ETHICS AND EVOLUTION

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Introduction

In October, 2017, one of the Danish state television channels, DR2, broadcast two programs about current religious opposition to Darwin's theory of evolution[1]. Much of this opposition originated in the United States, and was aimed at preventing the teaching of evolution in schools. The attacks on Darwin's theory (by now, not a theory but a well-established scientific fact) were twofold. First the claim that it is not true, and secondly, pointing out that historically, Social Darwinism has led to horrible consequences.

One of the arguments against the truth of Darwinian evolution is that it violates the second law of thermodynamics, according to which the disorder of the universe always increases with time. How then can life on earth, with its amazing order, be possible?

The answer is that the earth is not a closed system. A flood of information-containing free energy reaches the earth's biosphere in the form of sunlight. Passing through the metabolic pathways of living organisms, this information keeps the organisms far away from thermodynamic equilibrium, which is death. As the thermodynamic information flows through the biosphere, much of it is degraded to heat, but part is converted into cybernetic information and preserved in the intricate structures which are characteristic of life. The principle of natural selection ensures that when this happens, the configurations of matter in living organisms constantly increase in complexity, refinement and statistical improbability. This is the process which we call evolution, or in the case of human society, progress[2].

The second prong of the religious attacks on Darwinism deserves to be taken very seriously. Herbert Spencer, after reading Darwin's *The Origin of Species*, coined the phrase "the survival of the fittest", and he is considered to be the father of Social Darwinism. Darwin's half-cousin. Sir Francis Galton, founded the eugenics movement; and Thomas Henry Huxley, one of Darwin's strongest supporters, emphasized ruthless competition as the main mechanism in evolution[3].

Historically, Social Darwinism and the eugenics movement did indeed lead to horrors, the worst of these being the genocide committed by the Nazis during World War II in the name of "improving the race". Also today,

[1] *Med Gud Mod Darwin* and *Arven Efter Darwin*

[2] See Appendix A

[3] Darwin himself believed that symbiosis and cooperation played an equally important role, see Chapter 4

racism and exceptionalism are behind the neoconservative ideas which are driving the world towards a thermonuclear catastrophe[4].

The two programs broadcast by DR2 also focused on recent plans of humans to take evolution into their own hands, and to breed superhumans through eugenics and genetic engineering, making use of the rapidly developing techniques of modern biology. But the Darwinian picture itself provides the strongest possible argument against human intervention into the evolutionary process. According to the scientifically accepted picture, the earth is approximately 4.54 billion years old. Soon after its formation, the lowest forms of life appeared. These are thought to have derived their energy from iron-sulphur reactions at vents on the ocean floor, where super-heated mineral-rich water met the colder water of the ocean. Since this early origin of terrestrial life, ecosystems harmoniously tuned and balanced by the forces of natural selection have evolved. This immensely long period of natural evolution must be respected. Any human intervention into the process would be clumsy and disastrous.

Why is human solidarity needed so urgently?

Today the world is faced by three extremely serious dangers. We cannot be at all sure that we will get through the 21st century without a catastrophe. The three greatest threats will be discussed in more detail below, but briefly they are as follows:

- The threat of an all-destroying thermonuclear war
- The threat of catastrophic climate change
- The threat of a global famine leading to as many as a billion human deaths

In order to avert these threats and to pass safely through the next short period of history, we urgently need human solidarity.

The ideas of Social Darwinism and the Eugenics Movement undermine human solidarity. This is not the moment for genetic improvement of the human race! Genetic evolution proceeds extremely slowly, but today technological and political change are moving with blinding speed - constantly

[4] See Chapters 7 and 8.

accelerating speed. So fast, indeed, is the speed of change, that it threatens to shake human civilization to pieces.

For the sake of survival in a desperately precarious time, we can afford to allow humans to lose a percentage or two of their IQ's or to become very slightly less athletic, if that is the consequence of failing to breed humans as though they were farm animals. In any case, the horrors committed by the Nazi's during World War II in the name of "improving the race" should serve as a warning.

Today we live at a time of crisis for human civilization and the biosphere. We have a responsibility to save the planet for the sake of our children and grandchildren, and for the sake of all future generations. We need to save the earth for the sake of the animals an plants that might become extinct if we do not act to help them. No one can do this alone, but acting together, we can succeed. As Helen Keller said, "Alone we can do so little; together we can do so much!"

Contents

Chapter 1

WHAT IS SCIENCE? WHAT IS RELIGION?

What is science?

In his autobiography, Charles Darwin says that "science consists in arranging facts in such a way that general conclusions may be drawn from them". In other words, scientists try to find patterns in our observations of nature. These patterns stand temporarily as "laws of nature", until exceptions are found. Very often it is possible to use such patterns or laws to make accurate predictions about the future, and when this is possible, it strengthens the credibility of the pattern that was used to make the predictions. Thus the test of a law of nature is its usefulness in making predictions about the future; and scientists find it hardly worthwhile to talk about assertions from which no predictions can be made.

When exceptions to natural laws are found, they are of extreme importance, and great efforts must be made to clarify the situation: If an exception to a natural law is found to be genuine, it means that the law must be modified, and this is the way scientific progress is made; hence the extreme importance of exceptions, and the massive attention which is given to them by scientists.

We seem to live in a universe in which the behavior of matter and energy is predictable. For example, if you put a coin into a box and shut the lid, you can say with some confidence, "The coin is inside the box", even though you cannot see the coin. From this assertion, many predictions follow: You can predict that if you shake the box, the coin will rattle. The box will be slightly heavier than before because of the presence of the coin. An X-ray photograph would reveal the coin. If you open the box again, the coin will still be there, and so on. It would be hard to live in a world where this degree of predictability did not hold.

Besides predictability, the universe in which we live seems to have another remarkable characteristic: The most general and fundamental laws of nature that have been discovered have great simplicity and mathematical beauty. Pythagoras and his followers were the first to discover that "mathematics is the language of nature".

Pythagoras, who lived from 582 B.C. to 497 B.C., is one of the most important and interesting figures in the history of European culture. It is hard to decide whether he was a religious leader or a scientist. He was a leader and reformer of the Orphic religion of ancient Greece, and he was the first maintain that mathematics is the key to the understanding of nature. In the Pythagorean view of nature, mathematical harmony governs the fundamental laws of the universe. In the Pythagorean ethic, the highest vocation is that of the philosopher, and the aim of philosophy is to understand nature through the discovery of the mathematical relationships which govern the universe.

Today, much of what Pythagoras hoped to achieve in mathematics has been attained. For example, quantum theory has shown that the inner structure of an atom is governed by mathematical relationships closely analogous to those governing the harmonics of a lyre string. We have indeed found mathematical harmony in the fundamental laws of nature; but one can ask whether philosophy has brought harmony to human relations, as Pythagoras would have hoped!

As examples of the simplicity and beauty of the fundamental laws of nature, we can think of Maxwell's equations for electromagnetic fields, or Schrödinger's non-relativistic wave equation for electrons, or Dirac's relativistic wave equation. All of them require mathematical language to be properly expressed, and all have great mathematical beauty. In fact, P.A.M Dirac, whose relativistic wave equation was just mentioned, wrote a famous paper in the Canadian Journal of Physics, where he maintained that the beauty of fundamental physical laws can be taken as a fact of nature, and therefore we can find new laws by following our sense of mathematical beauty. Apparently this method of research worked for him!

Furthermore, all of the fundamental laws of nature that have until now been discovered, fit together in a self-consistent way. Therefore, when something new is discovered, the first reaction of the scientific community is to see how the new discovery is related to the entire existing body of knowledge. If no relationship can be found, then either the new discovery is suspect or else it is of enormous importance. In any case, no one rests until the situation is clarified.

Modern astronomy has shown the Universe to be almost unimaginably large. Wikipedia states that: "The size of the Universe is unknown; it may be infinite. The region visible from Earth (the observable universe) is a sphere

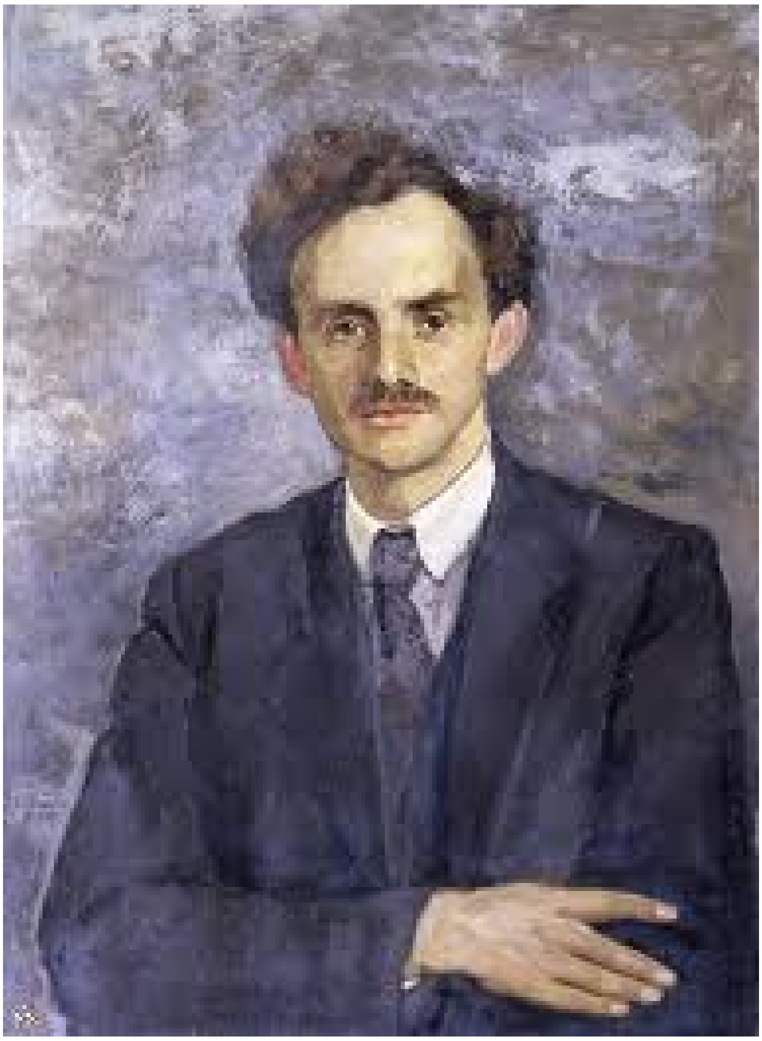

Figure 1.1: *Paul Adrian Maurice Dirac (1902-1984), discoverer of the relativistic wave equation that holds for electrons and other spin-*$\frac{1}{2}$ *particles. He maintained that since mathematical beauty is a characteristic of the most fundamental physical laws, we can find new ones by following our sense of mathematical beauty.*

with a radius of about 46 billion light years, based on where the expansion of space has taken the most distant objects observed. For comparison, the diameter of a typical galaxy is 30,000 light-years, and the typical distance between two neighboring galaxies is 3 million light-years. As an example, the Milky Way Galaxy is roughly 100,000 light years in diameter, and the nearest sister galaxy to the Milky Way, the Andromeda Galaxy, is located roughly 2.5 million light years away. There are probably more than 100 billion (10^{11}) galaxies in the observable Universe.Typical galaxies range from dwarfs with as few as ten million (10^7) stars up to giants with one trillion(10^{12}) stars, all orbiting the galaxy's center of mass. A 2010 study by astronomers estimated that the observable Universe contains 300 sextillion (3×10^{23}) stars."

Among this incredibly vast number of stars it is believed that there are innumerable stars that have planets similar to the Earth and hence able to support life. We also now know that given conditions that are favorable to life, it will almost certainly develop and evolve. The Earth seems to be only of extremely minor importance on the scale of the Universe. Given these facts, and given that the fundamental laws of nature are mathematical, I find it difficult to believe that the entire Universe and the laws that govern it were arranged for the benefit of humans, especially since humans have only existed for a brief instant on the time-scale of the Universe. If asked where the Universe came from and why, the scientist must answer with honesty, "I don't know".

The blindness of science

Ethical considerations have traditionally been excluded from scientific discussions. This tradition perhaps has its roots in the desire of the scientific community to avoid the bitter religious controversies which divided Europe following the Reformation. Whatever the historical reason may be, it has certainly become customary to speak of scientific problems in a dehumanized language, as though science had nothing to do with ethics or politics.

The great power of science is derived from an enormous concentration of attention and resources on the understanding of a tiny fragment of nature; but this concentration is at the same time a distortion of values. To be effective, a scientist must believe, at least temporarily, that the problem on which he or she is working is more important than anything else in the world, which is of course untrue. Thus a scientist, while seeing a fragment of reality better than anyone else, becomes blind to the larger whole. For example, when one looks into a microscope, one sees the tiny scene on the slide in tremendous detail, but that is all one sees. The remainder of the universe is blotted out by this concentration of attention.

The system of rewards and punishments in the training of scientists pro-

Figure 1.2: *The blindness of science: Enormous concentration of attention on a small fragment of reality blinds the researcher to the larger whole.*

duces researchers who are highly competent when it comes to finding solutions to technical problems, but whose training has by no means encouraged them to think about the ethical or political consequences of their work.

Scientists may, in fact, be tempted to escape from the intractable moral and political difficulties of the world by immersing themselves in their work. Enrico Fermi, (whose research as much as that of any other person made nuclear weapons possible), spoke of science as "soma" - the escapist drug of Aldous Huxley's Brave New World. Fermi perhaps used his scientific preoccupations as an escape from the worrying political problems of the '30's and '40's.

The education of a scientist often produces a person with a strong feeling of loyalty to a particular research discipline, but perhaps without sufficient concern for the way in which progress in that discipline is related to the general welfare of humankind. To remedy this lack, it would be very desirable if the education of scientists could include some discussion of ethics, as well as a review of the history of modern science and its impact on society.

The explosive growth of science-driven technology during the last two centuries has changed the world completely; and our social and political institutions have adjusted much too slowly to the change. The great problem of our times is to keep society from being shaken to pieces by the headlong progress of science, the problem of harmonizing our social and political institutions with technological change. Because of the great importance of this problem, it is perhaps legitimate to ask whether anyone today can be considered to be educated without having studied the impact of science on society. Should we not include this topic in the education of both scientists and non-scientists?

Science has given us great power over the forces of nature. If wisely used, this power will contribute greatly to human happiness; if wrongly used, it will result in misery. In the words of the Spanish writer, Ortega y Gasset, "We live at a time when man, lord of all things, is not lord of himself"; or as Arthur Koestler has remarked, "We can control the movements of a spaceship orbiting about a distant planet, but we cannot control the situation in Northern Ireland."

To remedy this situation, educational reforms are needed. Science and engineering students ought to have some knowledge of the history and social impact of science. They could be given a course on the history of scientific ideas; but in connection with modern historical developments, such as the industrial revolution, the global population explosion, the development of nuclear weapons, genetic engineering, and information technology, some discussion of social impact could be introduced. One might hope to build up in science and engineering students an understanding of the way in which their work is related to the general welfare of humankind. These elements are needed in science education if rapid technological development is to be beneficial rather than harmful.

What is religion?

All known human societies have religions; and this is true not only of societies that exist today, but also of all past societies of which we have any record. Therefore it is reasonable to suppose that the tendency to be religious is an intrinsic part of human nature. It seems to be coded into our genes.

If evolutionary forces have produced the human tendency to be religious, then it must have had some survival value. My own belief is that religion helps us because it is a mechanism for the preservation and transmission of human cultures. All living organisms on earth hand on information from one generation to the next in the form of messages coded into their DNA and RNA. Humans are unique in having also evolved extremely efficient non-genetic methods for transmitting information from one generation to the next, through our highly developed languages.

Cultural evolution is responsible for the success of our species. We dominate the earth because of cultural evolution. Thus if religion is a mechanism for the preservation and transmission of particular cultures, it would confer a great advantage to those societies that possessed religions, and a tendency to be religious would be favored by the Darwinian forces of natural selection.

Is there a conflict between science and religion?

Is there a conflict between science and religion? This is a frequently-asked question, and many different answers have been given. My own opinion is that there are two aspects to religion - ethics and cosmology. I think that when we talk about cosmology, there is often a conflict between science and religion. But with respect to ethics, there is very little room for conflict because science has almost nothing to say about ethics.

Why do I say "almost nothing" instead of "nothing"? It is often said that ethical principles cannot be derived from science, that they must come from somewhere else. Nevertheless, when nature is viewed through the eyes of modern science, we obtain some insights which seem almost ethical in character. Biology at the molecular level has shown us the complexity and beauty of even the most humble living organisms, and the interrelatedness of all life on earth. Looking through the eyes of contemporary biochemistry, we can see that even the single cell of an amoeba is a structure of miraculous complexity and precision, worthy of our respect and wonder.

Knowledge of the second law of thermodynamics , the statistical law favoring disorder over order, reminds us that life is always balanced like a tight-rope walker over an abyss of chaos and destruction. Living organisms distill their order and complexity from the flood of thermodynamic information which reaches the earth from the sun. In this way, they create local order; but life remains a fugitive from the second law of thermodynamics. Disorder, chaos, and destruction remain statistically favored over order, construction, and complexity.

It is easier to burn down a house than to build one, easier to kill a human than to raise and educate one, easier to force a species into extinction than to replace it once it is gone, easier to burn the Great Library of Alexandria than to accumulate the knowledge that once filled it, and easier to destroy a civilization in a thermonuclear war than to rebuild it from the radioactive ashes. Knowing this, we can form an almost ethical insight: To be on the side of order, construction, and complexity, is to be on the side of life. To be on the side of destruction, disorder, chaos and war is to be against life, a traitor to life, an ally of death. Knowing the precariousness of life, knowing the statistical laws that favor disorder and chaos, we should resolve to be loyal to the principle of long continued construction upon which life depends.

War is based on destruction, destruction of living persons, destruction of homes, destruction of infrastructure, and destruction of the biosphere. If we are on the side of life, if we are not traitors to life and allies of death, we must oppose the institution of war. We must oppose the military-industrial complex. We must oppose the mass media when they whip up war-fever. We must oppose politicians who vote for obscenely enormous military budgets at a time of financial crisis. We must oppose these things by working with dedication, as though our lives depended on it. In fact, they do.

But let us turn to religious ethics. Not only do they not conflict with science, but there is also a general agreement on ethical principles between the major religions of the world.

The central ethical principles of Christianity can be found in the Sermon on the Mount and in the Parable of the Good Samaritan. In the Sermon on the Mount, we are told that we must not only love our neighbors as much as we love ourselves; we must also love and forgive our enemies. This seemingly impractical advice is in fact of great practicality, since escalatory cycles of revenge and counter-revenge can only be ended by unilateral acts of kindness.

In the Parable of the Good Samaritan, we are told that our neighbor, whom we must love, is not necessarily a member of our own ethnic group. Our neighbor may live on the other side of the world and belong to an entirely different race or culture; but he or she still deserves our love and care.

It is an interesting fact that the Golden Rule, "Do unto others as you would have them do unto you", appears in various forms in all of the world's major religions. The Wikipedia article on the Golden Rule gives an impressive and

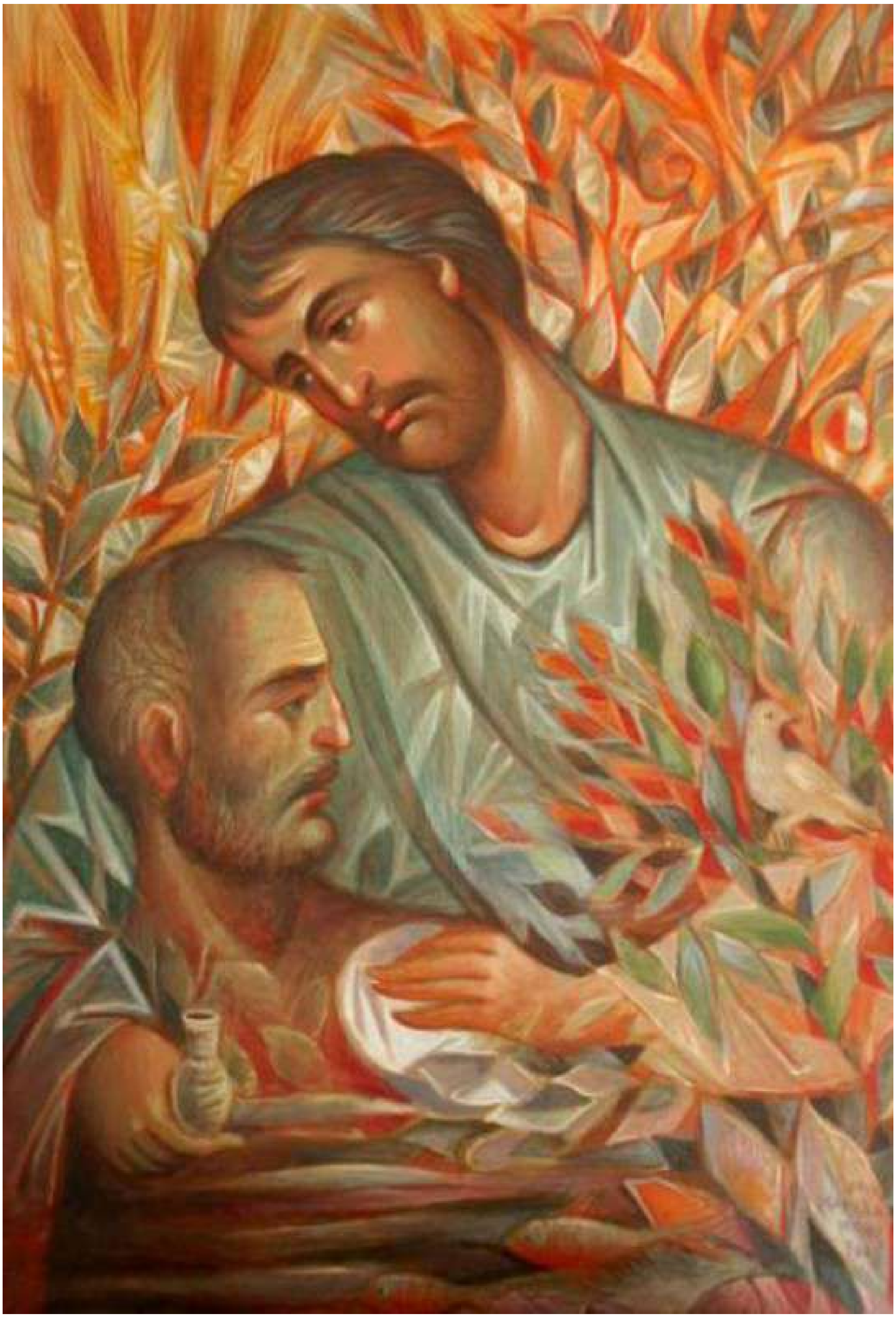

Figure 1.3: *A painting illustrating the Parable of the Good Samaritan*

fascinating list of the forms in which the rule appears in many cultures and religions. For example, in ancient China, both Confucius and Laozi express the Golden Rule, but they do it slightly differently: Zi Gong asked, saying,"Is there one word that may serve as a rule of practice for all one's life?" The Master said, "Is not reciprocity such a word?" (Confucius) and "The sage has no interest of his own, but takes the interests of the people as his own. He is kind to the kind; he is also kind to the unkind: for Virtue is kind. He is faithful to the faithful; he is also faithful to the unfaithful: for Virtue is faithful." (Laozi)

In the Jewish tradition, we have "The stranger who resides with you shall be to you as one of your citizens; you shall love him as yourself, for you were strangers in the land of Egypt" (Leviticus) In Islam: A Bedouin came to the prophet, grabbed the stirrup of his camel and said: O the messenger of God! Teach me something to go to heaven with it. The Prophet said: "As you would have people do to you, do to them; and what you dislike to be done to you, don't do to them. This maxim is enough for you; go and act in accordance with it!" (Kitab al-Kafi, vol. 2, p. 146)

The principle of reciprocity is an ancient one in human history, and it is thus embedded in our emotions. It is an important part of human nature. Reciprocity is the basis of non-market economies, and also the basis of social interactions between family members, friends and colleagues. In hunter-gatherer societies, it is customary to share food among all the members of the group. "Today I receive food from you, and tomorrow you will receive food from me." Similarly, among friends in modern society, no payment is made for hospitality, but it is expected that sooner or later the hospitality will be returned.

According to Wikipedia "Reciprocity in Social Psychology refers to responding to a positive action with another positive action, rewarding kind actions. As a social construct, reciprocity means that in response to friendly actions, people are frequently much nicer and much more cooperative than predicted by the self-interest model; conversely, in response to hostile actions they are frequently much more nasty and even brutal." As Wikipedia points out, reciprocity can also be negative, as in the case of escalatory cycles of revenge and counter-revenge.

The Buddhist concept of karma has great value in human relations. The word "karma" means simply "action". In Buddhism, one believes that actions return to the actor. Good actions will be returned, and bad actions will also be returned. This is obviously true in social relationships. If we behave with kindness and generosity to our neighbors, they will return our kindness. Conversely, a harmful act may lead to vicious circles of revenge and counter revenge, such as those we see today in the Middle East and elsewhere. These vicious circles can only be broken by returning good for evil.

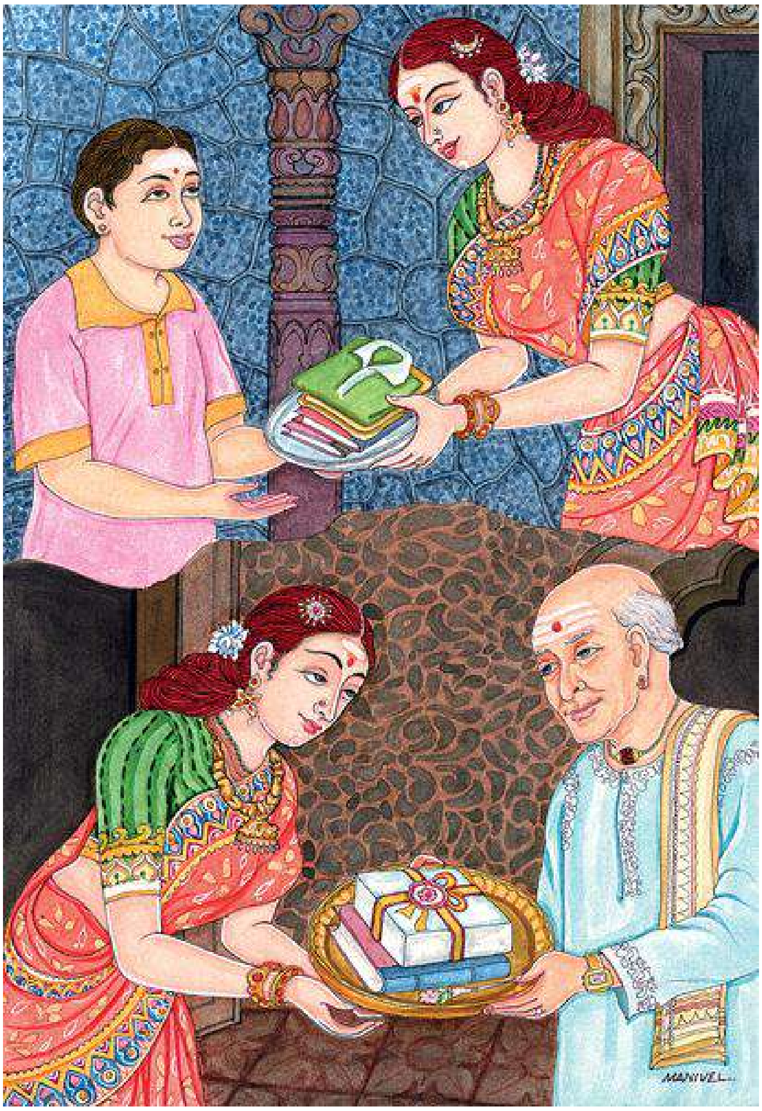

Figure 1.4: *This painting illustrates the concept of karma. A lady gives books and clothing to a poor student. Later she receives a gift from a neighbor. There may sometimes be a direct causal connection between such events, but often they are connected only by the fact that each act of kindness makes the world a better place. (Himalayan Academy Publications, Kapaa, Kauai, Hawaii.)*

However the concept of karma has a broader and more abstract validity beyond the direct return of actions to the actor. When we perform a good action, we increase the total amount of good karma in the world. If all people similarly behave well, the the world as a whole will become more pleasant and more safe. Human nature seems to have a built-in recognition of this fact, and we are rewarded by inner happiness when we perform good and kind actions. In his wonderful book, "Ancient Wisdom, Modern World", the Dalai Lama says that good actions lead to happiness and bad actions to unhappiness even if our neighbors do not return these actions. Inner peace, he tells us, is incompatible with bad karma and can be achieved only through good karma, i.e. good actions.

