THE SECRET OF GENIALITY (IV)

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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 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.

(Ana Bazac)

În loc de rezumat: Continuăm să publicăm, în serial, cartea SECRETUL GENIALITĂȚII (Erevan, Armenia, Tipografia Noyan Tapan, 2002) de colegul nostru Robert Djidjian, nu numai pentru că toți trebuie să cunoaștem cercetarea și creația filosofică (în domeniul nostru de epistemologia și filosofia științei și tehnologiei) dintr-o zonă geografică mai largă decât aceea oferită de moda consacrată atât din motive extra-științifice cât și dintr-o manieră încă învechită de a comunica și a valorifica cercetarea; dar și pentru că volumul ca atare este viu, provocator și foarte instructiv.

Titlul cărții este suficient de sugestiv pentru a ne face să ne concentrăm asupra unei probleme vechi: dialectica intuiției, a descoperirii – psihologia ei mișcându-se între sclipiri de intuiții și cunoștințe stocate în memorie – și logica compunerii cunoștințelor din ipoteze, și pe de altă parte, demonstrarea și verificarea lor. Tărâmul științei este cel mai favorabil pentru înțelegerea acestei dialectici și constituirea ideilor care sunt dovada a ceea ce este cel mai sigur pentru oameni: „lumea 3", cum a numit Popper regatul rezultatelor umane ale intelecției lor și, deși trecătoare și perisabilă atât în unicitatea, cât și în soarta lor cosmică, singura dovadă certă a rațiunii de a fi a lui *homo sapiens* în cadrul existenței multiversale. Așadar, puterea de a crea este secretul genialității umane, iar modul de a crea știință este o parte principală a acestui secret.

(Ana Bazac)

Step 9. TALENTS VERSUS "REAL" GENIUSES

> ***"Talent is that which is in a man's power; genius is that in whose power a man is."***
>
> *J. G. Holland*

You know geniuses by their fruits, while talents are known by their brilliant intellect. A scientist who made an epochal discovery wins the laurels of a true genius, independently of the level of his intellectual faculties. But if a prominent scientist had not the luck to make an epochal

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discovery, nothing can help him to be acknowledged as a genius even if he was endowed with an extraordinary powerful intellect. Geniuses are knighted by history. The greatness of a discovery can be tested only under the pressure of centuries. The history of science knows many cases when a brilliant scientist had been praised as the genius of his day but was completely forgotten just a few decades later.

It is well known that the main intellectual qualities required from people engaged in scientific research are the capacity to analyze research problems and the ability to synthesize new ideas. But up to the present time, there is no convincing method to measure analytic and synthetic abilities. And even if there were such a method, it would be very difficult to determine the dimension of the talent of a scientist who had passed away long ago.

So I will apply a different approach. First, I am going to explicate the features that appear characteristic by talented scientists. Then, finding out a genius of science who lacks the revealed set of capacities of talented thinkers (I already know a few of them), I will realize that he represents a very special case. Let us denote this type non-talented prominent scientist by the term "real genius". For, as I have mentioned above, a non-talented scientist cannot be supposed to achieve his great discovery with the help of the extreme power of his intellect. The "real" genius, apparently, had to possess some secret means to make great discoveries.

To proceed further, I would like to mention repeatedly that speaking about discoveries I mean the discoveries of theoretical sciences. In the case of empiric discoveries, we cannot find out much plausible information as they could be made non-purposefully, merely by chance.

So let us consider a big talent, a scientist gifted with an extreme power of intellect, having an immense ability of analytical thinking and possessing an unordinary capacity of imagination. What characteristic features should be expected from such a talented scientist?

Since we deal with theoretical sciences, it is clear that a talented theoretician, first of all, must have the gift of *mathematical thinking*. Being weak in mathematics, he would not be able even to assimilate modern theories. In the advanced theoretical sciences, to make a great discovery means, as a rule, to find out a fundamental law or a significant correlation of basic parameters of the phenomena under investigation[2].

Having an extreme power of intellect, talents must be extraordinarily *productive*. Due to the extreme power of their intellect, they can solve important problems that are out of reach of ordinary scientists. Like King Midas, they unceasingly transform each problem they touch into a precious discovery.

A talented scientist has *versatile mind*. He easily conceives the essential points of any new field of research. His natural interest in secrets of nature drives him to learn entirely different fields of science, each of them becoming an arena of his successful crusade.

Talents are the *best students* at high schools and universities. Their ability to analyze and understand helps them to be proficient in all disciplines they learn. Due to the power of their analytical thinking, they are highly effective in problem solving. The strength of their synthetic thinking brings them prizes of various creative contests. People around them, friends, teachers, and professors are sure that their brilliant success in learning will be followed by even more fascinating achievements in science.

Talents are *impressing*. Completely mastering all the means of theoretical argumentation, they present their discoveries so convincingly that their ideas get the warmest reception of their colleagues and gain high appreciation of wide circles of educated people.

[2] The indisputable authority of Mathematics became traditional already by the Greeks. At the dawn of modern science, Roger Bacon and shortly afterwards Francis Bacon insisted that mathematics was the key to all the success in science and industry. Karl Marx declared that there is as much science in a teaching as much mathematics it contains.

Creations of talents are *complete*. Talents successfully generalize and bring to completion the particular results and sporadic ideas of their contemporaries. Talented scientists understand deeper and see further than the rest of the scientific community. Having such a significant advantage, they evaluate the perspectives of theoretical conceptions better than other scientists, often even better than the authors of these conceptions do. Talents successfully reach the heights where other scientists are lost in despair.

Talents are *competitive*. In the sense, that they are eager to investigate the most actual problems of modern theories. Being always active in many fields of science, they are among the first explorers who recognize the problems that carry in them the seeds of important discoveries.

Talents like to inquire *newly formed branches* of science. Their extreme power of intellect enables them to catch up quickly with specific features of the newly discovered fields of natural phenomena and to see the ways of their effective research.

