Plenary Address

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The Unity of Science and Diversity of Culture

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Speaking today at the opening of this conference on the subject of the Unity of Science, in the beginning of our deliberations it would be proper to try and point out what are some of the main factors, that make the concept of unity so appropriate today.

We can begin with the outward, material setting of our wellbeing and here I would first of all single out the global problems now looming on our common horizon. Next we should look into science, first of all the natural sciences that have now given us a universal tool both for obtaining knowledge and in providing a powerful example of what has come to be known as the scientific method. Finally we shall look into our cultural heritage.

All who have encountered the might of science in studying science or in following up the results of the scientific endeavour come to recognize both the power of scientific reasoning, its universality and remarkable productivity in the incessant progress that we all witness.

All students of science know well that it can be mastered without ever dealing with the past of science. The modern expert and professional can be trained and is trained being unaware of the history of science. One does not have to read Newton or Euler, Mendeleev or Darwin to know modern science. This attitude has helped to dehumanize science as it is now taught.

When we encounter the problems of ourselves it is here that the grand concept on unity seemingly does not work. Not only everyone of us is cherishing his own self, his or her individuality. Even when we can overcome this selfcenteredness we encounter the limits imposed by language and culture, by our national and religious heritage at the same time when all recognize that we live in one world and experience a common environment. All humanistic development and education is deeply rooted in its

past, in its history of ideas and people. It is this dichotomy that more than ever is present and selfevident.

Today we are faced with these issues as never before. We cannot evade or escape them by closing ourselves up individually or nationally, intellectually or morally, isolating ourselves into a smaller world, for the world at large has now become so small and finite, that not a single sentinent being can really find his place without referring to the realm of this greater world. Perhaps today, when we are still clinging to the last expressions of the lesser world of our past, people find it so difficult to reconcile themselves with this greater unity. That is why the subject of our deliberations is so timely and relevant to the issues we all face.

The global problems are well known: resources and energy, water and food, the environment and health, finally, population. It is the population growth that certainly is the global problem, as the human race has become a decisive factor on a planetary scale.

When I was at school 50 years ago I learnt that the world had 2 billion inhabitants. Today we have passed the 5 billion mark and by the end of the century, and the millenia for that matter, the global population will be more than 6 billion. The number of people is much larger than that of animals. For example, the present and equilibrium number of elks in Russia is 750 000, the number of rabbits - 5 million. On the same territory 100 million people live supported by the artificial biosphere - our agriculture.

In describing population growth the exponential model is often applied. In this case the numbers double say every 30 years, as it is with the data I have given. Now as $5\ 10^9 = 2^{32}$, then 32 generations ago, a mere 1000 years we all began with Adam and Eve! Certainly the exponent is a very poor model, as 2000 years ago the world population was already between 100 and 200 million people.

Here I shall introduce an expression for the growth of the world population

$$N = \frac{C}{\tau}\mathrm{arcctg}\frac{t_0 - t}{\tau} = \frac{2 \cdot 10^{11}}{40}\mathrm{arcctg}\frac{2025 - t}{40} \approx \frac{2 \cdot 10^{11}}{2025 - t} \quad ,$$

that describes in remarkable accuracy the world population change over many millenia up to the present. The last approximation is a very simple expression and I found it out myself only to be told that it was first introduced in 1961 by Foerster.

On figure 1 the pertinent data for the last 250 years is shown, together with the difference between this formula and appropriate population counts. The fit is remarkable and only on the second chart magnified five times do we see two minima associated with

World War I and World War II and the rapid recovery that took place. The case presented as the best fit to all demographic data indicates that we are heading to a limit for world population of 12 to 15 billion.

The last expression suggests a divergence at year 2025, a divergence that is eliminated by modifying the equation, transforming it to a one leading to saturation rather than infinity. On the other hand these equations are more than merely a useful device to express the observational data. The solution is of a self-similar type describing a process that at any given moment follows the same scaling law as before. It may also be compared to the standard equations of chemical kinetics describing self-catalytic reactions. The divergence that it signals is an important indicator of an approaching crisis that is a significant feature of this model. One may compare it to the model of the expanding universe, also of a self-similar type. In that case we are receding from the Big Bang rather than approaching it as in the case of "population explosion".