In Buddhist philosophy, the concept of Karma, action and reaction, also extends to our relationship with nature. Both Hindu and Buddhist traditions emphasize the unity of all life on earth. Hindus regard killing an animal as a sin, and many try to avoid accidentally stepping on insects as they walk.

The Hindu and Buddhist picture of the relatedness of all life on earth has been confirmed by modern biological science. We now know that all living organisms have the same fundamental biochemistry, based on DNA, RNA, proteins and polysaccharides, and we know that our own human genomes are more similar to than different from the genomes of our close relations in the animal world.

The peoples of the industrialized nations urgently need to acquire a non-anthropocentric element in their ethics, similar to reverence for all life found in the Hindu and Buddhist traditions, as well as in the teachings of Saint Francis of Assisi and Albert Schweitzer. We need to learn to value other species for their own sakes, and not because we expect to use them for our own economic goals.

Today a few societies still follow a way of life similar to that of our hunter-gatherer ancestors. Anthropologists are able to obtain a vivid picture of the past by studying these societies. Often the religious ethics of the hunter- gatherers emphasizes the importance of harmony with nature. For example, respect for nature appears in the tribal traditions of Native Americans. The attitude towards nature of the Sioux can be seen from the following quotations from "Land of the Spotted Eagle" by the Lakota (Western Sioux) chief, Standing Bear (ca. 1834-1908):

"The Lakota was a true lover of Nature. He loved the earth and all things of the earth... From Waken Tanka (the Great Spirit) there came a great unifying life force that flowered in and through all things, the flowers of the plains, blowing winds, rocks, trees, birds, animals, and was the same force that had been breathed into the first man. Thus all things were kindred and were brought together by the same Great Mystery."

Figure 1.5: *Chief Luther Standing Bear, author of "Land of the Spotted Eagle" and many other books.*

"Kinship with all creatures of the earth, sky, and water was a real and active principle. For the animal and bird world there existed a brotherly feeling that kept the Lakota safe among them. And so close did some of the Lakota come to their feathered and furred friends that in true brotherhood they spoke a common tongue."

"The animal had rights, the right of man's protection, the right to live, the right to multiply, the right to freedom, and the right to man's indebtedness, and in recognition of these rights the Lakota never enslaved the animal, and spared all life that was not needed for food and clothing."

"This concept of life was humanizing and gave to the Lakota an abiding love. It filled his being with the joy and mystery of things; it gave him reverence for all life; it made a place for all things in the scheme of existence with equal importance to all. The Lakota could despise no creature, for all were one blood, made by the same hand, and filled with the essence of the Great Mystery."

A similar attitude towards nature can be found in traditional Inuit cultures, and in some parts of Africa, a man who plans to cut down a tree offers a prayer of apology, telling the tree why necessity has forced him to harm it. This preindustrial attitude is something from which the industrialized North could learn. In industrial societies, land "belongs" to some one has the "right" to ruin the land or to kill the communities of creatures living on it if this happens to give some economic advantage, in much the same way that a Roman slaveowner was thought to have the "right" to kill his slaves. Preindustrial societies have a much less rapacious and much more custodial attitude towards the land and towards its non-human inhabitants.

We have received many gifts from modern technology, but if we are to build a happy, sustainable and war-free world we must combine our new scientific techniques with humanity's ancient wisdom.

Complementarity

Can two contradictory statements both be true? The physicist Niels Bohr thought that this could happen, and he called such an occurrence "complementarity". I think that I understand what Niels Bohr meant: Whenever we make a statement about the real world we are making a model which is simpler than what it is supposed to represent. Therefore every statement must to some extent be false because it is an oversimplification. In fact, a model of the world is an abstraction, and it is possible to make two conflicting abstractions, starting with the same real object.

If you say, "The eye is like a camera", you are making an abstraction by concentrating on the way that the eye works and the way that a camera works. Both use a lens to form an image. If you say "The eye is like a small onion", you are again making an abstraction, but this time concentrating the size and texture of the eye. It is somewhat round, elastic and damp. If you drop it on a stone floor, it will bounce rather than breaking. Both these abstractions have a certain degree of truth, although they are contradictory.

Similarly, science and religion are both abstractions, and both oversimplify the real world, which is much more complex than either of them. Which abstraction we should use depends on the problem that we wish to discuss. If we are talking about atomic spectra, then Schrödinger and Dirac should be our guides. But if the lecture is on how to achieve peace in the world, I would far rather hear it from Mahatma Gandhi than from either Schrödinger or Dirac.

Right hand, left hand

I vividly remember a speech made by His Holiness Pope John Paul II on the relationship between science and religion. I think that it was in 1981 or 1982. I was in Rome, attending a conference on quantum theory applied to chemistry. One of the topics at the conference was research on drugs that could be used for treating cancer. Because of this humanitarian aspect of the conference, the Italian professor who organized it succeeded in arranging for the participants to have an audience with the Pope, the day after Easter.

On Easter day itself I was walking through Rome, and I happened to meet some Swedish friends. They told me that they were about to join a march protesting against nuclear weapons. They would march through Rome, carrying antinuclear banners, and end at the Vatican in time to hear the Pope's Easter address. I joined the march with my Swedish friends, and when we arrived at St. Peter's Cathedral the entire square was full people, packed tightly, shoulder to shoulder so that one could almost not move. The atmosphere was a festive one, and our antinuclear banners were matched by religious banners carried by others in the throng. I had never seen such a large crowd in my life, but it was a happy crowd.

After a while the doors of the Vatican were opened, and the Pope came out onto the terrace accompanied by the College of Cardinals. He began to address us in Latin. We were so far away that we would not have been able to see or hear him, had it not been for loudspeakers and two large screens showing his image, with subtitles in Italian and in English.

At the end of the Pope's address to the crowd, the Cardinals went into the Vatican and the doors were ceremonially closed, but the Pope himself walked down the steps of the terrace and into the crowd, where he mingled with everyone, shook hands with as many as he could, and talked with as many as he could. This showed remarkable courage, since he had only recently recovered from almost-fatal gunshot wounds at the hands of a would-be assassin.

Figure 1.6: *His Holiness Pope John Paul II*

On the appointed day for our audience, which was the day after Easter, we ascended the stairway to the audience chambers at the top of the Vatican, passing the impressive and colorful Swiss Guards on the way, and also passing beautiful tapestries that covered the walls.

The Pope was very busy because of his obligations to the many pilgrims who had come to Rome to celebrate Easter. We were told that it would be at least an hour before the Pope could address us. During that time we were free to wander about the audience chamber and to look at the tapestries. We would know when the Pope was about to arrive, because the lights would become brighter for the sake of the television, and because we would hear a choir singing. Then we should take our seats and wait for the Pope's arrival.

It happened just as we had been told. After an hour or so, the lights went up and we heard the choir singing. We took our seats, and a few minutes later the Pope arrived. As he began to speak with us he gave the impression of an energetic and physically strong person, with an extremely modest, attractive and charismatic personality.

The Pope spoke in English, both to us, and to a much larger public, since his address was televised. He talked about the relationship between science and religion, mentioning that one of the topics to which our conference had been devoted was the treatment of cancer. He said that science had done very much to improve human health and comfort. Science and technology have given us the material goods of our modern world. However, Pope John Paul told us, material goods are not enough to ensure happiness. It is possible to be very well off from a material standpoint, but at the same time, very miserable. He said that for happiness, we also need ethics and wisdom - the traditional wisdom of humanity. By "the traditional wisdom of humanity", I think that he meant the wisdom that is preserved in the world's religions, but he did not specifically mention religion.

When he had finished talking, the Pope came down to the floor of the audience chamber and shook hands with us. All through his speech a baby had been crying, and the Pope, who was undoubtedly used to such disturbances, made a point of kissing the baby. He shook my hand too. There was a Polish professor named Wlodzimierz Kolos with our group, and when the Pope came to the place where Kolos was standing, he stood and talked with the professor for about two minutes.

I was curious about what the Pope and Kolos had been saying to each other, but I did not have a chance to ask on that occasion. However, a year or so later I met Prof. Kolos at another conference, and I asked him. He replied, "I don't remember. I see the Pope so often that I don't remember what we said on that particular occasion."

I was astonished, and I asked Kolos to explain. He told me that when Pope John Paul took his summer vacations, he lived in a large villa near to Rome. He had the custom of inviting philosophers, theologians and scientists (many of them Polish) to visit him there for informal discussions. They always sat around a large table and talked about subjects like the relationship between science and religion. On those occasions, the Pope did not wear his robes of office, but only ordinary clothing. Every session ended with a discussion of the current situation in Poland.

Due to the Pope's efforts, the situation in Poland improved, and he also helped to make a reconciliation between science and the Catholic Church. I regard it as a great privilege to have seen his courage at Easter, and to have heard him speak. He is very justly regarded as one of the greatest Popes of all time.

I also had the privilege of hearing His Holiness the 14th Dalai Lama of Tibet speak on the same topic, the relationship between science and religion. The Dalai Lama was visiting Denmark, and I was invited to a lecture by him, arranged by the Danish-Tibetan Society.

The lecture took place at a very large hall called Forum, and such was the interest in his talk that the hall was completely filled. There were many flowers to greet the Dalai Lama, and many yellow-robed monks to assist him. When he began to talk, he gave the same impression as Pope John Paul II had done - energy and physical strength, combined with modesty and an attractive and charismatic personality.

Unfortunately, the acoustics of the hall were terrible, and it was difficult to hear what he said. The problem was made worse by his special accent as he spoke in English. Nevertheless, I managed to understand quite a bit of what he said.

The Dalai Lama told us that we need two hands for our tasks in life, the right hand and the left hand. Without both hands, we cannot cope properly with the problems of life. These two hands, both of which we need, are science and ethics. It was essentially the same message as that of Pope John Paul. The two hands are different, but both are needed.

How are science and religion related to war?

What is the relationship between science, religion and war? We mentioned that the world's major religions have at their core the principle of universal human brotherhood, which, if practiced, would be enough to make war impossible. However, the principle of loving and forgiving one's enemies is rarely practiced.

Many wars have been fought in the name of religion. We can think, for example, of the Crusades, or the Islamic conquests in the Middle East, North Africa and Spain, or the wars between Catholics and Protestants in Europe, or the brutal treatment of the native populations of Central and South America in the name of religion. The list by no means stops there.

What about science and technology? How are they related to war? As we start the 21st century and the new millennium, our scientific and technological civilization seems to be entering a period of crisis. Today, for the first time in history, science has given to humans the possibility of a life of comfort, free from hunger and cold, and free from the constant threat of infectious disease. At the same time, science has given us the power to destroy civilization through thermonuclear war, as well as the power to make our planet uninhabitable through pollution and overpopulation. The question of which of these alternatives we choose is a matter of life or death to ourselves and our children.

Science and technology have shown themselves to be double-edged, capable

Figure 1.7: *Three-stage (fission-fusion-fission) bombs may be made enormously powerful at little extra cost, since the last stage uses ordinary unenriched uranium. A 58 megaton bomb was exploded by the Soviet Union in 1961. It was roughly 5,000 times as powerful as the nuclear weapons that destroyed Hiroshima and Nagasaki. At present the total explosive power of the nuclear weapons in the world is approximately half a million times the power of the Hiroshima-Nagasaki bombs, enough to destroy human civilization and much of the biosphere.*

of doing great good or of producing great harm, depending on the way in which we use the enormous power over nature, which science has given to us. For this reason, ethical thought is needed now more than ever before. The wisdom of the world's religions, the traditional wisdom of humankind, can help us as we try to ensure that our overwhelming material progress will be beneficial rather than disastrous.

The crisis of civilization, which we face today, has been produced by the rapidity with which science and technology have developed. Our institutions and ideas adjust too slowly to the change. The great challenge which history has given to our generation is the task of building new international political structures, which will be in harmony with modern technology. At the same time, we must develop a new global ethic, which will replace our narrow loyalties by loyalty to humanity as a whole.

In the long run, because of the enormously destructive weapons, which have been produced through the misuse of science, the survival of civilization can only be insured if we are able to abolish the institution of war.

Chapter 2

EVOLUTION

Linnaeus, Lamarck and E. Darwin

During the 17th and 18th centuries, naturalists had been gathering information on thousands of species of plants and animals. This huge, undigested heap of information was put into some order by the great Swedish naturalist, Carl von Linné (1707-1778), who is usually called by his Latin name, Carolus Linnaeus.

Linnaeus reclassified all living things, and he introduced a binomial nomenclature, so that each plant or animal became known by two names - the name of its genus, and the name of its species. In the classification of Linnaeus, the species within a given genus resemble each other very closely. Linnaeus also grouped related genera into classes, and related classes into orders. Later, the French anatomist, Cuvier (1769-1832), grouped related orders into phyla.

In France, the Chevalier J.B. de Lamarck (1744-1829), was struck by the close relationships between various animal species; and in 1809 he published a book entitled *Philosophie Zoologique*, in which he tried to explain this interrelatedness in terms of a theory of evolution. Lamarck explained the close similarity of the species within a genus by supposing these species to have evolved from a common ancestor. However, the mechanism of evolution which he postulated was seriously wrong, since he believed that acquired characteristics could be inherited.

Lamarck believed, for example, that giraffes stretched their necks slightly by reaching upward to eat the leaves of high trees. He believed that these slightly-stretched necks could be inherited; and in this way, Lamarck thought, the necks of giraffes have gradually become longer over many generations. Although his belief in the inheritability of acquired characteristics was a serious mistake, Lamarck deserves much credit for correctly maintaining that the close similarity between the species of a genus is due to their descent from a common ancestral species.

Meanwhile, in England, the brilliant physician-poet, Erasmus Darwin (1731-1802), who was considered by Coleridge to have "...a greater range of knowledge than any other man in Europe", had published *The Botanic Garden* and *Zoonomia* (1794). Darwin's first book, *The Botanic Garden*, was written in verse, and in the preface he stated that his purpose was "...to inlist imagination under the banner of science.." and to call the reader's attention to "the immortal works of the celebrated Swedish naturalist, Linnaeus". This book was immensely popular during Darwin's lifetime, but modern readers might find themselves wishing that he had used prose instead of poetry.

Darwin's second book, *Zoonomia*, is more interesting, since it contains a clear statement of the theory of evolution:

"...When we think over the great changes introduced into various animals", Darwin wrote, "as in horses, which we have exercised for different purposes of strength and swiftness, carrying burthens or in running races; or in dogs, which have been cultivated for strength and courage, as the bull-dog; or for acuteness of his sense of smell, as in the hound and spaniel; or for the swiftness of his feet, as the greyhound; or for his swimming in the water, or for drawing snow-sledges, as the rough-haired dogs of the north... and add to these the great change of shape and colour which we daily see produced in smaller animals from our domestication of them, as rabbits or pigeons;... when we revolve in our minds the great similarity of structure which obtains in all the warm-blooded animals, as well as quadrupeds, birds and anphibious animals, as in mankind, from the mouse and the bat to the elephant and whale; we are led to conclude that they have alike been produced from a similar living filament."

Erasmus Darwin's son, Robert, married Suzannah Wedgwood, the pretty and talented daughter of the famous potter, Josiah Wedgwood; and in 1809, (the same year in which Lamarck published his *Philosophie Zoologique*), she became the mother of Charles Darwin.

Charles Darwin

As a boy, Charles Darwin was fond of collecting and hunting, but he showed no special ability in school. His father, disappointed by his mediocre performance, once said to him: "You care for nothing but shooting, dogs and rat-catching; and you will be a disgrace to yourself, and to all your family."

Robert Darwin was determined that his son should not turn into an idle, sporting man, as he seemed to be doing, and when Charles was sixteen, he was sent to the University of Edinburgh to study medicine. However, Charles Darwin had such a sensitive and gentle disposition that he could not stand to see operations (performed, in those days, without chloroform). Besides, he had found out that his father planned to leave him enough money to live on comfortably; and consequently he didn't take his medical studies very seriously. However, some of his friends were scientists,and through them, Darwin became interested in geology and zoology.

Robert Darwin realized that his son did not want to become a physician, and, as an alternative, he sent Charles to Cambridge to prepare for the clergy. At Cambridge, Charles Darwin was very popular because of his cheerful, kind and honest character; but he was not a very serious student. Among his many friends, however, there were a few scientists, and they had a strong influence on him. The most important of Darwin's scientific friends were John Stevens Henslow, the Professor of Botany at Cambridge, and Adam Sedgwick, the Professor of Geology.

Remembering the things which influenced him at that time, Darwin wrote:

"During my last year at Cambridge, I read with care and profound interest Humboldt's *Personal Narritive of Travels to the Equinoctal Regions of America.* This work, and Sir J. Hirschel's *Introduction to the Study of Natural Philosophy*, stirred up in me a burning desire to add even the most humble contribution to the noble structure of Natural Science. No one of a dozen books influenced me nearly so much as these. I copied out from Humboldt long passages about Teneriffe, and read them aloud to Henslow, Ramsay and Dawes... and some of the party declared that they would endeavour to go there; but I think they were only half in earnest. I was, however, quite in earnest, and got an introduction to a merchant in London to enquire about ships."

During the summer of 1831, Charles Darwin went to Wales to help Professor Sedgwick, who was studying the extremely ancient rock formations found there. When he returned to his father's house after this geological expedition, he found a letter from Henslow. This letter offered Darwin the post of unpaid naturalist on the *Beagle*, a small brig which was being sent by the British government to survey the coast of South America and to carry a chain of chronological measurements around the world.

Darwin was delighted and thrilled by this offer. He had a burning desire both to visit the glorious, almost-unknown regions described by his hero, Alexander von Humboldt, and to "add even the most humble contribution to the noble structure of Natural Science". His hopes and plans were blocked, however, by the opposition of his father, who felt that Charles was once again changing his vocation and drifting towards a life of sport and idleness. "If you can find any man of common sense who advises you to go", Robert Darwin told his son, "I will give my consent".

Deeply depressed by his father's words, Charles Darwin went to visit the estate of his uncle, Josiah Wedgwood, at Maer, where he always felt more

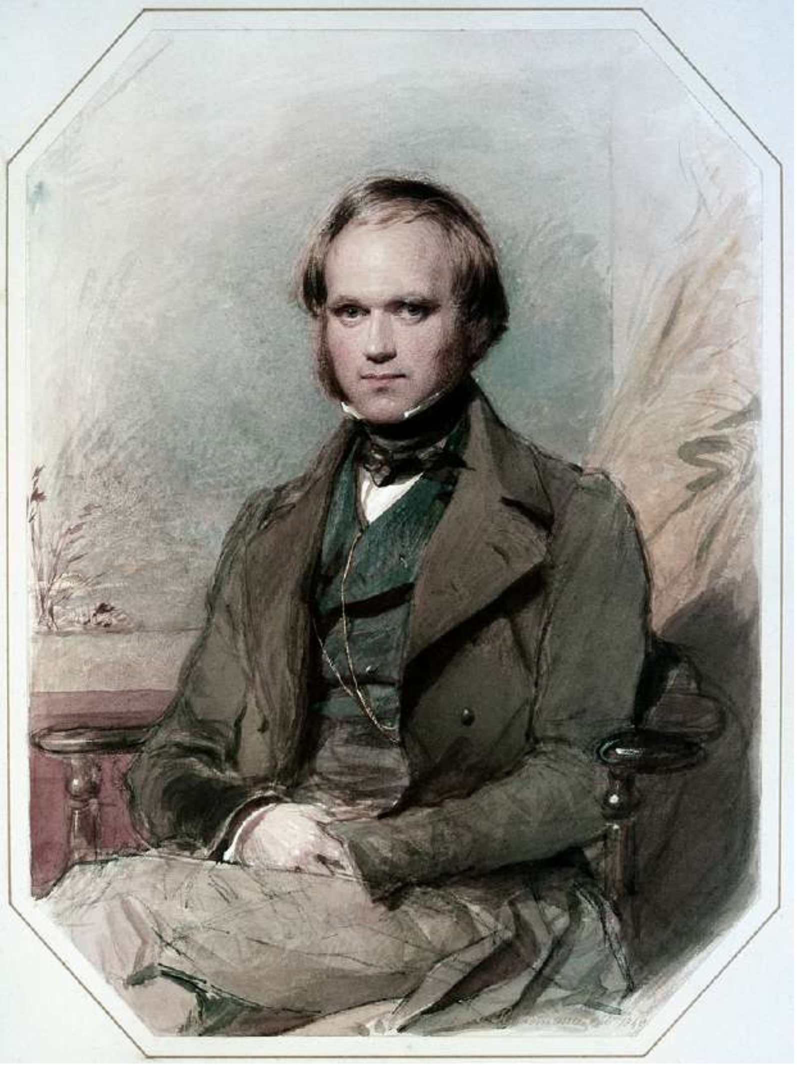

Figure 2.1: *Charles Darwin as a young man. Public domain, Wikimedia Commons*

comfortable than he did at home. In Darwin's words what happened next was the following:

"...My uncle sent for me, offering to drive me over to Shrewsbury and talk with my father, as my uncle thought that it would be wise in me to accept the offer. My father always maintained that my uncle was one of the most sensible men in the world, and he at once consented in the kindest possible manner. I had been rather extravagant while at Cambridge, and to console my father, I said that 'I should be deuced clever to spend more than my allowance whilst on board the *Beagle*', but he answered with a smile, 'But they tell me you are very clever!'."

Thus, on December 27, 1831, Charles Darwin started on a five-year voyage around the world. Not only was this voyage destined to change Darwin's life, but also, more importantly, it was destined to change man's view of his place in nature.

Lyell's hypothesis

As the *Beagle* sailed out of Devonport in gloomy winter weather, Darwin lay in his hammock, 22 years old, miserably seasick and homesick, knowing that he would not see his family and friends for many years. To take his mind away from his troubles, Darwin read a new book, which Henslow had recommended: Sir Charles Lyell's *Principles of Geology.* "Read it by all means", Henslow had written, "for it is very interesting; but do not pay any attention to it except in regard to facts, for it is altogether wild as far as theory goes."

Reading Lyell's book with increasing excitement and absorption, Darwin could easily see what Henslow found objectionable: Lyell, a follower of the great Scottish geologist, James Hutton (1726-1797), introduced a revolutionary hypothesis into geology. According to Lyell, "No causes whatever have, from the earliest times to which we can look back, to the present, ever acted, but those now acting; and they have never acted with different degrees of energy from those which they now exert".

This idea seemed dangerous and heretical to deeply religious men like Henslow and Sedgwick. They believed that the earth's geology had been shaped by Noah's flood, and perhaps by other floods and catastrophes which had occurred before the time of Noah. The great geological features of the earth, its mountains, valleys and planes, they viewed as marks left behind by the various catastrophes through which the earth had passed.

All this was now denied by Lyell. He believed the earth to be enormously old - thousands of millions of years old. Over this vast period of time, Lyell believed, the long-continued action of slow forces had produced the geological features of the earth. Great valleys had been carved out by glaciers and by the slow action of rain and frost; and gradual changes in the level of the land, continued over enormous periods of time, had built up towering mountain ranges.

Lyell's belief in the immense age of the earth, based on geological evidence, made the evolutionary theories of Darwin's grandfather suddenly seem more plausible. Given such vast quantities of time, the long-continued action of small forces might produce great changes in biology as well as in geology!

By the time the *Beagle* had reached San Thiago in the Cape Verde Islands, Darwin had thoroughly digested Lyell's book, with its dizzying prospects. Looking at the geology of San Thiago, he realized "the wonderful superiority of Lyell's manner of treating geology". Features of the island which would have been incomprehensible on the basis of the usual Catastrophist theories were clearly understandable on the basis of Lyell's hypothesis.

As the *Beagle* slowly made its way southward along the South American coast, Darwin went on several expeditions to explore the interior. On one of these trips, he discovered some fossil bones in the red mud of a river bed. He carefully excavated the area around them, and found the remains of nine huge extinct quadrupeds. Some of them were as large as elephants, and yet in structure they seemed closely related to living South American species. For example, one of the extinct animals which Darwin discovered resembled an armadillo except for its gigantic size.

The *Beagle* rounded Cape Horn, lashed by freezing waves so huge that it almost floundered. After the storm, when the brig was anchored safely in the channel of Tierra del Fuego, Darwin noticed how a Fuegan woman stood for hours and watched the ship, while sleet fell and melted on her naked breast, and on the new-born baby she was nursing. He was struck by the remarkable degree to which the Fuegans had adapted to their frigid environment, so that they were able to survive with almost no shelter, and with no clothes except a few stiff animal skins, which hardly covered them, in weather which would have killed ordinary people.

In 1835, as the *Beagle* made its way slowly northward, Darwin had many chances to explore the Chilean coast - a spectacularly beautiful country, shadowed by towering ranges of the Andes. One day, near Concepcion Bay, he experienced the shocks of a severe earthquake.

"It came on suddenly, and lasted two minutes", Darwin wrote, "The town of Concepcion is now nothing more than piles and lines of bricks, tiles and timbers."

Measurements which Darwin made showed him that the shoreline near Concepcion had risen at least three feet during the quake; and thirty miles away, Fitzroy, the captain of the *Beagle*, discovered banks of mussels ten feet

Figure 2.2: *Plate showing Fuegans from the voyage of the Beagle. Wellcome Images, Wikimedia Commons*

above the new high-water mark. This was dramatic confirmation of Lyell's theories! After having seen how much the level of the land was changed by a single earthquake, it was easy for Darwin to imagine that similar events, in the course of many millions of years, could have raised the huge wall of the Andes mountains.

In September, 1835, the *Beagle* sailed westward to the Galapagos Islands, a group of small rocky volcanic islands off the coast of Peru. On these islands, Darwin found new species of plants and animals which did not exist anywhere else in the world. In fact, he discovered that each of the islands had its own species, similar to the species found on the other islands, but different enough to be classified separately.

The Galapagos Islands contained thirteen species of finches, found nowhere else in the world, all basically alike in appearance, but differing in certain features especially related to their habits and diet. As he turned these facts over in his mind, it seemed to Darwin that the only explanation was that the thirteen species of Galapagos finches were descended from a single species, a few members of which had been carried to the islands by strong winds blowing from the South American mainland.

"Seeing this gradation and diversity of structure in one small, intimately related group of birds", Darwin wrote, "one might really fancy that from an original paucity of birds in this archipelago, one species had been taken and modified for different ends... Facts such as these might well undermine the stability of species."

