SPACE, TIME AND ENERGY LIMITS

by

George Marx
Department of Atomic Physics
Eötvös University
Budapest, HUNGARY

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Department of Atomic Physics, Eötvös University
Budapest H-1088

Mission accomplished?

Science started from home, from everyday experiences of people. The ob jects Archimedes studied were common tools – the wheel, level, pulley, screw – what were seen and handled day by day. From the measurement of land for agriculture geometry energed. When after a long day of work in the library Euclid went walking to the desert, he wathed the grains of sand laying around. The idea of *geometrical point* was born. A point is something like a sand grain but it is infinitely small and motionless. By putting such points side by side one gets a straight line, a plane, a cube. The laws of geometry had been understood. The antiquity had constructed the magnificent *architecture*: the geometry of Euclid, the layered four elements of Aristotle, the heavenly spheres of Ptolemeus.

People watched the Sun and stars to keep track of hours and seasons. The astrological dream of the connection between heavenly and earthly events, the astronomical quest for the rule of planetary motion lured man farer and farer away from home. Copernicus, Kepler, Galileo and Newton explored the Solar System, this magnificent *clockwork*. Classical mechanics added a new dimension to the geometric scenario: the dimension of *time*. Each *mass point* moves at constant speed, till the influence of nearby mass points forces it to change its velocity. Mass point is something you may get if you divide a grain of dust infinitly. If a demon understood the Law of Interaction (Newton's gravitational force, Coulomb's electric and magnetic forces), if he knew the present position and velocity of each mass point, then he would be able to compute their positions exactly for any moment in the past and in the future. (Laplace spoke about a demon. Modern philosopher would use computer instead.) This merciless determinism has left no any chance for free will, moral, prayer, providence. When Napoleon (the first ruler in history who knew calculus) remarked that he did not find the name of God in Laplace's works, the author answered: "Your Majesty, I have not needed this hypothesis."

The empirical study of the structure of materials has led to the concept of molecules. In a gas there are indeed tiny bodies flying around, hitting each other, pushing the piston.

The unsuccesful attempt to transform lead to gold in the oven of alchemists taught scientists that molecules were made of *atoms*, which can be rearranged in fire but atoms can be neither destroyed nor created. The number of atoms of gold is the same since the origin of time. As Maxwell put it: "The actual shapes and sizes of planetary orbits are not prescribed by any law, they just represent a special distribution of matter in space.The same can be said about the size of Earth what has given our standard unit of size: the meter. But the importance of these heavenly and earthly quantities fades away when compared to the measures characterizing the atomic structure of matter. Natural influences may change the orbits of planets, but neither the catastrophe of old worlds nor the emergence of new worlds in the sky can affect the properties and sizes of atoms from which these worlds are made of. Their number, size, weight remains unchanged."

Laplace's demon can keep track of the atoms in his computer-brain, thus future can be exactly foreseen. Imaginary mass points have been replaced by real indestructible atoms which are absolutely rigid and indestructible. The mission of science has been accomplished. At the end of 19th century professors advised young enthusiats, saying: "It is not worth to study science any longer."

Flying higher, diving deeper

Some minor details had been left to be clarified. There were some strange phenomena like *light* waving through the voids left empty by the atoms. When a peak of wave meets the valley of an other wave, the addition of positive and negative may result in zero. Light plus light may produce darkness. Never mind: these are just transient phenomena. Light dies away after sunset anyway.