Talents *easily overcome* the most difficult problems they encounter in their research. Since talents are much stronger of their ordinary colleagues, they need little time and effort to solve research problems that required their colleagues' complete concentration and immense effort.

Talents provide *best interpretations* to unordinary new discoveries. Their analytical power permits them to be among the first who understood the essence and significance of new revolutionary conceptions. Talents are the best advocates of revolutionary conceptions and new fundamental theories. Talents are the most enthusiastic heralds of new epochs of scientific progress.

Talents are eager to make science comprehensive for the wide public. Their deep understanding of all particularities of fundamental sciences along with their enormous creative abilities produces the *best handbooks* and compendiums of the science of their epoch.

Talents are fond of the atmosphere of professional *collective* discussions. They are the initiators of international meetings of prominent scientists. Attracted by the richness of ideas of talents and their readiness to discuss any suggested problem, the young scientists gather around prominent talents forming various *scientific schools.*

Talents *like to leave the impression of an odd personality*. They are aware of own extreme giftedness and preoccupied with the desire to be appreciated and remembered by contemporaries and coming generations.

Talents are best in *gaining* position in scientific hierarchy and in social community as well. Their intellectual power is effective not only in pure science but also in solving problems of professional career, good payment, and high social position.

In short, talents of science are *brilliant*. They shine like bright meteors over the intellectual sky of their epoch… But they often fade away, completely forgotten already by the following generation.

Now when over a dozen of characteristic features of talents are revealed I am in position to explicate the specific features of "real" geniuses who, by definition, are those prominent scientists that do not possess the characteristic features of talents.

As it was mentioned above, giftedness in mathematics is the most characteristic feature of a talented scientist. Since we have defined a "real" genius as opposed by his intellectual capacities to a talent, it must be supposed that a "real" genius *must not be strong in mathematics*. But what can do such an individual in modern theoretical science that is totally mathematized? Not being strong in quantitative research, real geniuses are very productive examining foundations and basic laws of new theoretical conceptions. They suggest the basic ideas of revolutionary conceptions leaving the detailed quantitative elaboration of their discoveries to mathematically gifted investigators[3].

[3] Charles Darwin was always terrified when his theory was criticized on the basis of mathematical calculations, as it was the case with Lord Kelvin's rejection of the long scale of time and Fleeming Jenkin's refutation of Darwin's mechanism of evolution through fortuitous variations. (Loren Eiseley, *Darwin's Century,* pp. 209-210, 238-240.) The

Talents are extremely productive. Creations of "real" geniuses are quite few. The founder of moral philosophy, Socrates, left no written account of his numerous discussions and arguments. George Mendel had written only two articles on his basic research in the field of genetics.

While talent is versatile, real geniuses are mainly *one sided*. Of course, it does not mean that a real genius must be preoccupied only with a single problem. Since he is a recognized genius of science, it presumes that he has already solved at least the problem that brought him to the great discovery. Obviously, he had to occupy himself also with some other questions after his great discovery. Nevertheless, a real genius can be one-sided in the sense that he can continue his research in the field closely related to his discovery. The best example, again, can be George Mendel who investigated only the problem of the nature of plant hybridization[4].

While talents are brilliant students, real geniuses *hate compulsory learning*. The history of science knows many cases when future big names of science had real difficulties during their school years and study at universities. It is enough to mention here the names of such famous scientists as Charles Darwin, Albert Einstein, and Gregor Mendel.

While talents impress by the brilliance of their publications, the works of real geniuses are often badly presented and poorly understood. In some cases, the work of a genius remained misunderstood and lost in oblivion until a talent would rediscover it and show its historic value and importance[5].

Talents are quick to generalize and bring to completeness ideas of their contemporaries. It must be clear from the above characteristics of real geniuses that building a complete theory cannot be their task. Geniuses themselves need the help of talents to develop their discoveries into complete theoretical systems. Albert Einstein's special theory of relativity was developed further by Hermann Minkowski who built the mathematical model of the four-dimensional space-time continuum. Heisenberg and Schrödinger suggested complete systems of quantum mechanics to the first step which had been made by Niels Bohr.

Talents are busy in new branches of science; real geniuses *dig to the roots* of the tree of knowledge. Just the solutions of fundamental problems bring great discoveries and fame to real geniuses. Possibly, real geniuses understand that they cannot compete with talents in the new branches of science. Kepler dedicated all his life to the research of the harmony of the Heavens. Einstein began with the special theory of relativity, then created the general theory of relativity and continued his line of research digging into the deepest level of the physical world with a wondrous goal to build the unified field theory.

Geniuses belong to history. Real geniuses investigate problems hardly anyone else is interested in. Talents, quite reasonably, avoid exploring supper-difficult problems that definitely appear unsolvable. Talents have an intuitive ability to recognize the problems, which can bring them fame being still in reach of their powerful intellect.

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mathematical conception of the four-dimensional space-time continuum developed by Hermann Minkowski was so essential for the theory of relativity that Minkowski claimed he was the real author of the theory. Dirac recalled that when Louis de Broglie came forward with his conception of wave-particle duality it appeared beautiful due to its symmetry. But the mathematical side of the conception, in Dirac's words, was so "primitive" that one hardly could attach it any theoretical significance. (See Paul Dirac, *Recollections of an Exciting Era*, p.118)

[4] Though Albert Einstein got brilliant results in statistical physics and theory of radiation, his predominant field of research was relativity. Even his later studies of the problem of unified field theory are often regarded as an attempt of further generalization of his conception of General Relativity. Niels Bohr extended his investigations of atomic physics only to take part in research of nuclear physics. Werner Heisenberg never crossed the boundaries of the physics of the micro-world.

[5] Gottlob Frege published his fundamental work the *Begriffsschrift* ("Concept-writing") in 1879. It contained the first system of mathematical logic and the first logicism project in the philosophy of mathematics. But the symbolic language that Frege used for logical operators was so awkward and difficult to comprehend that his contemporaries were unable to read and understand the book.