As Darwin closely examined the plants and animals of the Galapagos Islands, he could see that although they were not quite the same as the corre-

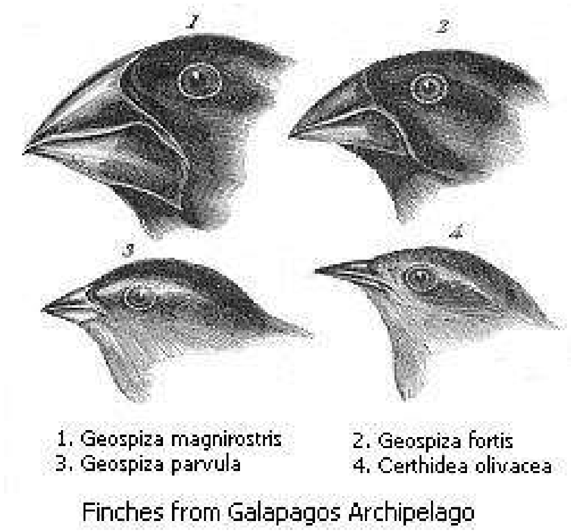

Figure 2.3: *Darwin's finches. Public domain, Wikimedia Commons*

sponding South American species, they were so strongly similar that it seemed most likely that all the Galapagos plants and animals had reached the islands from the South American mainland, and had since been modified to their present form.

The idea of the gradual modification of species could also explain the fact, observed by Darwin, that the fossil animals of South America were more closely related to African and Eurasian animals than were the living South American species. In other words, the fossil animals of South America formed a link between the living South American species and the corresponding animals of Europe, Asia and Africa. The most likely explanation for this was that the animals had crossed to America on a land bridge which had since been lost, and that they had afterwards been modified.

The Beagle continued its voyage westward, and Darwin had a chance to study the plants and animals of the Pacific Islands. He noticed that there were no mammals on these islands, except bats and a few mammals brought by sailors. It seemed likely to Darwin that all the species of the Pacific Islands had reached them by crossing large stretches of water after the volcanic islands had risen from the ocean floor; and this accounted for the fact that so many classes were missing. The fact that each group of islands had its own particular species, found nowhere else in the world, seemed to Darwin to be strong evidence that the species had been modified after their arrival. The strange marsupials of the isolated Australian continent also made a deep impression on Darwin.

The Origin of Species

Darwin had left England on the Beagle in 1831, an immature young man of 22, with no real idea of what he wanted to do with his life. He returned from the five-year voyage in 1836, a mature man, confirmed in his dedication to science, and with formidable powers of observation, deduction and generalization. Writing of the voyage, Darwin says:

"I have always felt that I owe to the voyage the first real education of my mind... Everything about which I thought or read was made to bear directly on what I had seen, or was likely to see, and this habit was continued during the five years of the voyage. I feel sure that it was this training which has enabled me to do whatever I have done in science."

Darwin returned to England convinced by what he had seen on the voyage that plant and animal species had not been independently and miraculously created, but that they had been gradually modified to their present form over millions of years of geological time.

Darwin was delighted to be home and to see his family and friends once again. To his uncle, Josiah Wedgwood, he wrote:

"My head is quite confused from so much delight, but I cannot allow my sister to tell you first how happy I am to see all my dear friends again... I am most anxious once again to see Maer and all its inhabitants."

In a letter to Henslow, he said:

"My dear Henslow, I do long to see you. You have been the kindest friend to me that ever man possessed. I can write no more, for I am giddy with joy and confusion."

In 1837, Darwin took lodgings at Great Marlborough Street in London, where he could work on his geological and fossil collections. He was helped in his work by Sir Charles Lyell, who became Darwin's close friend. In 1837 Darwin also began a notebook on *Transmutation of Species*. His *Journal of researches into the geology and natural history of the various countries visited by the H.M.S. Beagle* was published in 1839, and it quickly became a best-seller. It is one of the most interesting travel books ever written, and since its publication it has been reissued more than a hundred times.

These were very productive years for Darwin, but he was homesick, both for his father's home at the Mount and for his uncle's nearby estate at Maer, with its galaxy of attractive daughters. Remembering his many happy visits to Maer, he wrote:

"In the summer, the whole family used often to sit on the steps of the old portico, with the flower-garden in front, and with the steep, wooded bank opposite the house reflected in the lake, with here and there a fish rising, or a water-bird paddling about. Nothing has left a more vivid picture in my mind than these evenings at Maer."

In the summer of 1838, tired of his bachelor life in London, Darwin wrote in his diary:

"My God, it is intolerable to think of spending one's whole life like a neuter bee, working, working, and nothing after all! Imagine living all one's days in smoky, dirty London! Only picture to yourself a nice soft wife on a sofa with a good fire, and books and music perhaps.. Marry! Marry! Marry! Q.E.D."

Having made this decision, Darwin went straight to Maer and proposed to his pretty cousin, Emma Wedgwood, who accepted him at once, to the joy of both families. Charles and Emma Darwin bought a large and pleasant country house at Down, fifteen miles south of London; and there, in December, 1839, the first of their ten children was born.

Darwin chose this somewhat isolated place for his home because he was beginning to show signs of a chronic illness, from which he suffered for the rest of his life. His strength was very limited, and he saved it for his work by avoiding social obligations. His illness was never accurately diagnosed during his own lifetime, but the best guess of modern doctors is that he had Chagas' disease, a trypanasome infection transmitted by the bite of a South American blood-sucking bug.

Darwin was already convinced that species had changed over long periods of time, but what were the forces which caused this change? In 1838 he found the answer:

"I happened to read for amusement Malthus on *Population*", he wrote, "and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of the habits of animals and plants, it at once struck me that under these circumstances favorable variations would tend to be preserved, and unfavorable ones destroyed. The result would be the formation of new species"

"Here, then, I had at last got a theory by which to work; but I was so anxious to avoid prejudice that I determined not for some time to write down even the briefest sketch of it. In June, 1842, I first allowed myself the satisfaction of writing a very brief abstract of my theory in pencil in 33 pages; and this was enlarged during the summer of 1844 into one of 230 pages".

All of Darwin's revolutionary ideas were contained in the 1844 abstract, but he did not publish it! Instead, in an incredible Copernicus-like procrastination, he began a massive treatise on barnacles, which took him eight years to finish! Probably Darwin had a premonition of the furious storm of hatred and bigotry which would be caused by the publication of his heretical ideas.

Finally, in 1854, he wrote to his friend, Sir Joseph Hooker (the director of Kew Botanical Gardens), to say that he was at last resuming his work on the origin of species. Both Hooker and Lyell knew of Darwin's work on evolution, and for many years they had been urging him to publish it. By 1835, he had written eleven chapters of a book on the origin of species through natural selection; but he had begun writing on such a vast scale that the book might have run to four or five heavy volumes, which could have taken Darwin the rest of his life to complete.

Fortunately, this was prevented by the arrival at Down House of a bombshell in the form of a letter from a young naturalist named Alfred Russell Wallace. Like Darwin, Wallace had read Malthus' book *On Population*, and in a flash of insight during a period of fever in Malaya, he had arrived at a theory of evolution through natural selection which was precisely the same as the theory on which Darwin had been working for twenty years! Wallace enclosed with his letter a short paper entitled *On the Tendency of Varieties to Depart Indefinitely From the Original Type.* It was a perfect summary of Darwin's theory of evolution!

"I never saw a more striking coincidence", the stunned Darwin wrote to Lyell, "If Wallace had my MS. sketch, written in 1842, he could not have made a better short abstract! Even his terms now stand as heads of my chapters... I should be extremely glad now to publish a sketch of my general views in about a dozen pages or so; but I cannot persuade myself that I can do so honourably... I would far rather burn my whole book than that he or any other man should think that I have behaved in a paltry spirit."

Both Lyell and Hooker acted quickly and firmly to prevent Darwin from suppressing his own work, as he was inclined to do. In the end, they found a happy solution: Wallace's paper was read to the Linnean Society together with a short abstract of Darwin's work, and the two papers were published together in the proceedings of the society. The members of the Society listened in stunned silence. As Hooker wrote to Darwin the next day, the subject was "too novel and too ominous for the old school to enter the lists before armouring."

Lyell and Hooker then persuaded Darwin to write a book of moderate size on evolution through natural selection. As a result, in 1859, he published *The Origin of Species*, which ranks, together with Newton's *Principia* as one of the two greatest scientific books of all time. What Newton did for physics, Darwin did for biology: He discovered the basic theoretical principle which brings together all the experimentally-observed facts and makes them comprehensible; and he showed in detail how this basic principle can account for the facts in a very large number of applications.

Darwin's *Origin of Species* can still be read with enjoyment and fascination by a modern reader. His style is vivid and easy to read, and almost all of his conclusions are still believed to be true. He begins by discussing the variation of plants and animals under domestication, and he points out that the key to the changes produced by breeders is selection: If we want to breed fast horses,

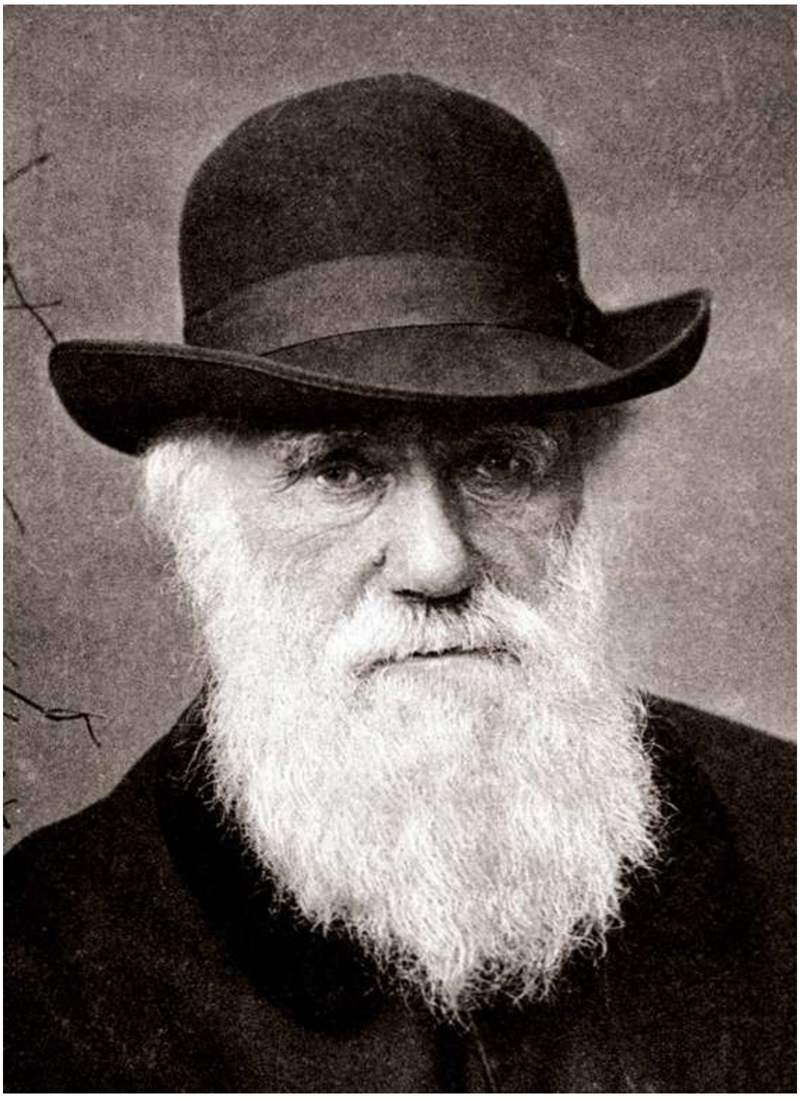

Figure 2.4: *Charles Darwin in 1880. The photograph is by Elliott and Fry. Public domain, Wikimedia Commons*

we select the fastest in each generation, and use them as parents for the next generation.

Darwin then points out that a closely similar process occurs in nature: Every plant or animal species produces so many offspring that if all of them survived and reproduced, the population would soon reach astronomical numbers. This cannot happen, since the space and food supply are limited; and therefore, in nature there is always a struggle for survival. Accidental variations which increase an organism's chance of survival are more likely to be propagated to subsequent generations than are harmful variations. By this mechanism, which Darwin called "natural selection", changes in plants and animals occur in nature just as they do under domestication.

If we imagine a volcanic island, pushed up from the ocean floor and completely uninhabited, we can ask what will happen as plants and animals begin to arrive. Suppose, for example, that a single species of bird arrives on the island. The population will first increase until the environment cannot support larger numbers, and it will then remain constant at this level. Over a long period of time, however, variations may accidentally occur in the bird population which allow the variant individuals to make use of new types of food; and thus, through variation, the population may be further increased. In this way, a single species "radiates" into a number of sub-species which fill every available ecological niche. The new species produced in this way will be similar to the original ancestor species, although they may be greatly modified in features which are related to their new diet and habits. Thus, for example, whales, otters and seals retain the general structure of land-going mammals, although they are greatly modified in features which are related to their aquatic way of life. This is the reason, according to Darwin, why vestigial organs are so useful in the classification of plant and animal species.

The classification of species is seen by Darwin as a geneological classification. All living organisms are seen, in his theory, as branches of a single family tree! This is a truly remarkable assertion, since the common ancestors of all living things must have been extremely simple and primitive; and it follows that the marvellous structures of the higher animals and plants, whose complexity and elegance utterly surpasses the products of human intelligence, were all produced, over thousands of millions of years, by random variation and natural selection!

Each structure and attribute of a living creature can therefore be seen as having a long history; and a knowledge of the evolutionary history of the organs and attributes of living creatures can contribute much to our understanding of them. For instance, studies of the evolutionary history of the brain and of instincts can contribute greatly to our understanding of psychology, as Darwin pointed out.

Among the many striking observations presented by Darwin to support his theory, are facts related to morphology and embryology. For example, Darwin includes the following quotation from the naturalist, von Baer:

"In my possession are two little embryos in spirit, whose names I have omitted to attach, and at present I am quite unable to say to what class they belong. They may be lizards or small birds, or very young mammalia, so complete is the similarity in the mode of formation of the head and trunk in these animals. The extremities, however, are still absent in these embryos. But even if they had existed in the earliest stage of their development, we should learn nothing, for the feet of lizards and mammals, the wings and feet of birds, no less than the hands and feet of man, all arise from the same fundamental form."

Darwin also quotes the following passage from G.H. Lewis: "The tadpole of the common Salamander has gills, and passes its existence in the water; but the *Salamandra atra*, which lives high up in the mountains, brings forth its young full-formed. This animal never lives in the water. Yet if we open a gravid female, we find tadpoles inside her with exquisitely feathered gills; and when placed in water, they swim about like the tadpoles of the common Salamander or water-newt. Obviously this aquatic organization has no reference to the future life of the animal, nor has it any adaption to its embryonic condition; it has solely reference to ancestral adaptations; it repeats a phase in the development of its progenitors."

Darwin points out that, "...As the embryo often shows us more or less plainly the structure of the less modified and ancient progenitor of the group, we can see why ancient and extinct forms so often resemble in their adult state the embryos of existing species."

No abstract of Darwin's book can do justice to it. One must read it in the original. He brings forward an overwhelming body of evidence to support his theory of evolution through natural selection; and he closes with the following words:

"It is interesting to contemplate a tangled bank, clothed with many plants of many different kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependant upon each other in so complex a manner, have all been produced by laws acting around us... There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning, endless forms most beautiful and wonderful have been and are being evolved."

Figure 2.5: *"Man is is But a Worm", a cartoon, published in Punch in 1882. Public domain, Wikimedia Commons*

Suggestions for further reading

1. Sir Julian Huxley and H.B.D. Kettlewell, *Charles Darwin and his World*, Thames and Hudson, London (1965).
2. Allan Moorehead, *Darwin and the Beagle*, Penguin Books Ltd. (1971).
3. Francis Darwin (editor), *The Autobiography of Charles Darwin and Selected Letters*, Dover, New York (1958).
4. Charles Darwin, *The Voyage of the Beagle*, J.M. Dent and Sons Ltd., London (1975).
5. Charles Darwin, *The Origin of Species*, Collier MacMillan, London (1974).
6. Charles Darwin, *The Expression of Emotions in Man and Animals*, The University of Chicago Press (1965).
7. D.W. Forest, *Francis Galton, The Life and Work of a Victorian Genius*, Paul Elek, London (1974).
8. Ruth Moore, *Evolution*, Time-Life Books (1962).

Chapter 3

MOLECULAR BIOLOGY AND EVOLUTION

Classical genetics

Charles Darwin postulated that natural selection acts on small inheritable variations in the individual members of a species. His opponents objected that these slight variations would be averaged away by interbreeding. Darwin groped after an answer to this objection, but he did not have one. However, unknown to Darwin, the answer had been uncovered several years earlier by an obscure Augustinian monk, Gregor Mendel, who was born in Silesia in 1822, and who died in Bohemia in 1884.

Mendel loved both botany and mathematics, and he combined these two interests in his hobby of breeding peas in the monastery garden. Mendel carefully self-pollinated his pea plants, and then wrapped the flowers to prevent pollination by insects. He kept records of the characteristics of the plants and their offspring, and he found that dwarf peas always breed true - they invariably produce other dwarf plants. The tall variety of pea plants, pollinated with themselves, did not always breed true, but Mendel succeeded in isolating a strain of true-breeding tall plants which he inbred over many generations.

Next he crossed his true-breeding tall plants with the dwarf variety and produced a generation of hybrids. All of the hybrids produced in this way were tall. Finally Mendel self-pollinated the hybrids and recorded the characteristics of the next generation. Roughly one quarter of the plants in this new generation were true-breeding tall plants, one quarter were true-breeding dwarfs, and one half were tall but not true-breeding.

Gregor Mendel had in fact discovered the existence of dominant and recessive genes. In peas, dwarfism is a recessive characteristic, while tallness is dominant. Each plant has two sets of genes, one from each parent. Whenever the gene for tallness is present, the plant is tall, regardless of whether it also has a gene for dwarfism. When Mendel crossed the pure-breeding dwarf plants with pure-breeding tall ones, the hybrids received one type of gene from each parent. Each hybrid had a tall gene and a dwarf gene; but the tall gene was dominant, and therefore all the hybrids were tall. When the hybrids were self-pollinated or crossed with each other, a genetic lottery took place. In the next generation, through the laws of chance, a quarter of the plants had two dwarf genes, a quarter had two tall genes, and half had one of each kind.

Mendel published his results in the *Transactions of the Brünn Natural History Society* in 1865, and no one noticed his paper[1]. At that time, Austria was being overrun by the Prussians, and people had other things to think about. Mendel was elected Abbot of his monastery; he grew too old and fat to bend over and cultivate his pea plants; his work on heredity was completely forgotten, and he died never knowing that he would one day be considered to be the founder of modern genetics.

In 1900 the Dutch botanist named Hugo de Vries, working on evening primroses, independently rediscovered Mendel's laws. Before publishing, he looked through the literature to see whether anyone else had worked on the subject, and to his amazement he found that Mendel had anticipated his great discovery by 35 years. De Vries could easily have published his own work without mentioning Mendel, but his honesty was such that he gave Mendel full credit and mentioned his own work only as a confirmation of Mendel's laws. Astonishingly, the same story was twice repeated elsewhere in Europe during the same year. In 1900, two other botanists (Correns in Berlin and Tschermak in Vienna) independently rediscovered Mendel's laws, looked through the literature, found Mendel's 1865 paper, and gave him full credit for the discovery.

Besides rediscovering the Mendelian laws for the inheritance of dominant and recessive characteristics, de Vries made another very important discovery: He discovered genetic mutations - sudden unexplained changes of form which can be inherited by subsequent generations. In growing evening primroses, de Vries found that sometimes, but very rarely, a completely new variety would suddenly appear, and he found that the variation could be propagated to the following generations. Actually, mutations had been observed before the time of de Vries. For example, a short-legged mutant sheep had suddenly appeared during the 18th century; and stock-breeders had taken advantage of this mutation to breed sheep that could not jump over walls. However, de Vries was the first scientist to study and describe mutations. He noticed that most mutations are harmful, but that a very few are beneficial, and those few tend in nature to be propagated to future generations.

[1] Mendel sent a copy of his paper to Darwin; but Darwin, whose German was weak, seems not to have read it.

After the rediscovery of Mendel's work by de Vries, many scientists began to suspect that chromosomes might be the carriers of genetic information. The word "chromosome" had been invented by the German physiologist, Walther Flemming, to describe the long, threadlike bodies which could be seen when cells were stained and examined through, the microscope during the process of division. It had been found that when an ordinary cell divides, the chromosomes also divide, so that each daughter cell has a full set of chromosomes.

The Belgian cytologist, Edouard van Benedin, had shown that in the formation of sperm and egg cells, the sperm and egg receive only half of the full number of chromosomes. It had been found that when the sperm of the father combines with the egg of the mother in sexual reproduction, the fertilized egg again has a full set of chromosomes, half coming from the mother and half from the father. This was so consistent with the genetic lottery studied by Mendel, de Vries and others, that it seemed almost certain that chromosomes were the carriers of genetic information.

The number of chromosomes was observed to be small (for example, each normal cell of a human has 46 chromosomes); and this made it obvious that each chromosome must contain thousands of genes. It seemed likely that all of the genes on a particular chromosome would stay together as they passed through the genetic lottery; and therefore certain characteristics should always be inherited together.

This problem had been taken up by Thomas Hunt Morgan, a professor of experimental zoology working at Colombia University. He found it convenient to work with fruit flies, since they breed with lightning-like speed and since they have only four pairs of chromosomes.

Morgan found that he could raise enormous numbers of these tiny insects with almost no effort by keeping them in gauze-covered glass milk bottles, in the bottom of which he placed mashed bananas. In 1910, Morgan found a mutant white-eyed male fly in one of his milk-bottle incubators. He bred this fly with a normal red-eyed female, and produced hundreds of red-eyed hybrids. When he crossed the red-eyed hybrids with each other, half of the next generation were red-eyed females, a quarter were red-eyed males, and a quarter were white-eyed males. There was not one single white-eyed female! This indicated that the mutant gene for white eyes was on the same chromosome as the gene for the male sex.

As Morgan continued his studies of genetic linkages, however, it became clear that the linkages were not absolute. There was a tendency for all the genes on the same chromosome to be inherited together; but on rare occasions there were "crosses", where apparently a pair of chromosomes broke at some point and exchanged segments. By studying these crosses statistically, Morgan and his "fly squad" were able to find the relative positions of genes on the chromosomes. They reasoned that the probability for a cross to separate two genes should be proportional to the distance between the two genes on the chromosome. In this way, after 17 years of work and millions of fruit flies, Thomas Hunt Morgan and his coworkers were able to make maps of the fruit fly chromosomes showing the positions of the genes.

This work had been taken a step further by Hermann J. Muller, a member of Morgan's "fly squad", who exposed hundreds of fruit flies to X-rays. The result was a spectacular outbreak of man-made mutations in the next generation.

"They were a motley throng", recalled Muller. Some of the mutant flies had almost no wings, others bulging eyes, and still others brown, yellow or purple eyes; some had no bristles, and others curly bristles. Muller's experiments indicated that mutations can be produced by radiation-induced physical damage; and he guessed that such damage alters the chemical structure of genes.

In spite of the brilliant work by Morgan and his collaborators, no one had any idea of what a gene really was.

The structure of DNA

Until 1944, most scientists had guessed that the genetic message was carried by the proteins of the chromosome. In 1944, however, O.T. Avery and his co-workers at the laboratory of the Rockefeller Institute in New York performed a critical experiment, which proved that the material which carries genetic information is not protein, but deoxyribonucleic acid (DNA) - a giant chain-like molecule which had been isolated from cell nuclei by the Swiss chemist, Friedrich Miescher.

Avery had been studying two different strains of pneumococci, the bacteria which cause pneumonia. One of these strains, the S-type, had a smooth coat, while the other strain, the R-type, lacked an enzyme needed for the manufacture of a smooth carbohydrate coat. Hence, R-type pneumococci had a rough appearance under the microscope. Avery and his co-workers were able to show that an extract from heat-killed S-type pneumococci could convert the living R-type species permanently into S-type; and they also showed that this extract consisted of pure DNA.

In 1947, the Austrian-American biochemist, Erwin Chargaff, began to study the long, chainlike DNA molecules. It had already been shown by Levine and Todd that chains of DNA are built up of four bases: adenine (A), thymine (T), guanine (G) and cytosine (C), held together by a sugar-phosphate backbone. Chargaff discovered that in DNA from the nuclei of living cells, the amount of A always equals the amount of T; and the amount of G always equals the amount of C.

When Chargaff made this discovery, neither he nor anyone else understood its meaning. However, in 1953, the mystery was completely solved by Rosalind Franklin and Maurice Wilkins at Kings College, London, together with James Watson and Francis Crick at Cambridge University. By means of X-ray diffraction techniques, Wilkins and Franklin obtained crystallographic information about the structure of DNA. Using this information, together with Linus Pauling's model-building methods, Crick and Watson proposed a detailed structure for the giant DNA molecule.

The discovery of the molecular structure of DNA was an event of enormous importance for genetics, and for biology in general. The structure was a revelation! The giant, helical DNA molecule was like a twisted ladder: Two long, twisted sugar-phosphate backbones formed the outside of the ladder, while the rungs were formed by the base pairs, A, T, G and C. The base adenine (A) could only be paired with thymine (T), while guanine (G) fit only with cytosine (C). Each base pair was weakly joined in the center by hydrogen bonds - in other words, there was a weak point in the center of each rung of the ladder - but the bases were strongly attached to the sugar-phosphate backbone. In their 1953 paper, Crick and Watson wrote:

"It has not escaped our notice that the specific pairing we have postulated suggests a possible copying mechanism for genetic material". Indeed, a sudden blaze of understanding illuminated the inner workings of heredity, and of life itself.

If the weak hydrogen bonds in the center of each rung were broken, the ladderlike DNA macromolecule could split down the center and divide into two single strands. Each single strand would then become a template for the formation of a new double-stranded molecule.

Because of the specific pairing of the bases in the Watson-Crick model of DNA, the two strands had to be complementary. T had to be paired with A, and G with C. Therefore, if the sequence of bases on one strand was (for example) TTTGCTAAAGGTGAACCA... , then the other strand necessarily had to have the sequence AAACGATTTCCACTTGGT... The Watson-Crick model of DNA made it seem certain that all the genetic information needed for producing a new individual is coded into the long, thin, double-stranded DNA molecule of the cell nucleus, written in a four-letter language whose letters are the bases, adenine, thymine, guanine and cytosine.

The solution of the DNA structure in 1953 initiated a new kind of biology - molecular biology. This new discipline made use of recently-discovered physical techniques - X-ray diffraction, electron microscopy, electrophoresis, chromatography, ultracentrifugation, radioactive tracer techniques, autoradiography, electron spin resonance, nuclear magnetic resonance and ultraviolet spectroscopy. In the 1960's and 1970's, molecular biology became the most exciting and rapidly-growing branch of science.

Protein structure

In England, J.D. Bernal and Dorothy Crowfoot Hodgkin pioneered the application of X-ray diffraction methods to the study of complex biological molecules. In 1949, Hodgkin determined the structure of penicillin; and in 1955, she followed this with the structure of vitamin B12. In 1960, Max Perutz and John C. Kendrew obtained the structures of the blood proteins myoglobin and hemoglobin. This was an impressive achievement for the Cambridge crystallographers, since the hemoglobin molecule contains roughly 12,000 atoms.

The structure obtained by Perutz and Kendrew showed that hemoglobin is a long chain of amino acids, folded into a globular shape, like a small, crumpled ball of yarn. They found that the amino acids with an affinity for water were on the outside of the globular molecule; while the amino acids for which contact with water was energetically unfavorable were hidden on the inside. Perutz and Kendrew deduced that the conformation of the protein - the way in which the chain of amino acids folded into a 3-dimensional structure - was determined by the sequence of amino acids in the chain.

