way all scientists do, namely, by considering known empiric facts.

Of course, there is no direct way from empiric data to abstract theoretical principles especially when there is a necessity of radical reconstruction of a basic theory. "The longer and the more despairingly I tried," continued his account Einstein, "the more I came to the conviction that only the discovery of a universal formal principle could lead us to assured results." The great scientist was absolutely right. The solution could be achieved only with the help of a new theoretical principle. But it would be wrong to conclude that one was able to discover this principle relying only on the power of "pure thought", isolated from empiric data and efforts and results of other investigators. Consider Einstein's cosmological model of the universe, possibly the only physical theory that could claim being completely free from empiric data. Yet even in regard of this extraordinary theory Albert Einstein had noticed a necessary coordination with observational data. One of the most startling features of Einstein's model of the universe was the cosmological term that should provide stability to the universe. In his famous 1917 paper Einstein directly mentioned, "That term is necessary only for the purpose of making possible a quasi-static distribution of matter, as required by the *fact* of the small velocity of the stars".

As we have mentioned earlier, no scientist is able to reconstruct the real succession of thoughts that have brought him to his great discovery. When a famous scientist recalls his great achievement, he partially reconstructs the real events and unavoidably thinks up the way this discovery should or could have been made. Einstein himself mentioned in his *Autobiographical notes*: "I can remember – or at least believe I can remember". True, it concerned of an event of his childhood, but a few pages earlier he had already admitted in most general way, "Every reminiscence is colored by today's being what it is."[11] In this regard, it can be added here that the above paradox of the observer travelling at the speed of light is not mentioned either in the sixteen years old Einstein's sketch concerning the theory of electromagnetic radiation or in his famous 1905 paper on the special theory of relativity.

Great discoveries are really amazing and fascinating. But if we remember that they have been reached step by step, that geniuses of science were supported by ideas of their predecessors and contemporaries, then even the greatest discoveries will significantly lose the aura of magic and mystery. In regard of the goal of this book, a related issue must be discussed here. I mean the legend that geniuses of science, using the immense power of their intellect, were able to penetrate into the future developments of science and foresee its progress centuries ahead.

The legend, most possibly, could arise due to the lack of knowledge of the real ways of great discoveries. But it has a rational ground too. The greatest scientific discoveries, resulting in the revolutionary reconstruction of the basic conceptions of their time, have symbolized the beginning of new epochs in the history of human knowledge. Actually science enters new epoch with the help of great discoveries of geniuses of science. So there is definite reason to believe that geniuses of science made their epochal discoveries foreseeing the future development of scientific conceptions centuries ahead.

A revolutionary idea is always put forth as a solution of a particular scientific problem. Its significance and role is understood only much later, and not always due to the efforts of the

[10] *Ibidem,* p.53
[11] *Ibidem*, p.3.

discoverer. The understanding of the true essence of the new discovery comes step by step, in the process of intensive discussions, constantly opposed to alternative approaches and interpretations.

I will begin again with Copernicus. He strongly believed in the ancient principle that the rotation of celestial spheres was eternal and self-sufficient. But ancient thinkers accepted this principle because they were sure in the reality of the rotation of the stars round the Earth. Being completely convinced in the reality of this motion, they had in their disposal a clear example of eternal motion – the uniform rotation of the stellar firmament. Centuries of astronomical observations of the stars proved that their positions on the sky and the speed of their rotation did not suffer a slightest change.

Copernicus continued to believe in the eternity of the rotation of planetary spheres as if he forgot that he had already "stopped" the rotation of the stellar firmament when he proved that, in reality, it was the Earth rotating round its axis. But the rotation of the firmament of the fixed stars was the only eternal motion known to mankind. And if there was no other factual evidence of the existence of eternal motion of heavenly spheres, why should one accept the principle of the eternal uniform rotation of celestial spheres as the basic principle of the physics of the heavens? Apparently, just because Copernicus believed the Earth and the planets were rotating uniformly round the real center of the universe, the Sun.

Immanuel Kant, one of the greatest thinkers of the eighteenth century, was sure that Aristotle's syllogistics is an embodiment of the absolute truth. In his *Logic*, Kant declared that no word could be added to Aristotle's theory of deduction. But already in the next century George Bool and Ernst Schröder created a completely new and more powerful system of the theory of deduction – *the algebra of logic*. At the end of the nineteenth century, Gottlob Frege built the first system of the modern theory of deduction later called mathematical or symbolic logic.