Those who still intended to complete the glorious system of physics, went on studying the emission and absorbtion of light by atoms. It turned out that with forceful hits atoms can be broken, and their fragments, the tiniest pieces of electric matter do not behave like the points of Euclid or Newton are supposed to do: the *electrons* are individual objects (like atoms were supposed to be beforehand) but they show the properties of *waves* as well. Police inspectors say that a thief can enter a house either through the door or through the window. An electron (having a fixed mass like a thief) can enter the house through the door and windows simultaneously which offers him extra chances for hide and seek. And light shows similar characteristics: a light beem is made of photons, each photon carries a definite energy quantum. ($E=h\nu$, where E is energy, ν is frequency and h is a constant factor.) Light can play interference as well due to its wave like behaviour, the wavelength (λ) being associated to the momentum ($p=h/\lambda$). This double behaviour is universal for all sorts of existing materials. The quantum play cannot be evaded. This recognition has deep philosophical and practical consequences:

$E=h\nu$, $p=h/\lambda$, where h is a fundamental constant of Nature. But what is p? The answer says: imagine a *mass point* that is at distance x_1 at time t_1, at distance x_2 at time t_2. then you can calculate its velocity as $v=(x_2-x_1)/(t_2-t_1)$. Momentum is $p=mv$, the product of mass by velocity. Energy is $E=mv^2/2$, it is the product of mass by velocity squared, divided by two. – And what are λ and ν? The answer says: Imagine a *spreading wave*. The distance of two peaks gives you the wave length λ. The number of peaks passing by per second gives the frequency ν – Each answer was understandable in itself, but it is hard to make sense out of both answers simultaneously. The quantities λ (characterizing a wave) and v (characterizing a mass point) do show up in the same formula: $mv=h/\lambda$.

That electron (photon, etc.) propagates like wave and hits like bullet is a fact of reality, like the existence of platypus which lays egg like a bird and brestfeed her baby like a mammal. The philosophical dilemma can be solved if we understand that our concept of point is a *macroscopic* mental picture, derived from the experience of sand grain. But a sand grain is a complex crystal network of silicon and oxygen nuclei, surrounded by electron orbitals. (If we try to split the dust grain to smaller and smaller pieces, we arrive at the electron what does not behave at all like a geometrcal point.) Our concept of wave is macroscopic as well, derived from the spectacle of water waves. (If we have a closer look at the waves on the surf, we discover water droplets splitting away, each droplet being a composite of molecules, each molecule containing 10 electrons and even more other constituents. In the wave they produce a majestic interplay enabled by their loose connections with hydrogen bridges.) Our brain has been imprinted by these concepts by direct sensual experiences. We cannot do anything better than to use them for orientation when we try to explore the deep structure of matter, even if these macroscopic concepts conflict with each other.

So much for philosophy.

The Price to the Paid

Mankind has learned that it pays off to understand the structure of matter. Materials science offered us nylon stockings and plastic bags, synthetic drugs and computer chips never known before the atomic era. If one wants to observe the deep structure of matter with a space resolution r, one has to use a microscope working with light rays or electron rays, but these rays give a blurred picture, photons or electrons play hide and seek with us in the region smaller than their wave length λ. The resolution r of our microscope is limited by the applied wave length: $r > \lambda$. If one intends to get a detailed picture (of a crystal or molecule or atom), one has to use small wave length: $\lambda < r$. But the wave length of a light wave is inversely proportional to the momentum of light quanta: $\lambda = h/p$. To achieve a better resolution, one needs larger momenta. Larger momentum p means higher energy because $E = cp$. This implies two bad news.

1. Higher resolution means larger demand in energy, according to the quantum formula $r = \lambda = hc/E$. Here $h = 6.67 * 10^{-34}$ joule second is Planck constant and $c = 3 * 10^8$ meter per second is the speed of light.) To sharpen the picture, to decrease r means increasing E. To see a point, to obtain exactly sharp resolution ($r = 0$) one would need an infinit amount of energy E. This can be strived, but cannot be reached within a finite time, with a finite investment.
2. If one intends to depict finer details of a crystal or molecule, one has to illuminate them by rays of shorter wave length. This implies larger momenta and higher energy. The hits of energetic quanta may destroy the structure we intend to see! To get a detailed geometric picture of a single molecule with a relative accuracy of one percent does not make sense because a ray with such a high resolution is made of energy quanta exceeding the binding energy of the molecule thousand times. Geometric precision does not make sence beyond a limit posed by the strength of the bond.

