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The Human Genome Project and Human Destiny

- Job Kozhamthadam[1]

Abstract: *The author discusses two research projects at the cutting-edge of contemporary science: the Human Genome Project and the Immortality Research. He points out that the cumulative effects of these two ventures will have far-reaching consequences for humanity. Prolongation of the human life span, although very attractive at first sight, entails many problems, particularly in the developing nations. Far more serious is the real possibility of the emergence of a trans-homo sapiens species. The author suggests that we look at these developments more as a positive opportunity for further growth than a negative challenge to our species. But this calls for developing a radically new set of ethical values that can meet this situation creatively and constructively. He concludes with an optimistic note that the humans who developed this science can also help in developing such an ethics.*

- Editor

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Introduction: The Three Ages of Nature-Human Interaction

The history of human interaction with nature has passed through three important phases: the age of mystery, the age of discovery and the age of mastery. In the age of mystery humans found themselves in the midst of an immense, mysterious, beautiful universe. This experience filled them with awe and wonder, evoking an aura of mystery around it. They believed that nature was endowed with special, hidden powers,

powers they were ill-equipped to handle. Hence they were willing to surrender to these powers. Some personified these strange but awesome powers and began worshiping them. A contemplative attitude towards nature dominated this period since the beauty and grandeur of nature overwhelmed them.

During this period humans felt that they were at the mercy of nature and its activities, living in fear and uncertainty about the future. They believed that keeping the powers of nature in good humour guaranteed a safe and secure future. Obviously, this age saw a plethora of gods and religions around them. The Greek mythological age, the age of the Presocratic thinkers in the 6th century BC, was a classic illustration of this age. In the history of India and other ancient cultures also one can see a similar age.

This period gradually gave way to the age of discovery, during which humans began to realize that nature wasn't all that unpredictable and uncertain. They began noticing a certain orderliness in the structure and behaviour of nature, a certain regularity in the occurrence and operations of natural phenomena. It seemed to them that nature and natural phenomena were law-governed; they were not arbitrary but had to follow certain laws. It also became clear to them that if they knew these laws, then natural phenomena could be predicted. Furthermore, they came to know that although these laws were not easily evident, they were accessible to the human mind. With serious and systematic investigation humans could come to know these laws. Hence this age witnessed eminent and ingenious humans engaging themselves in discovering these laws, thereby ushering in the age of discovery which is usually referred to as the age of science.

Although the Presocratic thinkers under the leadership of Thales of Ionia inaugurated this age in the 6th century BC in Greece, it began to flourish only during the scientific revolution beginning from the 16th century AD. Some of the founders of modern science like Francis Bacon wanted science to focus on conquering and subjugating nature, but this age was also strongly characterized by a desire to obey and conform to the laws of nature, applying and utilizing them in various fields. Consequently, this age gave rise to significant developments in technology and industry.

The third age is known as the age of mastery over nature because during this period humans became far more ambitious and aimed at controlling nature along the lines determined by them. This is the stage we are in today. Humans in this age are not content with conforming to the laws of nature, but want to have a say in determining the destiny of nature. They are not satisfied with being mere obedient subjects of nature, but want to go further to become its masters, channeling the resources of nature along their desired paths.

This age began in a conspicuous way already towards the end of the 19th century with the developments in the physical sciences. This trend was first evident in the physical sciences and remained conspicuous till the middle of the 20th century. Following the discovery of the atomic structure of matter, there were concerted and successful efforts to produce new elements and synthesize new compounds. Interventionist medicine became common in this period.

From the second half of the 20th century onwards the epicentre of scientific study and research shifted to the life sciences, witnessing many astounding breakthroughs in the field of genetics and genetic engineering. The discovery of the structure of DNA by Watson and Crick, the synthesis of genes, successful cloning of many animals, etc., are too well known to require any detailed discussion.

There is no doubt that total mastery over nature will elude humans. But in certain specific areas such a mastery seems to be well within human reach. The Human Genome Project I consider as an important milestone in this ambitious goal of mastering nature.