For the modern educated men, Charles Darwin's name is a synonym of the thesis that the human race has originated from apes. But in *The Origin of Species* the problem of human origin was mentioned only in a passing sentence on its last page. "His was a world of insects and pigeons, apes and curious plants, but man as he exists had no place in it," pointed out one of Darwin's critics. Only fourteen years later Darwin published a special study on this issue, the *Descent of Man*. Yet some historians of science believe that he was just forced by his position of the founder of the theory of evolution to discuss the issue. In actuality, there was a serious ground not to hurry with the theory of the descent of man. In Darwin's day, there were no fossil remnants in hands of paleontologists that could be ascribed to ancestors of the human race. By the mode of his thinking, Darwin was inclined to empiricism. He believed in things he could observe himself and strongly disliked theoretical speculations.[12]

It is widely known that Einstein did not approve Bohr's probabilistic interpretation of quantum mechanics. To the end of his life, Einstein insistently repeated that he did not believe God (= nature) played at dice. Heisenberg recalled that Paul Ehrenfest once reproached Einstein that he behaved in regard of quantum mechanics the same way as had the conservative scientists behaved in regard of the theory of relativity.[13]

In his turn, Heisenberg did not believe in the success of Einstein's attempts to build a unified field theory. He rejected also the quark conception of elementary particles, which by the end of the twentieth century established itself as a fundamental physical theory.[14]

---

[12] Loren Eiseley, *Darwin's Century. Evolution and the Men Who Discovered It*. New York, Anchor Books, 1961, p.256.

[13] Werner Heisenberg, *Erinnerungen an Niels Bohr aus den Jahren 1922-1927*. – In: W. Heisenberg. *Schritte uber Grenzen.* Munchen, 1973, S.70.

[14] Werner Heisenberg, Was ist ein Elementarteilchen? – *Die Naturwissenschaften*, 1976, Bd.63, S.7.

As we see, many great scientists have been mistaken in their assessments of new scientific conceptions suggested by their contemporaries. Mach and Avenarius doubted even the existence of atoms. By the end of the nineteenth century, Lord Kelvin, President of the Royal Society of London, the most prominent scientist of his day declared his deep conviction: “Heavier-than-air flying machines are impossible.” A couple of years later first airplanes conquered the sky.

So, one can conclude with certainty that there is little ground for the opinion that great scientists foresaw the development of science centuries ahead.

The only case when a great scientist predicted a discovery of the future science is that of Michael Faraday. In 1832, he wrote a letter, sealed it and asked to keep it in the archive of the Royal Society of London at least for one hundred years. The letter was opened in 1938. It contained Faraday’s prediction that magnetic action and electric induction are propagated in the form of waves. The existence of the waves of electromagnetic radiation was proved only half a century later.

Therefore, the belief that geniuses foresee centuries ahead is only a legend. There is little ground to think that geniuses of science have some special kind of extraordinary and supernatural abilities to penetrate into the essence of natural phenomena and solve the most difficult problems of science.

There is one more fact of the history of science, which can strengthen further my thesis that geniuses of science had not extraordinary intellectual capacities. I mean the very surprising fact of the history of science that some greatest names of science did not understand adequately their own scientific discoveries. The most striking case is presented by Max Planck’s discovery of quanta of radiation. As we have seen above, Planck suggested quanta of action just as a mathematical means to derive the correct formula of energy distribution in the spectra of electromagnetic radiation. The first scientist who put a physical sense in Planck’s conception of quanta was Albert Einstein. Though, even Einstein was cautious and qualified his own approach as a “heuristic viewpoint”.

On many occasions Max Planck liked to mention that the real proof of the quantum theory of radiation began with Einstein’s discovery on quanta of light. But apparently Planck was not completely convinced in quantum hypothesis even after the publication of Einstein’s historic paper. It is well known that Planck persistently continued to search a classical, non-quantum mechanism for the explanation of the discrete radiation of energy. “My futile attempts,” recalled Planck later, “to put the elementary quantum of action into the classical theory continued for a number of years and they cost me a great deal effort.”[15] Planck repeatedly tried to reconcile his quantum conception with classical theory developing mechanisms of continuous absorption of quanta of energy. His efforts were so serious that there a term was introduced – “Planck’s Second Theory”.[16]

Cases of misunderstanding and misinterpretation of own discoveries are quite numerable. Newton’s *Principia* and *Opticks* prove their author’s exceptional ability to reveal the very essence of the phenomena under investigation. Yet, even Newton not always appeared correct in his interpretations. In the *Principia* he clearly stated that absolute space and “true motion” are unobservable and that scientists have to deal only with relative space and time. Yet he was deeply convinced in the existence of absolute motion and in the necessity of the conception of absolute time and space.

---

[15] Max Planck, *Scientific Autobiography and Other Papers*. London, F. Gaynor, William and Norgate, 1950, p.7.
[16] Sir Edmund Whittaker, *A History of the Theories of Aether and Electricity*. *The Classical Theories*. London, Thomas Nelson and Sons, 1962 (First Published 1910), p.103.

