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## SCIENCE AND CIVILISATION: TASKS FOR THE NEXT MILLENNIUM İHSAN DOĞRAMACI

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Understanding the past is sufficiently difficult, understanding the future almost impossible. The past is where we have to seek clues for the future, and this is partly what I will do.

Today, it has become quite common to think of science and technology as dehumanising and alienating. But, is this thinking intrinsic to the pursuit of knowledge, or is it merely a characteristic of the state of science in our age? Quite contrary to the present, if we go back to earlier periods, even long before the Renaissance, we see that technical advances, such as innovation in agriculture and the mechanical arts and the harnessing of new sources of power, had a predominantly humanising effect. These technical advances highlighted the value of human intelligence for understanding and controlling the forces of nature.

Although I acknowledge the need to do so cautiously, it is worth noting some parallels between the modern scientific institutions and the medieval Church in Europe. While many religions have certain humanist elements in their origins, towards the centuries that led to the Renaissance, Church Learning had become increasingly intellectual and abstract. Perhaps representing a reaction shared by others as well the poet Petrarch felt the need for learning that would better reflect the conflicts and idiosyncrasies of human emotion and imagination. Rather than using doctrinal formulae, Petrarch relied on introspection and observation to obtain insights into the human condition. Petrarchan humanism was a culmination of the ideal posited by numerous Ancient Greek philosophers and enshrined in Protagoras' aphoristic statement in the fifth century B.C.E.: "Man is the measure of all things." It echoes Socratic humanism, which held that truth is immanent in human subjectivity and that the divine is imbedded in man.

Perhaps the source of current discontent with modern science and technology lies in the fact that despite their claims and promises of advancement and progress, people still feel that the great problems of humanity are as insurmountable as ever. Injustice, poverty, inequality, a planet which is about to become polluted beyond repair and aggression are only some of many seemingly intractable issues.

The present disillusionment with science and recognition of its dehumanising and alienating aspects bear more than a shadow of similarity to the case of the Church in medieval Europe. Some felt that the institution the Church had become was stifling the true essence of religion. Noting that the authority exercised by the institutions of modern science has parallels with that of the Church of that day, we are led to ask whether these institutions may also fall prey to a dogmatism that will hinder the true quest for knowledge, which is one of the inalienable essences of being human.

According to the historian Fernand Braudel "humanism is always against something: against exclusive submission to God; against a wholly materialist conception of the world; against any doctrine neglecting or seeming to neglect humanity; against any system that would reduce human responsibility.... It is a perpetual series of demands-a manifestation of pride."

With the Renaissance, humanism prevailed and attempted to restore the importance and power of humans over the institution of the Church. The Renaissance did not happen overnight; it had a long gestation period. It remains to be seen whether the sufferings and turmoil of our century are a sign of another Renaissance in the making.

The modern English term "science" come from the Latin word for "knowledge," scientia, and no one had a monopoly on it. But "science" no longer means knowledge anyone has or may have. It certainly does not mean a poet's knowledge, and not even a philosopher's or, in fact, a carpenter's or a mother's knowledge. Usually it does not mean mathematical knowledge. Today "science" is a special kind of knowledge possessed by special elites called scientists, obtained by strictly defined methods. Their customs, orders, rankings and costumes more than superficially resemble the clergy. So it is in this narrow sense that "science" is found to be self-limiting. It is knowledge in the more-encompassing and fuller meaning of the original scientia which people desire.

What are the ends of knowledge that science seeks and the nature of truth that philosophy explores? Has technological civilisation made a strong enough commitment to the abiding aspirations of human society-peace, equality, health, happiness, dignity and hope? Can the world eventually turn Mahatma Gandhi's Satyagraha and Ahimsa into reality? Gandhi called Satyagraha "Truthforce" or "Love-force," and Ahimsa "a weapon of matchless potency," "infinite love" and the "summum bonum of life." Can the world overcome its Hobbesian nightmare of enmity and destructiveness? Will peace ever prevail or genuine democracy be achieved? The Anatolian Sufi poet, Mawlana Djalal al-'din Rumi had observed in the thirteenth century: "When ignorance and weapons come together, tyrants arise to devastate the world with their cruelty." He further articulated the supremacy of love: "Whatever you think of war-I am far, far from it.... Whatever you think of love-I am that, only that, all that."