Layer by layer

Baron Münchausen was lying when he claimed that he had lifted himself from the swamp by his own hair. The atoms making the Earth pull and push each other vehemently, but these internal forces cannot affect the overall locomotion of Earth. In the Solar System the weak but long-ranged force of gravity rules over the orbiting planets. It is the good luck of physicists that Newton became able to decipher the laws of gravity and motion, without diving into the depth of condensed matter.

Within a solid or liquid, within a molecule or atom electric forces act between positive and negative charges, which are by forty orders of magnitude more intense than gravity. But positive and negative particles are equal in number, therefore this electricity does not reach out of material bodies, only in exceptional cases realized by technology. Within inanimate and animate bodies, however, electricity is the ruling force, it makes metals solid, flowers colorful, animals alive. In the past two centuries we dived into condensed matter, we learned to know and utilize electricity for illumination, transportation, telecommunication, computation.

The working agents for electricity are the electrons, negatively charged light particles which are held on leash by the positive nucleus, sitting heavily at the center of atoms. The nuclei were considered to be rigid force centrals, their ultimate stability guarantees the conservation of atoms, the inconvertibility of chemical elements. Almost. Radioactivity – observed at the turn of the century – taught us that the nuclei are not completely rigid. Some of them fall apart spontaneously. In the 20th century we learned breaking up other nuclei as well, but to achieve this one had to concentrate million times more energy then what was needed to break up a molecule, to overcome the binding of nuclear particles. Nuclear forces are much stronger and have much shorter range. Nuclei are million times smaller than atoms, to depict them we need microscopes with million times better resolution i.e. of million times higher energy. They cost not tens but millions of dollars. At the middle of the 20th century protons and neutrons (making the tight nuclei) and electrons (making the loose molecular clouds) were considered to be elementary particles without size or structure. This was knowledge enough to understand: *the energy of the Universe that lights the stars in the sky*, is nuclear. By copying the heavenly power stations, nuclear power stations were built, nuclear bombs were exploded, nuclear technology and nuclear medicine were developed. We succeded to look up into the stars and to look down into the nucleus at the expense of bigger machines and higher abstractions. Our jouney leading far away from home was not understood and appreciated by everyone, what resulted in the nuclear controversy.

In the second half of the 20th century even bigger "microscopes" with thousand times better resolution were constructed at the expense of billions of dollars. We have discovered that protons and neutrons are not pointlike, they have a size of 0.0000000000001 mm. We sighted compact grains sitting inside them. We named these grains *quarks*. To the greatest surprise of physicists, however, it turned out to be impossible to break a proton to pieces: quarks can be seen but cannot be isolated. There is a chance, however, that at sufficiently high temperatures (above 1000000000000 degrees) protons and neutrons can be melt. Such quark fluids, however, have to be cooked by such a huge energy contentration, for which the present largest machines are hardly powerful enough. Hot quark fluid cannot be found out there, either the present Universe is a place to cold for that. Anyway, to our present knowledge, *electrons and quarks are the constituents* of condensed matter, glued together by gravitational, electric and even stronger fields.

When a composite structure is made out of simple building blocks, a certain amount ot energy is emitted. (This has to be replaced, to take the complex apart again.) Energy means matter, the radiation carries mass with, according to Einstein's formula $E=mc^2$. Therefore we have a mass equation

composite=constituent + constituent - binding energy.

As we dive down to explore the deeper structure of matter, the binding energies increase. If the value of the binding energy approaches the masses of constituents, it may happen that the composite body is much lighter than any of its constituents. We notice that the traditional question "what is made of what?" seems to be about loosing its sense. Whole and parts are not so well defined as in the case of a car or watch.