The Human Genome Project (HGP)

The genome of any being is the sum-total of the genetic information locked up in its DNA. The HGP consists basically in identifying and locating the 3.1 nucleotides or chemical base units, arranged into 30 thousand genes within the 23 pairs of chromosomes in the nucleus of the human cell. Human biological life can be compared to a book, "the book of life," written in a language made up on 4 letters A (Adenine), G (Guanine), C (Cytocine), and T (Thymine), which are biochemical units known as nucleotides. Human DNA consists of a long chain of these

units repeated over 3.1 billion times in varying combinations. Genes are small, specific bits of this DNA, and can be compared to words formed by these letters. When the working draft of the human genome was announced in June of 2000, it was thought that the human DNA had 100,000 genes. Today it is found to be only 30,000. These genes are primarily responsible for determining how humans will be, what characteristics they will have, how they will carry out their essential functions, etc. These genes are arranged into 23 pairs of chromosomes in the human cell.

The ordering or sequencing of the 3.1 billion chemical units is not arbitrary. Indeed, it contains absolutely vital instructions and information for sustaining life, since it determines the production of the all-important proteins. However, it is also found that the actual genes and the bits of DNA controlling the on/off switch of the protein-producing activity of the genes, account for a mere 5% of the total DNA in the cell. The remaining massive chunk of 95% is left as "junk" since present day science is unable to assign any definite function for it.

This code or series of instructions contained in DNA can be compared to the Morse Code used in telecommunications, which when decoded conveys important messages. Today many scientists in various parts of the world are busy decoding this message to understand it and apply it to different fields like medicine, nutrition, etc.

The Importance and Implications of HGP

It is expected that in the future the genomic information of each individual will be available in CD or other inexpensive, user-friendly formats. This information, though absolutely fundamental and extremely useful, in itself can have only very limited impact on the individual and society. The situation can be compared to what happened in the physical sciences. Lord Rutherford's discovery of the structure of the atom was a trailblazer in the physical sciences. However, until it was combined with other theories and technological developments, it had only a limited impact. But when it was combined with breakthroughs in relativity, quantum theory, developments in nuclear and high energy particle physics, etc., it could transform our understanding of material reality. It opened the way for nuclear power, better understanding of stellar phenomena,

the origin of the universe, etc. It also spawned technologies like semi-conductors, transistors, radio, television, neon lights, lasers, etc., with numerous industrial applications. These developments transformed not only the scientific world, but also the life style of even ordinary people all over the world. Similarly, when combined with other developments, technologies and techniques, such as genetic engineering, nanotechnology, computer and Artificial Intelligence (AI) technology, cloning, etc., the data provided by HGP can be a powerful force with far reaching consequences for human destiny. We will discuss two such cases: the possibility of human immortality and of trans-human species.

The Human Genome and Physical Immortality

Here we are concerned not with spiritual immortality or the immortality of the soul, but with bodily or physical immortality. Bodily immortality is something all humans, even the most desperate ones when in their good senses, look for, but find it impossible to attain. The average life span of humans has increased significantly in recent times, thanks to better medical knowledge, better medical facilities, better food and living conditions. Yet, living beyond 100 years seems to be almost an impossible dream.

Today the HGP, in tandem with advanced knowledge about the process of aging, genetic engineering, nanotechnology, telomerase[2] treatment and cloning, has opened up the real possibility for some form of physical immortality or at least a significant prolongation of life. It may be noted that immortality is the ultimate, idealistic goal which may never be really attained by science. The hope today at the practical level is that science in the future will be able to prolong the human life-span substantially.

A number of theories have been advanced in recent times to explain how the human body ages and finally dies after a certain number of years. For instance, the free radical theory says that the biological activities of the organism produce certain free radicals as by-products, which gradually destroy the healthy cells. When a certain number of cells in an organ are destroyed, it becomes non-functional and dies. The programmed senescence theory, on the other hand, holds that the rate at

which living beings age is predetermined, the genetic makeup controlling the aging and death of the cells.