The curve describing the world population growth is really a remarkable example of scientific unification. For here in a single line we have a sum of all history, the outcome of billions of lives, the story of hundreds of countries and nations all put together into a single picture and described by a simple formula, averaging out all secondary events and presenting in a stark message the impending crisis we are all approaching.

At the same time we have to note that we are really approaching the number of people that our planet can support. This is what drives all other global problems that I have listed making them of secondary importance, however great they may seem.

Perhaps it is here that we should include yet another global issue, that of the arms race and of military confrontation. Technologically we have arrived at the position when the available arms are so great that the global conditions conductive to human life can be ruined, resolving in a tragic and bizzare way the global population pressure. Hopefully now this possibility conceptually has been if not removed completely, for the arms are very much here, but has become very much less likely.

It is here that it would be right to turn towards science. Modern science has also become a global phenomenon. A discovery made in one country or laboratory immediately becomes known everywhere. Scientific knowledge is still distributed freely, as the common property of humankind, a tradition that is long established and should definitely be kept and protected. This universal character of science is really remarkable, and scientists should see that their right to disseminate knowledge, exchange information is not in any way limited. At present we are in a favourable

phase for our activities. Scientists do have remarkable facilities at their disposal, mobility and support. But it was not always so. Some scientists are still limited in their capacity to travel by considerations of security and secrecy. Although we all know that the only secrets that matter are those of Nature. All other attempts to control scientific information is more a way of controlling the scientists, to keep them, as it has been said, "on tap, but not on top".

Indeed the responsibilities of scientists are great. Only recently they were one of the driving forces of the arms race, being also the first to signal the universal danger that the modern arms bear for humanity. Today major responsibilities of scientists are connected with pronouncements on global matters, on matters of the environment and development.

In the Soviet Union science at present has a hard time, especially after Chernobyl. That accident at a nuclear power station was more than an industrial accident. It was an event that showed most of all to ourselves, and hopefully to others, that the development of high technology, of nuclear energy is not only a scientific technical problem but also invokes major social responsibilities. We saw that there was no proper understanding of their duty by the nuclear technologists, by those in power and even by the medical profession on these issues. In a certain sense Chernobyl was inevitable, for in our society we did not have this broader vision of nuclear energy, did not take into account the human, social and psychological aspects of the problem. Chernobyl and its aftermath have all the marks of a technocratical crisis and here I think there is a lesson for all of us to learn.

The modern obsession with technology, with a scientific and technical fix for all problems is certainly an attitude fraught with dangers. To understand the magnitude of this danger I think we have to go back to the origins of modern science, to the 17th century, to trace the difficulty in coping with the seemingly absolute reason of the scientific endeavour.

The first great breakthrough of modern science was mechanics and the rapid development of the celestial mechanics of the Solar system. It certainly was a remarkable in its concept and execution model of the Universe. The very heavens as then seen by the naked eye and the first telescopes , the appropriate development of mathematical tools and basic concept of what the French aptly call rational mechanics led to a very complete understanding of the clockwork of the Universe.

This remarkable initial success of science set a pattern for intellectual

developments, repeated later in electrodynamics and quantum theory of the atom, and had a profound effect on human minds. Later in the development of biology, earth sciences a similar pattern was followed. But where it succeded least of all, it was in the social sciences.

It is here that the very painful experience of the Soviet Union can be mentioned. For the mechanistic concept of primitive egalitarian models based on ill-proven analogies and misuse of ideas introduced knowingly or not from the vocabulary of sciences that arrogantly called themselves exact, was most misleading. The result today is a total collapse of a system of ideas that professed to explain and even give guidance in matters of profound importance — how to construct and conduct the life of society. Here again there is an important lesson to be learnt.