A long way ahead

We have to be aware that the way done till today (from 1 meter to 0.0000000000001 mm)is certainly shorter than the route ahead of us to the complete knowledge (down to 0 mm), because spacial resolution depends on energy invested, and the two quantities are inversely proportional. To reach r=0 in resolution E=*infinity* is needed in energy investment. We may climb higher and higher on the energy ladder but we shall never reach its top because the ladder is infinitly high. There will be no closed gates, but there will be no arrival either.

Planets, molecules, atoms, nuclei, protons, quarks – does each box contain even smaller boxes? Opening a newer box takes more trouble, needs more energy, costs more money. Is it worth of efforts? As we get farer and farer away from home, our mental concepts offer less and less help. If Nature just keeps repeating herself (like the Russian dolls, containing a similar but smaller doll inside), will young talents become bored, will society loose its interest in financing the enterprise?

Medicine relied initially upon anatomy. By taking dead corpses apart doctors understood what is bone and liver, brain and gut, and how their defects look like. Nowadays we understand that the main troubles originate not from fractured bones but from the failures of regulation and cooperation within the body. This means that the rules of the game may be learned by observing the functioning of the body. This is how some of the ambitious theoreticians try to jump far ahead in speculations, in order to find the Ultimate Law of Nature. We have heard exclamations by giants of mind (like Einstein Heisenberg or younger contemporaries of us) that the "world equation" or the "theory of everything"has been already discovered. If so, this might mean end of the road, the investment in search might he stopped, science might have reached its ultimate goal. Everything else may be left to engineers. This could be a great moment for the scientists of today, but a rather sad news for our students.

The problem is that we have heard this proud statement several times before, during the history of human culture. The Grand Architecture of Aristotle and Euclid in the Antiquity was magnigficient enough for scolastic reproduction through two frozen millenia. The New Age had to come with Columbus, Galileo, Michelangelo, Monteverdi, Newton and Watt to offer the Grand Clockwork as final explanation of events, with its merciless determinism. Laplace promised to calculate future exactly, without any ambiguity left for moralists, politicians or poets. The French Academy was ready to declare the nonexistence of shooting stars, which did not fit to the clockwork.

Then there came the era of revolutions: Kant speculated about the birth of Solar System, Darwin about the origin of species, Faraday messed about fields, Maxwell introduced electromagnetic waves, Marconi built a radio, Planck recognized the quanta associated to light waves, Broglie predicted similar behaviour for electrons. Philsophers were shocked, but scientists developed modern chemistry, electronics, materials science, molecular genetics. Engineers made television, computers and nylon stockings.

When a man of praxis visited Faraday who played with coils and magnets to make currents the visitor asked: do these toys have any practical adventage? Faraday answered: "I am pretty sure that once upon a time the Treasurer will tax these gadgets." – When a similar question was raised to Franklin, who collected lightnings, he answered by asking back: "And what is the use of a newborn baby?"

When Rutherford splitted the nucleus in the 1930-es, he declared that "anyone who looked for a source of power in the transmutation of atoms was talking moonshine". – Now nuclear power is a central military, economical, enviromental and political issue. We have learned to live with electricity. We are learning hard to live with nuclear power.

Will the sequence of pleasant or unpleasant intellectual and technological surprises go on? This is a central question of science today. Big Science is expensive. Can we afford it? Or can we afford not financing it? The race is open. Nations make their bets. One of them will win.

The origin of time

The laws of classical physics inherently contradicted the clockwork universe, which was thought to be designed just on the base of Newton's laws. Scientists did not recognize this hint, until a political quake in Petrograd did not help to break through the mental block. In the 1920-es Alexei Fridman dared to spoke out the conclusion: the equations of motion do not allow any stable solution. Within a few years the technological progress supplied empirical proof. In Pasadena the 100 inch telescope was erected, and Edwin Hubble observed the runaway of galaxies. The whole Universe is in the state of expansion!