In 1966, D.C. Phillips and his co-workers at the Royal Institution in London found the crystallographic structure of the enzyme lysozyme (an egg-white protein which breaks down the cell walls of certain bacteria). Again, the structure showed a long chain of amino acids, folded into a roughly globular shape. The amino acids with hydrophilic groups were on the outside, in contact with water, while those with hydrophobic groups were on the inside. The structure of lysozyme exhibited clearly an active site, where sugar molecules of bacterial cell walls were drawn into a mouth-like opening and stressed by electrostatic forces, so that bonds between the sugars could easily be broken.

Meanwhile, at Cambridge University, Frederick Sanger developed methods for finding the exact sequence of amino acids in a protein chain. In 1945, he discovered a compound (2,4-dinitrofluorobenzene) which attaches itself preferentially to one end of a chain of amino acids. Sanger then broke down the chain into individual amino acids, and determined which of them was connected to his reagent. By applying this procedure many times to fragments of larger chains, Sanger was able to deduce the sequence of amino acids in complex proteins. In 1953, he published the sequence of insulin. This led, in 1964, to the synthesis of insulin.

The biological role and structure of proteins which began to emerge was as follows: A mammalian cell produces roughly 10,000 different proteins. All enzymes are proteins; and the majority of proteins are enzymes - that is, they catalyze reactions involving other biological molecules. All proteins are built from chainlike polymers, whose monomeric sub-units are the following twenty amino acids: glycine, aniline, valine, isoleucine, leucine, serine, threonine, pro-line, aspartic acid, glutamic acid, lysine, arginine, asparagine, glutamine, cysteine, methionine, tryptophan, phenylalanine, tyrosine and histidine. These individual amino acid monomers may be connected together into a polymer (called a polypeptide) in any order - hence the great number of possibilities. In such a polypeptide, the backbone is a chain of carbon and nitrogen atoms showing the pattern ...-C-C-N-C-C-N-C-C-N-...and so on. The -C-C-N- repeating unit is common to all amino acids. Their individuality is derived from differences in the side groups which are attached to the universal -C-C-N- group.

Some proteins, like hemoglobin, contain metal atoms, which may be oxidized or reduced as the protein performs its biological function. Other proteins, like lysozyme, contain no metal atoms, but instead owe their biological activity to an active site on the surface of the protein molecule. In 1909, the English physician, Archibald Garrod, had proposed a one-gene-one-protein hypothesis. He believed that hereditary diseases are due to the absence of specific enzymes. According to Garrod's hypothesis, damage suffered by a gene results in the faulty synthesis of the corresponding enzyme, and loss of the enzyme ultimately results in the symptoms of the hereditary disease.

In the 1940's, Garrod's hypothesis was confirmed by experiments on the mold, Neurospora, performed at Stanford University by George Beadle and Edward Tatum. They demonstrated that mutant strains of the mold would grow normally, provided that specific extra nutrients were added to their diets. The need for these dietary supplements could in every case be traced to the lack of a specific enzyme in the mutant strains. Linus Pauling later extended these ideas to human genetics by showing that the hereditary disease, sickle-cell anemia, is due to a defect in the biosynthesis of hemoglobin.

RNA and ribosomes

Since DNA was known to carry the genetic message, coded into the sequence of the four nucleotide bases, A, T, G and C, and since proteins were known to be composed of specific sequences of the twenty amino acids, it was logical to suppose that the amino acid sequence in a protein was determined by the base sequence of DNA. The information somehow had to be read from the DNA and used in the biosynthesis of the protein.

It was known that, in addition to DNA, cells also contain a similar, but not quite identical, polynucleotide called ribonucleic acid (RNA). The sugar-phosphate backbone of RNA was known to differ slightly from that of DNA; and in RNA, the nucleotide thymine (T) was replaced by a chemically similar nucleotide, uracil (U). Furthermore, while DNA was found only in cell nuclei, RNA was found both in cell nuclei and in the cytoplasm of cells, where protein synthesis takes place. Evidence accumulated indicating that genetic information is first transcribed from DNA to RNA, and afterwards translated from RNA into the amino acid sequence of proteins.

At first, it was thought that RNA might act as a direct template, to which successive amino acids were attached. However, the appropriate chemical complementarity could not be found; and therefore, in 1955, Francis Crick proposed that amino acids are first bound to an adaptor molecule, which is afterward bound to RNA.

In 1956, George Emil Palade of the Rockefeller Institute used electron microscopy to study subcellular particles rich in RNA (ribosomes). Ribosomes were found to consist of two subunits - a smaller subunit, with a molecular weight one million times the weight of a hydrogen atom, and a larger subunit with twice this weight.

It was shown by means of radioactive tracers that a newly synthesized protein molecule is attached temporarily to a ribosome, but neither of the two subunits of the ribosome seemed to act as a template for protein synthesis. Instead, Palade and his coworkers found that genetic information is carried from DNA to the ribosome by a messenger RNA molecule (mRNA). Electron microscopy revealed that mRNA passes through the ribosome like a punched computer tape passing through a tape-reader. It was found that the adapter molecules, whose existence Crick had postulated, were smaller molecules of RNA; and these were given the name “transfer RNA” (tRNA). It was shown that, as an mRNA molecule passes through a ribosome, amino acids attached to complementary tRNA adaptor molecules are added to the growing protein chain.

The relationship between DNA, RNA, the proteins and the smaller molecules of a cell was thus seen to be hierarchical: The cell’s DNA controlled its proteins (through the agency of RNA); and the proteins controlled the synthesis and metabolism of the smaller molecules.

The genetic code

In 1955, Severo Ochoa, at New York University, isolated a bacterial enzyme (RNA polymerase) which was able join the nucleotides A, G, U and C so that they became an RNA strand. One year later, this feat was repeated for DNA by Arthur Kornberg.

With the help of Ochoa’s enzyme, it was possible to make synthetic RNA molecules containing only a single nucleotide - for example, one could join uracil molecules into the ribonucleic acid chain, ...U-U-U-U-U-U-... In 1961, Marshall Nirenberg and Heinrich Matthaei used synthetic poly-U as messen-

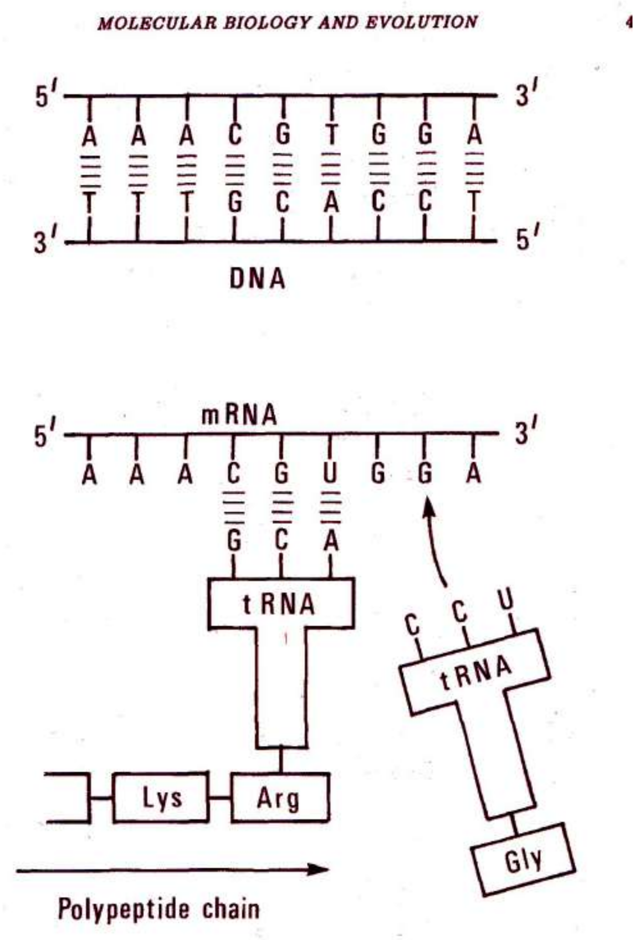

Figure 3.1: Information coded on DNA molecules in the cell nucleus is transcribed to mRNA molecules. The messenger RNA molecules in turn provide information for the amino acid sequence in protein synthesis.

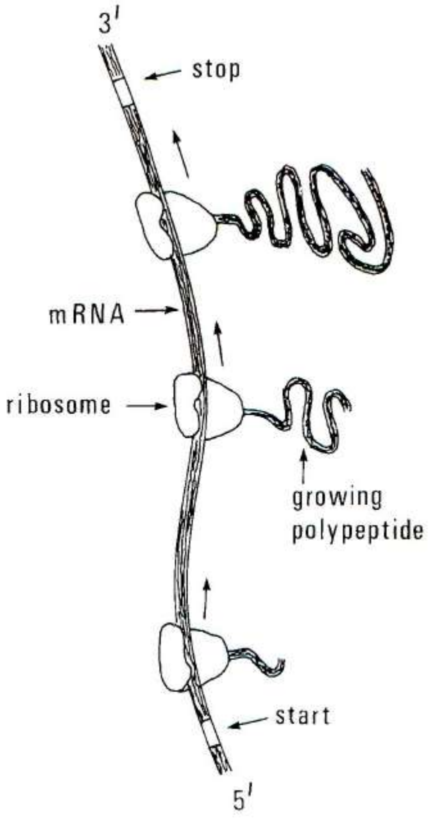

Figure 3.2: mRNA passes through the ribosome like a punched computer tape passing through a tape-reader.

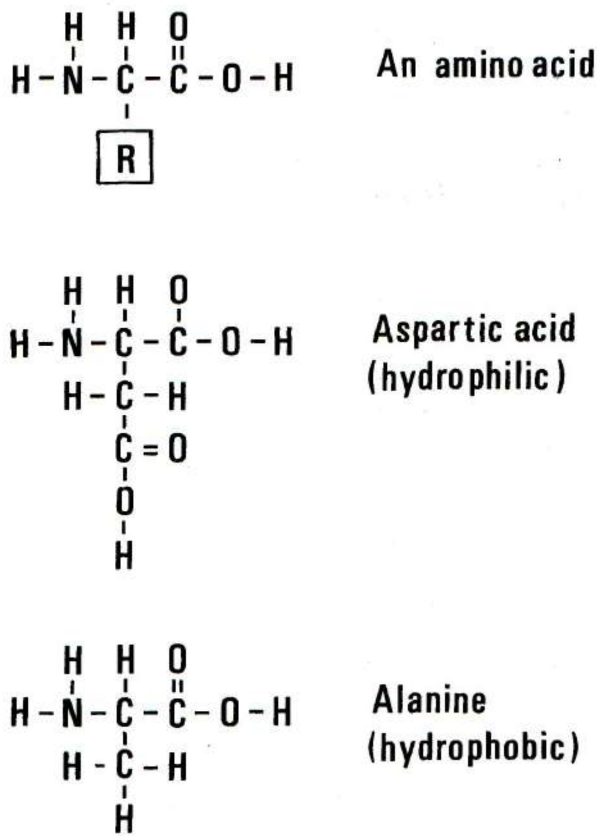

Figure 3.3: This figure shows aspartic acid, whose residue (R) is hydrophilic, contrasted with alanine, whose residue is hydrophobic.

ger RNA in protein synthesis; and they found that only polyphenylalanine was synthesized. In the same year, Sydney Brenner and Francis Crick reported a series of experiments on mutant strains of the bacteriophage, T4. The experiments of Brenner and Crick showed that whenever a mutation added or deleted either one or two base pairs, the proteins produced by the mutants were highly abnormal and non-functional. However, when the mutation added or subtracted three base pairs, the proteins often were functional. Brenner and Crick concluded that the genetic language has three-letter words (codons). With four different "letters", A, T, G and C, this gives sixty-four possible codons - more than enough to specify the twenty different amino acids.

In the light of the phage experiments of Brenner and Crick, Nirenberg and Matthaei concluded that the genetic code for phenylalanine is UUU in RNA and TTT in DNA. The remaining words in the genetic code were worked out by H. Gobind Khorana of the University of Wisconsin, who used other mRNA sequences (such as GUGUGU..., AAGAAGAAG... and GUUGUUGUU...) in protein synthesis. By 1966, the complete genetic code, specifying amino acids in terms of three-base sequences, was known. The code was found to be the same for all species studied, no matter how widely separated they were in form; and this showed that all life on earth belongs to the same family, as postulated by Darwin.

Genetic engineering

In 1970, Hamilton Smith of Johns Hopkins University observed that when the bacterium Haemophilus influenzae is attacked by a bacteriophage (a virus parasitic on bacteria), it can defend itself by breaking down the DNA of the phage. Following up this observation, he introduced DNA from the bacterium E. coli into H. influenzae. Again the foreign DNA was broken down.

Smith had, in fact, discovered the first of a class of bacterial enzymes which came to be called "restriction enzymes" or "restriction nucleases". Almost a hundred other restriction enzymes were subsequently discovered, and each was found to cut DNA at a specific base sequence. Smith's colleague, Daniel Nathans, used the restriction enzymes Hin dll and Hin dill to produce the first "restriction map" of the DNA in a virus.

In 1971 and 1972, Paul Berg, and his co-workers Peter Lobban, Dale Kaiser and David Jackson at Stanford University, developed methods for adding cohesive ends to DNA fragments. Berg and his group used the calf thymus enzyme, terminal transferase, to add short, single-stranded polynucleotide segments to DNA fragments. For example, if they added the single-stranded segment AAAA to one fragment, and TTTT to another, then the two ends joined spontaneously when the fragments were incubated together. In this way Paul Berg

Table 3.1: **The genetic code**

TTT=Phe	TCT=Ser	TAT=Tyr	TGT=Cys
TTC=Phe	TCC=Ser	TAC=Tyr	TGC=Cys
TTA=Leu	TCA=Ser	TAA=Ter	TGA=Ter
TTG=Leu	TGC=Ser	TAG=Ter	TGG=Trp
CTT=Leu	CCT=Pro	CAT=His	CGT=Arg
CTC=Leu	CCC=Pro	CAC=His	CGC=Arg
CTA=Leu	CCA=Pro	CAA=Gln	CGA=Arg
CTG=Leu	CGC=Pro	CAG=Gln	CGG=Arg
ATT=Ile	ACT=Thr	AAT=Asn	AGT=Ser
ATC=Ile	ACC=Thr	AAC=Asn	AGC=Ser
ATA=Ile	ACA=Thr	AAA=Lys	AGA=Arg
ATG=Met	AGC=Thr	AAG=Lys	AGG=Arg
GTT=Val	GCT=Ala	GAT=Asp	GGT=Gly
GTC=Val	GCC=Ala	GAC=Asp	GGC=Gly
GTA=Val	GCA=Ala	GAA=Glu	GGA=Gly
GTG=Val	GGC=Ala	GAG=Glu	GGG=Gly

and his group made the first recombinant DNA molecules.

The restriction enzyme Eco RI, isolated from the bacterium E. coli, was found to recognize the pattern, GAATTC, in one strand of a DNA molecule, and the complementary pattern, CTTAAG, in the other strand. Instead of cutting both strands in the middle of the six-base sequence, Eco RI was observed to cut both strands between G and A. Thus, each side of the cut was left with a “sticky end” - a five-base single-stranded segment, attached to the remainder of the double-stranded DNA molecule.

In 1972, Janet Mertz and Ron Davis, working at Stanford University, demonstrated that DNA strands cut with Eco RI could be rejoined by means of another enzyme - a DNA ligase. More importantly, when DNA strands from two different sources were cut with Eco RI, the sticky end of one fragment could form a spontaneous temporary bond with the sticky end of the other fragment. The bond could be made permanent by the addition of DNA ligase, even when the fragments came from different sources. Thus, DNA fragments from different organisms could be joined together.

Bacteria belong to a class of organisms (prokaryotes) whose cells do not have a nucleus. Instead, the DNA of the bacterial chromosome is arranged in a large loop. In the early 1950’s, Joshua Lederberg had discovered that bacteria can exchange genetic information. He found that a frequently-exchanged gene, the F-factor (which conferred fertility), was not linked to other bacterial genes; and he deduced that the DNA of the F-factor was not physically a part of the main bacterial chromosome. In 1952, Lederberg coined the word "plasmid" to denote any extrachromosomal genetic system. In 1959, it was discovered in Japan that genes for resistance to antibiotics can be exchanged between bacteria; and the name "R-factors" was given to these genes. Like the F-factors, the R-factors did not seem to be part of the main loop of bacterial DNA.

Because of the medical implications of this discovery, much attention was focused on the R-factors. It was found that they are plasmids, small loops of DNA existing inside the bacterial cell but not attached to the bacterial chromosome. Further study showed that, in general, between one percent and three percent of bacterial genetic information is carried by plasmids, which can be exchanged freely even between different species of bacteria.

In the words of the microbiologist, Richard Novick, "Appreciation of the role of plasmids has produced a rather dramatic shift in biologists' thinking about genetics. The traditional view was that the genetic makeup of a species was about the same from one cell to another, and was constant over long periods of time. Now a significant proportion of genetic traits are known to be variable (present in some individual cells or strains, absent in others), labile (subject to frequent loss or gain) and mobile - all because those traits are associated with plasmids or other atypical genetic systems."

In 1973, Herbert Boyer, Stanley Cohen and their co-workers at Stanford University and the University of California carried out experiments in which they inserted foreign DNA segments, cut with Eco RI, into plasmids (also cut with Eco RI). They then resealed the plasmid loops with DNA ligase. Finally, bacteria were infected with the gene-spliced plasmids. The result was a new strain of bacteria, capable of producing an additional protein coded by the foreign DNA segment which had been spliced into the plasmids.

Cohen and Boyer used plasmids containing a gene for resistance to an antibiotic, so that a few gene-spliced bacteria could be selected from a large population by treating the culture with the antibiotic. The selected bacteria, containing both the antibiotic-resistance marker and the foreign DNA, could then be cloned on a large scale; and in this way a foreign gene could be "cloned". The gene-spliced bacteria were chimeras, containing genes from two different species.

The new recombinant DNA techniques of Berg, Cohen and Boyer had revolutionary implications: It became possible to produce many copies of a given DNA segment, so that its base sequence could be determined. With the help of direct DNA-sequencing methods developed by Frederick Sanger and Walter

Gilbert, the new cloning techniques could be used for mapping and sequencing genes.

Since new bacterial strains could be created, containing genes from other species, it became possible to produce any protein by cloning the corresponding gene. Proteins of medical importance could be produced on a large scale. Thus, the way was open for the production of human insulin, interferon, serum albumin, clotting factors, vaccines, and protein hormones such as ACTH, human growth factor and leuteinizing hormone.

It also became possible to produce enzymes of industrial and agricultural importance by cloning gene-spliced bacteria. Since enzymes catalyze reactions involving smaller molecules, the production of these substrate molecules through gene-splicing also became possible.

It was soon discovered that the possibility of producing new, transgenic organisms was not limited to bacteria. Gene-splicing was also carried out on higher plants and animals as well as on fungi. It was found that the bacterium Agrobacterium tumefaciens contains a tumor-inducing (Ti) plasmid capable of entering plant cells and producing a crown gall. Genes spliced into the Ti plasmid quite frequently became incorporated in the plant chromosome, and afterwards were inherited in a stable, Mendelian fashion.

Transgenic animals were produced by introducing foreign DNA into embryo-derived stem cells (ES cells). The gene-spliced ES cells were then selected, cultured and introduced into a blastocyst, which afterwards was implanted in a foster-mother. The resulting chimeric animals were bred, and stable transgenic lines selected.

Thus, for the first time, humans had achieved direct control over the process of evolution. Selective breeding to produce new plant and animal varieties was not new - it is one of the oldest techniques of civilization. However, the degree, precision, and speed of intervention which recombinant DNA made possible was entirely new. In the 1970's it became possible to mix the genetic repertoires of different species: The genes of mice and men could be spliced together into new, man-made forms of life!

The Polymerase Chain Reaction

One day in the early 1980's, an American molecular biologist, Kary Mullis, was driving to his mountain cabin with his girl friend. The journey was a long one, and to pass the time, Kary Mullis turned over and over in his mind a problem which had been bothering him: He worked for a California biotechnology firm, and like many other molecular biologists he had been struggling to analyze very small quantities of DNA. Mullis realized that it would be desirable have a highly sensitive way of replicating a given DNA segment - a method much more sensitive than cloning. As he drove through the California mountains, he considered many ways of doing this, rejecting one method after the other as impracticable. Finally a solution came to him; and it seemed so simple that he could hardly believe that he was the first to think of it. He was so excited that he immediately pulled over to the side of the road and woke his sleeping girlfriend to tell her about his idea. Although his girlfriend was not entirely enthusiastic about being wakened from a comfortable sleep to be presented with a lecture on biochemistry, Kary Mullis had in fact invented a technique which was destined to revolutionize DNA technology: the Polymerase Chain Reaction (PCR)[2].

The technique was as follows: Begin with a small sample of the genomic DNA to be analyzed. (The sample may be extremely small - only a few molecules.) Heat the sample to 95 °C to separate the double-stranded DNA molecule into single strands. Suppose that on the long DNA molecule there is a target segment which one wishes to amplify. If the target segment begins with a known sequence of bases on one strand, and ends with a known sequence on the complementary strand, then synthetic "primer" oligonucleotides[3] with these known beginning ending sequences are added in excess. The temperature is then lowered to 50-60 °C, and at the lowered temperature, the "start" primer attaches itself to one DNA strand at the beginning of the target segment, while the "stop" primer becomes attached to the complementary strand at the other end of the target segment. Polymerase (an enzyme which aids the formation of double-stranded DNA) is then added, together with a supply of nucleotides. On each of the original pieces of single-stranded DNA, a new complementary strand is generated with the help of the polymerase. Then the temperature is again raised to 95 °C, so that the double-stranded DNA separates into single strands, and the cycle is repeated.

In the early versions of the PCR technique, the polymerase was destroyed by the high temperature, and new polymerase had to be added for each cycle. However, it was discovered that polymerase from the bacterium Thermus aquaticus would withstand the high temperature. (Thermus aquaticus lives in hot springs.) This discovery greatly simplified the PCR technique. The temperature could merely be cycled between the high and low temperatures, and with each cycle, the population of the target segment doubled, concentrations of primers, deoxynucleotides and polymerase being continuously present.

After a few cycles of the PCR reaction, copies of copies begin to predominate over copies of the original genomic DNA. These copies of copies have a standard length, always beginning on one strand with the start primer, and

[2] The flash of insight didn't take long, but at least six months of hard work were needed before Mullis and his colleagues could convert the idea to reality.

[3] Short segments of single-stranded DNA.

ending on that strand with the complement of the stop primer.

Two main variants of the PCR technique are possible, depending on the length of the oligonucleotide primers: If, for example, trinucleotides are used as start and stop primers, they can be expected to match the genomic DNA at many points. In that case, after a number of PCR cycles, populations of many different segments will develop. Within each population, however, the length of the replicated segment will be standardized because of the predominance of copies of copies. When the resulting solution is placed on a damp piece of paper or a gel and subjected to the effects of an electric current (electrophoresis), the populations of different molecular weights become separated, each population appearing as a band. The bands are profiles of the original genomic DNA; and this variant of the PCR technique can be used in evolutionary studies to determine the degree of similarity of the genomic DNA of two species.

On the other hand, if the oligonucleotide primers contain as many as 20 nucleotides, they will be highly specific and will bind only to a particular target sequence of the genomic DNA. The result of the PCR reaction will then be a single population, containing only the chosen target segment. The PCR reaction can be thought of as autocatalytic, and as we shall see in the next section, autocatylitic systems play an important role in modern theories of the origin of life.

Theories of chemical evolution towards the origin of life

The possibility of an era of chemical evolution prior to the origin of life entered the thoughts of Charles Darwin, but he considered the idea to be much too speculative to be included in his published papers and books. However, in February 1871, he wrote a letter to his close friend Sir Joseph Hooker containing the following words:

"It is often said that all the conditions for the first production of a living organism are now present, which could ever have been present. But if (and oh what a big if) we could conceive in some warm little pond with all sorts of ammonia and phosphoric salts, - light, heat, electricity etc. present, that a protein compound was chemically formed, ready to undergo still more complex changes, at the present day such matter would be instantly devoured, or absorbed, which would not have been the case before living creatures were formed."

The last letter which Darwin is known to have dictated and signed before his death in 1882 also shows that he was thinking about this problem: "You have expressed quite correctly my views", Darwin wrote, "where you said that I had intentionally left the question of the Origin of Life uncanvassed as being altogether ultra vires in the present state of our knowledge, and that I dealt only with the manner of succession. I have met with no evidence that seems in the least trustworthy, in favor of so-called Spontaneous Generation. (However) I believe that I have somewhere said (but cannot find the passage) that the principle of continuity renders it probable that the principle of life will hereafter be shown to be a part, or consequence, of some general law.."

Modern researchers, picking up the problem where Darwin left it, have begun to throw a little light on the problem of chemical evolution towards the origin of life. In the 1930's J.B.S. Haldane in England and A.I. Oparin in Russia put forward theories of an era of chemical evolution prior to the appearance of living organisms.

In 1924 Oparin published a pamphlet on the origin of life. An expanded version of this pamphlet was translated into English and appeared in 1936 as a book entitled *The Origin of Life on Earth*. In this book Oparin pointed out that the time when life originated, conditions on earth were probably considerably different than they are at present: The atmosphere probably contained very little free oxygen, since free oxygen is produced by photosynthesis which did not yet exist. On the other hand, he argued, there were probably large amounts of methane and ammonia in the earth's primitive atmosphere[4]. Thus, before the origin of life, the earth probably had a reducing atmosphere rather than an oxidizing one. Oparin believed that energy-rich molecules could have been formed very slowly by the action of light from the sun. On the present-day earth, bacteria quickly consume energy-rich molecules, but before the origin of life, such molecules could have accumulated, since there were no living organisms to consume them. (This observation is similar to the remark made by Darwin in his 1871 letter to Hooker.)

The first experimental work in this field took place in 1950 in the laboratory of Melvin Calvin at the University of California, Berkeley. Calvin and his co-workers wished to determine experimentally whether the primitive atmosphere of the earth could have been converted into some of the molecules which are the building-blocks of living organisms. The energy needed to perform these conversions they imagined to be supplied by volcanism, radioactive decay, ultraviolet radiation, meteoric impacts, or by lightning strokes.

The earth is thought to be approximately 4.6 billion years old. At the time when Calvin and his co-workers were performing their experiments, the earth's primitive atmosphere was believed to have consisted primarily of hydrogen, water, ammonia, methane, and carbon monoxide, with a little carbon dioxide. A large quantity of hydrogen was believed to have been initially present in the primitive atmosphere, but it was thought to have been lost gradually over a period of time because the earth's gravitational attraction is too weak to

[4] It is now believed that the main constituents of the primordial atmosphere were carbon dioxide, water, nitrogen, and a little methane.

effectively hold such a light and rapidly-moving molecule. However, Calvin and his group assumed sufficient hydrogen to be present to act as a reducing agent. In their 1950 experiments they subjected a mixture of hydrogen and carbon dioxide, with a catalytic amount of Fe^{2+}, to bombardment by fast particles from the Berkeley cyclotron. Their experiments resulted in a good yield of formic acid and a moderate yield of formaldehyde. (The fast particles from the cyclotron were designed to simulate an energy input from radioactive decay on the primitive earth.)