Real geniuses do not often realize the gamble they got involved in when they dedicate all their thoughts and efforts to the solution of a given super-difficult problem. It is very probable that many potential geniuses spent fruitless years trying to solve the super-difficult problems they had got interested in. A talent can hardly be involved in such a troublesome situation. His acute and penetrating mind easily feels the danger and keeps him at a secure distance from the insurmountable task. In its turn, a super-difficult problem may bring immortality to its brave investigator. Alas, only few potential geniuses have the luck to solve the problem to which they have dedicated their lives. Talents flashlight the sky of their epoch like bright meteors, geniuses shine forever. Talents belong to their epoch, geniuses – to eternity[6].

Talents make their discoveries effortless. Real geniuses are far from being a big success in problem solving. Their research is carried on in hard effort and constant strain. Truly, genius is 99% perspiration and only 1% inspiration, especially in the case of *real* geniuses.

Talents are the best interpreters of revolutionary discoveries; real geniuses are often in need of a master interpreter themselves. Paul Dirac recalls that up to Eddington's enthusiastic publications on the theory of relativity few people knew Einstein and his works. Gregor Mendel was rediscovered in 1900 by De Vries, Correns, and Tshermak, thirty-five years after his first public report and sixteen years after his death[7].

Talents are fond of popularizing science; the speech and work of geniuses is often difficult to understand[8]. People always admired Niels Bohr, but even his colleagues had serious problems to follow his line of argumentation.

Talents like to build scientific schools and train young scientists. Unlike talents, "real" geniuses prefer to carry on their research work in solitude. They are the lonely pilgrim knights of science[9].

Talents are most successful in gaining good position in society; real geniuses need to be cared about[10].

Talents like to be acknowledged as odd persons; real geniuses hide their oddness as much as they can.

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[6] In the early part of the twentieth century, Henry Poincaré was such a great authority that he did not respond to the suggestion of introducing to him young Albert Einstein at the first Solvay congress of scientists. Today and for centuries to come, Einstein is unanimously appreciated as the greatest genius of modern physics, while the theoretical physicist Poincaré is mentioned as one of Einstein's forerunners only. Another popular name of the first decades of the century was Eddington. The impact of his papers dealing with interpretation of the theory of relativity was unprecedented. Following the confirmation of the predictions of the general theory of relativity, the entire educated world suddenly began discussing and interpreting relativity. Einstein's name became world vide popular, and yet often in the shadow of Eddington. (Paul Dirac. *Recollections of an Exciting Era*, p. 111). Today few students of physical faculties have ever heard the name of Eddington. But the greatness of Einstein's achievements becomes more and more clear with each passing decade.

[7] Carl Correns, *G. Mendel's Law Concerning the Behavior of Progeny of Varietal Hybrids*. – In: *The Origin of Genetics. A Mendel Source Book.* Ed. Curt Stern and Eva R. Sherwood. San Francisco, W.H. Freeman and Company, 1966.

[8] Aristotle's works, rigorous and condensed, are very difficult for thorough understanding. That is one of the reasons that medieval science was limited to numerous commentaries of the works of the great genius. In modern time, many prominent scientists were involved in intensive discussions and interpretations of Einstein's conception of relativity.

[9] J. J. Thomson had such an enormous success in educating young talents that by the early twentieth century nearly all chairs of physics in the British Empire were filled by his disciples. By contrast, Einstein and Darwin were lonely researchers. "It is so strange to be known so universally and yet to be so lonely," remarked once the greatest physicist of our time. (Jeremy Bernstein, *Einstein*. New York, Penguin Books, 1973, p.7.)

[10] Lindemann recalled Einstein's "pathetic naïveté in the ordinary affairs of life". Einstein appeared to him "to be living in a universe of his own creation, and almost to need protection when he touched the mundane sphere". (Ronald W. Clark, *Einstein. The Life and Time*. New York, The World Publishing Company, 1971, p. 145.)

Yet, I would like to point out again that of all differences between talents and geniuses the main difference is that of the significance of their discoveries. Geniuses suggest ideas and theories that open a new epoch in the history of science. The revolutionary essence of their conceptions radically changes the entire vision of nature and the universe. “Doing easily what others find difficult is *talent*; doing what is impossible for *talent* is genius,” pointed out Henri-Frederic Amiel.

Step 10. A SAMPLE OF BRILLIANT TALENT

“Mediocrity knows nothing higher than itself,
but talent instantly recognizes genius.”

Sir Arthur Conan Doyle

While real geniuses are as rare as are the great scientific revolutions, talents are innumerable. So I have no choice but to bring in for illustration just a sample of scientific talent. The hero of this chapter is the most publicized physicist of mid-twentieth century Richard Feynman (1918-1988). He was highly appreciated by his colleagues as well admired by his student audience. And what is not less important, his life and activity in science are thoroughly documented[11].

The secret of Feynman’s outstanding discoveries was his “double giftedness”. Richard Feynman was an ideal of a theoretical physicist. The twentieth century theoretical physics was predominantly a mathematical science. But it required also a deep understanding of the laws of physics. So, to be a big success in modern theoretical physics, one had to have a mathematical talent and deep understanding of foundations of physics.

Feynman perfectly met both these requirements. From his early teens he was known as some kind a genius in arithmetic. Young Richard became leader of the mathematics team at high school. Three excellent volumes of the *Feynman Lectures on Physics* clearly demonstrate the depth of Richard Feynman’s comprehension of physical science[12].

Modern theoretical science requires such a deep specialization that there are few investigators who have significant achievements in the different fields of physics. Feynman was among these few. His main contribution to science was the original version of quantum electrodynamics for which he was awarded the 1965 Nobel Prize for Physics. Quite naturally for the type of person Feynman was, his next attempt was to create the quantum theory of gravitation. Among the most important achievements of the twentieth century physics will always be mentioned

[11] There are two solid biographies of this famous scientist, the first published in 1992 and the second in 1997. James Gleick wrote his book under the title “*Genius. The Life and Science of Richard Feynman*”. The title of the biography written by John and Mary Gribbin is more traditional, “*Richard Feynman. A Life in Science*”. But they too hold it natural comparing Feynman’s achievements in science with those of Albert Einstein. A 1994 illustrated book presents Richard Feynman under the title *No Ordinary Genius.* Jagdish Mehra wrote about Feynman’s theoretical contribution to science by an unordinary title, *The Beat of a Different Drum*. There were also two autobiographical sketches written in cooperation with Ralph Leighton.