Things are even more perplexing with the epochal discovery of gravitation. Undoubtedly, the question of the essence of gravitation appeared the most difficult one in the history of physics. Even after Einstein's fundamental research scientists are not sure they have eventually come to grips with gravitation. One can easily understand the caution in regard of this question. Nearly a decade after the publication of *Principia*, Newton mentioned in a letter to Richard Bentley, "You sometimes speak of gravity as essential and inherent to matter. Pray, do not ascribe that notion to me; for the cause of gravity is what I do not pretend to know, and therefore would take more time to consider of it".

So, to shed light on Newton's view on the essence of gravitation, writers usually quote the following peace from his another letter to Bentley: "That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man, who has in philosophical matters a competent faculty of thinking, can ever fall into it". Since modern readers are absolutely sure that gravity is an innate property of matter, they conceive Newton's statement as a direct rejection of the possibility to present gravitation as action at a distance.

In actuality, Newton did not assume that gravity is an innate property of matter. On the contrary, in *Opticks* he even tried to explain gravity as resulting from the pressure of the world ether. Moreover, he even considered the possibility that gravitation is mediated by something non-material or immaterial. "Gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material *or immaterial*, I have left to the consideration of my readers," speculated the great physicist in the same letter to Bentley.[17]

Hendrick Lorentz is rightly acknowledged as one of the founders of new relativistic mechanics, which eventually brought to complete rejection of the conception of the world ether. He is known also for his positive position in regard of Einstein's conception of the special theory of relativity. Yet, he apparently was unable to abandon completely the conception of ether. Even in 1909, Lorentz still insisted, "I cannot but regard the ether, which can be the seat of an electromagnetic field with its energy and its vibrations, as endowed with a certain degree of substantiality, however different it may be from all ordinary matter".[18]

The other instructive example is Charles Darwin's attitude to the principles of the theory of evolution. Today, speaking about Darwinism, two main factors of evolution are necessarily mentioned: fortuitous variations and natural selection. But Darwin himself was not much strong and consistent in these Darwinian principles. As Loren Eiseley showed, Charles Darwin, when under the pressure of criticism and radical objection, did often open space for the Lamarckian conception of genetic transmission of characteristics acquired by an animal during its own life. Darwin's thinking was transitional from the Lamarckian conception to genetic evolutionism. "He is half modern, half experimental, yet in times of difficulty he is capable of obscure retreats in the direction of eighteen-century concepts," noticed Eiseley.[19]

James Clerk Maxwell belonged to the most brilliant physicists of the nineteenth century. Developing the theory of electromagnetic phenomena, Maxwell supposed in 1870, long before the discovery of the electron, that there should exist charged particles radiating light. Yet he concluded,

---

[17] Newton to Bentley, 25 February 1692. – In: *The Correspondence of Isaac Newton*, vol.3. Cambridge, Cambridge University Press, 1961, p.253.
[18] Quoted Jeremy Bernstein, *Einstein*. New York, Penguin Books, 1973, p.55.
[19] Loren Eiseley, *Darwin's Century,* p.217.

"no force can alter ever very slightly either their mass or their period of oscillation". But already by the end of the century it was experimentally proved that the mass of an electron depends on its speed.

The two decades of the history of formation of *quantum mechanics* provide a collection of curious misunderstandings too. One of the first systems of the theory of the atom, the *wave mechanics*, was developed by Erwin Schrödinger. He succeeded to explain the discreet spectra of atomic radiation with the help of wave function. So he concluded that within the atom electrons were dispersed in the form of standing waves. It is unanimously accepted today that the wave function (the square of its amplitude) describes only the probability of corresponding physical parameters.

Some months earlier of Schrödinger, Werner Heisenberg used the multiplication of the matrixes to describe the phenomenon of radiation dispersion. He was not even slightly aware that he had elaborated the matrix system of quantum mechanics. Pushing further his method of multiplication of matrixes, he suddenly saw that the product of the matrixes *uw* was not equal to *wu* (the same product with the interchanged places of the matrixes). Paul Dirac recalls that Heisenberg was very much disappointed by this fact and believed there was some serious mistake in his method. To Heinsenberg's great relief, soon Dirac and Jordan showed that this property of the "non-commutativeness" was the main characteristic feature of quantum mechanics.[20]

There was an interesting case of misinterpretation in Paul Dirac's research work, too. When he applied a relativistic approach to the equations of quantum mechanics, he discovered that there should be states with negative energy and particles symmetrical to the "normal" particles with positive energy. His theory predicted the existence of the anti-electron, an analogue of electron but positively charged. Since the only atomic particle with positive charge known by that time was the proton, Dirac suggested that just protons were the anti-particles of electrons. It was quite a strange suggestion. Not only because the anti-particle of electron had to have the same mass as the electron, while in actuality the mass of the proton is almost 2000 times greater. The more striking moment was connected with the conclusion that a particle and anti-particle should annihilate in the case of their collision. So it was surprising that the existing world built predominantly of electrons and protons did not yet annihilate. The situation got "stabilized" after the discovery of the positron, the real anti-particle of the electron.