Two years later, Stanley Miller, working in the laboratory of Harold Urey at the University of Chicago, performed a much more refined experiment of the same type. In Miller's experiment, a mixture of the gases methane, ammonia, water and hydrogen was subjected to an energy input from an electric spark. Miller's apparatus was designed so that the gases were continuously circulated, passing first through the spark chamber, then through a water trap which removed the non-volatile water soluble products, and then back again through the spark chamber, and so on. The resulting products are shown as a function of time in Figure 3.5.

The Miller-Urey experiment produced many of the building-blocks of living organisms, including glycine, glycolic acid, sarcosine, alanine, lactic acid, N-methylalanine, β-alanine, succinic acid, aspartic acid, glutamic acid, iminodiacetic acid, iminoacetic-propionic acid, formic acid, acetic acid, propionic acid, urea and N-methyl urea[5]. Another major product was hydrogen cyanide, whose importance as an energy source in chemical evolution was later emphasized by Calvin.

The Miller-Urey experiment was repeated and extended by the Ceylonese-American biochemist Cyril Ponnamperuma and by the American expert in planetary atmospheres, Carl Sagan. They showed that when phosphorus is made available, then in addition to amino acids, the Miller-Urey experiment produces not only nucleic acids of the type that join together to form DNA, but also the energy-rich molecule ATP (adenosine triphosphate). ATP is extremely important in biochemistry, since it is a universal fuel which drives chemical reactions inside present-day living organisms.

Further variations on the Miller-Urey experiment were performed by Sydney Fox and his co-workers at the University of Miami. Fox and his group showed that amino acids can be synthesized from a primitive atmosphere by means of a thermal energy input, and that in the presence of phosphate esters, the amino acids can be thermally joined together to form polypeptides. However, some of the peptides produced in this way were cross linked, and hence not of biological interest.

[5] The chemical reaction that led to the formation of the amino acids that Miller observed was undoubtedly the Strecker synthesis: $HCN + NH_3 + RC{=}O + H_2O \rightarrow RC(NH_2)COOH$.

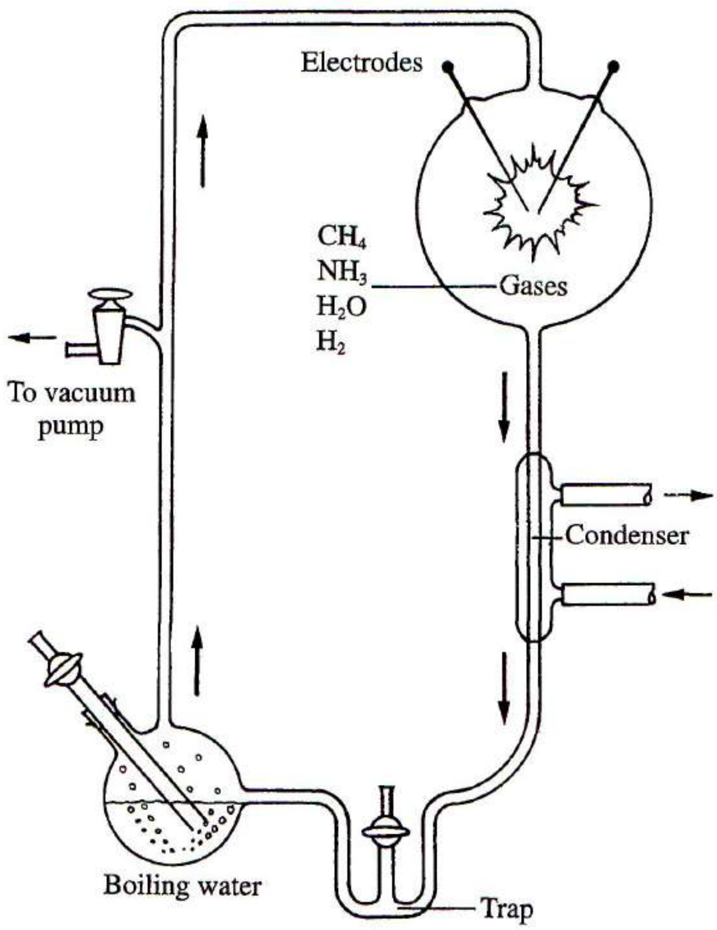

Figure 3.4: Miller's apparatus.

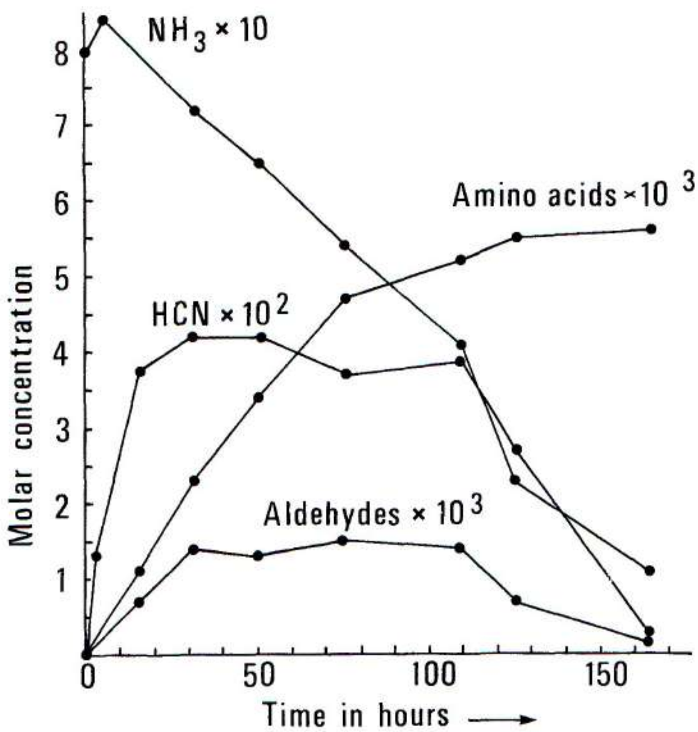

Figure 3.5: Products as a function of time in the Miller-Urey experiment.

In 1969, Melvin Calvin published an important book entitled *Chemical Evolution; Molecular Evolution Towards the Origin of Living Systems on Earth and Elsewhere.* In this book, Calvin reviewed the work of geochemists showing the presence in extremely ancient rock formations of molecules which we usually think of as being produced only by living organisms. He then discussed experiments of the Miller-Urey type - experiments simulating the first step in chemical evolution. According to Calvin, not only amino acids but also the bases adenine, thymine, guanine, cytosine and uracil, as well as various sugars, were probably present in the primitive ocean in moderate concentrations, produced from the primitive atmosphere by the available energy inputs, and not broken down because no organisms were present.

The next steps visualized by Calvin were dehydration reactions in which the building blocks were linked together into peptides, polynucleotides, lipids and porphyrins. Such dehydration reactions are in a thermodynamically uphill direction. In modern organisms, they are driven by a universally-used energy source, the high-energy phosphate bond of adenosine triphosphate (ATP). Searching for a substance present in the primitive ocean which could have driven the dehydrations, Calvin and his coworkers experimented with hydrogen cyanide (HC=N), and from the results of these experiments they concluded that the energy stored in the carbon-nitrogen triple bond of HC=N could indeed have driven the dehydration reactions necessary for polymerization of the fundamental building blocks. However, later work made it seem improbable that peptides could be produced from cyanide mixtures.

In Chemical Evolution, Calvin introduced the concept of autocatalysis as a mechanism for molecular selection, closely analogous to natural selection in biological evolution. Calvin proposed that there were a few molecules in the ancient oceans which could catalyze the breakdown of the energy-rich molecules present into simpler products. According to Calvin's hypothesis, in a very few of these reactions, the reaction itself produced more of the catalyst. In other words, in certain cases the catalyst not only broke down the energy-rich molecules into simpler products but also catalyzed their own synthesis. These autocatalysts, according to Calvin, were the first systems which might possibly be regarded as living organisms. They not only "ate" the energy-rich molecules but they also reproduced - i.e., they catalyzed the synthesis of molecules identical with themselves.

Autocatalysis leads to a sort of molecular natural selection, in which the precursor molecules and the energy-rich molecules play the role of "food", and the autocatalytic systems compete with each other for the food supply. In Calvin's picture of molecular evolution, the most efficient autocatalytic systems won this competition in a completely Darwinian way. These more efficient autocatalysts reproduced faster and competed more successfully for precursors and for energy-rich molecules. Any random change in the direction of greater efficiency was propagated by natural selection.

What were these early autocatalytic systems, the forerunners of life? Calvin proposed several independent lines of chemical evolution, which later, he argued, joined forces. He visualized the polynucleotides, the polypeptides, and the metallo-porphyrins as originally having independent lines of chemical evolution. Later, he argued, an accidental union of these independent autocatalysts showed itself to be a still more efficient autocatalytic system. He pointed out in his book that "autocatalysis" is perhaps too strong a word. One should perhaps speak instead of "reflexive catalysis" , where a molecule does not necessarily catalyze the synthesis of itself, but perhaps only the synthesis of a precursor. Like autocatalysis, reflexive catalysis is capable of exhibiting Darwinian selectivity.

The theoretical biologist, Stuart Kauffman, working at the Santa Fe Institute, has constructed computer models for the way in which the components of complex systems of reflexive catalysts may have been linked together. Kauffman's models exhibit a surprising tendency to produce orderly behavior even when the links are randomly programmed.

In 1967 and 1968, C. Woese, F.H.C. Crick and L.E. Orgel proposed that there may have been a period of chemical evolution involving RNA alone, prior to the era when DNA, RNA and proteins joined together to form complex self-reproducing systems. In the early 1980's, this picture of an "RNA world" was strengthened by the discovery (by Thomas R. Cech and Sydney Altman) of RNA molecules which have catalytic activity.

Today experiments aimed at throwing light on chemical evolution towards the origin of life are being performed in the laboratory of the Nobel Laureate geneticist Jack Sjostak at Harvard Medical School. The laboratory is trying to build a synthetic cellular system that undergoes Darwinian evolution.

In connection with autocatalytic systems, it is interesting to think of the polymerase chain reaction, which we discussed above. The target segment of DNA and the polymerase together form an autocatalytic system. The "food" molecules are the individual nucleotides in the solution. In the PCR system, a segment of DNA reproduces itself with an extremely high degree of fidelity. One can perhaps ask whether systems like the PCR system can have been among the forerunners of living organisms. The cyclic changes of temperature needed for the process could have been supplied by the cycling of water through a hydrothermal system. There is indeed evidence that hot springs and undersea hydrothermal vents may have played an important role in chemical evolution towards the origin of life. We will discuss this evidence in the next section.

Throughout this discussion of theories of chemical evolution, and the experiments which have been done to support these theories, energy has played a central role. None of the transformations discussed above could have taken place without an energy source, or to be more precise, they could not have taken place without a source of free energy. In Chapter 4 we will discuss in detail the reason why free energy plays a central role, not only in the origin of life but also in life's continuation. We will see that there is a connection between free energy and information, and that information-containing free energy is needed to produce the high degree of order which is characteristic of life.

Molecular evidence establishing family trees in evolution

Starting in the 1970's, the powerful sequencing techniques developed by Sanger and others began to be used to establish evolutionary trees. The evolutionary closeness or distance of two organisms could be estimated from the degree of similarity of the amino acid sequences of their proteins, and also by comparing the base sequences of their DNA and RNA. One of the first studies of this kind was made by R.E. Dickerson and his coworkers, who studied the amino acid sequences in Cytochrome C, a protein of very ancient origin which is involved in the "electron transfer chain" of respiratory metabolism. Some of the results of Dickerson's studies are shown in Figure 3.6.

Comparison of the base sequences of RNA and DNA from various species proved to be even more powerful tool for establishing evolutionary relationships. Figure 3.7 shows the universal phylogenetic tree established in this way by Iwabe, Woese and their coworkers.[6] In Figure 3.7, all presently living organisms are divided into three main kingdoms, Eukaryotes, Eubacteria, and Archaebacteria. Carl Woese, who proposed this classification on the basis of comparative sequencing, wished to call the three kingdoms "Eucarya, Bacteria and Archaea". However, the most widely accepted terms are the ones shown in capital letters on the figure. Before the comparative RNA sequencing work, which was performed on the ribosomes of various species, it had not been realized that there are two types of bacteria, so markedly different from each other that they must be classified as belonging to separate kingdoms. One example of the difference between archaebacteria and eubacteria is that the former have cell membranes which contain ether lipids, while the latter have ester lipids in their cell membranes. Of the three kingdoms, the eubacteria and the archaebacteria are "prokaryotes", that is to say, they are unicellular organisms having no cell nucleus. Most of the eukaryotes, whose cells contain

[6] "Phylogeny" means "the evolutionary development of a species". "Ontogeny" means "the growth and development an individual, through various stages, for example, from fertilized egg to embryo, and so on." Ernst Haeckel, a 19th century follower of Darwin, observed that, in many cases, "ontogeny recapitulates phylogeny."

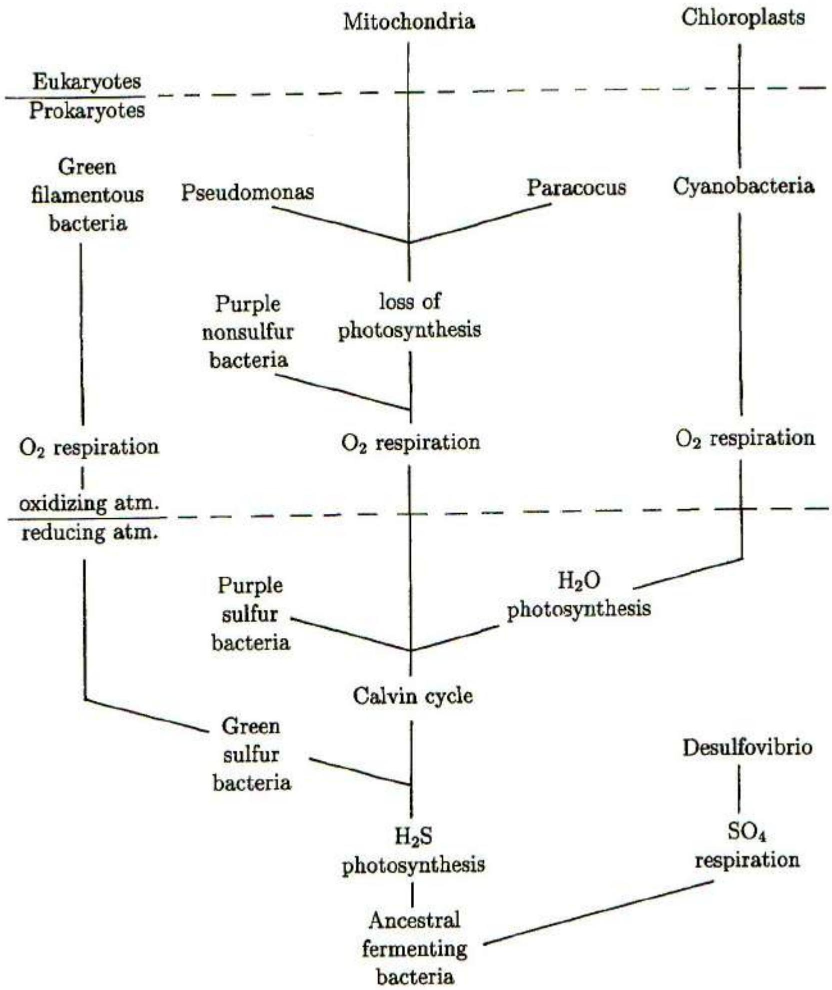

Figure 3.6: Evolutionary relationships established by Dickerson and coworkers by comparing the amino acid sequences of Cytochrome C from various species.

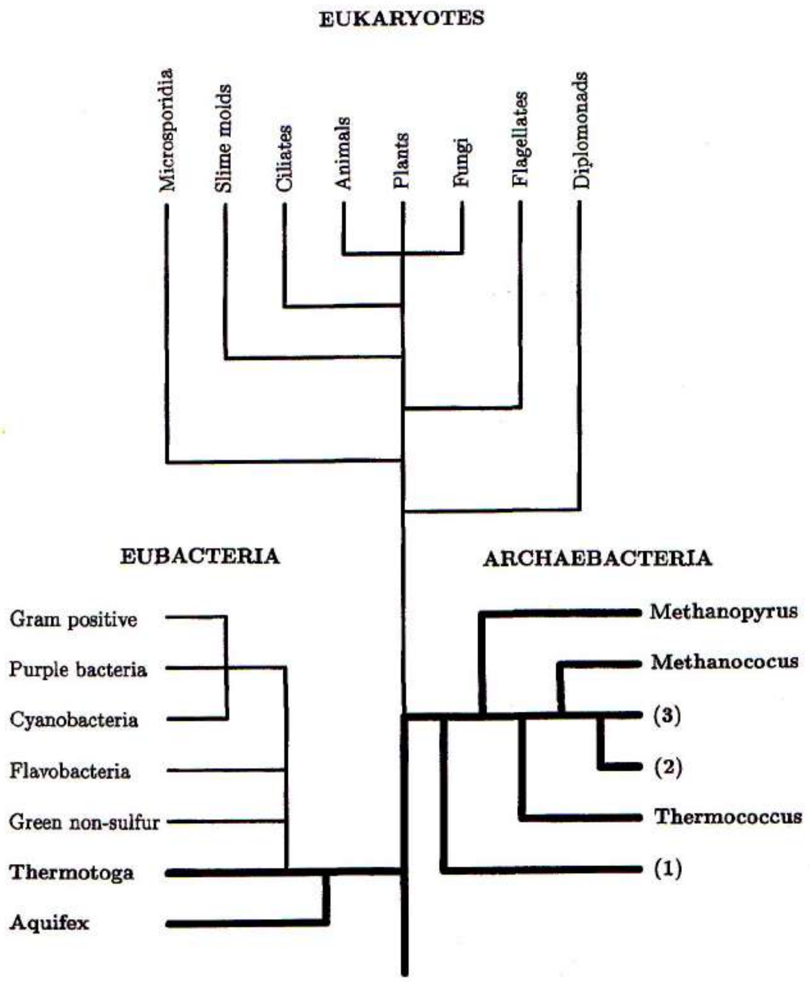

Figure 3.7: This figure shows the universal phylogenetic tree, established by the work of Woese, Iwabe et al. Hyperthermophiles are indicated by bold lines and by bold type.

a nucleus, are also unicellular, the exceptions being plants, fungi and animals.

One of the most interesting features of the phylogenetic tree shown in Figure 3.7 is that the deepest branches - the organisms with shortest pedigrees - are all hyperthermophiles, i.e. they live in extremely hot environments such as hot springs or undersea hydrothermal vents. The shortest branches represent the most extreme hyperthermophiles. The group of archaebacteria indicated by (1) in the figure includes **Thermofilum, Thermoproteus, Pyrobaculum, Pyrodictium, Desulfurococcus**, and **Sulfolobus** - all hypothermophiles[7]. Among the eubacteria, the two shortest branches, Aquifex and Thermatoga are both hyperthermophiles[8]

The phylogenetic evidence for the existence of hyperthermophiles at a very early stage of evolution lends support to a proposal put forward in 1988 by the German biochemist Günter Wächterhäuser. He proposed that the reaction for pyrite formation,

$$FeS + H_2S \rightarrow FeS_2 + 2H + +2e^-$$

which takes place spontaneously at high temperatures, supplied the energy needed to drive the first stages of chemical evolution towards the origin of life. Wächterhäuser pointed out that the surface of the mineral pyrite (FeS_2) is positively charged, and he proposed that, since the immediate products of carbon-dioxide fixation are negatively charged, they would be attracted to the pyrite surface. Thus, in Wächterhäuser's model, pyrite formation not only supplied the reducing agent needed for carbon-dioxide fixation, but also the pyrite surface aided the process. Wächterhäuser further proposed an archaic autocatylitic carbon-dioxide fixation cycle, which he visualized as resembling the reductive citric acid cycle found in present-day organisms, but with all reducing agents replaced by FeS + H_2S, with thioester activation replaced by thioacid activation, and carbonyl groups replaced by thioenol groups. The interested reader can find the details of Wächterhäuser's proposals in his papers, which are listed at the end of this chapter.

A similar picture of the origin of life has been proposed by Michael J. Russell and Alan J. Hall in 1997. In this picture "...(i) life emerged as hot, reduced, alkaline, sulphide-bearing submarine seepage waters interfaced with colder, more oxidized, more acid, Fe^{2+} >>Fe^{3+}-bearing water at deep (*ca.* 4km) floors of the Hadean ocean *ca.* 4 Gyr ago; (ii) the difference in acidity, temperature and redox potential provided a gradient of pH (*ca.* 4 units),

[7] Group (2) in Figure 3.7 includes **Methanothermus**, which is hyperthermophilic, and Methanobacterium, which is not. Group (3) includes **Archaeoglobus**, which is hyperthermophilic, and Halococcus, Halobacterium, Methanoplanus, Methanospirilum, and Methanosarcina, which are not.

[8] Thermophiles are a subset of the larger group of extremophiles.

temperature (*ca.* 60°C) and redox potential (*ca.* 500 mV) at the interface of those waters that was sustainable over geological time-scales, providing the continuity of conditions conducive to organic chemical reactions needed for the origin of life..." [9]. Russell, Hall and their coworkers also emphasize the role that may have been played by spontaneously-formed 3-dimensional mineral chambers (bubbles). They visualize these as having prevented the reacting molecules from diffusing away, thus maintaining high concentrations.

Table 3.2 shows the energy-yielding reactions which drive the metabolisms of some organisms which are of very ancient evolutionary origin. All the reactions shown in the table make use of H_2, which could have been supplied by pyrite formation at the time when the organisms evolved. All these organisms are lithoautotrophic, a word which requires some explanation: A heterotrophic organism is one which lives by ingesting energy-rich organic molecules which are present in its environment. By contrast, an autotrophic organism ingests only inorganic molecules. The lithoautotrophs use energy from these inorganic molecules, while the metabolisms of photoautotrophs are driven by energy from sunlight.

Evidence from layered rock formations called "stromatolites", produced by colonies of photosynthetic bacteria, show that photoautotrophs (or phototrophs) appeared on earth at least 3.5 billion years ago. The geological record also supplies approximate dates for other events in evolution. For example, the date at which molecular oxygen started to become abundant in the earth's atmosphere is believed to have been 2.0 billion years ago, with equilibrium finally being established 1.5 billion years in the past. Multi-cellular organisms appeared very late on the evolutionary and geological time-scale - only 600 million years ago. By collecting such evidence, the Belgian cytologist Christian de Duve has constructed the phylogenetic tree shown in Figure 3.8, showing branching as a function of time. One very interesting feature of this tree is the arrow indicating the transfer of "endosymbionts" from the eubacteria to the eukaryotes. In the next section, we will look in more detail at this important event, which took place about 1.8 billion years ago.

Symbiosis

The word "symbiosis" is derived from Greek roots meaning "living together". It was coined in 1877 by the German botanist Albert Bernard Frank. By that date, it had become clear that lichens are composite organisms involving a fungus and an alga; but there was controversy concerning whether the relationship

[9]See W. Martin and M.J. Russell, *On the origins of cells: a hypothesis for the evolutionary transitions from abiotic geochemistry to chemoautotrophic prokaryotes, and from prokaryotes to nucleated cells*, Philos. Trans. R. Soc. Lond. B Biol. Sci., **358**, 59-85, (2003).

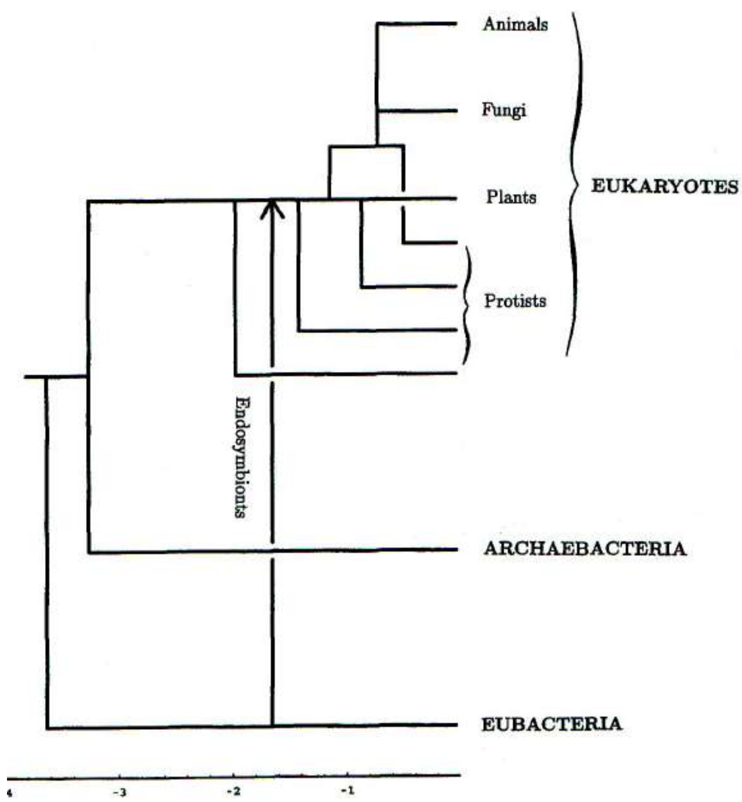

Figure 3.8: Branching of the universal phylogenetic tree as a function of time. "Protists" are unicellular eukaryotes.

Table 3.2: **Energy-yielding reactions of some lithoautotrophic hyperthermophiles. (After K.O. Setter)**

Energy-yielding reaction	Genera
$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$	Methanopyrus, Methanothermus, Methanococcus
$H_2 + S^\circ \rightarrow H_2S$	Pyrodictium, Thermoproteus, Pyrobaculum, Acidianus, Stygiolobus
$4H_2 + H_2SO_4 \rightarrow H_2S + 4H_2O$	Archaeoglobus

was a parasitic one. Was the alga held captive and exploited by the fungus? Or did the alga and the fungus help each other, the former performing photosynthesis, and the latter leeching minerals from the lichen's environment? In introducing the word "symbiosis" (in German, "Symbiotismus"), Prank remarked that "We must bring all the cases where two different species live on or in one another under a comprehensive concept which does not consider the role which the two individuals play but is based on the mere coexistence, and for which the term symbiosis is to be recommended." Thus the concept of symbiosis, as defined by Frank, included all intimate relationships between two or more species, including parasitism at one extreme and "mutualism" at the other. However, as the word is used today, it usually refers to relationships which are mutually beneficial.

Charles Darwin himself had been acutely aware of close and mutually beneficial relationships between organisms of different species. For example, in his work on the fertilization of flowers,he had demonstrated the way in which insects and plants can become exquisitely adapted to each other's needs. However, T.H. Huxley, "Darwin's bulldog", emphasized competition as the predominant force in evolution. "The animal world is on about the same level as a gladiator's show", Huxley wrote in 1888, "The creatures are fairly well treated and set to fight - whereby the strongest, the swiftest and the cunningest live to fight another day. The spectator has no need to turn his thumbs down, as no quarter is given." The view of nature as a sort of "gladiator's contest" dominated the mainstream of evolutionary thought far into the 20th century; but there was also a growing body of opinion which held that symbiosis could be an extremely important mechanism for the generation of new species.

Among the examples of symbiosis studied by Frank were the nitrogen-fixing bacteria living in nodules on the roots of legumes, and the mycorrhizal fungi which live on the roots of forest trees such as oaks, beech and conifers. Frank believed that the mycorrhizal fungi aid in the absorption of nutrients. He distinguished between "ectotrophic" fungi, which form sheaths around the root fibers, and "endotrophic" fungi, which penetrate the root cells. Other examples of symbiosis studied in the 19th century included borderline cases between plants and animals, for ex- ample, paramecia, sponges, hydra, planarian worms and sea anemones, all of which frequently contain green bodies capable of performing photosynthesis.