Radioactive elements like uranium and radium are present around us. They have finite life times, they had to be produced a few billion years ago. But there is no place hot enough in the whole Solar System to cook these heavy nuclei. The Past had to be very much different from the Present!

Constructive interplay of high technology and nuclear physics was needed to understand that the whole Universe is evolving from an early hot and dense singularity towards a cool and quiet state. The fundamental laws of physics indicate that the density of the Universe decreses from an infinitely high value. We call this past singularity the Big Bang. (I our world is now about t=16 billion years old.) Nuclear science was needed to understand, how particles, nuclei, chemical elements, stars and planets were formed during the history of the Universe, how some planets had got air and ocean, climate and life. After having understood the whole scenario, we may raise questions like the stability of climate, the prospects of energy supply, the role and destiny of mankind.

As we explore space deeper and deeper with more and more sophisticated telescopes, we dive deeper and deeper in time, because the light of faraway galaxies travelled billions of years, before it reached our eyes or our instruments. Just in this months Alex Szalay (professor of Budapest and Baltimore) discovered the unexpected whipped-cream-structure of the All, in which galaxies are distributed in thin layers, surrounding huge voids with diameters of 400 millions light years. Diving deeper in space, what means diving deeper in the past we expect to understand the formation of galaxies, to sight the first astronomical accumulations in a fast cooling young Universe, rather different from our present relaxed world.

"Non in tempore, sed cum tempore fixit Deus mundum" – Saint Augustin wrote. God created the world, not in time but with the time.

Events are ordered causally. Each event was preceded by other events which served as its causes. If there were an event without scientific cause we could call it creation. This is the problem of t=0.

From local experiences (from laboratory experimentation and from obserations made within the Solar System) scientists discovered equations of motion for material objects (planets, atoms, electrons, fields). It has turned out that these nonlinear equations have strange mathematical properties: none of their solutions can be extrapolated to infinity in both directions on the time axis (with the expeption of emptiness). One certainly hits an unavoidable singularity! In case of the simplest homogeneous world model the singularity of density behaves like t^{-2}, that of temperature behaves like $1/\sqrt{t}$. Recent satellite observations indicate that this homogenity assumption is rather justified for the early radiation-dominated era. But the singularity is not included in the region of validity of any analytical function! In the strict mathematics one cannot extrapolate a function beyond its singularity. Mathematically speaking: the time axis is not a closed internal ($t \geq 0$), but it is an open one ($t > 0$). Each real event (at $t > 0$) has infinitely many other ones preceding it (serving as its canses). Scientifically speaking, there is no "first event". The event $t=0$ which does not have a cause, is not included in the physical time axis.

(E.P. Wigner quoted Dirac's remark: If someone dislikes this limitation $t < 0$, he can get rid of it by using $s = \log(t)$ instead of t, so instead of the $t > 0$ region he may work with $-\infty < s < +\infty$. This escape route is, however, not so comfortable as it looks to be. For practical reasons, every scientist and engineer would prefer using t instead of s, because t is the independent variable which offers the simplest form for the equations of motion. It would be hard to teach and to learn e.g. the law of inertia: in terms of s lonely bodies slow down. Mechanical clocks show t and not s.

In this sense the origin of time at $t=0$ is not a physical event but a limit what we may strive for but what we cannot ever reach. Running the cosmic movie picture show backwards, we may try to reconstruct the events of the past layer by layer, based upon our present knowledge. Galaxies were made 1 billion years after Big Bang, when it became cold enough for clouds to condense. Atoms were made 1 million years after Big Bang, when it was already cool enough (thousand degrees or so) for them to survive. Nuclei were formed 1 minute after Big Bang, when temperature dropped below billion degrees. Particles were frozen out of quark liquids after a microsecond (a millionth of a second), when temperature fell below thousand billion degrees. Our intellectual penetration in the very depth of the past must stop here now because we don't know yet the behaviour of matter at higher temperatures, at larger energies. Our present terrestrial laboratories have not passed yet through the technical "teraelectronvolt" barrier, but such machines are already on the design tables of engineers. By working hard, we may approach $t=$ step by step. But always infinitely many further steps are left to be done by the coming generations.