Only gradually did science, natural science gain the understanding of phenomena that cannon be explained in terms of simple causal laws. As is often the case the extremes are more easily treated. That is why probability theory and statistical mechanics established themselves first, where the laws of complete random behaviour are dominant.

It is only now that we are gaining some insight into phenomena, where not all is chance and not all is law. From the weather of tomorrow to the stockmarket prices on the next day, from the strange and seemingly irregular pattern on maps of land and galaxies and to the behaviour of human aggregations we are now gradually and hesitantly learning how to think about such problems, described by their common feature of chaos. But what are the limits of chaos, when we have to deal with climate and when with weather, when with history and when with the turbulence of our daily news? How does a system evolve when complexity grows although no goal or guiding idea can point the way be it in nature or society?

In the beginning I referred to the formula for world population. In a deeper sense it is a formula that of a description of the average of self-similar behaviour of a large system. It sums up the processes each on its own, following a more or less random course, but where finally a certain common pattern does emerge. This trend can be described by a universal formula, although limited in its use to certain boundaries.

It is this way of thinking that has to be now propagated and that is why I have introduced this expression right at the beginning of my talk, to bring it out again to demonstrate a method, a point of more general importance.

In describing nature we have gradually learnt how not only to find the laws but what is even more important to outline their limits. It is here that the unity of science comes in for. For our quest is to go beyond these limits in trying to connect and unify items that are seemingly separate and far apart. It is here that the intellectual breakthrough of the Copernican system was so important, for it placed the Earth, the Sun, the Moon and the planets into the same frame of reference. It was the universal law of gravitation that set the pace for that system, gave it order and remarkable predictability.

Each great step of science was that of unifying concepts, as in electricity and magnetism that became electrodynamics and now incorporating in modern theories weak nuclear interactions, and going further towards ambitious steps of the grand unification of forces. The same thing happened in biology in the unifying principles of evolution, in the discovery of the remarkable similarity of the biochemistry and hereditary mechanisms of all forms of life.

Here again we have a very powerful intellectual pattern, a pattern of development that we can observe in yet another field of human endeavour, older and in many ways very human - that of our religions and beliefs.

Again the development is certainly guided by the concept of unification. From the assortment of lesser gods and deities each in charge of his own domain all religious systems have come to the concept of a single deity. As in science this has led to a greater level of abstraction, when the homely, even human and understandable lesser gods became absorbed into the universal God, often so remote, as to be unmentionable.

It seems that this trend toward unity transcends the difference between the religious and the scientific. Or was it first developed in religious systems, and then introduced into science? Or does this go beyond, to the very foundations of the human intelligence in seeking for a common cause?

Today more than ever before we are again examining the interface of science and religion. For many centuries, at any rate in Europe, they became rather strictly segregated. For was it not said "to render unto Ceasar the things which are Ceasar's" (Mat. 22:21).

Indeed this separation after the experience of Galileo was well established. The scientific understanding of the world was developing on its own and respective roads did not really cross, although we still as in the past have encroachments mainly from some militant and dogmatic

religious groups on some matters of science. But it is not that what matters.

In the first place the personality of a scientist was a point at which science and religion crossed. A student of the history of science can point out many such occasions. This year the world of science is observing the bicentenary of Faraday, the scientist who unified electricity and magnetism. One of the greatest of all scientists, he belonged to a very proper and strict protestant sect of Sandemanians. A recent biographer notes that here the scientific and religious matters did not mix, although it is well-known that in his public behaviour and attitudes Faraday was a remarkably outspoken and morally consistent person.

In the case of Newton the way in which he questioned the logic of the Scripture led him into great difficulties with the church in 17th century England. It was mainly due to his influential friends that he was kept out of trouble.

The great Russian physiologist I.Pavlov was outwardly religious and after the Revolution it led to many complications and again influential friends and understanding of the authorities kept him out of trouble.