Writing in 1897, the American lichenologist Albert Schneider prophesied that "future studies may demonstrate that.., plasmic bodies (within the eukaryote cell), such as chlorophyll granules, leucoplastids, chromoplastids, chromosomes, centrosomes, nucleoli, etc., are perhaps symbionts comparable to those in less highly specialized symbiosis. Reinke expresses the opinion that it is not wholly unreasonable to suppose that some highly skilled scientist of the future may succeed in cultivating chlorophyll-bodies in artificial media."

19th century cytologists such as Robert Altman, Andreas Schimper and A. Benda focused attention on the chlorophyll-bodies of plants, which Schimper named chloroplasts, and on another type of subcellular granule, present in large numbers in all plant and animal cells, which Benda named mitochondria, deriving the name from the Greek roots mitos (thread) and chrondos (granule). They observed that these bodies seemed to reproduce themselves within the cell in very much the manner that might be expected if they were independent organisms. Schimper suggested that chloroplasts are symbionts, and that green plants owe their origin to a union of a colorless unicellular organism with a smaller chlorophyll-containing species.

The role of symbiosis in evolution continued to be debated in the 20th century. Mitochondria were shown to be centers of respiratory metabolism; and it was discovered that both mitochondria and chloroplasts contain their own DNA. However, opponents of their symbiotic origin pointed out that mitochondria alone cannot synthesize all their own proteins: Some mitochondrial proteins require information from nuclear DNA. The debate was finally settled in the 1970's, when comparative sequencing of ribosomal RNA in the laboratories of Carl Woese, W. Ford Doolittle and Michael Gray showed conclusively that both chloroplasts and mitochondria were originally endosymbionts. The ribosomal RNA sequences showed that chloroplasts had their evolutionary root in the cyanobacteria, a species of eubacteria, while mitochondria were traced to a group of eubacteria called the alpha-proteobacteria. Thus the evolutionary arrow leading from the eubacteria to the eukaryotes can today be drawn with confidence, as in Figure 3.8.

Cyanobacteria are bluish photosynthetic bacteria which often become linked to one another so as to form long chains. They can be found today growing in large colonies on seacoasts in many parts of the world, for example in Baja California on the Mexican coast. The top layer of such colonies consists of the phototrophic cyanobacteria, while the organisms in underlying layers are heterotrophs living off the decaying remains of the cyanobacteria. In the course of time, these layered colonies can become fosilized, and they are the source of the layered rock formations called stromatolites (discussed above). Geological dating of ancient stromatolites has shown that cyanobacteria must have originated at least 3.5 billion years ago.

Cyanobacteria contain two photosystems, each making use of a different type of chlorophyll. Photosystem I, which is thought to have evolved first, uses the energy of light to draw electrons from inorganic compounds, and sometimes also from organic compounds (but never from water). Photosystem II, which evolved later, draws electrons from water. Hydrogen derived from the water is used to produce organic compounds from carbon-dioxide, and molecular oxygen is released into the atmosphere. Photosystem II never appears alone. In all organisms which possess it, Photosystem II is coupled to Photosystem I, and together the two systems raise electrons to energy levels that are high enough to drive all the processes of metabolism. Dating of ancient stromatolites makes it probable that cyanobacteria began to release molecular oxygen into the earth's atmosphere at least 3.5 billion years ago; yet from other geological evidence we know that it was only 2 billion years ago that the concentration of molecular oxygen began to rise, equilibrium being reached 1.5 billion years ago. It is believed that ferrous iron, which at one time was very abundant, initially absorbed the photosynthetically produced oxygen. This resulted in the time-lag, as well as the ferrous-ferric mixture of iron which is found in the mineral magnetite.

When the concentrations of molecular oxygen began to rise in earnest, most of the unicellular microorganisms living at the time found themselves in deep trouble, faced with extinction, because for them oxygen was a deadly poison; and very many species undoubtedly perished. However, some of the archaebacteria retreated to isolated anaerobic niches where we find them today, while others found ways of detoxifying the poisonous oxygen. Among the eubacteria, the ancestors of the alpha-proteobacteria were particularly good at dealing with oxygen and even turning it to advantage: They developed the biochemical machinery needed for respiratory metabolism.

Meanwhile, during the period between 3.5 and 2.0 billion years before the present, an extremely important evolutionary development had taken place: Branching from the archaebacteria, a line of large[10] heterotrophic unicellular organisms had evolved. They lacked rigid cell walls, and they could surround smaller organisms with their flexible outer membrane, drawing the victims into their interiors to be digested. These new heterotrophs were the ancestors of present-day eukaryotes, and thus they were the ancestors of all multicellular organisms.

Not only are the cells of present-day eukaryotes very much larger than the cells of archaebacteria and eubacteria; their complexity is also astonishing. Every eukaryote cell contains numerous intricate structures: a nucleus, cytoskeleton, Golgi apparatus, endoplasmic reticulum, mitochondria, peroxisomes, chromosomes, the complex structures needed for mitotic cell division, and so on. Furthermore, the genomes of eykaryotes contain very much more information than those of prokaryotes. How did this huge and relatively sudden increase in complexity and information content take place? According to a growing body of opinion, symbiosis played an important role in this development.

The ancestors of the eukaryotes were in the habit of drawing the smaller prokaryotes into their interiors to be digested. It seems likely that in a few cases the swallowed prokaryotes resisted digestion, multiplied within the host, were transmitted to future generations when the host divided, and conferred an evolutionary advantage, so that the result was a symbiotic relationship. In particular, both mitochondria and chloroplasts have definitely been proved to have originated as endosymbionts. It is easy to understand how the photosynthetic abilities of the chloroplasts (derived from cyanobacteria) could have conferred an advantage to their hosts, and how mitochondria (derived from alpha-proteobacteria) could have helped their hosts to survive the oxygen crisis. The symbiotic origin of other sub-cellular organelles is less well understood and is currently under intense investigation.

If we stretch the definition of symbiosis a little, we can make the concept include cooperative relationships between organisms of the same species. For example, cyanobacteria join together to form long chains, and they live together in large colonies which later turn into stromatolites. Also, some eubacteria have a mechanism for sensing how many of their species are present, so that they know, like a wolf pack, when it is prudent to attack a larger organism. This mechanism, called “quorum sensing”, has recently attracted much attention among medical researchers.

The cooperative behavior of a genus of unicellular eukaryotes called slime

[10] not large in an absolute sense, but large in relation to the prokaryotes

molds is particularly interesting because it gives us a glimpse of how multicellular organisms may have originated. The name of the slime molds is misleading, since they are not fungi, but heterotrophic protists similar to amoebae. Under ordinary circumstances, the individual cells wander about independently searching for food, which they draw into their interiors and digest, a process called "phagocytosis". However, when food is scarce, they send out a chemical signal of distress. Researchers have analyzed the molecule which expresses slime mold unhappiness, and they have found it to be cyclic adenosine monophosphate (cAMP). At this signal, the cells congregate and the mass of cells begins to crawl, leaving a slimy trail. At it crawls, the community of cells gradually develops into a tall stalk, surmounted by a sphere - the "fruiting body". Inside the sphere, spores are produced by a sexual process. If a small animal, for example a mouse, passes by, the spores may adhere to its coat; and in this way they may be transported to another part of the forest where food is more plentiful.

Thus slime molds represent a sort of missing link between unicellular and multicellular or organisms. Normally the cells behave as individualists, wandering about independently, but when challenged by a shortage of food, the slime mold cells join together into an entity which closely resembles a multicellular organism. The cells even seem to exhibit altruism, since those forming the stalk have little chance of survival, and yet they are willing to perform their duty, holding up the sphere at the top so that the spores will survive and carry the genes of the community into the future. We should especially notice the fact that the cooperative behavior of the slime mold cells is coordinated by chemical signals.

Sponges are also close to the borderline which separates unicellular eukaryotes (protists) from multicellular organisms, but they are just on the other side of the border. Normally the sponge cells live together in a multicellular community, filtering food from water. However, if a living sponge is forced through a very fine cloth, it is possible to separate the cells from each other. The sponge cells can live independently for some time; but if many of them are left near to one another, they gradually join together and form themselves into a new sponge, guided by chemical signals. In a refinement of this experiment, one can take two living sponges of different species, separate the cells by passing the sponges through a fine cloth, and afterwards mix all the separated cells together. What happens next is amazing: The two types of sponge cells sort themselves out and become organized once more into two sponges - one of each species.

Slime molds and sponges hint at the genesis of multicellular organisms, whose evolution began approximately 600 million years ago. Looking at the slime molds and sponges, we can imagine how it happened. Some unicellular organisms must have experienced an enhanced probability of survival when they lived as colonies. Cooperative behavior and division of labor within the colonies were rewarded by the forces of natural selection, with the selective force acting on the entire colony of cells, rather than on the individual cell. This resulted in the formation of cellular societies and the evolution of mechanisms for cell differentiation. The division of labor within cellular societies (i.e., differentiation) came to be coordinated by chemical signals which affected the transcription of genetic information and the synthesis of proteins. Each cell within a society of cells possessed the entire genome characteristic of the colony, but once a cell had been assigned its specific role in the economy of the society, part of the information became blocked - that is, it was not expressed in the function of that particular cell. As multicellular organisms evolved, the chemical language of intercellular communication became very much more complex and refined. We will discuss the language of intercellular communication in more detail in a later section.

Geneticists have become increasingly aware that symbiosis has probably played a major role in the evolution of multicellular organisms. We mentioned above that, by means of genetic engineering techniques, transgenic plants and animals can be produced. In these chimeras, genetic material from a foreign species is incorporated into the chromosomes, so that it is inherited in a stable, Mendelian fashion. J.A. Shapiro, one of whose articles is referenced at the end of this chapter, believes that this process also occurs in nature, so that the conventional picture of evolutionary family trees needs to be corrected. Shapiro believes that instead of evolutionary trees, we should perhaps think of webs or networks.

For example, it is tempting to guess that symbiosis may have played a role in the development of the visual system of vertebrates. One of the archaebacteria, the purple halobacterium halobium (recently renamed halobacterium salinarum), is able to perform photosynthesis by means of a protein called bacterial rhodopsin, which transports hydrogen ions across the bacterial membrane. This protein is a near chemical relative of rhodopsin, which combines with a carotinoid to form the "visual purple" used in the vertebrate eye. It is tempting to think that the close similarity of the two molecules is not just a coincidence, and that vertebrate vision originated in a symbiotic relationship between the photosynthetic halobacterium and an aquatic ancestor of the vertebrates, the host being able to sense when the halobacterium was exposed to light and therefore transporting hydrogen ions across its cell membrane.

In this chapter, we have looked at the flow of energy and information in the origin and evolution of life on earth. We have seen how energy-rich molecules were needed to drive the first steps in the origin of life, and how during the evolutionary process, information was preserved, transmitted, and shared between increasingly complex organisms, the whole process being driven by an input of energy. In the next chapter, we will look closely at the relationships between energy and information.

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Chapter 4

THE EVOLUTION OF COOPERATION

Introduction

The success of humans as a species is due to our genius for cooperation. Cultural evolution, a new form of evolution, in which information is passed between generations in the form of linguistic symbols rather than genetically, has been the key to human success. Cultural evolution depends on the sharing of knowledge, and humans have developed remarkable linguistic and cooperative abilities.

At the same time, human nature also has a darker side, inherited from our ancestors who were hunter-gatherers, living in small genetically homogeneous tribes, competing for territory, on the grasslands of Africa. The pattern of intra-tribal altruism and inter-tribal aggression, which humans have inherited from their remote ancestors, has been explained by the theories of population genetics and group selection put forward in the 1930's by R.A. Fischer and J.B.S Haldane, and discussed more recently by W.D. Hamilton and E.O. Wilson. In this picture, the tribe itself, rather than the individual, is the unit on which evolutionary forces acted.

This essay will try to show that symbiosis and cooperation have been responsible for all of the great upward steps in evolution, including the development of the first prokareotic cells, the first eukareotes, the first multi-cellular organisms, and the first cooperative groups of multicellular organisms. The views of T.H. Huxley, who stressed competition as an evolutionary force, will be contrasted with the ideas of Charles Darwin, Peter Kropotkin and Lynn Margulis and others, who fully understood the importance of symbiosis and cooperation in evolution.

The explosion of human knowledge

Cultural evolution depends on the non-genetic storage, transmission, diffusion and utilization of information. The development of human speech, the invention of writing, the development of paper and printing, and finally in modern times, mass media, computers and the Internet - all these have been crucial steps in society's explosive accumulation of information and knowledge. Human cultural evolution proceeds at a constantly-accelerating speed, so great in fact that it threatens to shake society to pieces.

Every species changes gradually through genetic evolution; but with humans, cultural evolution has rushed ahead with such a speed that it has completely outstripped the slow rate of genetic change. Genetically we are quite similar to our neolithic ancestors, but their world has been replaced by a world of quantum theory, relativity, supercomputers, antibiotics, genetic engineering and space telescopes - unfortunately also a world of nuclear weapons and nerve gas.

Because of the slowness of genetic evolution in comparison to the rapid and constantly-accelerating rate of cultural change, our bodies and emotions (as Malthus put it, the "passions of mankind") are not completely adapted to our new way of life. They still reflect the way of life of our hunter-gatherer ancestors.

Within rapidly-moving cultural evolution, we can observe that technical change now moves with such astonishing rapidity that neither social institutions, nor political structures, nor education, nor public opinion can keep pace. The lightning-like pace of technical progress has made many of our ideas and institutions obsolete. For example, the absolutely-sovereign nation-state and the institution of war have both become dangerous anachronisms in an era of instantaneous communication, global interdependence and all-destroying weapons.

In many respects, human cultural evolution can be regarded as an enormous success. However, at the start of the 21st century, most thoughtful observers agree that civilization is entering a period of crisis. As all curves move exponentially upward - population, production, consumption, rates of scientific discovery, and so on - one can observe signs of increasing environmental stress, while the continued existence and spread of nuclear weapons threatens civilization with destruction. Thus while the explosive growth of knowledge has brought many benefits, the problem of achieving a stable, peaceful and sustainable world remains serious, challenging and unsolved.

Tribal emotions and nationalism

In discussing conflicts, we must be very careful to distinguish between two distinct types of aggression exhibited by both humans and animals. The first is intra-group aggression, which is often seen in rank-determining struggles, for example when two wolves fight for pack leadership, or when males fight for the privilege of mating with females. Another, completely different, type of aggression is seen when a group is threatened by outsiders. Most animals, including humans, then exhibit a communal defense response - self-sacrificing and heroic combat against whatever is perceived to be an external threat. It is this second type of aggression that makes war possible.

Arthur Koestler has described inter-group aggression in an essay entitled *The Urge to Self-Destruction* [1], where he writes: "Even a cursory glance at history should convince one that individual crimes, committed for selfish motives, play a quite insignificant role in the human tragedy compared with the numbers massacred in unselfish love of one's tribe, nation, dynasty, church or ideology... Wars are not fought for personal gain, but out of loyalty and devotion to king, country or cause..."

"We have seen on the screen the radiant love of the Führer on the faces of the Hitler Youth... They are transfixed with love, like monks in ecstasy on religious paintings. The sound of the nation's anthem, the sight of its proud flag, makes you feel part of a wonderfully loving community. The fanatic is prepared to lay down his life for the object of his worship, as the lover is prepared to die for his idol. He is, alas, also prepared to kill anybody who represents a supposed threat to the idol."

Members of tribe-like groups are bound together by strong bonds of altruism and loyalty. Echos of these bonds can be seen in present-day family groups, in team sports, in the fellowship of religious congregations, and in the bonds that link soldiers to their army comrades and to their nation.

Warfare involves not only a high degree of aggression, but also an extremely high degree of altruism. Soldiers kill, but they also sacrifice their own lives. Thus patriotism and duty are as essential to war as the willingness to kill.

Tribalism involves passionate attachment to one's own group, self-sacrifice for the sake of the group, willingness both to die and to kill if necessary to defend the group from its enemies, and belief that in case of a conflict, one's own group is always in the right. Unfortunately these emotions make war possible; and today a Third World War might lead to the destruction of civilization.

[1] in *The Place of Value in a World of Facts*, A. Tiselius and S. Nielsson editors, Wiley, New York, (1970)

The mystery of self-sacrifice in war

At first sight, the willingness of humans to die defending their social groups seems hard to explain from the standpoint of Darwinian natural selection. After the heroic death of such a human, he or she will be unable to produce more children, or to care for those already born.Therefore one might at first suppose that natural selection would work strongly to eliminate the trait of self-sacrifice from human nature. However, the theory of population genetics and group selection can explain both the willingness of humans to sacrifice themselves for their own group, and also the terrible aggression that they sometimes exhibit towards competing groups. It can explain both intra-group altruism and inter-group aggression.

Fisher, Haldane and Hamilton

The idea of group selection in evolution was proposed in the 1930's by J.B.S. Haldane and R.A. Fischer, and more recently it has been discussed by W.D. Hamilton.

If we examine altruism and aggression in humans, we notice that members of our species exhibit great altruism towards their own children. Kindness towards close relatives is also characteristic of human behavior, and the closer the biological relationship is between two humans, the greater is the altruism they tend to show towards each other. This profile of altruism is easy to explain on the basis of Darwinian natural selection since two closely related individuals share many genes and, if they cooperate, the genes will be more effectively propagated.

To explain from an evolutionary point of view the communal defense mechanism - the willingness of humans to kill and be killed in defense of their communities - we have only to imagine that our ancestors lived in small tribes and that marriage was likely to take place within a tribe rather than across tribal boundaries. Under these circumstances, each tribe would tend to consist of genetically similar individuals. The tribe itself, rather than the individual, would be the unit on which the evolutionary forces of natural selection would act.

According to the group selection model, a tribe whose members showed altruism towards each other would be more likely to survive than a tribe whose members cooperated less effectively. Since several tribes might be in competition for the same territory, successful aggression against a neighboring group could increase the chances for survival of one's own tribe. Thus, on the basis of the group selection model, one would expect humans to be kind and cooperative towards members of their own group, but at the same time to sometimes

Figure 4.1: *A photo of the statistician R.A. Fischer, who proposed the idea of group selection in the 1930's, together with J.B.S. Haldane. Group selection explains the profile of tribal altruism and inter-tribal aggression that we observe in humans. Public domain, Wikimedia Commons*

exhibit aggression towards members of other groups, especially in conflicts over territory. One would also expect intergroup conflicts to be most severe in cases where the boundaries between groups are sharpest - where marriage is forbidden across the boundaries.

Language, religion and tribal markings

In biology, a species is defined to be a group of mutually fertile organisms. Thus all humans form a single species, since mixed marriages between all known races will produce children, and subsequent generations in mixed marriages are also fertile. However, although there is never a biological barrier to marriages across ethnic and racial boundaries, there are often very severe cultural barriers.

Irenäus Eibl-Eibesfeldt, a student of Konrad Lorenz, introduced the word *pseudospeciation* to denote cases where cultural barriers between two groups of humans are so strongly marked that marriages across the boundary are difficult and infrequent. In such cases, he pointed out, the two groups function as though they were separate species, although from a biological standpoint this is nonsense. When two such groups are competing for the same land, the same water, the same resources, and the same jobs, the conflicts between them can become very bitter indeed. Each group regards the other as being "not truly human".

In his book *The Biology of War and Peace*, Eibl-Eibesfeldt discusses the "tribal markings" used by groups of humans to underline their own identity and to clearly mark the boundary between themselves and other groups. One of the illustrations in his book shows the marks left by ritual scarification on the faces of the members of certain African tribes. These scars would be hard to counterfeit, and they help to establish and strengthen tribal identity. Seeing a photograph of the marks left by ritual scarification on the faces of African tribesmen, it is impossible not to be reminded of the dueling scars that Prussian army officers once used to distinguish their caste from outsiders.

Surveying the human scene, one can find endless examples of signs that mark the bearer as a member of a particular group - signs that can be thought of as "tribal markings": tattoos; piercing; bones through the nose or ears; elongated necks or ears; filed teeth; Chinese binding of feet; circumcision, both male and female; unique hair styles; decorations of the tongue, nose, or naval; peculiarities of dress, kilts, tartans, school ties, veils, chadors, and headdresses; caste markings in India; use or nonuse of perfumes; codes of honor and value systems; traditions of hospitality and manners; peculiarities of diet (certain foods forbidden, others preferred); giving traditional names to children; knowledge of dances and songs; knowledge of recipes; knowledge of common stories, literature, myths, poetry or common history; festivals, ceremonies, and rituals; burial customs, treatment of the dead and ancestor worship; methods of building and decorating homes; games and sports peculiar to a culture; relationship to animals, knowledge of horses and ability to ride; nonrational systems of belief. Even a baseball hat worn backwards or the professed ability to enjoy atonal music can mark a person as a member of a special "tribe".

By far the most important mark of ethnic identity is language, and within a particular language, dialect and accent. If the only purpose of language were communication, it would be logical for the people of a small country like Denmark to stop speaking Danish and go over to a more universally-understood international language such as English. However, language has another function in addition to communication: It is also a mark of identity. It establishes the boundary of the group.

Next after language, the most important "tribal marking" is religion. It seems probable that in the early history of our hunter-gatherer ancestors, religion evolved as a mechanism for perpetuating tribal traditions and culture. Like language, and like the innate facial expressions studied by Darwin, religion is a universal characteristic of all human societies. All known races and cultures practice some sort of religion. Thus a tendency to be religious seems to be built into human nature.

Formation of group identity

Although humans originally lived in small, genetically homogeneous tribes, the social and political groups of the modern world are much larger, and are often multiracial and multiethnic.

There are a number of large countries that are remarkable for their diversity, for example Brazil, Argentina and the United States. Nevertheless it has been possible to establish social cohesion and group identity within each of these enormous nations. India and China too, are mosaics of diverse peoples, but nevertheless, they function as coherent societies. Thus we see that group identity is a social construction, in which artificial "tribal markings" define the boundaries of the group.

As an example of the use of tribal markings to establish social cohesion over a large group of genetically dissimilar humans, one can think of the role of baseball and football in the United States. Affection for these sports and knowledge of their intricacies is able to establish social bonds that transcend racial and religious barriers.

One gains hope for the future by observing how it has been possible to produce both internal peace and social cohesion over very large areas of the globe

- areas that contain extremely diverse populations. The difference between making large, ethnically diverse countries function as coherent sociopolitical units and making the entire world function as a unit is not very great.

Since group identity is a social construction, it is not an impossible goal to think of enlarging the already-large groups of the modern world to include all of humanity.

The social insects

The social insects, ants, bees, wasps and termites, exhibit nearly perfect altruism towards members of their own group. This extreme form of altruism towards near relations (kin altruism) is closely connected with the peculiar method of reproduction of the social insects. The workers are sterile or nearly sterile, while the queen is the only reproductive female. The result of this special method of reproduction is that very nearly perfect altruism is possible within a hive or nest, since genetic changes favoring antisocial behavior would be detrimental to the hive or nest as a whole. The hive or nest can, in some sense, be regarded as a superorganism, with the individuals cooperating totally in much the same way that cells cooperate within a multicellular organism. The social insects exhibit aggression towards members of their own species from other hives or nests, and can be said to engage in wars. Interestingly a similar method of reproduction, associated with extreme intra-group altruism has evolved among mammals, but is represented by only two species: the naked mole rat and Damaraland mole rat.

From Thomas Huxley to Lynn Margulis and symbiosis

Charles Darwin (1809-1882) was acutely aware of close and mutually beneficial relationships between organisms. For example, in his work on the fertilization of flowers, he studied the ways in which insects and plants can become exquisitely adapted to each other's needs.

On the other hand Thomas Henry Huxley (1825-1895), although he was a strong supporter of Darwin, saw competition as the main mechanism of evolution. In his essay *Struggle for Existence and its Bearing Upon Man* Huxley wrote: "From the point of view of the moralist, the animal world is about on the same level as a gladiators' show. The creatures are fairly well treated and set to fight; hereby the strongest, the swiftest, and the cunningest live to fight another day. The spectator has no need to turn his thumbs down, as no quarter is granted."

Prince Peter Kropotkin (1842-1921) argued strongly against Huxley's point of view in his book *Mutual Aid; A Factor of Evolution.* "If we ask

Nature", Kropotkin wrote, "'who are the fittest: those who are continually at war with each other, or those who support one another?', we at once see that those animals that acquire habits of mutual aid are undoubtedly the fittest. They have more chances to survive, and they attain, in their respective classes, the highest development of intelligence and bodily organization."

Today, the insights of modern biology show that although competition plays an important role, most of the great upward steps in evolution have involved cooperation. The biologist Lynn Margulis (1938-2011) has been one of the pioneers of the modern viewpoint which recognizes symbiosis as a central mechanism in evolution.

One-celled organisms seen as examples of cooperation

The first bacterial cells (prokaryotic cells) can be thought of as cooperative communities in which autocatalytic molecules thrived better together than they had previously done separately.

The next great upward step in evolution, the development of large and complex (eukaryotic) cells, also involved cooperation: Many of their components, for example mitochondria (small granular structures that are needed for respiration) and chloroplasts (the photosynthetic units of higher plants) are believed to have begun their existence as free-living prokaryotic cells. They now have become components of complex cells, cooperating biochemically with the other subcellular structures. Both mitochondria and chloroplasts possess their own DNA, which shows that they were once free-living bacteria-like organisms, but they have survived better in a cooperative relationship.

Cooperation between cells; multicellular organisms

Multicellular organisms evolved from cooperative communities of eukaryotic cells. Some insights into how this happened can be gained from examples which are just on the borderline between the multicellular organisms and single-celled ones. The cooperative behavior of a genus of unicellular eukareotes called slime molds is particularly interesting because it gives us a glimpse of how multicellular organisms may have originated. The name of the slime molds is misleading, since they are not fungi, but are similar to amoebae.

Under ordinary circumstances, the individual cells wander about independently searching for food, which they draw into their interiors and digest. However, when food is scarce, they send out a chemical signal of distress. (Researchers have analyzed the molecule which expresses slime mold unhappiness, and they have found it to be cyclic adenosine monophosphate.) At this signal, the cells congregate and the mass of cells begins to crawl, leaving a slimy

Figure 4.2: *The biologist Lynn Margulis (1938-2011), who contributed importantly to our modern understanding of symbiosis as a central mechanism of evolution. Source: LynnMargulis.jpg, [CC BY-SA 2.5], Wikimedia Commons*

trail. At it crawls, the community of cells gradually develops into a tall stalk, surmounted by a sphere - the "fruiting body". Inside the sphere, spores are produced by a sexual process. If a small animal, for example a mouse, passes by, the spores may adhere to its coat; and in this way they may be transported to another part of the forest where food is more plentiful.

Slime molds represent a sort of missing link between unicellular and multicellular or organisms. Normally the cells behave as individualists, wandering about independently, but when challenged by a shortage of food, the slime mold cells join together into an entity which closely resembles a multicellular organism.

The cells even seem to exhibit altruism, since those forming the stalk have little chance of survival, and yet they are willing to perform their duty, holding up the sphere at the top so that the spores will survive and carry the genes of the community into the future.

Multicellular organisms often live in a symbiotic relationship with other species. For example, in both animals and humans, bacteria are essential for the digestion of food. Fungi on the roots of plants aid their absorption of water and nutrients. Communities of bacteria and other organisms living in the soil are essential for the recycling of nutrients. Insects are essential to many plants for pollination.