To establish an international order attuned to Rumi's moral imperatives and Gandhi's ethical ideals, science and the humanities, as well as technology and the social sciences will have to create a new educational system. The accomplishment of this goal requires adjustments in methodologies. To achieve a new enlightenment, a new age of scientific discovery for the sake of humanity and for peace, we should now glance at some tasks for the future:

1. Learn to study and recover the whole instead of the parts;
2. Avoid polarising knowledge and stress its unity;
3. Bend our methods to nature, not nature to our methods;
4. Bring science down to the people;
5. Pay attention to social inventions as much as technical inventions;
6. Learn how to manage the new fractal-global knowledge network;
7. Reshape education and research institutions.

We must find ways of recovering the whole from the pieces. To this end it is necessary to realise that science as an institution is not immune to dogmatism, and the very power and respect it draws make it all the more important to examine it critically.

The next important task is to avoid polarising knowledge and to stress its unity. In Western thought, there is a tendency to create opposing poles. Indeed, this tradition has presented us with various dualisms. Dualisms are found in other cultures and traditions as well though with a somewhat different bent - a subject I will not digress into here. Some of these dualisms stand out among the others such as those between science and ethics, and between fact and value. Furthermore, after prolonged conflict and stepping on each others feet, science and religion today have finally receded to mutually exclusive domains. Religion gave precedence to science in explaining the material world, whereas science no longer made claims regarding values, whether they were based on religion or otherwise. Whereas this is often shown as a victory of science and human reason, the result has been a fragmentation of human knowledge. Humans cannot exist without values, whether they are devout believers or atheists. Thus, an important task we face is not to let these deeply ingrained dualisms fragment our understanding of the world. We need to recognise their artificiality and superficiality, and to stress the unity of humanity and knowledge.

The next task is to bend our methods to nature, not nature to our methods. Modern science makes the assumption that there is a real world and that knowledge of it can be obtained through observation. It also assumes that this knowledge is objective and independent of its subject. In making these observations, it restricts itself to those aspects of the world that truly fit this picture, resulting in a special emphasis on exactness and quantitatively measurable events. The insistence on exactness and quantification limits the range of subjects amenable to investigation, excluding whole areas of knowledge in which humans yearn for and are in urgent need of better understanding.

A tale of Nasreddin Hodja, an Anatolian folk hero who lived in the thirteenth century, sheds some light on the matter. Nasreddin had lost a precious belonging in a barn. Those bewildered to see him searching in the courtyard asked him why he was searching not in the barn but in the courtyard. He replied, "I am searching here because it is dark in the barn." Similarly, science often investigates what it can measure, not what human beings want to learn about. The Western tradition owes a lot to the ancient Greeks, and it is worth paying attention to what Aristotle had to say on the subject:

It is the mark of an instructed mind to rest satisfied with the degree of precision, which the nature of the subject permits, and not to seek an exactness where only an approximation of the truth is possible.

The need to depart from exactness in the conventional sense features itself in many of the fashionable recent trends in science. After a long-lasting but only partially fruitful effort of trying to imitate the methods of physics and mathematics, the social sciences have also been recognising that their strength lies precisely in what they thought was their weakness. Human beings are complex and ambiguous, so any attempt to understand or predict them using precise and well-defined systems is bound to exclude their essence from the very beginning. Thus, the methods of social and human sciences, while not perfect, are perhaps better able to increase our understanding of ourselves.

This leads us to the third task. We must realise that not all areas in which we seek knowledge are amenable to the methods that have been found successful to date. However difficult this may be, we must learn to bend our methods to nature, not to bend nature to our methods.

Our fourth task is to bring science down to the people. We are all familiar with the close relationship between science, technology, industry and the economy. When people speak of science today, what comes to mind are usually big and expensive projects that have captured the imagination: space exploration, chemicals, pharmaceuticals, electronics, information technology and the human genome project. As more money and resources are poured into such research, ordinary people become increasingly discontented. They are simultaneously impressed and disillusioned by the exponential progress, which despite the many conveniences it brings, somehow falls short of solving their real problems and providing the life which they seek.

Though quietly a new concept has been emerging in Europe and more slowly in the United States as an answer to this dilemma. It is called community research. It is contrasted with what advocates call "Big Science"-research heavily funded by governments and corporations and practiced by professional scientists, research that they believe does not serve the more immediate needs of the people. Community-based research is rooted in communities. Communities often identify the issue or problem they wish to address and participate in defining the research question, conducting the research and finally using the results toward an action-oriented outcome. The definition of community-based research, as understood at Bilkent University in Ankara, is research conducted by, with or for communities.