But in all these cases that would be easy to multiply, the matters of science and religion were kept apart, although they did coexist in the minds of these remarkable scientists, original and independent in their contributions to human knowledge. Thus, for many years, even decades the issues of science and religion were held well separated. Most practicing scientists would hardly ever bring up the subject and in the cases when these issues did appear they were usually treated as a matter of personal convictions, something private and of no great professional significance.

It is only recently that the connections of these two reals of human spirit were reactivated, when scientists, those pursuing natural science in the first place had to face their social responsibilities. Painfully they discovered that they themselves have to answer direct and often unpleasant questions on the consequences of their discoveries. Sometimes even in an outspoken and personal way, but usually as broad issues of society, of the human destiny and the impact of science on our life.

I have already mentioned the issue of the arms race. Today pronouncements of science on the environment are becoming of great inmportance. Next year in Rio de Janeiro a major international conference by the UN is to be held on the environment and development. What will be the

message of science to this great gathering of statesmen and executives?

On a lesser but perhaps deeper scale moral issues are raised concerning the Human genome project. Somehow this great international biological endeavour excites profound feelings as unravelling something very private and individually significant. An example as to what these studies may lead to is the recent statement on the existence of a single woman, who became the progenitor of the entire human race. To what extent are we ready to face such results? What are the principles of morality we have to follow? It is here that again we meet with matters that religious systems have dealt with well before modern science appeared. Modern medicine has led to a host of new problems, although doctors are better equipped to deal with issues of the human destiny.

How to reconcile these discoveries and options they open with the established moral norms and ethical rules? One of the most powerful concepts of science is a trend to reduce complex phenomena to the more simple and tractable ones and then to apply what is called the first principles. In no science this has been so developed as in physics. A physicist will spend all effort to understand the simplest of molecules, say of H_2 , of hydrogen. Water H_20 is much too complicated and indeed this most common substance is remarkably complex in its properties. The students of genetics also have their favourite objects like the drosophila - the fruit fly or E.Coli in molecular biology studies, removed from everyday practice..

This reductionist approach is powerful and has led to a remarkable depth of understanding. The laws and lessons learnt on these simple objects are then applied to more complex systems, as an industrial chemist or agronomist well knows.

But apart from exporting the results of our fundamental understanding there always has been a tendency to generalize in the study of systems of a more complex nature. This way of thinking as opposed to the reductionist one is known as the holistic, integrative approach, practiced in systems analysis, nonlinear mechanics and synergetics. Both in their ways lead to a greater unity.

It has so happened that over the last centuries the integrative approach has certainly lagged, for it was the reductionist who produced more tangible and practical results and greater insights rather than an overview. Another reason for this was the specialisation of knowledge, that due to its sheer volume and detail also enhanced the reductionist way of thinking of the expert.

Today we have come to recognize once again the importance of the integrative approach. For instance, all global problems are of such a type and in studying them we see how poorly modern science is equipped to deal with them. Including into a committee scientists of all specialities is indeed a rather primitive way of integrating our understanding.

I have digressed into discussing the integrative approach to bring up the point that all moral and religious systems are integrative. They treat the whole world, the complete human being summing up and expounding in an understandable way a world point of view. A "Weltanschauung" as a German would say or "mirovozzreniye" in Russian. It is no accident that in English no such world does exist, for it seems that the British mind is singularly opposed to such an integrative, holistic approach. The Newtonian "Hypothesis non fingo" certainly expresses this attitude in its extreme.

In Russia we have a single science, not only natural science, for again in the English-speaking world science is only hard science, exact sciences as physics, chemistry, biology. In German and Russian "Wissenschaft" and "nauka" include all sciences — another point worth noting.

On the other hand we have about ten major religions, world religions as they have come to be known. These systems of ideas and concepts present a most precious cultural heritage and here again I can refer to the recent Soviet experience, where we are going through a remarable revival of our religions. Painfully and even tragically we have discovered that it is in the religious tradition we can seek for moral quidance. Indeed it seems that in the modern world the church provides for "the custodians of moral values", to use the expression due to Professor V.Weisskopf, who among modern physicists was one who explored the complex interface of science and religion. I will remind you that Weisskopf was at Los Alamos and was one of the first to inspect the site of the first nuclear explosion.