Cooperation in groups of animals and human groups

The social behavior of groups of animals, flocks of birds and communities of social insects involves cooperation as well as rudimentary forms of language. Various forms of language, including chemical signals, postures and vocal signals, are important tools for orchestrating cooperative behavior.

The highly developed language of humans made possible an entirely new form of evolution. In cultural evolution (as opposed to genetic evolution), information is passed between generations not in the form of a genetic code, but in the form of linguistic symbols. With the invention of writing, and later the invention of printing, the speed of human cultural evolution greatly increased. Cooperation is central to this new form of evolution. Cultural advances can be shared by all humans.

Trading in primitive societies

Although primitive societies engaged in frequent wars, they also cooperated through trade. Peter Watson, an English historian of ideas, believes that long-distance trade took place as early as 150,000 before the present. There is evidence that extensive trade in obsidian and flint took place during the stone

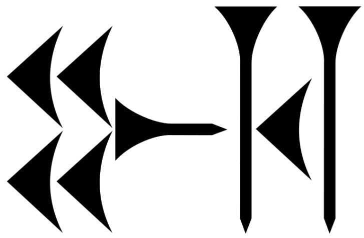

Figure 4.3: *The invention of writing was prompted by the necessities of trade. Public domain, Wikimedia Commons*

age. Evidence for wide ranging prehistoric obsidian and flint trading networks has been found in North America. Ancient burial sites in Southeast Asia show that there too, prehistoric trading took place across very large distances. Analysis of jade jewelry from the Phillipines, Thailand, Maylasia and Viet Nam shows that the jade originated in Taiwan.

The invention of writing was prompted by the necessities of trade. In prehistoric Mesopotamia, clay tokens marked with simple symbols were used for accounting as early as 8,000 BC. Often these tokens were kept in clay jars, and symbols on the outside of the jars indicated the contents. About 3,500 BC, the use of such tokens and markings led to the development of pictographic writing in Mesopotamia, and this was soon followed by the cuneiform script, still using soft clay as a medium. The clay tablets were later dried and baked to ensure permanency. The invention of writing led to a great acceleration of human cultural evolution. Since ideas could now be exchanged and preserved with great ease through writing, new advances in technique could be shared by an ever larger cooperating community of humans. Our species became more and more successful as its genius for cooperation developed.

Gracilization and decreasing sexual dimorphism

Early ancestors of modern humans had a relatively heavy (robust) bone structure in relation to their height. This robust bone structure seems to have been favored by frequent combat. During their evolution, modern humans became less robust and more gracile. In other words, their skeletons became lighter in relation to their height. Simultaneously the height and weight of males became less different from the height and weight of females. These trends are generally interpreted as indicating that combat became less important as present-day humans evolved.

Ethics and growth of the social unit

Early religions tended to be centered on particular tribes, and the ethics associated with them were usually tribal in nature. However, the more cosmopolitan societies that began to form after the Neolithic agricultural revolution required a more universal code of ethics. It is interesting to notice that many of the great ethical teachers of human history, for example Moses, Socrates, Plato, Aristotle, Lao Tzu, Confucius, Buddha, and Jesus, lived at the time when the change to larger social units was taking place. Tribalism was no longer appropriate. A wider ethic was needed.

Today the size of the social unit is again being enlarged, this time enlarged to include the entire world. Narrow loyalties have become inappropriate and there is an urgent need for a new ethic - a global ethic. Loyalty to one's nation needs to be supplemented by a higher loyalty to humanity as a whole.

Interdependence in modern human society

All of the great upward steps in the evolution of life on earth have involved cooperation: Prokaryotes, the first living cells, can be thought of as cooperative communities of autocatylists; large, complex eukaryote cells are now believed to have evolved as cooperative communities of prokaryotes; multicellular organisms are cooperative communities of eukaryotes; multicellular organisms cooperate to form societies; and different species cooperate to form ecosystems. Indeed, James Lovelock has pointed out that the earth as a whole is a complex interacting system that can be regarded as a huge organism.

The enormous success of humans as a species is due to their genius for cooperation. The success of humans is a success of cultural evolution, a new form of evolution in which information is passed between generations, not in the form of DNA sequences but in the form of speech, writing, printing and finally electronic signals. Cultural evolution is built on cooperation, and has reached great heights of success as the cooperating community has become larger and larger, ultimately including the entire world.

Without large-scale cooperation, modern science would never have evolved. It developed as a consequence of the invention of printing, which allowed painfully gained detailed knowledge to be widely shared. Science derives its great power from concentration. Attention and resources are brought to bear on a limited problem until all aspects of it are understood. It would make no sense to proceed in this way if knowledge were not permanent, and if the results of scientific research were not widely shared. But today the printed word and the electronic word spread the results of research freely to the entire world. The whole human community is the repository of shared knowledge.

The achievements of modern society are achievements of cooperation. We can fly, but no one builds an airplane alone. We can cure diseases, but only through the cooperative efforts of researchers, doctors and medicinal firms. We can photograph and understand distant galaxies, but the ability to do so is built on the efforts of many cooperating individuals.

An isolated sponge cell can survive, but an isolated human could hardly do so. Like an isolated bee, a human would quickly die without the support of the community. The comfort and well-being that we experience depends on far-away friendly hands and minds, since trade is global, and the exchange of ideas is also global.

Finally, we should be conscious of our cooperative relationships with other species. We could not live without the bacteria that help us to digest our food. We could not live without the complex communities of organisms in the soil that convert dead plant matter into fertile topsoil. We could not live without plants at the base of the food chain, but plants require pollination, and pollination frequently requires insects. An intricate cooperative network of inter-species relationships is necessary for human life, and indeed necessary for all life. Competition plays a role in evolution, but the role of cooperation is greater.

Two sides of human nature

Looking at human nature, both from the standpoint of evolution and from that of everyday experience, we see the two faces of Janus; one face shines radiantly; the other is dark and menacing. Two souls occupy the human breast, one warm and friendly, the other murderous. Humans have developed a genius for cooperation, the basis for culture and civilization; but they are also capable of genocide; they were capable of massacres during the Crusades, capable of genocidal wars against the Amerinds, capable of the Holocaust, of Hiroshima, of the killing-fields of Cambodia, of Rwanda, and of Darfur

As an example of the two sides of human nature, we can think of Scandinavia. The Vikings were once feared throughout Europe. The Book of Common Prayer in England contains the phrase "Protect us from the fury of the Northmen!". Today the same people are so peaceful and law-abiding that they can be taken as an example for how we would like a future world to look. Human nature has the possibility for both kinds of behavior depending on the circumstances. This being so, there are strong reasons to enlist the help of education and religion to make the bright side of human nature win over the dark side. Today, the mass media are an important component of education, and thus the mass media have a great responsibility for encouraging the cooperative and constructive side of human nature rather than the dark and destructive side.

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Chapter 5

ARTIFICIAL LIFE

The border between life and non-life

It is difficult to give a precise definition of artificial life. Of course the term means "life produced by humans rather than by nature", but what is life? Is self-replication the only criterion? The phrase "produced by humans" also presents difficulties. Humans have played a role in creating domestic species of animals and plants. Can cows, dogs, and high-yield wheat varieties be called "artificial life" ? In one sense, they can. These species and varieties certainly would not have existed without human intervention.

We come nearer to what most people might call "artificial life" when we take parts of existing organisms and recombine them in novel ways, using the techniques of biotechnology. For example, Steen Willadsen, working at the Animal Research Station, Cambridge England, was able to construct chimeras by operating under a microscope on embryos at the eight-cell stage. The *zona pelucida* is a transparent shell that surrounds the cells of the embryo. Willadsen was able to cut open the *zona pelucida*, to remove the cells inside, and to insert a cell from a sheep embryo together with one from a goat embryo. The chimeras which he made in this way were able to grow to be adults, and when examined, their cells proved to be a mosaic, some cells carrying the sheep genome while others carried the genome of a goat. By the way, Willadsen did not create his chimeras in order to produce better animals for agriculture. He was interested in the scientifically exciting problem of morphogenesis: How is the information of the genome translated into the morphology of the growing embryo? [1]

Human genes are now routinely introduced into embryos of farm animals, such as pigs or sheep. The genes are introduced into regulatory sequences

[1] Willadsen is famous for having made the first verified and reproducible clone of a mammal. In 1984 he made two genetically identical lambs from early sheep embryo cells. (Dolly)

which cause expression in mammary tissues, and the adult animals produce milk containing human proteins. Many medically valuable proteins are made in this way. Examples include human blood-clotting factors, interleukin-2 (a protein which stimulates T-lymphocytes), collagen and fibrinogen (used to treat burns), human fertility hormones, human hemoglobin, and human serum albumin.

Transgenic plants and animals in which the genes of two or more species are inherited in a stable Mendelian way have become commonplace in modern laboratory environments, and, for better or for worse, they are also becoming increasingly common in the external global environment. These new species might, with some justification, be called “artificial life”.

In discussing the origin of life in a previous chapter, we mentioned that a long period of molecular evolution probably preceded the evolution of cells. In the early 1970’s, S. Spiegelman performed a series of experiments in which he demonstrated that artificial molecular evolution can be made to take place in vitro. Spiegelman prepared a large number of test tubes in which RNA replication could take place. The aqueous solution in each of the test tubes consisted of RNA replicase, ATP, UTP (uracil triphosphate), GTP (guanine triphosphate), CTP (cytosine triphosphate) and buffer. He then introduced RNA from a bacteriophage into the first test tube.

After a predetermined interval of time, during which replication took place, Spiegelman transferred a drop of solution from the first test tube to a new tube, uncontaminated with RNA. Once again, replication began and after an interval a drop was transferred to a third test tube. Spiegelman repeated this procedure several hundred times, and at the end he was able to demonstrate that the RNA in the final tube differed from the initial sample, and that it replicated faster than the initial sample. The RNA had evolved by the classical Darwinian mechanisms of mutation and natural selection. Mistakes in copying had produced mutant RNA strands which competed for the supply of energy-rich precursor molecules (ATP, UTP, GTP and CTP). The most rapidly-reproducing mutants survived. Was Spiegelman’s experiment merely a simulation of an early stage of biological evolution? Or was evolution of an extremely primitive life-form actually taking place in his test tubes?

G.F. Joyce, D.P. Bartel and others have performed experiments in which strands of RNA with specific catalytic activity (ribozymes) have been made to evolve artificially from randomly coded starting populations of RNA. In these experiments, starting populations of 1013 to 1015 randomly coded RNA molecules are tested for the desired catalytic activity, and the most successful molecules are then chosen as parents for the next generation. The selected molecules are replicated many times, but errors (mutations) sometimes occur in the replication. The new population is once again tested for catalytic activity, and the process is repeated. The fact that artificial evolution of ribozymes is possible can perhaps be interpreted as supporting the "RNA world" hypothesis, i.e. the hypothesis that RNA preceded DNA and proteins in the early history of terrestrial life.

The mathematician John von Neumann speculated on the possibility of constructing artificial self-reproducing automata. In the early 1940's, a period when there was much discussion of the Universal Turing Machine, he became interested in constructing a mathematical model of the requirements for self-reproduction. Besides the Turing machine, another source of his inspiration was the paper by Warren McCulloch and Walter Pitts entitled *A logical calculus of the ideas immanent in nervous activity*, which von Neumann read in 1943. In his first attempt (the kinematic model), he imagined an extremely large and complex automaton, floating on a lake which contained its component parts.

Von Neumann's imaginary self-reproducing automaton consisted of four units, A, B, C and D. Unit A was a sort of factory, which gathered component parts from the surrounding lake and assembled them according to instructions which it received from other units. Unit B was a copying unit, which reproduced sets of instructions. Unit C was a control apparatus, similar to a computer. Finally D was a long string of instructions, analogous to the "tape" in the Turing machine. In von Neumann's kinematic automaton, the instructions were coded as a long binary number. The presence of what he called a "girder" at a given position corresponded to 1, while its absence corresponded to 0. In von Neumann's model, the automaton completed the assembly of its offspring by injecting its progeny with the duplicated instruction tape, thus making the new automaton both functional and fertile.

In presenting his kinematic model at the Hixton Symposium (organized by Linus Pauling in the late 1940's), von Neumann remarked that "...it is clear that the instruction [tape] is roughly effecting the function of a gene. It is also clear that the copying mechanism B performs the fundamental act of reproduction, the duplication of the genetic material, which is clearly the fundamental operation in the multiplication of living cells. It is also easy to see how arbitrary alterations of the system...can exhibit certain traits which appear in connection with mutation, lethality as a rule, but with a possibility of continuing reproduction with a modification of traits."

It is very much to von Neumann's credit that his kinematic model (which he invented several years before Crick and Watson published their DNA structure) was organized in much the same way that we now know the reproductive apparatus of a cell to be organized. Nevertheless he was dis- satisfied with the model because his automaton contained too many "black boxes". There were too many parts which were supposed to have certain functions, but for which it seemed very difficult to propose detailed mechanisms by which the functions could be carried out. His kinematic model seemed very far from anything which could actually be built.

Von Neumann discussed these problems with his close friend, the Polish-American mathematician Stanislaw Ulam, who had for a long time been interested in the concept of self-replicating automata. When presented with the black box difficulty, Ulam suggested that the whole picture of an automaton floating on a lake containing its parts should be discarded. He proposed instead a model which later came to be known as the Cellular Automaton Model. In Ulam's model, the self-reproducing automaton lives in a very special space. For example, the space might resemble an infinite checkerboard, each square would constitute a multi-state cell. The state of each cell in a particular time interval is governed by the states of its near neighbors in the preceding time interval according to relatively simple laws. The automaton would then consist of a special configuration of cell states, and its reproduction would correspond to production of a similar configuration of cell states in a neighboring region of the cell lattice.

Von Neumann liked Ulam's idea, and he began to work in that direction. However, he wished his self-replicating automaton to be able to function as a universal Turing machine, and therefore the plans which he produced were excessively complicated. In fact, von Neumann believed complexity to be a necessary requirement for self-reproduction. In his model, the cells in the lattice were able to have 29 different states, and the automaton consisted of a configuration involving hundreds of thousands of cells. Von Neumann's manuscript on the subject became longer and longer, and he did not complete it before his early death from prostate cancer in 1957. The name "cellular automaton" was coined by Arthur Burks, who edited von Neumann's posthumous papers on the theory of automata.

Arthur Burks had written a Ph.D. thesis in philosophy on the work of the nineteenth century thinker Charles Sanders Pierce, who is today considered to be one of the founders of semiotics9. He then studied electrical engineering at the Moore School in Philadelphia, where he participated in the construction of ENIAC, one of the first general purpose electronic digital computers, and where he also met John von Neumann. He worked with von Neumann on the construction of a new computer, and later Burks became the leader of the Logic of Computers Group at the University of Michigan. One of Burks' students at Michigan was John Holland, the pioneer of genetic algorithms. Another student of Burks, E.F. Codd, was able to design a self-replicating automaton of the von Neumann type using a cellular automaton system with only 8 states (as compared with von Neumann's 29). For many years, enthusiastic graduate students at the Michigan group continued to do important research on the relationships between information, logic, complexity and biology.

Meanwhile, in 1968, the mathematician John Horton Conway, working in England at Cambridge University, invented a simple game which greatly increased the popularity of the cellular automaton concept. Conway's game, which he called "Life", was played on an infinite checker-board-like lattice of cells, each cell having only two states, "alive" or "dead". The rules which Conway proposed are as follows: "If a cell on the checkerboard is alive, it will survive in the next time step (generation) if there are either two or three neighbors also alive. It will die of overcrowding if there are more than three live neighbors, and it will die of exposure if there are fewer than two. If a cell on the checkerboard is dead, it will remain dead in the next generation unless exactly three of its eight neighbors is alive. In that case, the cell will be 'born' in the next generation".

Originally Conway's Life game was played by himself and by his colleagues at Cambridge University's mathematics department in their common room: At first the game was played on table tops at tea time. Later it spilled over from the tables to the floor, and tea time began to extend: far into the afternoons. Finally, wishing to convert a wider audience to his game, Conway submitted it to Martin Gardner, who wrote a popular column on "Mathematical Games" for the Scientific American. In this way Life spread to MIT's Artificial Intelligence Laboratory, where it created such interest that the MIT group designed a small computer specifically dedicated to rapidly implementing Life's rules.

The reason for the excitement about Conway's Life game was that it seemed capable of generating extremely complex patterns, starting from relatively simple configurations and using only its simple rules. Ed Fredkin, the director of MIT's Artificial Intelligence Laboratory, became enthusiastic about cellular automata because they seemed to offer a model for the way in which complex phenomena can emerge from the laws of nature, which are after all very simple. In 1982, Fredkin (who was independently wealthy because of a successful computer company which he had founded) organized a conference on cellular automata on his private island in the Caribbean. The conference is notable because one of the participants was a young mathematical genius named Stephen Wolfram, who was destined to refine the concept of cellular automata and to become one of the leading theoreticians in the field.[2]

One of Wolfram's important contributions was to explore exhaustively the possibilities of 1-dimensional cellular automata. No one before him had looked at 1-dimensional CA's, but in fact they had two great advantages: The first of these advantages was simplicity, which allowed Wolfram to explore and classify the possible rule sets. Wolfram classified the rule sets into 4 categories, accord-

[2]As many readers probably know, Stephen Wolfram was also destined to become a millionaire by inventing the elegant symbol-manipulating program system, Mathematica.

ing to the degree of complexity which they generated. The second advantage was that the configurations of the system in successive generations could be placed under one another to form an easily-surveyed 2-dimensional visual display. Some of the patterns generated in this way were strongly similar to the patterns of pigmentation on the shells of certain molluscs. The strong resemblance seemed to suggest that Wolfram's 1-dimensional cellular automata might yield insights into the mechanism by which the pigment patterns are generated.

In general, cellular automata seemed to be promising models for gaining insight into the fascinating and highly important biological problem of morphogenesis: How does the fertilized egg translate the information on the genome into the morphology of the growing embryo, ending finally with the enormously complex morphology of a fully developed and fully differentiated multicellular animal? Our understanding of this amazing process is as yet very limited, but there is evidence that as the embryo of a multicellular animal develops, cells change their state in response to the states of neighboring cells. In the growing embryo, the "state" of a cell means the way in which it is differentiated, i.e., which genes are turned on and which off - which information on the genome is available for reading, and which segments are blocked. Neighboring cells signal to each other by means of chemical messengers. Clearly there is a close analogy between the way complex patterns develop in a cellular automaton, as neighboring cells influence each other and change their states according to relatively simple rules, and the way in which the complex morphology of a multicellular animal develops in the growing embryo.

Conway's Life game attracted another very important worker to the field of cellular automata: In 1971, Christopher Langton was working as a computer programmer in the Stanley Cobb Laboratory for Psychiatric Research at Massachusetts General Hospital. When colleagues from MIT brought to the laboratory a program for executing Life, Langton was immediately interested. He recalls "It was the first hint that there was a distinction between the hardware and the behavior which it would support... You had the feeling that there was something very deep here in this little artificial universe and its evolution through time. [At the lab] we had a lot of discussions about whether the program could be open ended - could you have a universe in which life could evolve?"

Later, at the University of Arizona, Langton read a book describing von Neumann's theoretical work on automata. He contacted Arthur Burks, von Neumann's editor, who told him that no self-replicating automaton had actually been implemented, although E.F. Codd had proposed a simplified plan with only 8 states instead of 29. Burks suggested to Langton that he should start by reading Codd's book.

When Langton studied Codd's work, he realized that part of the problem was that both von Neumann and Codd had demanded that the self-reproducing automaton should be able to function as a universal Turing machine, i.e., as a universal computer. When Langton dropped this demand (which he considered to be more related to mathematics than to biology) he was able to construct a relatively simple self-reproducing configuration in an 8-state 2-dimensional lattice of CA cells. As they reproduced themselves, Langton's loop-like cellular automata filled the lattice of cells in a manner reminiscent of a growing coral reef, with actively reproducing loops on the surface of the filled area, and "dead" (nonreproducing) loops in the center.

Langton continued to work with cellular automata as a graduate student at Arthur Burks' Logic of Computers Group at Michigan. His second important contribution to the field was an extension of Wolfram's classification of rule sets for cellular automata. Langton introduced a parameter A to characterize various sets of rules according to the type of behavior which they generated. Rule sets with a value near to the optimum ($A = 0.273$) generated complexity similar to that found in biological systems. This value of Langton's A parameter corresponded to a borderline region between periodicity and chaos.

After obtaining a Ph.D. from Burks' Michigan group, Christopher Langton moved to the Center for Nonlinear Studies at Los Alamos, New Mexico, where in 1987 he organized an "Interdisciplinary Workshop on the Synthesis and Simulation of Living Systems" - the first conference on artificial life ever held. Among the participants were Richard Dawkins, Astrid Lindenmeyer, John Holland, and Richard Laing. The noted Oxford biologist and author Richard Dawkins was interested in the field because he had written a computer program for simulating and teaching evolution. Astrid Lindenmeyer and her coworkers in Holland had written programs capable of simulating the morphogenesis of plants in an astonishingly realistic way. As was mentioned above, John Holland pioneered the development of genetic algorithms, while Richard Laing was the leader of NASA's study to determine whether self-reproducing factories might be feasible.

Langton's announcement for the conference, which appeared in the Scientific American, stated that "Artificial life is the study of artificial systems that exhibit behavior characteristic of natural living systems...The ultimate goal is to extract the logical form of living systems. Microelectronic technology and genetic engineering will soon give us the capability to create new life in silico as well as in vitro. This capacity will present humanity with the most far-reaching technical, theoretical, and ethical challenges it has ever confronted. The time seems appropriate for a gathering of those involved in attempts to simulate or synthesize aspects of living systems."

In the 1987 workshop on artificial life, a set of ideas which had gradually emerged during the previous decades of work on automata and simulations of living systems became formalized and crystallized: All of the participants agreed that something more than reductionism was needed to understand the phenomenon of life. This belief was not a revival of vitalism; it was instead a conviction that the abstractions of molecular biology are not in themselves sufficient. The type of abstraction found in Darwin's theory of natural selection was felt to be nearer to what was needed. The viewpoints of thermodynamics and statistical mechanics were also helpful. What was needed, it was felt, were insights into the flow of information in complex systems; and computer simulations could give us this insight. The fact that the simulations might take place in silico did not detract from their validity. The logic and laws governing complex systems and living systems were felt to be independent of the medium.

As Langton put it, "The ultimate goal of artificial life would be to create 'life' in some other medium, ideally a virtual medium where the essence of life has been abstracted from the details of its implementation in any particular model. We would like to build models that are so life-like that they cease to become models of life and become examples of life themselves."

Most of the participants at the first conference on artificial life had until then been working independently, not aware that many other researchers shared their viewpoint. Their conviction that the logic of a system is largely independent of the medium echoes the viewpoint of the Macy Conferences on cybernetics in the 1940's, where the logic of feedback loops and control systems was studied in a wide variety of contexts, ranging from biology and anthropology to computer systems. A similar viewpoint can also be found in biosemiotics, where, in the words of the Danish biologist Jesper Hoffmeyer, "the sign, rather than the molecule" is considered to be the starting point for studying life. In other words, the essential ingredient of life is information; and information can be expressed in many ways. The medium is less important than the message.

The conferences on artificial life have been repeated each year since 1987, and European conferences devoted to the new and rapidly growing field have also been organized. Langton himself moved to the Santa Fe Institute, where he became director of the institute's artificial life program and editor of a new journal, *Artificial Life*. The first three issues of the journal have been published as a book by the MIT Press, and the book presents an excellent introduction to the field.

Among the scientists who were attracted to the artificial life conferences was the biologist Thomas Ray, a graduate of Florida State University and Harvard, and an expert in the ecology of tropical rain forests. In the late 1970's, while he was working on his Harvard Ph.D., Ray happened to have a conversation with a computer expert from the MIT Artificial Intelligence Lab, who mentioned to him that computer programs can replicate. To Ray's question "How?", the AI man answered "Oh, it's trivial."

Ray continued to study tropical ecologies, but the chance conversation from his Cambridge days stuck in his mind. By 1989 he had acquired an academic post at the University of Delaware, and by that time he had also become proficient in computer programming. He had followed with interest the history of computer viruses. Were these malicious creations in some sense alive? Could it be possible to make self-replicating computer programs which underwent evolution by natural selection? Ray considered John Holland's genetic algorithms to be analogous to the type of selection imposed by plant and animal breeders in agriculture. He wanted to see what would happen to populations of digital organisms that found their own criteria for natural selection - not humanly imposed goals, but self-generated and open-ended criteria growing naturally out of the requirements for survival.

Although he had a grant to study tropical ecologies, Ray neglected the project and used most of his time at the computer, hoping to generate populations of computer organisms that would evolve in an open-ended and uncontrolled way. Luckily, before starting his work in earnest, Thomas Ray consulted Christopher Langton and his colleague James Farmer at the Center for Nonlinear Studies in New Mexico. Langton and Farmer realized that Ray's project could be a very dangerous one, capable of producing computer viruses or worms far more malignant and difficult to eradicate than any the world had yet seen. They advised Ray to make use of Turing's concept of a virtual computer. Digital organisms created in such a virtual computer would be unable to live outside it. Ray adopted this plan, and began to program a virtual world in which his freely evolving digital organisms could live. He later named the system "Tierra".

Ray's Tierra was not the first computer system to aim at open-ended evolution. Steen Rasmussen, working at the Danish Technical University, had previously produced a system called "VENUS" (Virtual Evolution in a Non-stochastic Universe Simulator) which simulated the very early stages of the evolution of life on earth. However, Ray's aim was not to understand the origin of life, but instead to produce digitally something analogous to the evolutionary explosion of diversity that occurred on earth at the start of the Cambrian era. He programmed an 80-byte self-reproducing digital organism which he called "Ancestor", and placed it in Tierra, his virtual Garden of Eden.

Ray had programmed a mechanism for mutation into his system, but he doubted that he would be able to achieve an evolving population with his first attempt. As it turned out, Ray never had to program another organism. His 80-byte Ancestor reproduced and populated his virtual earth, changing under the action of mutation and natural selection in a way that astonished and delighted him.

In his freely evolving virtual zoo, Ray found parasites, and even hyperparasites, but he also found instances of altruism and symbiosis. Most astonishingly of all, when he turned off the mutations in his Eden, his organisms invented sex (using mechanisms which Ray had introduced to allow for parasitism). They had never been told about sex by their creator, but they seemed to find their own way to the Tree of Knowledge.

Thomas Ray expresses the aims of his artificial life research as follows:12 "Everything we know about life is based on one example: Life on Earth. Everything we know about intelligence is based on one example: Human intelligence. This limited experience burdens us with preconceptions, and limits our imaginations... How can we go beyond our conceptual limits, find the natural form of intelligent processes in the digital medium, and work with the medium to bring it to its full potential, rather than just imposing the world we know upon it by forcing it to run a simulation of our physics, chemistry and biology?..."

"In the carbon medium it was evolution that explored the possibilities inherent in the medium, and created the human mind. Evolution listens to the medium it is embedded in. It has the advantage of being mindless, and therefore devoid of preconceptions, and not limited by imagination."

"I propose the creation of a digital nature - a system of wildlife reserves in cyberspace in the interstices between human colonizations, feeding off unused CPU-cycles and permitted a share of our bandwidth. This would be a place where evolution can spontaneously generate complex information processes, free from the demands of human engineers and market analysts telling it what the target applications are - a place for a digital Cambrian explosion of diversity and complexity..."

"It is possible that out of this digital nature, there might emerge a digital intelligence, truly rooted in the nature of the medium, rather than brutishly copied from organic nature. It would be a fundamentally alien intelligence, but one that would complement rather than duplicate our talents and abilities."