Generalizing the experience of his generation of physicists, Werner Heisenberg noticed ones, "New ideas never appear clear at the very start". The first system of quantum mechanics was created in 1926. But by that time, admitted Heisenberg, neither he nor three other co-authors of the system, Born, Jordan and Dirac had a clear understanding of the physical essence of their discovery. "We did not know," recalled later Heisenberg, "how should one interpret this quantum mechanics and what was its real content".[21]

"Even the paradise is imperfect," said a poet. Apparently, creations of the greatest minds of mankind were not free of dark spots, too. In general, geniuses of science suggesting their fascinating ideas make only the first decisive steps in building new revolutionary theories. No surprise that at these early stages of the development of the completely new theoretical conceptions they were not able to embrace all the particularities and conclusions. "The infancy of a theory," pointed out Mario Bunge, "is usually so confuse that historical documents and testimonies are of

---

[20] Paul Dirac, *Recollections on an Exciting Era*. – In: *History of Twentieth Century Physics.* Proceedings of the International School of Physics "Enrico Fermi". Course LVII. New York; London: Academic Press, 1977, p.121.

[21] Werner Heisenberg, *Begegnungen und Gesprache mit Albert Einstein*. – In: Werner Heisenberg, *Tradition in der Wissenschaft*. Munchen, 1977, S.116.

little avail unless accompanied by penetrating analyses of the problem situation and of the theory itself. Very often the inventor himself is not aware of all heuristic clues he used and of the very character of his creation".[22]

Even the geniuses of science were true sons of their epochs biased by the ways of thinking of their day. We have to reconsider our romantic conviction that great geniuses of science could resolve all mysteries of nature and foresee the progress of science centuries ahead. Alexander Pope noticed, "Wisdom never lies, though it sometimes fails to recognize the Truth."

References

1. Aristotle, *Physica* VIII 10, 267 b 9.
2. Bernstein, J. *Einstein*. New York, Penguin Books, 1973.
3. Bunge, M. *Foundations of Physics*. Springer Tracts in Natural Philosophy, vol.10. Berlin, Springer Verlag, 1967.
4. D'Abro, A. The Rise of the New Physics. Its mathematical and physical theories. New York, Dover Publications, 1951 (first edition 1931).
5. Dirac, P. Recollections on an Exciting Era. – In: History of Twentieth Century Physics. Proceedings of the International School of Physics "Enrico Fermi". Course LVII. New York; London: Academic Press, 1977, p.121.
6. Einstein, A. *Autobiographical Notes*. – In: *Albert Einstein*: *Philosopher-Scientist*, vol.1. La Salle, Ill., The Open Court Publishing Co., 1970, p. 51.
7. Einstein, A. *Fundamental Ideas and Problems of the Theory of Relativity*. – In: *Nobel Lectures. Physics*, vol.1. Amsterdam, Elsevier Publishing Company, 1967, p.p.482-484.
8. Eiseley, L. *Darwin's Century. Evolution and the Men Who Discovered It*. New York, Anchor Books, 1961,Darwin, Ch. *The Origin of Species by Means of Natural Selection*.
9. Heisenberg, W. *Begegnungen und Gesprache mit Albert Einstein*. – In: Werner Heisenberg, *Tradition in der Wissenschaft*. Munchen, 1977, S.116.
10. Heisenberg, W. *Erinnerungen an Niels Bohr aus den Jahren 1922-1927*. – In: Werner Heisenberg. *Schritte uber Grenzen.* Munchen, 1973, S.70.
11. Heisenberg, W. Was ist ein Elementarteilchen? – *Die Naturwissenschaften*, 1976, Bd.63, S.7.
12. Newton to Bentley, 25 February 1692. – In: *The Correspondence of Isaac Newton*, vol.3. Cambridge, Cambridge University Press, 1961, p.253.
13. Newton, I. *The Correspondence of Isaac Newton*, vol.1. Cambridge, Cambridge University Press, 1959, Burton, R. K. *On the Shoulders of Giants.* New York, The Free Press, 1965.
14. Planck, M. *Scientific Autobiography and Other Papers*. London, F. Gaynor, William and Norgate, 1950.
15. Whittaker, E. *A History of the Theories of Aether and Electricity*. *The Classical Theories*. London, Thomas Nelson and Sons, 1962 (First Published 1910).

[22] Mario Bunge, *Foundations of Physics*. Springer Tracts in Natural Philosophy, vol.10. Berlin, Springer Verlag, 1967, p.297.