[12] I would like to make a parallel with another famous talent, the French physicist and mathematician Pier Simon Laplace (1749-1827). Laplace was a brilliant student. Still at high school, he studied serious mathematical works that were not even known to his teachers. His first research in mathematics was accomplished at the age of seventeen. Graduating from college, Laplace got the position of mathematics teacher in the military school. He was extremely successful applying mathematical methods to various problems of physics and astronomy. Apart from it, Laplace had significant achievements in pure mathematics too, namely in the theory of differential and algebraic equations. Together with the brilliant mathematical talent, Laplace had also a gift for deep understanding of the nature of physical phenomena. Using this lucky combination of physical insight and mathematical instrumentality, Laplace achieved significant results, which he later generalized in five volumes of his fundamental *Celestial Mechanics*.

the theory of weak interaction, Feynman being one of its discoverers. Feynman's diagrams and his conception of strong interaction were important factors in the development of the theory of elementary particles[13].

Still an undergraduate student at Princeton, Richard Feynman, together with his supervising professor John Wheeler, worked out an extraordinary version of the theory of electromagnetic radiation that was labeled as "time-symmetric" conception. Developing further this conception, Feynman made his most important discovery – the path-integral approach to the theory of electromagnetic interactions. So when Julian Schwinger offered his version of relativistic invariant theory of quantum electrodynamics, Feynman was ready to propose, almost simultaneously, a path-integral version of quantum electrodynamics. To their surprise, Schwinger and Feynman learned soon that there was one more discoverer of the relativistic quantum electrodynamics, a Japanese physicist Shin'ichiro Tomonaga. All the three brilliant theoreticians – Feynman, Schwinger, and Tomonaga – were awarded the Nobel Prize for their outstanding discovery.

As a real scientific talent, Richard Feynman was extremely productive in his investigations. Using his path-integral approach, Feynman succeeded to explain the phenomenon of super-fluidity and tried to work out also the theory of superconductivity. But this time other explorers came first to the finishing tape. In 1962, the Nobel Prize for the theory of liquid helium was awarded to Soviet theoretician Lev Landau. Ten years later, John Barden, Leon Cooper and Robert Schrieffer received the Nobel Prize for the theory of superconductivity.

Feynman got involved also in the efforts of physicists to build the quark theory of elementary particles. By the year of Gell-Mann's discovery of quarks, Feynman was already 46 years old, far beyond the unavoidable age limit for a theoretician's creative work. Many writers believe that a theoretician's thought, *like* his love, is lame at fifty. But Richard Feynman never stopped being competitive.

In 1968, he proposed a model of interaction of high-energy elementary particles that, in his biographer's words, "swept through the research teams like wildfire". Even by the age of sixty, Richard Feynman published an important paper on the quark theory[14].

Feynman's greatest gift was to impress people. When Richard happened to repair a radio, he became famous as a kid who "fixes radios by thinking". John and Mary Gribbin believe that young Richard, studying geometry at high school, "worked out most of the rules of Euclidean geometry for himself". At college Richard made the impression of a "boy genius". His teachers admitted that he was the best student they had seen for many years. As a research student at Princeton, young Feynman had such a high level of self-confidence that he had no hesitation in objecting even Albert Einstein. For him, "the name and the reputation didn't mean a thing"[15]. His Ph.D. thesis examiners

[13] I would like to continue the parallel with Laplace. The celebrated French physicist published numerous scientific papers on celestial mechanics, astronomy, physics of liquids, mathematical analysis and theory of probability. The main topics of his investigations were theoretical mechanics and its various applications. Laplace succeeded to explain the irregularities of the motion of the Moon, proved the stability of the solar system, described the interactions of Jupiter and Saturn, predicted the discrete structure of the Saturn ring, studied the exciting world of comets. He got significant results in the theory of probability. Laplace inquired also ocean tides, capillarity, electricity and magnetic field, and the propagation of sound and light. Last but not the least, he is acknowledged as the founder of scientific cosmogony.

[14] I would like to present here another historic parallel**.** Laplace liked also to inquire the newest branches of science. Although his main interest was in mechanics, he was eager to respond to discoveries in various branches of science. In 1780, Laplace repeated Volta's experiments with atmospheric electricity. He took part in the experimental studies of thermal phenomena carried on by Lavoisier. The cosmogonical conception suggested by Laplace was based on William Herschel's discovery of so-called planetary nebulae. Laplace was involved in tense competition with his senior colleague, famous mathematician and physicist Joseph Louis Lagrange. For instance, one of the most important results of Laplace was his proof that the solar system is stable. He came to this conclusion continuing and improving the method suggested by Lagrange.

[15] John and Mary Gribbin**,** *Richard Feynman,* p. 60.

John Wheeler and Eugene Wigner described the dissertation as “exceptionally original”. According to Wheeler, Feynman’s Ph.D. thesis made quantum theory simpler than that of classical theory[16].

If you believe all stories told about Richard Feynman, in many of them he would appear not only impressive, but sometimes even pretentious. A story tells that, being in the group of the observers of the first atomic bomb explosion test, Feynman was the only person to watch the explosion with naked eyes. Another time Feynman managed to give such evidence concerning the closure of a night-bar he liked to visit regularly that he got into many newspaper headlines like the following one: “Caltech’s Feynman Tells Lewd Case Jury He Watched Girls While *Doing Equations*”.

Sometimes there arises impression that Feynman would like to be recognized as a very odd personality. At the age of thirty-six, he was elected a member of US National Academy of Sciences. But the reports and conversations of academicians, all of them prominent American scientists, seemed to him so unimportant that Feynman eventually resigned from the Academy. The other similar story tells about the “nuisance” of receiving the Nobel Prize. When one of the first reporters congratulated Feynman with the reward of the most famous scientific title, he asked the reporter if there was some way not to accept the Prize[17].

