Buddhism and Science: A Personal View

by Clarence Hisatsune

INTRODUCTION

"I have run through a course of many births looking for the maker of this dwelling and finding him not; painful is birth again and again."[1] Gautama Buddha at the moment of his enlightenment is said to have uttered these words. Here, the term "dwelling" refers to the physical body or the self of the Buddha; and, in effect, the Buddha is teaching us that there are no answers to the fundamental questions, "What am I?", "Where did I come from?", and "Where am I going?" These questions are undoubtedly asked by all of us at one time or another; and perhaps, may even have become sources of our mental anguish. However, Buddha lived some 2,500 years ago, whereas we are now in a technologically and scientifically more sophisticated age approaching the twenty-first century. So, why have our scientists not provided us with readily understandable answers to these questions? This is a fair question and I feel that I should attempt to respond to it, since I was an active member of the scientific community until my retirement three years ago.

IDENTITY OF SELF

As one of the major conclusions of his teaching, Gautama held consistently that we are all brothers and sisters regardless of our race or color. The unity of the world of living beings has been a major theme of Buddhist tradition. The significant scientific findings concerning the building blocks of life enhance and illuminate the Buddhist insights. Let us first consider the question "What am I?" If I examine my California driver's license or my U.S. passport, I am identified on the basis of my birth date, a not-so-good three-year-old photograph, and limited personal physical characteristics, such as weight, height, and color of my hair and eyes. As you know, much of these identification data change with time and are not very reliable. Furthermore, consider all the "look-alike" contests that we have seen on TV and in newspapers, as well as the amazing results from modern plastic surgical procedures.

A better way to distinguish myself from everyone else is through my handprint and/or bare footprint, including all digits. Markings on such prints are unique to each of us—so much so that we can claim with confidence that no one else with identical print pattern has existed or ever will exist on this planet. Why is this so? Simply put, it is because of our genes, the chemical carriers of all hereditary information about ourselves.

Our bodies are made of building blocks called cells. Starting from our head, we have the hair cells, the skin cells, the bone cells, the brain cells, the nerve cells, the blood cells, etc., all of various sizes and shapes, but all too small to see with the naked eye. These different cells have one important common feature, an identical set of chromosomes (so named because they readily pack up dye colors) in their cell nuclei. Whether it is a blood cell or a muscle cell, each has exactly the same set of chromosomes. These chemical entities called chromosomes are the genetic material

of life; they determine the shape, the growth, and other important functions of each cell. Our physical appearance, our internal structures, and even our resistance or proneness to diseases are fundamentally determined by our chromosomes. Because of my chromosomes, I am different from you and from all other living things on this planet. My chromosomes make me unique.

Our inquiry into the question "What am I?" has now been reduced to the level of our chromosomes. If my uniqueness is due to my chromosomes, then where did I get these chemical substances? This question is, in fact, a biological restatement of our original question, "Where did I come from?"

The existence of my chromosomes began at the moment of my conception in my mother's womb. When that single egg cell was fertilized by my father's sperm cell, a completely new set of chromosomes, my own unique set, was created. This fertilized egg cell then divided into two cells; the two cells divided further into four cells; the four into eight, etc.; and here I am. In other words, all chromosomes that I now possess are essentially clones of that original set in the nucleus of the single fertilized egg cell. I must use the qualifier "essentially" since changes in one's chromosomes, that is genetic mutations, can occur during one's life. For example, as we know, excessive x-ray radiation and many chemical carcinogens are believed to cause chromosome abnormalities.

Getting back to my chromosomes, can I now claim that my uniqueness originated at the moment of creation of the fertilized egg cell? Although many would prefer to do so, I as a scientist cannot make such a claim, because during the fertilization process, half of my chromosomes came from my mother, more or less ready-made, and the remaining half came from my father, again essentially ready-made. My chromosomes, therefore, were not made from scratch but were recycled from those of my parents. An egg cell contains only one-half of the chromosomes found in the mother's normal body cell; and similarly, a sperm cell has only half of the number of chromosomes found in the father's tissue cells. A fertilized egg cell, on the other hand, has the normal number of chromosomes for a human cell, each parent contribution being half of the required total.