We have introduced the concept of community research at Bilkent, initially to our engineering students, as part of a course called "Science, Technology and Society." More than 160 students take this course each year and are required to propose and undertake a community-based research project in groups of 8 to 12 students. Some of the projects are: "Improving the Life of the Disabled at Bilkent University," "Evaluation of the Nutritional Intake of Students at Bilkent University," "Conservation of Energy and Resources at Bilkent University," "A Critical Comparison of University Entrance Exam Systems in Turkey" and "Factors Affecting Life Expectancy in Turkey." Since knowledge is ultimately pursued by people for the sake of people, it should be another of our tasks to ensure that common people are actively involved in solving their own problems. They should be knowledgeable enough to have a say in which areas they want to spend public research money. Our fifth task is to pay as much attention to social as to technical inventions. The language of modern management books goes a long way in reflecting the spirit of change in our times. "Concentrate on doing the right things, rather than doing things right," is a principle we find between the covers of such books. The advancement of technology demonstrates how much we have progressed in doing things right. Sophisticated and expensive medical procedures are awe-inspiring accomplishments. Yet, it is not dear whether they add to the greater happiness of a greater number of people in the same way that certain neglected but cheaper public health measures might have.

Society has devoted considerable energy and resources to developing technical inventions and patentable devices and processes in the conventional sense. Compared to advancements in this sphere, society's accomplishments in the area of social inventions fall quite short. Checks and balances, stabilising and efficiency-ensuring mechanisms and efforts at restoring human organisations and societies look ad hoc, primitive and neglected, compared to the energy and attention devoted to exploring outer space, discovering the origins of life or developing electronic products with millions of transistors even for the most mundane tasks. Thus, it can be argued that the problems of society itself are much in need of the application of the genius and brilliance that has mostly been directed elsewhere.

The sixth task is to learn how to manage the new fractal-global knowledge network. All of the features we have mentioned illustrate that modern science and technology have excluded certain objectives as well as means of obtaining knowledge. One of the most common trends in science and technology is that of ever-increasing specialisation. We have all heard the joke about knowing more and more about less and less until we know everything about nothing. It is often commented that this process of continual fragmentation necessarily increases the importance of interaction at the fragments' interfaces. As conventional scientific disciplines break into several parts, new disciplines that cut across the boundaries emerge. Computer science, control engineering, mechatronics and optoelectronics are some examples of disciplines that have been newly born at the interfaces of traditional disciplines such as mathematics and physics, and mechanical and electrical engineering.

We are psychologically comfortable knowing a small domain very well but we are less comfortable knowing a little of everything. Our hopes are that information technology will offer a solution. Of course, technology itself is never the answer, but it provides the setting in which we are experimenting and the means through which we will eventually find the answers.

The last task is to reshape education and research institutions according to the pyramid paradigm. Speaking of knowing more about less and less versus knowing less about more and more, one is led to inquire about the proper balance. How much should we know about how much? Clearly, it makes sense to know a lot about a few things, but also to know a little about many things. This leads me to the hierarchical scheme shown in figure 1.

DEPTH OF KNOWLEDGE

The horizontal axis corresponds to the depth of knowledge. The scientist of the future will have to be very well specialised in a narrow area, represented by the broadest string at the bottom. He or she will then still have to have a deep level of knowledge in several other areas, and lesser amounts of knowledge in progressively greater number of areas, represented by the higher levels in the figure. The highest level should cover the whole range of knowledge, including positive and social sciences, and arts and humanities, as well as other kinds of knowledge neglected until now. Beyond being a model for scientists, all people will probably have to be educated or educate themselves according to such a scheme in order to be able to cope effectively with what awaits us.

Let me now turn to the most remarkable advances that have taken place in science, especially in nuclear physics, information sciences and molecular biology. In the 1920s and early 1930s, nuclear research was pursued innocently and idealistically as the exploration of an invisible world. It seemed to fulfill an old dream about understanding the ultimate structure of matter. An Indian scientist, Satyendranath Bose, is remembered as co-authoring with Albert Einstein an important work in quantum mechanics, the Bose-Einstein statistics of 1924 to 1925. The pioneer of Indian nuclear research was Homi Bhabha, who had studied science in England. Bhabha's family was related by marriage to the Tatas, who had founded and endowed a university institute for the study of science in 1911. In 1944 Tata Industries established the Institute for Fundamental Research to ensure that nuclear physics would have a home in India, and that Bhabha's genius would not be lost to the nation.