Richard Feynman was born to be famous. Any activity he undertook brought him success and fame; and that not only in science. Feynman learned drumming from a Nigerian medical student, and soon he was mentioned as “drum-beating physics professor”. In 1994, Jagdish Mehra wrote a book about Feynman, and the title of the book was *The Beat of a Different Drum*. A Californian artist Jirayr Zorthian gave Feynman some lessons in art. Soon, painting became a life’s passion for him. Eventually, there was an exhibition of Feynman’s artistic works. Some of Feynman drawings and paintings found place in *The Art of Richard Feynman* published by his daughter Michelle in 1995.

For six month Feynman worked in the Rogers Commission which investigated the causes of the 1986 Challenger disaster. Feynman became a national hero proving experimentally the cause of the disaster though another member of the Commission, General Donald Kutyna, had hinted him the idea. Feynman always appeared at the center of all discussions at the Commission. “It seemed,” recalled Feynman, “like I was always the one answering the reporters’ questions.”

Although all professors give lectures, few of them deserve the privilege of publication. And only a small part of such publications are appreciated as a valuable handbook. *The Feynman Lectures on Physics* (1963) were published in three volumes and brought him worldwide fame[18].

Supported by his outstanding talent, Feynman made many of his discoveries apparently without effort. He liked to say that scientific research was just a fun to him. His colleagues recall that Feynman solved in a single night a problem that required from them intensive research work during long months. His lectures proceeded so easily and smoothly that the adoring audience

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[16] Turning again to Laplace. His scientific works were so impressive and significant that already at the age of 35 he was full member of the French Academy of Sciences. Laplace wrote the first popular account of the entire scope of modern astronomical science *Treatise of the System of the Universe* by the end of the eighteenth century. His *Celestial Mechanics* had presented in a systematic form all the achievements of contemporary astronomical science. Admiring Laplace’s scientific talent, Emperor Napoleon Bonaparte wrote, “I am sure, the *Celestial Mechanics* will make our century more brilliant”. The prominent French mathematician Joseph Fourier emphasized, “Nature gave Laplace a genius which was sufficient for great scientific discoveries.”

[17] Richard Feynman & Ralph Leighton, *Surely You are Joking, Mr. Feynman*. New York, Bantam Books, 1986, p. 278.

[18] In 1995 there were published also *The Feynman Lectures on Gravitation*, in 1996 – *The Feynman Lectures on Computation*. Apart from these handbooks, Feynman published *The Character of Physical Law* (1965), *QED: The Strange Theory of Light and Matter* (1985), *Elementary Particles and the Laws of Physics* (1987).

conceived them as pure improvisation. As a matter of fact, there was a lot of planning and preparation of the structure and content of lectures, as well as of numerous jokes and funny terms[19].

One can suppose some planning and effort in his professional career, too. Still a 27-year-old scientist whose main works had to come yet, Feynman was invited to a position of professor at Cornell University. He became the highest paid professor at California Institute of Technology in 1960, with a salary above the $ 20.000.[20]

Richard Feynman was an extraordinary scientific talent. But all his activities in life and science suggest that he would definitely prefer to be acknowledged as an ordinary genius.

Step 11. THE CASE OF "REAL" GENIUSES

"We repudiate the love of hard work
in order that people may think about us we are geniuses."

Aristotle

I am now going to show that at least four most celebrated figures in the history of modern science – Michael Faraday (1791-1867), Charles Darwin (1809-1882), Gregor Mendel (1822-1884), and Albert Einstein (1879-1955) – were "real" geniuses, in the above defined sense of being opposite to talents.

The first thing one should point out about my heroes is that their discoveries were epoch making. In the history of modern natural science there were few conceptions comparable by their significance whether to the electromagnetic field conception, or to the theory of evolution, or genetics, or the Special and General Theories of Relativity. All these great discoveries belong to my real geniuses.

Turning to individual intellectual characteristics of these greatest minds, I would like to begin the discussion with the remarkable fact that that they all unreservedly disliked compulsory learning.

In his autobiography, Darwin was very negative in regard of his school education. He wrote with an unconcealed feeling of reprehension: "nothing could have been worse for the development of my mind than Dr. Butler's school, as it was strictly classical, nothing else being taught except a little ancient geography and history".

Things did not change essentially when Darwin went to Edinburgh University and then to Cambridge. "During the three years which I spent at Cambridge," mentioned Darwin in his autobiography, "my time was wasted, as far as the academic studies were concerned, as completely as at Edinburgh and at school." He attempted to learn some mathematics privately. Even being helped by private tutor, he got on very slowly. Learning mathematics, especially algebra, was

[19] Perhaps, the only physicist able to challenge Feynman was his good friend Robert Oppenheimer. When he completed his course of lectures at the University of California and went to teach at the Institute of Technology at Pasadena, numbers of his pupils followed from San Francisco to Los Angeles not to be separated for six months from their adorable professor. (Michel Rouze, *Robert Oppenheimer. The Man and His Theories*. London, Souvenir Press, 1962, p. 37.)

[20] Now: a final parallel with Laplace. Laplace made his first attempt to be chosen to the Academy of Sciences in 1772. He literally bombarded the celebrated society with his original scientific papers and notices. The huge number and variety of his reports made the impression that scientific research was for Laplace as a natural occupation as for winds to blow and for birds to fly. The thing for which he also spared no effort and means was the goal to reach an honorable position in society. Napoleon Bonaparte highly appreciated Laplace genius and even appointed him Interior Minister, though for a very short time. Laplace was among the first prominent Frenchmen who were decorated with a Legion of Honor. He was knighted and rewarded the titles of the count, then marquis and peer of France.

"repugnant" to him. Darwin was sure that even after significant efforts he would remain beyond a very low grade.