More recent studies reveal that death occurs because the process of cell division or replication ceases after a certain limit. It has been found that under normal conditions a cell dies after 50 divisions. This limit is known as Hayflick Limit.[3] Once a certain number of cells die the organs involved cease to function and the organism dies. Hence immortality research targets on slowing down, or even arresting, the process of cell deterioration.

Recent researches enable us to have a clearer idea about the process of cell deterioration. It is found today that cell life depends on telomeres which occur like caps at the ends of chromosomes, protecting the chromosomes from deterioration. Every cell division results in the shortening of the telomere. Gradually it gets depleted and the cell division stops. Obviously, a better and detailed knowledge of the genome can help in arresting, or at least controlling, the depletion of telomeres.

It has been found that the enzyme telomerase can prevent this shortening process. Hence better knowledge and utilization of this enzyme can be of great help in the search for possible physical immortality. Since telomeres are part of the chromosomes, genomic knowledge is vital for prolonging the life span using this method.

Immortality / Long Life through Cloning

As has been pointed out, HGP in itself is incapable of prolonging the life span. But, in combination with cloning, nanotechnology and other techniques, it claims to be able to achieve this goal, although the actual realization will take a very long time and far more developments in technology. Long life can be made possible in two ways: by repair/ replacement of defective parts and by cloning a living being just before its death.

Defective parts can be repaired by using nanotechnology which is technology at the molecular or atomic level. At present it is in the initial stages, but it is expected to develop rapidly in the coming years, thanks to parallel developments in computer and other technologies.

Parts to be replaced in an organism can be obtained by cloning[4] although the morality of this process raises many serious questions. We are considering at the moment only the scientific possibility of this process. In this kind of replacement or transplantation of organs, the main difficulty is the rejection by the host. But if a clone is made by using the nucleus of the host itself and a part from this clone is used for the transplantation, then the possibility of rejection is considerably reduced.

Transgenetic products also can be of great help in this context. This involves introducing into the DNA of one animal the genes of another living being. For instance, human genes can be introduced into a pig's DNA to produce a transgenetic animal, and its parts can be used for carrying out a transplant operation.

Another way to prolong the life is by cloning the individual at the moment of death. Since cloning is claimed to produce an exact duplicate, the individual in a way continues to live through the clone.

In all these cases genomic knowledge is fundamental for the success of the process.

The Human Genome Project and Trans-human Species

We know that all religions and civilizations have accorded human beings a unique status, deeming them as the greatest of all creation. The Bible describes humans as the roof and crown of creation. In fact, after humans no further creation took place. Humans are creatures with unique privileges and responsibilities. Other religions also hold a similar position, and do not envisage the arrival of more advanced species beyond humans. Religions talk of the attainment of salvation as the ultimate goal; but this is attained by humans as humans. The process of attaining salvation does not involve humans passing through some other or better trans-human species.

Even progressive, scientific-minded religious thinkers like Teilhard de Chardin give humans a unique place in the cosmos. Although he believes in universal evolution in the sense that every being in the universe has come as a result of evolution, according to him, physical evolution has come to an end with humans. No new species beyond humans is

expected. In fact, he goes on to say that the human being was the goal of evolution, and once the goal was reached, physical evolution stopped.

But today many scientists believe that the arrival of the species *Homo sapiens* was not so special and unique as to put an end to any further progress in the process of evolution. There is no need to believe that *Homo sapiens* is the unbreachable species-limit. According to Philip Morrison of Massachusetts Institute of Technology (MIT), a typical complex species becomes extinct in 10 million years. This means that the lifetime of a typical species is less than 10 million years. He believes that there is no reason to believe that *Homo sapiens* should be treated as an exemption. Hence if we were to follow the normal course of events, we can expect a trans-homo sapiens species in less than 10 million years. Scientists point out that just as many species of the *Homo* genus have become extinct, *Homo sapiens* may become extinct in 10 million years time. It may be noted that according to the findings of contemporary science, our solar system has about 5 billion years more to go. This will obviously allow the appearance and extinction of many more new trans-homo sapiens species. At the end of our solar system there may be no one like us in the universe!