As soon as the practical and destructive uses of nuclear discoveries were being exploited, the nature of the research changed radically. Instead of being open and international as was the case at the Cambridge laboratory, which hosted Russian, Indian and Japanese scientists,

research became secretive and bureaucratic. Idealism was replaced by the pursuit of vested interests as the atomic bomb became the great symbol of national status and military power. For nuclear research to recover some of its idealism, internationalism and esteem it had previously enjoyed, there was a need to show that it could contribute constructively to human development. At the United Nations in December 1953, U.S. President Dwight D. Eisenhower took the initiative. He suggested taking "this weapon out of the hands of soldiers" and giving it to those who could "adapt it to the arts of peace." In discussions that followed over the next few months, there was much talk of using nuclear devices in the fight against cancer. Today, the use of isotopes has an important place in diagnostic and therapeutic medicine.

The information sciences have made similar advances, inspiring what we call today the Information Age. The Internet has been a major factor in the realisation of the Information Age. It has eased access to information, facilitated communication and fostered collaboration. One of the major innovations that made the Internet popular was that it allowed all kinds of users to access the resources on the Internet. The Internet now forms the infrastructure for the Information Age. It is the main artery or highway where the members of the Information Age society work, do business, communicate, educate and entertain.

In the Information Age, more and more people will be using information technology in their daily lives. Therefore, the human-computer interface will be an increasingly important factor. One of the natural means of communicating with a computer system is speech. There are many speech recognition systems today, and research on better speech-understanding systems is continuing. Most of the present systems are effective in well-structured narrow domains. In the future, most of the commands given to a computer will be words spoken by the user. Another use of speech-understanding systems will be the translation of spoken sentences from one language to another. A person speaking in English in the United States will be able to carry on a conversation with a person speaking Japanese in Japan, using a computer system to translate English into Japanese and Japanese into English online during the conversation. Prototypes of such systems have been built with some degree of success, and in the near future translation systems with limited domains may be commercially available. It is also expected that speech systems will be combined with artificial intelligence to determine the context in which the words are spoken to achieve better understanding of the speech.

Computer vision is another area of active research where the computer is expected to recognise objects as an image. Image understanding is more complicated than speech understanding. Therefore, it will take more time and research to reach the level of speech-recognition systems. Image-understanding systems will be used in narrow domains, for example to recognise buildings in an image of a certain area in a city or to recognise certain parts of the human body in X-rays.

In the Information Age the way in which business is conducted, the way organisations function, the educational system and daily life are changing considerably. In education, course materials are already available on the Web in many universities worldwide. Libraries will continue to function as sources of information. Books will be converted into electronic form so users of the Internet in remote locations can have access to them. Since digital libraries can be linked together, they will form a virtual digital library distributed all over the world.

In health care, image-processing techniques are already being used in neurosurgery. Mini-robots may be used under computer control with an imageprocessing interface for finding and carving out an unwanted growth in the body. All the medical information about a person,

from childhood onwards, will be kept in a database. In case the person needs medical attention, the doctor or the hospital will be able to access this database in seconds using a mobile terminal. The computing system will also warn a person when to have a checkup, according to his medical condition. It may also have an interface to devices that will measure blood pressure, pulse and other vital signs at regular intervals and record the results in the database for that person. However, with all these developments, will patients still be getting tender loving care that a sympathetic physician gives through personal contact? This is a factor that cannot be replaced, and its loss would be a great pity in my opinion.

Computing systems in hand-held devices are gaining importance every day and multimedia applications will make these devices even more useful. In the Information Age, every person will carry a device, which will function as a pager, cellular phone, personal digital assistant for keeping various kinds of information, laptop computer, digital camera and calculator. These devices will have voice and image input and output. Using these devices, anyone will be able to send messages, access the Web, send e-mail or connect to a Global Positioning System.

The life sciences provide yet another promising chapter in what the future will bring us. After the discovery of DNA as a double helix in the 1950s, research activities in the life sciences entered one of the most extraordinary phases in the whole history of humanity. Biology and its associated scientific fields (molecular biology, genetics, medicine and biotechnology) have now become the center of interest for both basic and applied research all over the world. During the last ten years, we have also seen a big shift in the research policies of major international pharmaceutical and chemical companies, which have started their own research and development laboratories in the life sciences. This new trend is a good indication that life sciences are not only a major focus of basic research, but also a major source of technological developments that will shape the future of humanity.

Scientific knowledge has a double impact on society. On the one hand, progress in scientific knowledge is the main driving force toward a more civilised and unified world. On the other hand, science opens doors to new technologies and new products for the well-being of humanity. If we consider the life sciences from this angle, we can expect great changes for society in the next century.