Message from the Otherworld?

There are theoreticians – a minority among scientists – who are ready to raise the question: what was before the Big Bang, at times $t < 0$? Such a question is generally considered to be unscientific, because the infinit density and temperature at the singularity destroyed every structure, therefore there is no way of getting information about negative times, even if there were any. ("What one can measure, that exists" – as Max Planck said. What cannot be checked, is not worth of scientific attention.) But it may be that this argumentation is not completely true: i might be that the mathematical singularity of the cosmic stuff had been introduced only for computational comfort, and there could be a quantum leakage through the Big Bang singularity. A possible witness inharited from the pre-Big-Bang era could be the *entropy*, according to Ya. B. Zeldovich. The Second Law of Thermodynamics states that the disorder produced in a former Universe cannot be destroyed by a Big Crunch, it is compulsorily inherited by the new world. We may imagine a scenario in which the overall energy of the world of galaxies is negativ. In this case the life time of a physical universe is finite: it starts from a singularity with a runaway of galaxies, but gravity dominates over kinetic energy, therefore the expansion stops sooner or later, then the galaxies fall back to a Big Crunch. During the existence of the world irreversible processes happen, the resulting final entropy is larger than the initial one. Well, the dynamic equations of general relativity are symmetric with respect to time reflection, therefore mathematically it its imaginable, that the contracting world climbs through the point singularity and starts expanding again, but having inherited a higher entropy, more particles, larger pressure. The consequence is a new universe with wider ocillation, bigger size, longer life time. If you are ready to stretch your imagination, the very first universe might be small, initially fully ordered, cold and short lived. It produced a tiny disorder. The next oscillation started with a certain amount of entropy, therefore it lasted longer. And so on. After a while an era arrived with just the appropriate amount of disorder, with los of particles, with space and time ample enough for life – and here we are. This offers a possible explanation for the Anthropic Principle.

Repeated oscillation may be a mathematical possibility if the overall energy is negative. According to astronomical evidence, the energy of the present world is zero – within a wide observational error margin. Such a zero energy may be explained – a bit anthropomorphically – by saying that World originated out of Nothing. Nonexistence does not possess energy, therefore – due to energy conservation – the emerging world must be of zero energy. It is suspicious argumentation to apply energy conservation for creation, but – alas – the exact balance of positive kinetic and negative gravitational energy is the most confortable choise to create a universe ample enough for biological evolution resulting in human intellect. A distinguished school of Russian cosmologists, led by A. Linde proposes that our present World emerged by chance via quantum tunnelling out of Nonexistence. They think they have succeeded to prove that such a quantum leakage has a nowanishing probability. It is a brave mathematics of daring theoreticians.

Shadows of Creation

Cosmology was a hunting territory for theologians, philosophers and poets for too long. This is why the majority of astronomers and astrophysicists try to stick to facts. The facts are that we are able to trace time back to the first microsecond of creation. From that early moment on we have all the "archeological evidences" available in forms of protons, photons, nuclei and galaxies, thus the evolution of our present world from a Hot Universe by expansion and cooling is considered to be an empirically confirmed scientific knowledge.

The picture of events before the first microsecond is fuzzy, because at those early times the constituents had so high energies what we could not produce yet in the lab, therefore we could not reconstruct the events so deep in the well of the past. On the other hand, this is the main attraction of the era within the first microsecond: that Early Universe was an exciting high energy lab what we cannot afford today. It would be great to find some leftover documents carrying information about that high energy frontier. (You should not forget that gravity was discovered in the Planetary System, helium was discovered in the Sun, even nuclear fusion was understood in the sky at first.)