All these considerations may not have any practical value for us since our lifetime of a maximum 100 years is just a minuscule compared to 10 million years. Yet we cannot pass it off as mere speculation since it impinges directly on our future, the very destiny of us humans.

Developments like the HGP render this situation even more significant and relevant, since they bring in a new and important dimension to this area. Not only does the HGP confirm the main conclusions of evolution, it offers the real possibility of the appearance of a new trans-homo sapiens species in a much shorter time. This can bring about a serious qualitative change in the status and destiny of humans, involving extremely important social, ethical, and religious implications.

HGP and Evolution

The HGP has lent strong and highly reliable support to the theory of evolution since it gives strong evidence for the unity of all living beings. It reconfirms the view that all living beings have a common origin, have

originated from the same primordial stuff. It is well known that the different discoveries in particle physics revealed the unity in diversity of the non-living world since, according to it, the whole material world is made up of the same fundamental particles like protons, neutrons, electrons, etc. The genome project and related developments show this unity in diversity of the living world. Just as atoms of different material elements are made up of the same fundamental particles, the DNA of different beings is made up of the same kind of nucleotides. Even in the sequencing also one can see a remarkable similarity. Thus the genomes of yeast, nematode worm, fruit fly, mouse, etc. show a remarkable similarity with the human genome. According to some estimates, humans share 98.4% of DNA with chimps. This means the difference between the genomes of a human being and a chimp is only 1.6%. With cow the overlap or the DNA shared is 90%, with mouse 75%, with yeast about 30%, with *E. coli* bacterium 15%, etc.[5] The human race has crossed the six billion mark some time ago. Despite such large numbers spread over many continents, cultures, and races, humans show a remarkable deeper unity in their biology. It is found that any two individuals differ on the average only in one nucleotide per one thousand. Craig Venter, the founder-director of Celera Genomics Corporation, which along with the Center for Human Genome Research jointly announced the first draft of the human genome in June 2000, points out that the "genome research shows humans to be 'clearly part of a biological continuum.'" In fact, according to him, "if we showed you the mouse genome today, you would not be able to tell its difference from the human genome. There are very few changes."[6]

It is found that "60% of the known human disease genes have equivalents in flies and that about 7,000 (50%) of all fly proteins show similarities to known mammalian proteins."[7] In the case of the proteins of the nematode worms, roughly one third is similar to those of mammals. 38% of all yeast proteins also show similarity with mammalian proteins. The mouse genome is even closer since more than 90% of mouse proteins identified till recently show similarities to known human proteins. All these data reveal the deep unity existing among the innumerable living beings. Biologically humans seem to be an integral part of the continuum of living beings, and there seems to be hardly any reason to treat them as exceptional.

Developments in genome research have placed the theory of evolution on a firmer scientific ground. The fact that the genomes of various levels of living beings show such striking similarity is a clear evidence for their common origin. As Susan Alridge remarks, "with a few exceptions the genetic code is universal. Organisms as diverse as the bacterium *Escherichia coli,* higher plants and humans use the same DNA dictionary to translate the messages in their genes. This is one of the strongest proofs we have for the common ancestry of all life...."[8]

The fact that at the DNA level *E. coli*, yeast, etc. have so much in common with humans shows that all living beings can be traced to a common source from which evolution emerged gradually, giving rise to the different higher beings on its way. In fact, the overlap (i.e., the percentage shared in common) between two different species can be used to estimate their relative age: the more the overlap, the less the age difference between them.

Towards the Trans-homo Sapiens Species

As mentioned already, the strong unity of beings as evidenced by the HGP would argue against treating human as basically different or unique among other beings. It argues strongly that humans are also subject to the laws and processes of nature, just like other beings. Humans also will have to be subject to the law of evolution. This leads to the conclusion that there is no compelling reason to believe that the process of evolution should stop with humans. It should continue, and we can expect trans-homo sapiens species.