Charles' father came to the conclusion that there remained only one opportunity for his son – to become a clergyman. "The final recourse of Victorian society for the maintenance of misfits and dullards was the church," mentioned in regard of this point of Darwin's life Gertrude Himmelfarb[21]. Since it required a university degree, Charles went to Cambridge. But only two things occupied his mind at the university – collecting beetles and shooting. Though Charles got interested in geology, yet he admitted sincerely that at the time of graduating Cambridge he should have thought himself "mad" to give up the shooting for geology or any other science.

There is an amazing parallel between Einstein and Darwin's attitudes to compulsory learning. For five years Einstein had been learning at a gymnasium in Munich. The gymnasium was of humanities, and the main subjects were languages, the emphasis being put on Latin and Greek. Young Albert Einstein disliked ancient languages. He never made an effort to learn them.

Einstein's negative feelings in regard of compulsory learning were very strong. "It is, in fact, nothing short of miracle that the modern methods of instruction have not entirely strangled the holy curiosity of inquiry," wrote Albert Einstein in his *Autobiographical Notes*.

Biographers proved that the real cause of young Einstein's difficulties at school was the archaic method of instruction used in Prussian gymnasiums. Indeed, for Albert Einstein, already from his childhood, the most important thing was the freedom of judgment, the possibility to inquire and understand each problem he got interested in. So he had to come inevitably to a bitter conflict with the principle of complete obedience to rules and commands reigning in Prussian gymnasiums.

But, apparently, no method of education would please young Einstein, if it involved examinations. At the Zurich Polytechnic Institute, he had to pass only a few final exams, all the remaining time having at his own disposal. But even these examinations were intolerable to him. After examinations he was so much exhausted that the consideration of any serious scientific problem was to him distasteful for an entire year.

Michael Faraday and Gregor Mendel, too, fit well in the above outlined pattern of real geniuses. It is difficult to judge about young Faraday's attitude to compulsory learning since he went to work in a bookshop already from the age of twelve. At the elementary school he learned only reading, writing and some arithmetic.

By a lucky chance, he got a position of assistant in the chemical laboratory of Humphry Davy who later became President of the Royal Society of London. Through self-education and hard work Michael Faraday rose to the ranks of the best chemists of England.

Fame came to Faraday later, due to his fundamental physical discoveries. But even creating the field theory of electromagnetic phenomena, he never used any significant mathematical apparatus in his investigations and theoretical conceptions. And this occurred in days when his contemporaries successfully built their theories using differential and integral calculus. James Clerk Maxwell mentioned that Faraday was so far from mathematics that he was simply unable to understand the complex mathematical formulas present in the works of his continental colleagues[22].

Gregor Mendel disliked compulsory education, too. He learned a certain amount of compulsory subjects at the Augustinian College in Brunn, Austria (now Brno, Czech Republic). Graduating from college, Mendel taught natural science at a technical high school. But he failed to take the examination for certificate as a regular teacher. And even after years of learning at Vienna University, Gregor Mendel never succeeded to pass the examination for a teacher's license.

[21] Gertrude Himmelfarb, *Darwin and Darwinian Revolution*. Gloucester, Massachusetts, 1967, p. 31.

[22] James Clerk Maxwell, *On Faraday's Lines of Force*. – In: *The Scientific Papers of James Clerk Maxwell*. Ed. by W. D. Niven. New York, Dover Publications, 1965 (First publication 1890).

Ironically, the future founder of genetics and brilliant investigator of plant hybridization got the worst marks just in botany[23].

So my heroes, the real geniuses of science, had serious difficulties at elementary schools and high schools, at colleges and universities. They and their biographers blamed for these failures chiefly the wrong system of education.

This opinion had a definite ground. But one has to realize the other side of the problem, too. Consider a student who has a steady motivation for learning, a good memory and strong analytical mind, capacities to generalize particular facts and generate new ideas with the help of analogy. Such a student will successfully learn languages. He would have no difficulties in perceiving new subjects, including arithmetic and algebra. After learning some examples of solutions of mathematical problems, he would anticipate the general approach to the solution of the wide range of similar problems. In short, a good motivated student with a satisfactory memory and strong analytic-synthetic capacities will never fail in learning, quite independently from any particular system of education. *Vice versa*, the difficulties in compulsory learning prove that the real geniuses of science either had poor memory or the level of their analytic and synthetic capacities was insufficient. That, in turn, could reduce their motivation for learning.

For my heroes, not only the years of learning brought hardship and tension. Their first steps into the real life were even harder.

Young Darwin was absolutely indifferent to his future occupation. The only things he was interested in, or more correctly, had an enormous passion for, were collecting beetles and shooting. Darwin's farther, a successful physician and a very lenient person, was seriously worried by the deem prospects of his elder son. Once he got so much angry with Charles that reproached him with the following painful words: "You care for nothing but shooting, dogs and rat-catching, and you will be a disgrace to yourself and all your family".

Darwin's father and his teachers had no illusions in regard of his intellectual capacities. "Neither his family nor his masters," noticed Gertrude Himmelfarb, "saw anything in the least praiseworthy in him". They considered him a very ordinary boy, rather below the common standard. And his complete lack of interest in any worthwhile profession seemed even more disastrous.

Post factum, it is quite apparent that only the isolation from the idle life of his circle of youngsters and a serious occupation of an explorer could open to Darwin the way to science. Such an opportunity was presented to Darwin by a lucky chance when he was permitted to go as naturalist on the voyage of the *Beagle*. Charles Darwin underwent a complete transformation on the board of the *Beagle*. The love for science gradually became the dominant motive of his life. "I discovered, though unconsciously and insensibly, that the pleasure of observing and reasoning was a much higher one than that of skill and sport," recalled Darwin later.

Again one can notice here a Darwin-Einstein remarkable parallel. At the Luitpold Gymnasium in Munich, young Albert revealed no special aptitude and no premature gift. Even when Einstein became the most popular scientist of his day, his teachers were unable to recall facts proving young Einstein's extreme intellect. Antonina Vallentin admitted bitterly, "No teacher claimed to have molded the mind of genius. His former teachers, in fact, did not even remember having had him in their classes"[24].