Well, we can find out the mass of the Earth from the observed gravitational acceleration of dropped stones on its surface. We can find out the mass of the Sun from the time of its planets. We can learn even the gravitational mass of the Galaxy from the orbiting periods of stars, globular clusters, dwarf galaxies orbiting around the center of our Milky Way Galaxy. Even the mass distribution can be mapped by observing orbiting objects at different distances.

Just this method was applied in the past decades, with suprizing results. It turned out that the amount of matter in our Galaxy is at least by one order of magnitude larger than the overall mass of visible stars; possibly by one order of magnitude larger than the mass of atoms. This extra invisible mass distribution seems to stretch well beyond the optical boundaries of the Galaxy.

Strange enough, but similar conclusions can be obtained at other giant spiral galaxies and in clusters of galaxies. The Coma Cluster is a stable relaxed formation in spite of the fact that the pull of its galaxies seems to be far insufficient to compensate the kinetic energy of these glaxies. Something else must be there, to contribute to stabilization by it mass.

Let us extend our look at the whole visible Universe. It seems to be a fine-tuned entity where the negative gravitational potential energy is just equal in value to the positive kinetic energy. But atomic stuff is far insufficient to create gravity enough. David Schramm has concluded from the present abundances of light composite nuclei that atoms cannot make out more than a few percentage of the overall gravitational mass, derived indirectly from the motion of galaxies.

If all these are true, if we do not commit a huge error somehow, if we know the Laws of Nature well enough from laboratory experiments, then more than 90 percentage of the stuff in the Universe is unknown and undetected. This puzzle of the Dark Matter is the most burning problem of contemporary empirical science. Physicists compare it to the centuries-old problem of the Fifth Essence, that of the Ether (supposed to be everywhere and not seen by anyone). But Dark Matter is observable through its pull! It originated at the dawn of our world, in the era of very high energies not yet familiar for us. It should be the first stuff which condensed to clumps due to its enormous gravitational pull. The gravitational valleys created in this way collected the atoms to make galaxies in the later period of cooling. The recently discovered whipped-cream-map of the cosmos may carry vital information about this early era. Let us hope that we shall become able to read the message written on the sky, about the first moments of time.

Frontiers, not barriers

In this review I have tried to convince you that the space, time and energy limits are just one single limit. Zero space resolution, zero time, the most distant past, most far-away regions of space and the infinit-energy-end of the energy ladder mean the same singularity, what can be approached step by step. To climb the whole ladder would need infinite amount of investment and efforts. This is the good news for the incoming generations: science is a never ending story.

E.P. Wigner is afraid that increasing set of information without basic comprehension may decrease the attraction of science just for the brightest young people. Science was always driven by the quest of understanding totality. I am not afraid in this respct: each level had turned out exciting and demanding enough, to satisfy the adventure-seeking young people.

The bright young people may ask back: will society be ready to finance all those particle accelerators, supercomputers, telescopes, space flights? Will society be willing to pay the billion dollar bills?

Well, to pay the bills for Faraday who tossed magnets into coils, to make electricity, or for Franklin who collected lightnings to get high voltage was a good investment. People may agree about the economic value of atomic physics and molecular biology as well. They may hesitate a bit longer about the nuclear bill, but this hesitation is slowly fading away as the oil bill increases. But how about quarks and even Dark Matter? Can we make weapons out of them or can we use them as fuel in the emptying tank of our car?

There are so many maladies to be cured around us: air pollution, drought, cancer, AIDS... Let me leave the answer to other speakers.

I conclude with a quotation from Paul Claudel. In his play "Les souliers de satin" he asks:

"What do you think, who did more for the poor souls suffering in malaria: the self-sacrifying old doctor who spent his days and nights at their beds, and tried hard, according to his best knowledge to soften their sufferings, meanwhile risking his own health as well, or the good-for-nothing vagabond who became intrested in having a look at the opposite side of Earth, and discovered the quinine tree?"