We have seen that under normal conditions there can be a gap of 10 million years between two consecutive species. But this time period can be shortened, thanks to detailed knowledge of the genomes and the availability of advanced genetic engineering techniques. Lee Silver in his *Remaking Eden*[9] describes such a scenario. Making use of the developments in science the rich and famous will be able to produce healthier, better looking, far more intelligent humans. They will be very different from the less fortunate ones. One can expect this privileged class forming an exclusive, elite race intermarrying among themselves and segregating themselves from the rest. Using advanced scientific know-how they can extend the difference between them and others

further and further. If they were to marry someone from the underprivileged group, the difference between the two could be large enough to render the marriage infertile. Since the accepted definition of a species is that interbreeding is possible between its members, this situation of the cessation of interbreeding would establish the formation of a new species. According to Owen Gingerich of Harvard University, given the expected future developments in science, this need not take millions of years, but could happen in 2000 years or less. Although compared to the normal human lifetime 2000 years is long, in terms of historical time, this is not very long.

The scenario becomes even more interesting in the context of the developments in physical immortality research because before long there is a good possibility that human life, at least in some cases, will be prolonged to 2000 years. This opens up the possibility not only for a trans-homo sapiens species but to have it side by side with homo sapiens. What will be the kind of relationship between the two species? How will these two species with rationality, highly developed intelligence, free will and sophisticated communication capabilities interact with each other? What will be some of the moral, social and religious implications in this situation? These and related issues can be very disturbing and frightening. In fact, the consequences can be far more serious than the spectre of human cloning, especially if it were to become commercialized when cloned humans could be manufactured in factories on demand.

Comments and Reflections

Humans as Co-creators

The HGP and other related developments in the biological sciences can be looked upon as a shot in the arm of human dignity since it raises humans from the level of mere creatures to that of co-creators or partners in the ongoing process of creation. The created world, despite being so breathtakingly amazing, still remains incomplete with almost infinite possibilities of further developments. Humans with their powerful resources of science are called upon to collaborate in completing this most sublime task. The HGP emphasizes this positive aspect of scientific developments.

The Limits of HGP

Some of the claims made concerning the capabilities of HGP, especially by the non-professionals, are highly exaggerated. HGP has given us only the ordering and location of the nucleotides in the 23 pairs of human chromosomes. It is a long way from here to the actual production of human characteristics. As Phillip Sloan of Notre Dame University points out, "Working scientists and molecular biologists are fully aware of the enormous complexities that are interposed between the paired base sequences ... and the actual expression of phenomenal traits – e.g., blue eye colour, a nose of a specific shape, or a defined behavioural pattern."[10] This comes about because "even though each cell contains the same nuclear information in the form of DNA located on the chromosomes, between the DNA base sequence and expressed traits lies a very complex system of relationships involving regulator genes (operons), introns, exons, messenger and transfer RNA's, triplet codons, protein synthesis from specific amino acids, and time-dependent embryological formation of specific structures from proteins."[11] That is why metaphors like "blueprint," "code of life," etc., are misleading simplifications, since they imply direct causal connections, whereas the actual connections seem to be statistical.

Reductionism

HGP and its claims are based on a strong reductionism – the sum of the parts is equal to the whole. Can this be held in the case of living beings, especially rational, free beings? An answer to this question depends on what life and rationality are. Reductionism presupposes that life is made up of parts and hence can be reduced to its component parts. Although we have a good idea about the manifestations of life, the question of what exactly life is seems still to defy any definitive answer.[12] The same can be said about rationality and human freedom.

Nature vs Nurture

HGP is related to the physical aspect of a human person, which, though absolutely necessary, is seriously inadequate to describe the human person since humans are far more than pure physical or material beings. A human person is not just a collection of atoms and molecules, however

sophisticatedly organized, but is very much a product of his/her social, cultural, religious surroundings. Both what is given by way of nature and what is given by nurture are important in shaping a person. Hence HGP can provide only a partial explanation of a human person.