Almost the same was the picture at the Zurich Polytechnic Institute. In one of his letters to his friend Marcel Grossmann, Einstein confessed that he "was not in the good books" of his former teachers. "No professor had marked his exceptional faculties, none had enough interest in him to forward his career," mentioned Antonina Vallentin. Another notable fact was Hermann

[23] Hugo Itlis, *Life of Mendel*. New York, 1932.

[24] Antonina Vallentin, *The Drama of Albert Einstein*. 1954, p. 22.

Minkowski's curious reaction in regard of Einstein's great discovery: "When the theory of relativity was enunciated, Minkowski remarked that it was last thing he could have expected of his student at the Zurich Polytechnic"[25].

Soon Einstein realized the disastrous perspectives of his early life. None of the Polytechnic Institute professors agreed to take him as an assistant lecturer, as it was usual with gifted graduates. In fact, the position of assistant was practically the only way left to Einstein to continue his education and become a scientist since with the graduation of the Polytechnic Institute the Koch family, his distant relatives, stopped their financial support. By that time, Einstein's father had no means to help him.

Einstein tried hard to continue his education. He applied for each vacancy he learned about from his friends and newspapers. He wrote numerous letters asking for work. Einstein joked bitterly that he was going to honor all physicists from the North Sea to the southern tip of Italy with his offers for vacancies. No professor got interested in his offer, no faculty responded to his letters.

Meanwhile all friends of Einstein got positions of assistants of different professors. Especially hurting was the fact that Einstein's professor of physics, Heinrich Weber, took two engineers, but not the physicist Albert Einstein. "I was suddenly abandoned by everyone, standing at loss on the threshold of life", recalled Einstein later. It was not only the material side of the situation that pressed Einstein hardly. His pride and self-esteem should be immensely hurt, too.

"The *fate* is always against great things", noticed the Comte de Buffon. Judging by severe sufferings to which young Einstein was exposed, one might assume that fate took into account the unparalleled significance of his destiny.

Only Marcel Grossmann's warmhearted attention to the fate of his friend helped Einstein to get out of the disastrous situation. Marcel's uncle was the chief of the Patent Office in Bern. By his protection Einstein got the position of an expert at the Patent Office. Just working at this office, Einstein wrote the famous papers that brought him the Nobel Prize and worldwide fame.

Now I would like to show that there is certain historical evidence to evaluate Socrates as a real genius, too. To make my discussion effective, I find it useful reminding some key points concerning the paradox of "real" geniuses. A genius must be the author of an epochal theoretical conception, which *excludes the possibility of a mere chance discovery*. On the other hand, the "real" genius must be opposite to the brilliant talents, thus proving the possibility of making great discoveries *with the help of normal intellectual capacities*.

I am sure that there should not be much difficulty to convince my readers that Socrates, the founder of moral philosophy, was an outstanding thinker. So my main task is to show that he was a "real" genius.

The great Greek thinker was opposite to brilliant talents, so numerous in the Athenian society of his day; for he did not succeed in any field of social or private life. Moreover, he never demonstrated any interest in achieving prominence and authority and seemed "otherworldly", remote from the needs of everyday life.

Socrates was not just different from his numerous talented friends. He was a very odd and peculiar individual. According to Plato's evidence, there were many cases when at sundry times and in diverse places a sign came to him. This sign was a kind of voice that first began to come to Socrates already at his childhood. Like other rare individuals inclined to hear voices from above, the great philosopher possessed an exceptional endurance to physical hardship. One of the participants of a discussion in the *Symposium* draws the picture of the prominent philosopher during severe winter days with his bare feet on the ice and in his ordinary clothes.

[25] Boris G. Kuznetsov, *Einstein*. New York, 1970, p. 28.

Plato tells also of Socrates' strange way of stopping anywhere and "losing himself" without any reason. The state of such extraordinary self-concentration and absent-mindedness could continue for many hours.

Youngsters inclined to hear voices and to lose attention to their surroundings had never appeared to be good learners, especially studying such "dry" subjects as geometry and calculation. So Plato's early dialogues give sufficient evidence to insist that young Socrates could not be a brilliant student. There is also indirect evidence that the great philosopher should not have a particular interest in mathematical sciences. The discussions from Plato's early dialogues – which are believed to portray Socrates – deal predominantly with questions and notions having nothing common with mathematical knowledge.

Socrates was absolutely opposite to a talent also regarding scientific "productivity". Devoting all his long life to discussions of philosophical problems, he nevertheless did not write a single work of his own.

I am strongly tempted to recruit to the ranks of real geniuses also Isaac Newton. Such a thought may be considered as a contradiction in terms since we have agreed the mathematical giftedness to be the first indicator of a theoretical talent as the opposite pole to a real genius. A mathematical talent is an inborn capacity that should demonstrate itself from the early childhood. On the other hand, a mathematical talent necessarily assumes excellent memory, strict analytic thinking, and ability for synthesis and generalization, as well as a quick mind and easy understanding of complex problems. In short, a talent must be a brilliant pupil from his early childhood. Being a brilliant pupil may be considered the most decisive indicator, especially in cases when there was not given sufficient place to mathematics in the pupil's early education.

Young Isaac Newton was not among the brilliant pupils at high school. His mother called him home from the Grammar school at the age of seventeen to help with their flocks of sheep. Since she could easily afford his further education, Newton would not have been put into such level of family business if he had proved to be a promising student. When Newton eventually got to Trinity College in 1661, he was one year older than the average student was. Neither this fact does support the image of an early talent.

Moreover, at the university young Newton was never considered among the brightest students. The author of Newton's biography Richard Westfall had to admit that in his first three years at Trinity College "Newton had not distinguished himself in any way". It is just unbelievable, but the fact is that none of his fellow students left any recorded mention that they had once known the greatest scientist of England[26].

Now that we have succeeded to overcome the main obstacle, I can present some essential features of Isaac Newton as of real genius.