The field of life sciences is quite large and covers many interesting and important domains. I will mention only three domains, which appear to be the most important ones. Then we should be able to make some predictions about the potential impact of this research for humanity in the twenty-first century.

About ten years ago, the "Human Genome Project" was started in the United States with the aim of deciphering the whole genetic code for the human genome. Most of the industrialised countries including England, France and Japan have now joined the human genome project. In addition to the human genome, the genomes of other organisms (animals, plants and microorganisms) are also being analysed. It is believed that the human genome contains about 100,000 genes that are necessary and sufficient for a human being to exist as a biological unit. It is expected that by the year 2003 the human genome project will be completed. Consequently, we will be able to read the nucleotide sequences of almost 100,000 human genes. This knowledge will have an immediate and major impact on medicine. It is expected that, in the next ten years or so, the genetic information of different animals, plants and microorganisms will also be available. This information will lead to better drugs and new



vaccines as well as improvements in agriculture and food sciences. Genetically modified organisms, for example insect-resistant crops and high-yielding milk cows, will replace traditional plants and animals to increase agricultural and agribusiness productivity. As the natural resources of our globe start to decline the use of genetically modified organisms will help to decrease the problems of famine and malnutrition in the world.

The genetic code of an organism is the ultimate source of its biological destiny. Research in the fields of cell and developmental biology is important for a better understanding of the biological processes that are involved in normal development, carcinogenesis and aging. This research has also been the basis of major breakthroughs during the last few years. For example, scientists in Scotland successfully cloned an adult sheep, the highly publicised "Dolly" in 1997. This new scientific progress may be the basis for large-scale production of selected animal species, as well as human tissues badly needed for transplantation. However, one should keep in mind that such new techniques must be used under strict control in order to avoid unethical applications contrary to human dignity.

In the next 10 to 20 years, we may expect to uncover the basic mechanisms of the human brain and to understand why it is so different from the brains of other animals. Research in the cognitive sciences will also help us to understand the molecular basis of intelligence and the genetic and cellular causes of behavioral diseases.

In addition, new techniques such as "Gene Chip Technology" will allow the performance of a "genetic check-up" of an individual to calculate his or her risks for many different diseases. This new medical specialty is called "predictive medicine," which will be one of the major features of the new medicine in the next century. Better prediction means better protection. Therefore predictive medicine will consequently lead to improved preventive medicine. Knowledge of the genetic make-up of an individual will serve as a basis for preventive measures (selection of a professional occupation, diet or lifestyle) in order to minimise the risks for different diseases.

As a consequence of these advances, another major change in medicine will be the way health workers treat patients. When a direct relation between a given gene and a given disease is established, it will be possible to provide personalised treatment for almost any type of disease. It is now evident that many diseases are the result of either a deficit or an excess of a gene product, namely a protein. New medicines will use a treatment to restore the normal state of gene function, thus restoring the patient to a healthy state.

With all this scientific progress and emerging technologies, one major problem remains unresolved: how will humanity as a whole benefit from these new and unprecedented results of scientific knowledge? Scientific progress and the new technologies are still under the control of a handful of industrialised countries. It is presently unclear how people living in developing countries will be affected by this progress. Unfortunately, the future does not appear to be bright for those countries. The twenty-first century is apt to see a new type of discrimination based on the monopoly of scientific knowledge and new technologies by industrialised countries. The only way for developing countries to escape from this new type of colonialism will be for them to also invest in science and new technologies.

But it is not enough to escape neocolonialism. Humans should not only invest natural and material resources, but also intellectual power in science and the humanities and arts to shape the new millennium. This monumental effort will require a new ethos and spiritual dimension

if it is to create an international system based on justice and equality of men and women, as well as equality of nations and cultures, and health and a dignified life for all. This is the best way to put human rights in the place of human wrongs. Can disaster be averted and a new world of prosperity and beauty be created? Yes, if-as Alfred Tennyson articulated long ago-we are "strong in will to strive, to seek, to find, and not to yield."

Can we cherish hope and optimism for better days to come? The answer lies, I think in a four-line poem by the great twentieth-century Turkish poet Nazım Hikmet who wrote shortly following the darkness of World War II:

The most beautiful ocean is the one we have yet to cross.  
The loveliest child has yet to grow up;  
The most beautiful days of our lives are those we have yet to live-  
And the loveliest things I'd like to tell you are those I have yet to tell.