We have traced my origin one generation back in time to the sets of chromosomes of my parents. I would not have existed, nor have been what I am without my parents. However, before we blame our parents for all positive and negative attributes we were born with, we must continue our search further. By using the same reasoning discussed above, I may conclude that my parents' chromosomes came from their parents, making me what I am because of my grandparents. But my grandparents would not have existed without their parents and grandparents. It should be apparent to you by now that I am creating a chromosome family tree, one that is the reverse of the usual genealogical family tree. My set of chromosomes forms the tree trunk and all the outer branches represent the chromosome pool of my ancestors. At this point, for scientific accuracy, let me replace the term "chromosome pool" with a new term "genetic pool" or simply "gene pool" because those parts of a chromosome that control heredity are the molecular units called genes. Note that the progress in science has reduced heredity to a molecular level. Today we have, in addition, molecular medicine, molecular engineering, and even molecular psychology.

OUR GENETIC ORIGINS

The gene pool from which my genes originated is enormously vast. It is astronomically large, as I will show you. First, my genes came from my parents; so one generation back, my gene pool consisted of contributions from two individuals. Two

generations back, there were four or 2^2 (two squared or two-to-the-power-two) individuals, since each of us has or has had four grandparents related by blood. With each generation back in time, we increase the exponent on 2 to obtain the number of individuals contributing to the gene pool of that generation. For example, the number of great-great-grandparents related by blood is given by 2^4 which is 2x2x2x2 or 16, since these ancestors were 4 generations before us.

Let us extend this analysis to the time of Shinran Shonin (1173-1262), which is about 800 years ago. If we assume that the average life of each generation is 50 years, which may be an underestimation for the more recent generations but may be a serious overestimation for earlier times, we come out with 800/50, or 16 generations, a conservative but not an unreasonable number. My gene pool at the time of Shinran would involve 2^{16} or 65,536 individuals. (These numbers are listed in standard mathematical tables found in most libraries.) This is a sizable number; if all of these people lived in a single city, that city would have approached the size of Kyoto at the time of Shinran. The size of this gene pool tells me that I am related genetically to a very large number of individuals in Japan where my parents and grandparents came from.

Because of the relative isolation of the Japanese islands, I also expect genetic homogeneity to have been established by now; and, hence, there should be many look-alikes living in present day Japan. However, if even one individual in this gene pool were replaced by another individual, I would be different today. Just what the difference would be between the present me and the individual who would replace me in such a case may not be readily apparent without a clear genetic marker of some sort. For example, where sufficient records were available, some hereditary diseases have been traced back to medieval times. Hypothetically, if one of my ancestors 16 generations back carried within himself or herself an abnormally high content of radioactive carbon-14, then I would expect a significant number of Japanese, including myself, to show abnormality in carbon-14 content in our bodies. Note that this radioactive carbon isotope is present in our environment, and its decay properties can be used to determine the age of ancient wood or plant samples (radiocarbon dating method).

That I am from the Japanese stock is self-evident, but my genetic origin actually extends well beyond that of the Japanese people. We can show this by applying the gene pool analysis to the time of Gautama Buddha. If we again take one generation to be about 50 years long, we obtain 2,500/50 or 50 generations. Therefore, the number of individuals making up my gene pool becomes 2^{50} or 50 generations. Therefore, the number of individuals making up my gene pool becomes 2^{50} or 1,125,899,906,842,624—an astronomical figure. Recall that the current population of this planet is only about five billion, the largest it has ever been. My gene pool is more than two hundred thousand times greater than the current human gene pool. What does this mean? It means that I am a member of the human race, and that we are all brothers and sisters regardless of our race or color, as the Buddha and other spiritual leaders have already pointed out. Interestingly, genetic analyses have been carried out in recent years to determine the origin of mankind, and it appears that we originated from Africa and/or Asia. Humanoid fossils, a few million years old, have been discovered in eastern Africa, but so far fossil records of comparable age have not been uncovered or searched for in Asia.