The remarkable thing about world religions is not their seeming diversity. Mainly due to ecumenical studies by the German theologist Dr. Hans Kung it has been shown that in their basic moral teachings all religious systems have more in common than one usually thinks. This is also a major attempt of unification in a field where one could hardly think such insight is possible.

At the same time as we observe a tendency towards unification in a discovery of a common frame of reference in science and morals we also notice powerful trends to have a diversity of cultures, languages and

intellectual traditions.

Take languages. They can both unify and be an instrument of separatism. At one time Latin was the language of learning in science and much of religion in Europe. Following the development of science, trade and diplomacy French became dominant, after that for a brief period German. Now finally English has become the language of science and business. It also has a great influence on computerees, a peculiar new pidgin English for software, rapidly spreading throughout the world.

At the same time language has become the identity tag in a globally observed trend towards demands in recognizing ethnic groups or those of established nation states. These trends often develop in opposition to powerful processes of unification in business and commerce, in scientific, technological and other forms of international communication. This diversity has to be looked into and preserved in spite of pressures to unify.

The diversity of species in nature has become an important issue for preserving and protecting our environmental and the remarkable variety of all living kind. Today ecologists note that every year many hundreds of species vanish, vanish forever, irrevocably from our planet mainly due to human activities. It would be very sad for the human story to wind up in an animal farm and not the world zoo. The variety of different intellectual traditions and cultures is also an important type of diversity that we have to cherish and protect.

I have already mentioned the semantic difference in the use of word "science" in English and Russian. This difference in usage is more than a difference in meaning. The integrative, holistic approach is to a greater extent developed and dominates the Eastern European church and intellectual tradition than in the West, Catholic branch of christianity. If we go to the Far East, the East of the great civilisations of China, Japan and Korea, these integrative trends are even more pronounced. Perhaps the most obvious demonstration is in the ideographic, rather than linear writing that is so characteristic of them. It certainly points to a different dominant mode in the mentality of the East, perhaps even pointing in the anatomy of the brain to the greater use of the right hemisphere, rather than the left one, more engaged in logic and language.

At present in Russia we are noticing an important revival of interest to the writings of philosophers active at the end of the XIX century, in the first place V.Soloviev and N.Fedorov. These writers and religious thinkers explored in a novel way the interface of science and morality. Their

writings were not accepted either by the Orthodox Church of Russia or, after the revolution, by the Communists. Now their works are published and read anew in a rebirth of an important part of our heritage. Will it lead, as these writers hoped, to a new synthesis of science and spiritual values is to be seen.

The demand for a consistent moral system is declared in many parts of the modern world. Is the vacuum produced by the decline of the established faiths to be filled by a new set of morals, of human behaviour or will the old systems prevail? Or will superstitions and primitive sects spring up following the inherent to human nature tendencies to mythologize the world? Unfortunately the current outburst of such social manifestations are widespread signalling a profound crisis through which some of the so-called advanced nations are now passing.

This regression into mythological thinking, in the sense that it has been studied by Claude Levy-Strauss explains much of the public yearning for the supernatural, extraordinary, of all that is beyond the realm of our common experience, challenging not only all scientific reasoning, but common sense itself. As far as these manifestations are inherent, have not organised themselves, they may be treated as abberations, in fact even be useful in the sense that they question the established wisdom for complacency and preventing fossilisation. As a Russian saying put it: "Na to i myshi chtoby koty ne dremali" "Mice are here so that cats will not go to sleep". But these attempts offer no alternatives to science.

Our world, world where so much is now due to science has really become too arrogant and so inhuman that it is no accident that today after all the advances of technology, of our material wellbeing we have finally to admit that our material hardware has gone for beyond our social and moral software. In the world of computers it is now well known that the human effort in developing software has to be much greater than in producing all the hardware. I do hope we will finally recognize that this applies to the real world to which we all belong and will pay due attention to develop our software, taking into account the diversity of forms and unity of purpose.