Unlike brilliant talents, which always appear surrounded by friends and admirers, Newton could not get along with other boys at the Grammar school. Biographers of Newton try to explain it by his "intellectual superiority". But an intellectually superior child would be clever enough not to make enemies of his classmates. Life proves that the really superiors never give occasion to feel their superiority. Most probably, as Westfall had remarked, the reason of the enmity should be young Newton's bad temper.

Biographers of the great scientists like to repeat the characteristics of Newton given by an acquaintance of his boyhood as of "a sober, silent, thinking led." Like many real geniuses, Newton

[26] Richard S. Westfall, *Never at Rest. A Biography of Isaac Newton.* Cambridge, Cambridge University Press, 1980, p. 75. Each year, ten distinguished students of Trinity College got scholarship. Isaac Newton first got this honor in 1664. But even this fact does not prove that Newton's mathematical genius had at last demonstrated itself. Examining the young pretender of scholarship, Isaac Barrow found out to his great disappointment that Isaac Newton had not yet studied Euclid's elementary book of geometry.

remained a solitary thinker all his life, even a bit more than it is usual by real geniuses. "Genius of Newton's order," speculated Richard Westfall, "does not readily find companionship in any society in any age"[27].

As it is a rule by real geniuses, Isaac Newton disliked compulsory learning. At Trinity College he had to participate in seminars on several classical subjects like formal logic, ethics, rhetoric, and philosophy. So he took a voluminous registry and began to work out the main sources on these basic subjects of the established university curriculum. But Newton did not finish the study of any of these works, usually advancing only as far as the first few chapters.

Newton's passionate nature demonstrated itself with all its tremendous power in 1664 when he all of a sudden fell in a vehement love with mathematics. It took him not over twelve months to digest all contemporary ideas on mathematical analysis. And already the following year he prepared three brilliant papers which involved also his revolutionary method of "fluxions", the main instrument of differential calculus. The same year should be dated Newton's another passion to which he remained lifelong true. It was natural science. He composed a systematic set of questions, which should be cleared up to come to the adequate understanding of the physical world. From these days on, he began the unceasing collection of all relevant information for his *Quaestiones.* This way started the intellectual adventure, which gave the educated world the *Opticks,* and the *Principia,* and *The System of the World.*

Real geniuses get their biographers into serious trouble and sometimes even into direct self-contradiction. One cannot resist the feeling of fascination and admiration by the magnificent scientific heritage of real geniuses, especially by their fundamental and revolutionary ideas and conceptions. Yet the main indicator of a real genius is the point that, prior to his great discovery, no one had ever noticed any clear demonstration of his outstanding intellectual power.

Naturally, biographers of real geniuses strongly believe that their revolutionary discoveries could be produced only by an intellect of extraordinary capacities. These writers usually miss the apparent point that there is no direct logical way to a revolutionary conception. And they often fail to realize that the works of many contemporaries of their heroes contained the most part of the material that composed the core of their revolutionary conceptions.

So some biographers, consciously or not, readily help to emerge and multiply stories and myths about the extraordinary and wonderful power of intellect allegedly demonstrated by their beloved heroes. In the case of Isaac Newton, this kind myths came from William Stukeley and Conduit. Telling fascinating stories of wonderful demonstrations of the unlimited intellectual power of the great physicist, Stukeley always mentioned that he learned these stories directly from Isaac Newton himself. But often even this only source comes under doubt since no one else except Stukeley had ever heard Newton telling many of these mythical stories.

According to Stukeley, in his later life Newton told the stories of falling apple and of the miraculous years 1665-1666 when he allegedly made all his greatest discoveries in mathematics, optics, theoretical physics, and celestial mechanics[28].

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[27] Yet Newton somehow managed to get his piece of cake. He got his Lucassian professorship on a special royal act. In 1696, he was appointed to a good paid and influential position of the warden of the Royal Mint, which appears absolutely unthinkable for a lonely and isolated scientist. Also, there could hardly be isolation from colleagues and public in his later life when he was elected President of the Royal Society of London and kept this very prestigious position during twenty years.

[28] Newton's story, according to Stukeley's account, was as follows: "In the beginning of the year 1665 I found the method of approximating series and the Rule for reducing any dignity of any Binomial into such a series. The same year in May I found the method of Tangents of Gregory and Slusius, and in November had the direct method of fluxions and the next year in January had the Theory of Colours and in May following I had entrance into the inverse method of fluxions. And the same year I began to think of gravity extending to the orb of the Moon and (having found how to estimate the force with which a globe revolving within a sphere presses the surface of the sphere) from Kepler's rule of

The authority of Newton's genius is so high that it seems unthinkable to deny any of these myths. But people who know Robert Hooke's formulation of the law of universal gravitation regard the story of falling apple with an excusing smile only. And how can one seriously consider a myth designed to demonstrate Newton's early mathematical genius by telling a story that when Newton first read Euclid's geometry and found some of its theorems obvious "he despised that as a trifling book"? Even if the source of some of these stories was Newton himself, one should not place much weight on the recollections of the aging genius about events that occurred sixty years earlier, rightfully advised Richard Westfall.

Examining closely the myth of *anni mirabiles* of 1665-1666, Richard Westfall came to the conclusion that when 1666 closed Newton was not yet in command of the final formulation of his main theoretical conceptions. "What he had done," pointed out Richard Westfall, "was to lay foundations. Nothing was complete at the end of 1666, and most were not even close to complete. Far from diminishing Newton's stature, such a judgment enhances it by treating his achievement as a human drama of toil and struggle rather than a tale of divine revelation".

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the periodical times of the Planets being in sesquialterate proportion of their distances from the center of the Orbs, I deduced that the forces which keep the Planets in their Orbs must be reciprocally as the squares of their distances from the centers about which they revolve: and thereby compared the force requisite to keep the Moon in her Orb with the Force of gravity at the surface of the earth, and found them answer pretty nearly. All this was in the two plague years of 1665-1666." (Richard S. Westfall, *Never at Rest. A Biography of Isaac Newton*. Cambridge, Cambridge University Press, 1980, p. 143.)