DEPENDENT ORIGINATION

In Buddhism, a central teaching is that of Dependent Origination. This principle indicates the interrelation of all things and is a correlate of the emphasis on cause and effect. The Principle of Dependent Origination is

also the basis for the Buddhist assertion of non-self.

According to current scientific views, this principle may be illustrated and given substance in the comparison of the cells and structures of living things. Homo sapiens became genetically distinguishable, i.e., differences in bone structure, teeth, etc., from other higher primates (gorillas, chimpanzees, and orangutans) about one hundred million years ago. Earlier, our ancestors were simply a part of the general mammalian world, which in turn evolved from life forms living in the seas. Plants also trace their origins to the seas. Oceanic fish and worms appeared about a half billion years ago, and these in turn evolved from the simplest life forms that began some three billion years ago.

The extent of common features or structural universality in the genes from nuclei or cells from all living things, be it a single cell bacterium or an elephant, suggests a common evolutionary origin for all life forms on this planet. After all, the chemical building blocks needed in the construction of these animal and plant bodies are restricted in kind, leading to extensive indistinguishable features appearing in the genes of these living systems. For example, there are only twenty kinds of amino acid molecules; and they are the building blocks of all proteins, those of a soybean as well as of the meat we eat. The genes, on the other hand, are made of combinations of sugar molecules, phosphoric acid molecules (a good fertilizer for plants), and only four different kinds of molecular units called chemical bases. A human gene, i.e., DNA, contains approximately thirty billion such bases. The exact sequence of these bases, or the structure of a human gene, is yet to be determined. It is estimated that with the presently available technology, it would take more than ten years at a cost of billions of dollars to accomplish this task. Such a monumental task is, however, being contemplated by our government and the scientific community because of its importance, not only in understanding human evolution but in the control of many human diseases including cancer.

The enormously large number of chemical structural units present in a gene of a living system leads to another important consequence, that of storing vast amounts of very specific information necessary for the control of the life of each organism. These genes provide the basis for the oneness or interrelatedness of all life; and, at the same time, for the uniqueness of each life. Whether it is a plant or an animal, each is entitled to live on this planet. Human beings who believe themselves to be at the apex of terrestrial evolution generally tend to extend their compassion only to other mammals, but there is no genetic reason to establish such a relative value scale for different forms of life on this planet. For example, being a vegetarian does not free oneself from the act of destroying other living systems. According to the sutras, Gautama Buddha was deeply aware of this fact and was not a vegetarian. He knew that our lives cannot continue without being sustained by other living things. Regardless of how painful or painless the act of taking other lives may be, we are burdened with such acts if we are born into this world and want to continue to live.

We have sought an answer to the question "Where did I come from?" and found none. Even with the aid of information from modern genetic science, we were only able to establish that there is no definitive beginning to our existence. The origin of our first set of chromosomes that developed in the single fertilized egg cell and determined our individuality was traced back beyond the gene pool of humanity to the evolution of life on this planet and to the genesis of our universe. Our analysis, however, is not completely futile since it illustrated unequivocally an important Buddhist concept, the Principle of Dependent Origination, or Dependent Genesis of our lives. It is truly remarkable that the Buddha, without the benefit of any scientific informa-

tion, was able to deduce this revolutionary idea 2,500 years ago.