The Possibility of Long Life

Long Life through Repair

It is indeed possible to extend ones life by careful and effective repair of defective or damaged parts. However, if a more effective and lasting effect is desired, one will have to resort to nanotechnology. The expectation is that this technology will soon be very much within the capabilities of science. Since this is technology at the molecular level, the assumption is that the conditions at the micro-level are the same as those at the macro-level. But physics tells us that the micro-world of physics is governed by the uncertainty principle, which puts certain specific limits to what is attainable by science. Wouldn't there be some such principle in the world of biology also? If so wouldn't it put some limit to what is attainable in the micro-world of biology?

Long Life through Cloning

Cloning plays an important part in the efforts by science to prolong life since it can not only supply suitable body parts for replacement of defective parts, but also produce a true replica of a dying person so that he/she "continues to live." However, both these possibilities involve serious questions, technical as well as moral. The practice of producing clones to supply parts for the human body is a matter of serious controversy since this demeans human dignity, reducing humans to a commercial commodity.

Cloning a dying person involves a number of problems. First of all, a perfect duplicate cannot be formed, not even physically. The process of cloning requires three agents: the donor who supplies the agent to be cloned in the form of a cell nucleus, the denucleated[13] egg which provides the required nourishment to the clone in its early stages, and the surrogate mother who takes care of the clone during pregnancy. A perfect duplicate can be produced only if the denucleation process is 100% complete, but

it has been found that it is usually only 99% complete. Hence 1% of the ovum nucleus is present in the clone, thereby bringing in some of the features of the egg donor. This 1% can in no way be overlooked since we know that a difference of 1.6% at the genome level changes a being from a chimpanzee to a human being.[14] Thus even physically a perfect duplicate is impossible.

Even if science were to perfect its techniques and get a perfectly denucleated egg, this in no way guarantees a perfect duplicate since the womb of the surrogate mother provides the environment and nourishment for the clone in its embryonic and fetus stage, and so this surrogate mother will have a role in shaping this cloned being. Once the cloned child is born, the social, cultural factors take over the development of the child in significant ways, thereby foreclosing the possibility of real continuity with the original. All these considerations raise serious questions about the claim that cloning can be a reliable and authentic means for prolonging the life of a dying person.

The moral problems associated with this process are enormous. Since this has been discussed elsewhere, we will not take up this point here.[15]

Is a Long Life Desirable?

Although at first thought a long life is highly desirable and everlasting on earth even more attractive, a moment's reflection on the matter can reveal that this tempting prospect is not all that rosy, particularly so if there is no guarantee about the good quality of life. If every person lives up to a thousand years rather than up to a hundred, as it is today, and if the current rate of increase of population continues, will there be enough material resources in the world to meet the normal needs of all? We also need to keep in mind that as people age more, their needs and the level of care required increase. Will there be enough space for people to live comfortably since there is no way of expanding the size of the earth? Migrating to other planets may be a solution; but so far we have not spotted any inhabitable planet. Will there be enough jobs to keep all employed? Already today taking care of senior citizens has become a frightening responsibility even for the most economically developed countries. If humans cannot be guaranteed of a life with dignity

and reasonable comforts, a long life may be more a punishment than a blessing. These problems will be multiplied many times over if physical immortality for humans were to become a reality.

Trans-homo Sapiens Species

The possibility of our species developing is good tidings for all, and the prospect of humans being collaborators in this noble task is indeed a matter of honour for the human species. But if this onward progressive march should lead to the emergence of a trans-homo sapiens species, the situation could be extremely challenging and even alarming. For one thing, like all the past phases of evolution, this too would be a slow, gradual process – it would not be the case that the existing species disappears abruptly and a new one appears at once. This means that at a given time, both homo sapiens and trans-homo sapiens would be existing side by side. How would they look at each other? What kind of relationship would there be between the two? How would the expected superiority complex on the one side and the inferiority complex on the other be tackled? Can we deny that this situation would bring back the accursed slavery with a vengeance? One can expect social, economical and ethical unrest in this state of affairs. Chaos and confusion may become the law of the land.