The Principle of Dependent Origination applies not just to the formation of the first unique cell involved in one's life but to the subsequent growth and development of this cell into a new human being. Let us see how we can come to this conclusion. All changes taking place during the development of the single fertilized egg cell into an embryo and during the lifetime of the resulting individual are chemical in nature. These chemical reactions, whether we are aware of them or not, obey the scientific Law of Conservation of Energy and Matter. In simple terms, this principle states that matter and energy in chemical reactions are neither created nor destroyed; they only change forms. Consequently, when the original egg cell divides into multiple cells, this process requires both energy and matter, the source of which, of course, being the mother who in turn is dependent on the external world to provide energy and matter that sustain both herself and the unborn child. After its birth, the external world is still the source of energy and matter for the child's growth into an adult.

Just how much change in matter and energy occurs in one's lifetime? Let us assume that the mass of an egg cell is of the order of a microgram (one millionth of a gram) and that of an average adult is 60 kilograms (about 130 lbs.). Then, there occurred an increase in mass of one's life system by at least ten-billion-fold. All this matter came from our environment, so our growth is indeed one of "dependent origination." For the estimation of energy requirement, let us assume that about 1,000 calories per day are necessary to maintain life. Individuals who are still growing or participate in heavy labor require two or three times this amount, but under normal circumstances, 1,000 calories may keep us alive without causing gain in body weight. Taking an average lifetime of 60 years, we get for the lifelong energy requirement at least 20 million calories. To get an equivalent amount of energy from coal, we would have to burn about three tons with 100% efficiency. These numbers, again, illustrate how dependent we are on our environment and how amazing was Buddha's insight in deducing the Principle of Dependent Origination.

NON-EXISTENCE OF SELF

Finally, the identification of our uniqueness with the first set of chromosomes in the single fertilized egg cell permits us to discuss another fundamental principle of Buddhism, that of the non-existence of a permanent self. All human beings instinctively long to survive, as evidenced, for example, by the presence of our body's natural immune system that protects us from foreign matter, be it a small splinter of wood, or a harmful bacterium, or even a transplanted body organ. Nevertheless, we acknowledge willy-nilly the inevitability of death and consequently develop a desire for the existence of an entity identifiable with each individual and with a permanence beyond that of one's natural body. Among the major religions, it seems only Buddhism teaches the non-existence of such an entity, call it a soul, an ego, or the self. Is such a view consistent with science? The answer is in the affirmative, since it can be shown that the notion of a self is arbitrary.

Today, the problem of abortion, for example, has made it acutely necessary to define the beginning of a human life. Should it be the moment of conception when a unique set of chromosomes is first generated? Should it be some specified number of weeks thereafter? Or, should it be at the moment of birth? These may be legal questions, but not scientific ones. For example, if one takes the fertilized egg cell as the origin of a self, then that self has only a short life. For this cell to develop, it must undergo division into two new cells, and each of these must divide further into two new cells, and so on. Perhaps we can consider a collection of cells as the "self", but the collec-

tion itself undergoes continuous change. Furthermore, a collection of cells generally does not think, sing, or appreciate a beautiful sunset. Is the brain, then, to be identified as the self? If so, what happens if one has a permanent loss of memory due to illness or accident? Does one become a new self? What happens to the old self? Does a "self" become diluted with other "selves" when one receives blood transfusions or organ transplants? Numerous unanswerable questions arise when we attempt to identify a permanent self with any portion of one's physical body. Any assignment of self external to our bodies also encounters serious difficulties. The Buddha, 2,500 years ago, taught that we are continuously changing and that we do not possess an identifiable permanent self. This is a much wiser way of avoiding these unanswerable questions. Our lives are, indeed, cycles of "birth again and again" from the standpoint of human cell biology.

Let us return to the final question, "Where am I going?", for which a partial answer has already been provided, at least for the growth phase of one's life from the original fertilized egg cell to a fully developed adult. Remaining points that require consideration pertain to why all growth processes apparently come to an end or why decay processes appear, leading to the death of all life forms. A common human concern is the ultimate question of what happens to us after death. This difficult question might be set aside by simply referring to the teachings of the Gautama Buddha, namely that life is ever-changing in an endless cycle of birth and death. Let us, instead, examine these questions from a scientific standpoint.

THE SIMULTANEITY OF GROWTH AND DECAY

Earlier, it was stated that all life processes are chemical in nature and that such changes, i.e., chemical reactions, follow the Law of Conservation of Energy and Matter. These chemical reactions show another universal trait, namely that they proceed in either direction. That is, if A and B combine to produce C and D, then C and D can also combine to produce A and B. Such reactions are called equilibrium, or reversible reactions, and when equilibrium is reached, there is no change in the overall amount of A, B, C, or D. An equilibrium process is a dynamic one. Even if the overall amounts of chemical species involved in a reaction are not changing, some A and B molecules are always reacting to produce C and D molecules while at the same time C and D molecules are reacting to produce molecules A and B. In the language of chemistry, an equilibrium reaction is usually indicated by the equality sign, viz.

$$A + B = C + D$$

Sometimes a set of parallel arrows pointing in opposite directions is used instead of the equality sign.

Biological reactions including all those taking place in our bodies are equilibrium reactions. They are delicately balanced, highly efficient processes that take place in a relatively narrow range of temperature and reaction conditions. We are all too aware of the consequences of disrupting such equilibrium processes. Too high or too low a body temperature can be fatal. On the other hand, controlled lowering of one's body temperature decreases one's rates of metabolism and oxygen consumption, making it a useful procedure in organ transplant surgeries. Replacing the air we breathe with pure oxygen leads to oxygen poisoning, while decreasing the amount of oxygen in the air causes high altitude sickness.

We are now ready to apply the idea of an equilibrium reaction to the growth and decay of our bodies. When we are in a growth phase, forward reactions (that is, reactions represented by A and B reacting to form the products C and D) are dominant. It is not essential that we know the identities of all

such reactions. As long as new body matter C and D are being produced from some external matter A and B, there is obviously growth. Once such reactions reach their equilibrium states, overall growth ceases. Although our growth is genetically limited, making it impossible for us to grow as tall as a giraffe, or as large as a whale, there are some variations in the final equilibrium growth states. For example, improved diet and living conditions affect our growth, as evidenced by the remarkable change in the average height and weight of Japanese children after the Second World War.

When reactions represented by C and D producing A and B become dominant, decay becomes evident. However, whether the forward or the reverse reactions are playing their major roles, the reactions are still equilibrium processes are are occurring in both directions. That is, growth and decay occur simultaneously; they are not necessarily sequential processes. It is relatively easy to become aware of the presence of growth processes, even during the declining years of one's life when decay is dominant; but it is difficult to accept the fact that one's body is decaying while it is still undergoing overall growth. Healing of wounds and mending of broken bones occurring throughout one's lifetime, although definitely a slower process with advancing age, are manifestations of the ever present growth processes. Decay processes are more evident at the cellular level. For example, our skin cells are constantly being replaced. Just scratch your skin surface and the presence of dead skin cells will be readily apparent even though you may refer to them as "dry skin".

THERMODYNAMICS OF LIFE

We have deduced that, in life, growth and decay occur at the same time and are inseparable, being parts of the same equilibrium processes. There are, however, fundamental differences between these processes. Without the support of external sources of energy and matter, it is difficult, if not impossible, to have growth. Although one can survive for a short time without taking food or water by relying on one's internal sources of matter and energy, such as body fat and tissues, it is unlikely that growth will be a dominant factor under such circumstances. Decay processes, on the other hand, do not depend fundamentally on external supports; they are spontaneous processes. In order to discuss these differences, it is necessary to refer to another law in the science of thermodynamics which deals with the movement and accounting of energy and matter in changes taking place in our universe. Earlier, we introduced the idea that energy and matter are neither created nor destroyed in chemical reactions. This notion is a law in this particular branch of science and is called the First Law of Thermodynamics. Now, the additional law needed in our discussion is called, not surprisingly, the Second Law of Thermodynamics.