The Need for a New Ethics

The scenario depicted above may look like pure science fiction not to be taken seriously. However, the history of science tells us that when it comes to science, today's fiction is often tomorrow's fact; today's dream tomorrow's reality. It is true that the scenario above will not take place within a few years, but it will take place and we will have to be prepared for it. Some effects of the developments in genetic engineering will hit us in the near future. For instance, eugenical use of genetic engineering knowledge and techniques for enhancing the characteristics of offspring in desired directions is very much on the cards now. This is something only the super-rich can afford under the present conditions. Rich nations can profit from it more than less rich ones. All these will lead to discriminations within a nation and between nations, with accompanying political and moral problems. As the developments progress the problems will become more acute and the divide between

the haves and the have-nots will widen. Cloned humans can appear any time in our scene today.

All these considerations point to a situation far beyond the purview of science, far beyond the competence of professional scientists, however gifted and well-intentioned they be. These matter far too full of grave consequences to be left in the hands of scientists. We need to develop a broader perspective and broader approach. We need to develop new and effective ethical values to respond responsibly and creatively to this challenge, an ethics that will enable us to benefit from the advantages of science without having to suffer from the bad effects of technological developments, or at least enable us to maximize the blessings of science while at the same time minimizing its curses.

I believe that humans can do this. Just as humans have developed such a successful science, they can also help in developing new and revolutionary ethical principles and values. This is the principal challenge and task facing science-religion dialogue today. Both scientists and religious scholars need to join hands in this momentous task because our experience shows that science without values can lead to monstrous minds (particularly in the context of the genetic revolution), and values without science can lead to mindless monsters (particularly in the context of the fundamentalist wave in our world).

Notes

1. Job Kozhamthadam is a professor of philosophy of science and religion at Jnana-Deepa Vidyapeeth, Pune, India. He is the founder-president of the Association of Science, Soceity, and Religion (ASSR), Pune. He is a member of the Indian National Commission for the History of Science, Indian National Science Academy (INSA).
2. Telemerase is an enzyme that protects cells from degeneration.
3. Leonard Hayflick in 1962 discovered that cultured human cells die after undergoing 50 divisions. The death of a human cell after about 50 divisions is known as Hayflick Limit.
4. The basic idea of cloning is quite well known today. The process involves obtaining an egg cell and denucleating it or stripping it of its nucleus. To this denucleated cell the nucleus of the cell to be cloned is inserted. The

new cell is introduced into the womb of a surrogate mother where it grows into an exact duplicate of the original donor of the nucleus.

5. For details see Michio Kaku, *Visions* (Oxford: Oxford University Press, 1998), pp. 152-153. Please note that the percentages given are only approximate, since different researchers give slightly different figures.
6. Thomas Jay Oord, "The World in a Grain of Sand: Genome Project Center Stage at AAAS, *Research News and Opportunities* I (April 2001), p. 15.
7. Julia Karow, "The Other Genes," *Scientific American,* July 2000, p. 43.
8. Susan Aldridge, *The Thread of Life* (Cambridge: Cambridge University Press, 1998), p. 35.
9. Lee Silver, *Remaking Eden* (New York: Avon Books, 1997), p. 6.
10. Phillip Sloan, "New Human Genetics and Religious Vision," Job Kozhamthadam (ed.) *Contemporary Science and Religion in Dialogue: Challenges and Opportunities* (Pune, India: ASSR Publications, 2002), p. 130.
11. Ibid., p. 130.
12. In recent times attempts have been made to explain life, the spiritual dimension of humans, etc., in certain sophisticated versions of emergentism, supervenience, etc. However, all these attempts leave many questions unanswered.
13. Denucleated egg means that the nucleus has been removed from the egg.
14. Scientists have found that the genome of a chimp differs from that of a human being only by 1.6%.
15. See my "Cloning of Dolly: Scientific and Ethical Reflections on Cloning," *Vidyajyoti* 62 (1998), pp.110-118.