There are many spontaneous changes taking place around us, changes occurring by themselves without apparent external assistance. Such changes cannot be fully explained on the basis of energy consideration alone. Drop a glass cup on a concrete floor, and it breaks into many small pieces. This is a common phenomenon, but has anyone ever seen broken pieces of glass come together by themselves to form the original cup? Take a deck of playing cards and throw it high into the air. Do you expect the cards to land on the floor all arranged in their proper order? Can one recreate a piece of log after it has been burned in a fireplace? These very common examples show that there must be some preferred direction in events taking place around us. The Second Law of Thermodynamics helps to explain and quantify such changes. It does so by introducing a new concept called "entropy" that depends on both energy and temperature.

Entropy is a measure of the degree of

disorder associated with any system. It is also related to the notion of probability (gambler's mathematics). A highly disordered state is more probable than one that is well ordered, and the entropy of such a disorganized state is consequently larger than that for the ordered state. The entropy of an unbroken glass is lower than that of the same glass in a thousand pieces. A randomly arranged deck of cards has a greater entropy value than the same deck arranged in proper sequential order. The entropy of the heat and ashes resulting from the burning of a wooden log is greater than the entropy of the original unburnt log.

The concept of time does not appear in thermodynamics. Hence, *when* decay starts, or *when* death occurs, is not answerable by the application of thermodynamic laws to life processes. Time is introduced into chemical reactions through a field of science called "chemical kinetics". In this field, the speeds and paths of chemical changes are studied. We try to answer such questions as how fast does something appear or disappear, and how changes actually take place. Unfortunately, this field, as applied to living systems, is still in a very primitive state, making discussion of life processes in terms of time sequence not possible at present. Thus, our discussions so far have dealt only with the *sequence* of events and not with *when* such events take place.

The phenomenon of death can be discussed without the knowledge of the time variable. However, death is an event that extends over a period of time, a very long one from the standpoint of molecular behavior. Death is not an instantaneous event; and this fact causes difficulties similar to those encountered in trying to identify the beginning of a human life. For example, the absence of a heartbeat does not necessarily indicate death, since many individuals have been revived after their hearts have stopped beating. Cardiac arrest arises often from the death of heart muscle cells, so defining death in terms of heart motion involves an element of arbitrariness, for it is unlikely that we will ever be able to specify the exact number of dead cells necessary for heart muscles to stop functioning. The notion of brain death, although a useful one from a legal and medical standpoint, is also an arbitrary definition of death. Just because there is cessation of electrical signals in one's brain does not mean that the rest of the body is biologically dead. If it were so, no organ transplant would be possible.

Scientifically, the term "decay" gives a more appropriate description of the events surrounding the phenomenon of death. At the cellular and molecular levels, there is no death, only continuous decay and changes from biological to organic to inorganic chemical levels. Moreover, these changes do not terminate at the inorganic level, because our bodily constituents become readily incorporated into the bodies of other forms of life on this planet. Since the Law of Conservation of Energy and Matter is still operative during the decay phase of a living organism, all that a living organism is made of will remain on this planet to be used by other living things, including humans. In other words, bodies of living things are continually recycled. One example should suffice to illustrate this point. More than one half of our body weight consists of water. If one tries to estimate the number of water molecules in a typical individual, it comes out to be over 2×10^{27} (2 followed by 27 zeros or two thousand trillion trillion) molecules. The world population is only about 5×10^{9} (five billion), so there are plenty of water molecules to go around. Thus, matter and energy making up the bodies of living things are used over and over again.

Life has no beginning, nor does it have any ending; it is a continuous cycle of birth and rebirth. But Gautama Buddha already said that 2,500 years ago. He also said, "Our life is shaped by our mind; we become what we think."[1] Therefore, how each of us thinks can make a difference in this world.

FOOTNOTES:

1. *The Dhammapada*, no. 153, trans. by S. Radhakrishnan

2. *The Dhammapada*, no. 1, trans. by Eknath Easwaran (Petaluma: Nilgiri Press, 1986), p. 78