Have Thomas Ray and other "a-lifers"[3] created artificial living organisms? Or have they only produced simulations that mimic certain aspects of life? Obviously the answer to this question depends on the definition of life, and there is no commonly agreed-upon definition. Does life have to involve carbon chemistry? The a-lifers call such an assertion "carbon chauvinism". They point out that elsewhere in the universe there may exist forms of life based on other media, and their program is to find medium-independent characteristics which all forms of life must have.

[3]In this terminology, ordinary biologists are "b-lifers".

All of the forms of artificial life that we have discussed derive their complexity from the consumption of free energy. For example, Spiegelman's evolving RNA molecules feed on the Gibbs free energy of the phosphate bonds of their precursors, ATP, GTP, UTP, and CTP. This free energy is the driving force behind artificial evolution which Spiegelman observed. In his experiment, thermodynamic information in the form of high-energy phosphate bonds is converted into cybernetic information.

Similarly, in the polymerase chain reaction, discussed in a previous chapter, the Gibbs free energy of the phosphate bonds in the precursor molecules ATP, TTP, GTP and CTP drives the reaction. With the aid of the enzyme DNA polymerase, the soup of precursors is converted into a highly improbable configuration consisting of identical copies of the original sequence. Despite the high improbability of the resulting configuration, the entropy of the universe has increased in the copying process. The improbability of the set of copies is less than the improbability of the high energy phosphate bonds of the precursors.

The polymerase chain reaction reflects on a small scale, what happens on a much larger scale in all living organisms. Their complexity is such that they never could have originated by chance, but although their improbability is extremely great, it is less than the still greater improbability of the configurations of matter and energy from which they arose. As complex systems are produced, the entropy of the universe continually increases, i.e., the universe moves from a less probable configuration to a more probable one.

In Thomas Ray's experiments, the source of thermodynamic information is the electrical power needed to run the computer. In an important sense one might say that the digital organisms in Ray's Tierra system are living. This type of experimentation is in its infancy, but since it combines the great power of computers with the even greater power of natural selection, it is hard to see where it might end. One fears that it may end badly for humans.

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Chapter 6

RELIGIOUS OPPOSITION T0 EVOLUTION

Darwin's own views on religion

In 1839 Darwin married his pretty cousin, Emma Wedgwood, the youngest daughter of his much-admired Uncle Jos. She was a charming and light-hearted girl who has studied piano under Chopin. Emma and Charles Darwin were to have ten children together (of whom three were knighted for their contributions to science) and thirty years later he wrote of her: "I can declare that in my whole life I have not heard her utter one word which had rather had been left unsaid."

Emma Darwin was devoutly religious, and the wish not to hurt her feelings was an important reason for the two decades of delay between his 1838 notebook on *Transmutation of Species*,[1] which he showed only to his close friends Sir Charles Lyell and Sir Joseph Hooker, and the 1859 publication of *The Origin of Species*.

Darwin's own views changed during his lifetime. Darwin's father had at first wished him to become a physician, but when this proved to be too unpleasant for his son's sensitive nature, Robert Darwin proposed that Charles should study theology at Cambridge University. Darwin's religious beliefs at that time were such that he had no objection to becoming a clergyman. During the remainder of his life he very gradually lost his religious beliefs and finally he became an agnostic. The last elements of his religious faith were destroyed by the illness and death of his beloved daughter Annie, which seemed to him to be inconsistent with the actions of a benevolent and all-powerful God. Darwin was very anxious not to offend the religious beliefs of others, but scientific

[1]and his 1844 230-page notes on transmutation of species through natural selection

Figure 6.1: *Darwin's wife Emma was highly religious. His wholehearted devotion to her delayed for many decades the publication of "The Origin of Species"*

honesty forced him to write books which were interpreted as undermining religion. During his entire life at Down, Darwin gave generous financial support to the activities of the local church, St. Mary's, and he maintained a warm personal friendship with the Vicar, John Brodie Innes.

Figure 6.2: *Darwin's friend and mentor, the geologist Adam Sedgwick, was one of the founders of modern geology. As a young man, Darwin accompanied Sedgwick on expeditions to study the geology of Wales, and learned much from him. However, Sedgwick, who was a deeply religious man, later bitterly attacked his former pupil.*

The Oxford debate

Darwin's *Origin of Species*, published in 1859, was both an immediate success and an immediate scandal. Darwin had sent an advance copy of his book to *The Times* to be reviewed; and because of the illness of the usual reviewer, T.H. Huxley (1825-1895) was asked to comment on the book.

Huxley, who was one of the most brilliant zoologists of the period, immediately recognized the validity and importance of Darwin's work and exclaimed: "How exceedingly stupid not to have thought of that!" He wrote a long and favorable review for *The Times*, and partly as a result of this review, the first edition of The *Origin of Species* (1200 copies) was sold out on the day of publication. A second edition, published six weeks later, also sold out quickly; and new editions, reprintings and translations have been published ever since in a steady stream.

Darwin had avoided emphasizing the emotionally-charged subject of man's ancestry, but he did not think that it would be honest to conceal his belief that the human race belongs to the same great family which includes all other living organisms on earth. As a compromise, he predicted in a single sentence that through studies of evolution "light would be thrown on the origin of man and his history". This single sentence, and the obvious implications of Darwin's book, were enough to create a storm of furious opposition. One newspaper commented that "society must fall to pieces if Darwinism be true."

The storm of scandalized opposition was still growing in June 1860, when three anti-Darwinian papers were scheduled for reading at an open meeting of the British Association for the Advancement of Science at Oxford. The meeting hall was packed with 700 people as Samuel Wilberforce, Bishop of Oxford, took the floor to "smash Darwin". Darwin himself was too ill (or too diffident) to be present, but T.H. Huxley had been persuaded to attend the meeting to defend Darwin's ideas. After savagely attacking Darwin for half an hour, the bishop turned to Huxley and asked sneeringly, "Is it through your grandfather or your grandmother that you claim to be descended from an ape?"

Huxley, who was 35 at the time and at the height of his powers, rose to answer the bishop. He first gave scientific answers, point by point, to the objections which had been made to the theory of evolution. Finally, regarding the bishop's question about his ancestry, Huxley said: "If I had to choose between a poor ape for an ancestor and a man, highly endowed by nature and of great influence, who used those gifts to introduce ridicule into a scientific discussion and to discredit humble seekers after truth, I would affirm my preference for the ape." Huxley later recalled: "My retort caused inextinguishable laughter among the people."

Pandemonium broke out in the hall. Lady Brewster fainted, and Admiral FitzRoy, the former captain of the Beagle, rose to his feet, lifting a Bible in his hand, exclaiming that the Scriptures are the only reliable authority. Had he known Darwin's true nature, FitzRoy said, he would never have allowed him to sail on board the Beagle. As Macmillan's Magazine reported later, "Looks of bitter hatred were directed to those who were on Darwin's side." However, later that evening, in the discussions of the events of the day which took place in the Oxford colleges, Darwin's ideas were given a surprisingly fair hearing.

The debate at Oxford marked the turning-point in the battle over evolution. After that, Huxley and Hooker defended Darwin's theories with increasing success in England, while in Germany most of the prominent biologists, led by Professor Ernst Haeckel, were soon on Darwin's side. In America the theory of evolution was quickly accepted by almost all of the younger scientists, despite the opposition of the aging "creationist" Louis Agassiz. However, opposition from religious fundamentalists continued in most parts of America, and in Tennessee a school teacher named John T. Scopes was brought to trial for teaching the theory of evolution. He was prosecuted by the orator and three-time presidential candidate William Jennings Bryan, and defended by the brilliant Chicago lawyer Clarence Darrow. In this famous "Monkey Trial", Scopes was let off with a small fine, but the anti-evolution laws remained in force. It was only in 1968 that the State Legislature of Tennessee repealed its laws against the teaching of evolution.

In 1863 Huxley, who was not afraid of controversy, published a book entitled *Evidences of Man's Place in Nature*, and this was followed in 1871 by Darwin's book *The Descent of Man*. Huxley and Darwin brought forward a great deal of evidence to show that human beings are probably descended from an early ape-like primate which is now extinct. Darwin believed that the early stages of human evolution took place in Africa. In order to show that men and apes represent closely-related branches of the same family tree, Darwin and Huxley stressed the many points of similarity - resemblances in structure, reproduction, development, psychology and behavior, as well as susceptibility to the same parasites and diseases.

Figure 6.3: *Bishop Wilberforce and Thomas Huxley*

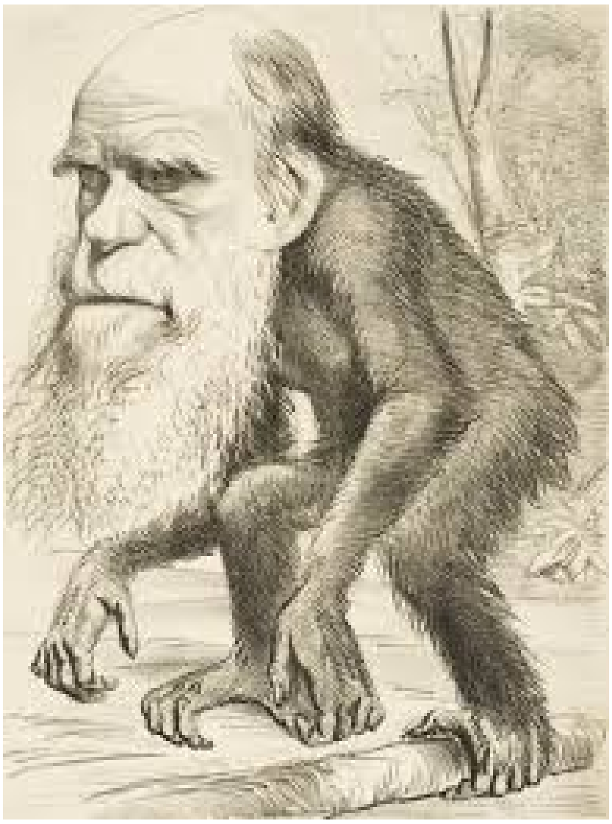

Figure 6.4: *One of the many characatures showing Darwin as an ape*

The Scopes "Monkey Trial"

The Butler Act was a law, passed in Tennessee in 1925, which prohibited public school teachers from denying the Biblical account of man's origin. In the same year, a substitute high-school teacher deliberately pleaded guilty to violating the Butler Act in order to test the Act's constitutionality. The result was the famous Scopes "Monkey Trial".

The trial took place in the small town of Dayton Tennessee, to which reporters and observers from around the United States flocked, attracted by the subject of the trial and the great fame of the the prosecuting and defending attorneys. The prosecuting attorney was William Jennings Bryan, who had run three times for the Presidency of the United States. Almost equally famous was the defending attorney, Clarence Darrow, who was known for his exceptional brilliance as a lawyer.

Although Scopes was found guilty and fined, he never had to pay the fine because the verdict was overthrown on a technicality. The famous trial of Scopes called attention to a controversy which was already raging within American churches: the Fundamentalist-Modernist Controversy. Modernests maintained the evolution was not consistent with religion, while Fundamentalists held that the word of God, as revealed in the Bible, took priority over all human knowledge. The Scopes "Monkey Trial" was seen by both sides as a theological and legal battle over the question of whether modern science should be taught in schools.

The battle over whether theology has supremacy over scientific knowledge is much older than Darwin's evolutionary theory. We can recall, for example, the trial of Galileo. Under threat of torture, he renounced his conviction that the earth is in a orbit around the sun. But, rising from his kneeling recantation, he is said to have muttered inaudibly, "Still it moves!"

Galileo was held in house attest for the remainder of his life, but the Renaissance was moving northward. Interestingly, on the day when Galileo died, Isaac Newton was born.

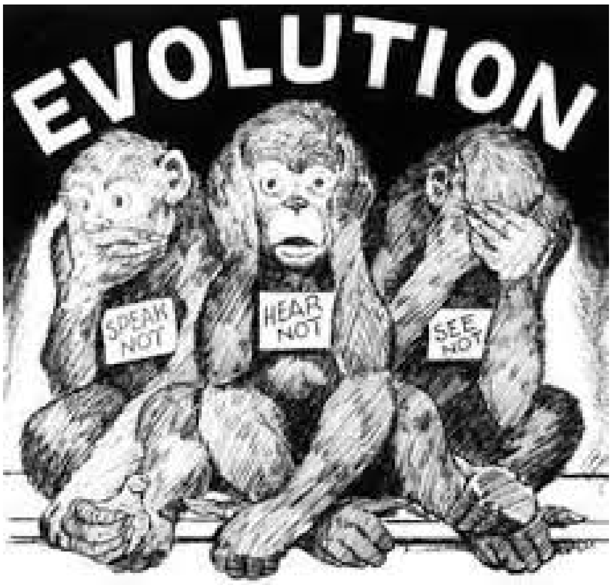

Figure 6.5:


THE ONION

SCOPES MONKEY TRIAL RAISES TROUBLING QUESTION:

IS SCIENCE BEING TAUGHT IN OUR SCHOOLS?

Scopes Trial Called 'Trial of the Century'

SHOULD CHILDREN BE EXPOSED TO FACTS?

Are Reason and Empirical Evidence Suitable School Subjects?

Scopes Defended By Super-Intelligent Chimpanzee-Man from Future

Figure 6.6:

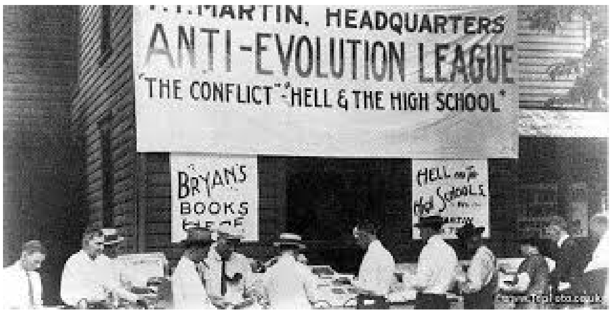

Figure 6.7:

Attitudes in various countries

The United States

Wikipedia states that "The US has one of the highest levels of public belief in biblical or other religious accounts of the origins of life on earth among industrialized countries."

"A 2017 Gallup creationism survey found that 38% of adults in the United States inclined to the view that 'God created humans in their present form at one time within the last 10,000 years' when asked for their views on the origin and development of human beings, which was noted as being at the lowest level in 35 years. 19% believed that 'human beings have developed over millions of years from less advanced forms of life, but God had no part in this process', despite 49% of respondents indicating they believed in evolution. Belief in creationism is inversely correlated to education; only 22% of those with post-graduate degrees believe in strict creationism. A 2000 poll for People for the American Way found 70% of the American public felt that evolution was compatible with a belief in God."

Attitudes of religious groups in the United States

Percentages in the United States who believe that evolution is the best explanation for the origin of human life on earth:[2]

- Buddhist 81%
- Hindu 81%
- Jewish 77%
- Unaffiliated 72%
- Catholic 58%
- Orthodox 54%
- Mainline Protestant 51%
- Muslim 45%
- Jehova's Witnesses 8%

[2] Pew Forum, 2006

A 2007 Gallup Poll found that 68% of Republicans do not believe in evolution, while among Democrats and Independents the corresponding figures were 40% and 38% respectively.

Among Americans who attend church every week, only 1% believe in evolution without the intervention of God.

India

Among those who had heard of Charles Darwin and knew something about the theory of evolution, 77% of people in India agree that enough scientific evidence exists to support Charles Darwin's Theory of Evolution. Also, 85% of God believing Indians who know about evolution agree that life on earth evolved over time as a result of natural selection.

Norway

According to a 2008 Norstat poll, only 8% of Norwegians disagree with the theory of evolution, while 4% are undecided.

Chapter 7

HORRORS LINKED TO SOCIAL DARWINISM

The "Great Man Theory"

The Wikipedia article on this subject states that "The great man theory is a 19th-century idea according to which history can be largely explained by the impact of great men, or heroes; highly influential individuals who, due to either their personal charisma, intelligence, wisdom, or political skill used their power in a way that had a decisive historical impact. The theory was popularized in the 1840s by Scottish writer Thomas Carlyle. But in 1860 Herbert Spencer formulated a counter-argument that has remained influential throughout the 20th century to the present: Spencer said that such great men are the products of their societies, and that their actions would be impossible without the social conditions built before their lifetimes.

"Carlyle stated that 'The history of the world is but the biography of great men', reflecting his belief that heroes shape history through both their personal attributes and divine inspiration. In his book On Heroes, Hero-Worship and the Heroic in History, Carlyle set out how he saw history as having turned on the decisions of 'heroes', giving detailed analysis of the influence of several such men (including Muhammad, Shakespeare, Luther, Rousseau, Pericles, Napoleon, and Wagner). Carlyle also felt that the study of great men was 'profitable' to one's own heroic side; that by examining the lives led by such heroes, one could not help but uncover something about one's true nature."

Napoleon

Napoleon Bonaparte's successful conquest of of much of Europe was so impressive that it seemed to be a prime example of the Great Man Theory. Did he

Figure 7.1: *According to the "Great Man Theory", human history is shaped by the ideas and actions of "great men", and they have the right to commit crimes for the sake of a greater good.*

have the right to sacrifice the enormous number of soldiers and civilians killed in his wars for the sake of a greater good - the unification of Europe? Is a "great man" above the usual laws of morality? Napoleon's disastrous invasion of Russia brought about his downfall, but it was also such a traumatic event for Russia that two of that country's most gifted authors wrote books refuting the "Great Man Theory".

Refutation by Tolstoy

The second part of the Epilogue of his famous novel, *War and Peace.* contains Tolstoy's refutation of the "Great Man Theory" which claims that historical events are the result of the actions of "heroes" and other great individuals. Tolstoy argues that "... this is impossible because of how rarely these actions result in great historical events." Rather, he argues, "Great historical events are the result of many smaller events driven by the thousands of individuals involved (he compares this to calculus, and the sum of infinitesimals). He then goes on to argue that these smaller events are the result of an inverse relationship between necessity and free-will, necessity being based on reason and therefore explainable by historical analysis, and free-will being based on 'consciousness' and therefore inherently unpredictable."

Figure 7.2: *A portrait of Napoleon (as he liked to see himself).*

Figure 7.3: *The Napoleonic Empire in 1812.*

Figure 7.4: *A Russian stamp commemorating Tolstoy's "War and Peace"*

Furthermore, in *War and Peace*, the portrait of Napoleon is neither heroic nor admirable nor in control of events. We see him in the burned-out remains of Moscow, giving futile orders, while the situation in which he has placed his army becomes increasingly desperate because of the approaching Russian winter. Tolstoy's Napoleon is entirely egocentric and lacking in human sympathy for the vast suffering that his ambitions have caused.

Refutation by Dostoyevsky

The Russian writer Feodor Dostoyevsky also felt compelled to write an anti-Napoleon novel - a novel refuting the "Great Man Theory". His *Crime and Punishment* deals with a poor student in St. Petersburg, Radion Raskolnikov, who murders an old woman. The victim is an unscrupulous pawnbroker, and Raskolnikov justifies his crime by explaining to himself that he could do a great deal of good with the money that he intends to steal from the old woman, while at the same time riding the world of a vermin.

Several times throughout the novel, Raskolnikov compares himself with Napoleon Bonaparte and shares his belief that murder is permissible in pursuit of a higher purpose. He also wishes to test the theory that some people are capable of such actions and that they have a right to perform them.

Having committed the murder, Raskolnikov finds that he is unable to live with his guilt. He deliberately incriminates himself, is condemned, and is sent to penal servitude Siberia. In the end, however, Raskolnikov achieves moral regeneration through the love of a woman, the prostitute Sonia, who has followed him to Siberia.

Figure 7.5: *A portrait of Dostoyevsky by Vasily Perov, 1872.*

Herbert Spencer

Herbert Spencer (1820-1903) achieved great fame as a philosopher during the 19th century. He was "the single most famous European intellectual during the closing decades of the 19th century." His books on ethics, religion, anthropology, economics, political theory, philosophy, literature, astronomy, biology, sociology, and psychology were translated into many languages. These languages included German, Italian, Spanish, French, Russian, Japanese and Chinese, and many others. In England alone, his books sold over a million copies.

Spencer's father was a member of the Derby Philosophical Society, and members of the society as well as members of his own family contributed to Herbert Spencer's education. Spencer was also influenced by members of the publisher John Chapman's salon, which included some of the leading intellectuals of the day.

Herbert Spencer's main philosophical work was his enormous 10-volume *System of Synthetic Philosophy*, which took him four decades to complete. The aim of this colossal work was to demonstrate that universal laws govern the behavior and evolution of all systems in the universe, including the evolution of life. Spencer believed that sociology too was governed by these universal laws. After reading Darwin's book, *The Origin of Species*, Spencer coined the phrase "the survival of the fittest".

According to the Wikipedia article about him, "For many, the name of Herbert Spencer would be virtually synonymous with Social Darwinism, a social theory that applies the law of the survival of the fittest to society; humanitarian impulses had to be resisted as nothing should be allowed to interfere with nature's laws, including the social struggle for existence.

"Spencer's association with Social Darwinism might have its origin in a specific interpretation of his support for competition. Whereas in biology the competition of various organisms can result in the death of a species or organism, the kind of competition Spencer advocated is closer to the one used by economists, where competing individuals or firms improve the well being of the rest of society. Spencer viewed private charity positively, encouraging both voluntary association and informal care to aid those in need, rather than relying on government bureaucracy or force. He further recommended that private charitable efforts would be wise to avoid encouraging the formation of new dependent families by those unable to support themselves without charity.

"In a letter to the Japanese government regarding intermarriage with Westerners, Spencer stated that 'if you mix the constitution of two widely divergent varieties which have severally become adapted to widely divergent modes of life, you get a constitution which is adapted to the mode of life of neither -

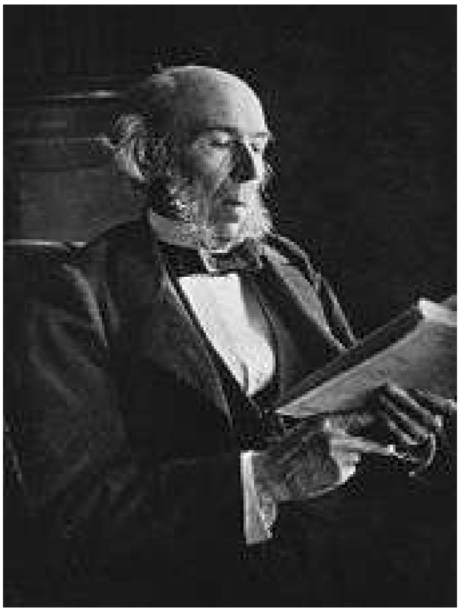

Figure 7.6: *Herbert Spencer at the age of 70.*

a constitution which will not work properly'. He goes on to say that America has failed to limit the immigration of Chinese and restrict their contact, especially sexual, with the presumed European stock. He states 'if they mix they must form a bad hybrid' regarding the issue of Chinese and (ethnically European) Americans. Spencer ends his letter with the following blanket statement against all immigration: 'In either case, supposing the immigration to be large, immense social mischief must arise, and eventually social disorganization. The same thing will happen if there should be any considerable mixture of European or American races with the Japanese.' "

Sir Francis Galton

Sir Francis Galton (1822-1911), one of the founders of the Eugenics movement, was Charles Darwin's half-cousin. They shared a grandfather, Erasmus Darwin. Many members of both the Galton and Darwin families were Fellows of the Royal Society.

Francis Galton was a child prodigy. By the age of 2 he could read. By five he had started to learn Latin, Greek and long division. At the age of 6, he was reading adult books for pleasure, including Shakespeare, which he quoted at length from memory.

As a young man, Galton studied Medicine at King's College London Med-

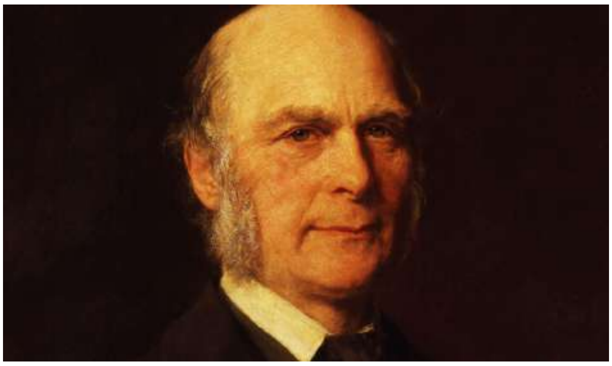

Figure 7.7: *Charles Darwin's cousin, Sir Francis Galton (1822-1911), was one of the founders of the Eugenics movement.*

ical School, and Mathematics at the University of Cambridge (1840-1844). His adult interests covered a range of topics, including Statistics, Sociology, Psychology, and Anthropology. He was also an explorer and an inventor.

Wikipedia states that "Galton produced over 340 papers and books. He also created the statistical concept of correlation and widely promoted regression toward the mean. He was the first to apply statistical methods to the study of human differences and inheritance of intelligence, and introduced the use of questionnaires and surveys for collecting data on human communities, which he needed for genealogical and biographical works and for his anthropometric studies.

"As an investigator of the human mind, he founded psychometrics (the science of measuring mental faculties) and differential psychology and the lexical hypothesis of personality. He devised a method for classifying fingerprints that proved useful in forensic science.

"As the initiator of scientific meteorology, he devised the first weather map, proposed a theory of anticyclones, and was the first to establish a complete record of short-term climatic phenomena on a European scale. He also invented the Galton Whistle for testing differential hearing ability.

"He was a pioneer in eugenics, coining the term itself and the phrase 'nature versus nurture'.His book Hereditary Genius (1869) was the first social scientific attempt to study genius and greatness."

Frederich Nietzsche

The extremely influential German philosopher Frederich Nietzsche (1844-1900), began his career as a classical philologist. At the age of 24, he became the youngest ever to hold the Chair of Classical Philology at the University of

Basel. However, ten years later he was forced to resign from this position because of health problems. During the following decade, cared for by his mother, Nietzsche completed most of his writing. At the age of 44, he suffered a breakdown and the complete loss of his mental facilities. He died in 1900 at the age of 55.

Wikipedia states that "Nietzsche defined master morality as the morality of the strong-willed. Nietzsche criticizes the view, which he identifies with contemporary British ideology, that good is everything that is helpful, and bad is everything that is harmful. He argues proponents of this view have forgotten the origins of its values, and is based merely on a non-critical acceptance of habit: what is useful has always been defined as good, therefore usefulness is goodness as a value. He continues explaining, that in the prehistoric state, 'the value or non-value of an action was derived from its consequences,' but ultimately, 'There are no moral phenomena at all, only moral interpretations of phenomena.' For strong-willed men, the 'good' is the noble, strong, and powerful, while the 'bad' is the weak, cowardly, timid, and petty."

Nietzsche states that "The noble type of man experiences itself as determining values; it does not need approval; it judges, 'what is harmful to me is harmful in itself'; it knows itself to be that which first accords honor to things; it is value-creating." In this sense, the master morality is the full recognition that oneself is the measure of all moral truths. Insofar as something is helpful to the strong-willed man, it is like what he values in himself; therefore, the strong-willed man values such things as good, because they aid him in a lifelong process of self-actualization through the will to power.

By contrast Nietzsche describes slave morality as follows: "Slave morality does not aim at exerting one's will by strength but by careful subversion. It does not seek to transcend the masters, but to make them slaves as well. The essence of slave morality is utility:[4] the good is what is most useful for the whole community, not the strong. Nietzsche saw this as a contradiction. Since the powerful are few in number compared to the masses of the weak, the weak gain power by corrupting the strong into believing that the causes of slavery (viz., the will to power) are 'evil', as are the qualities they originally could not choose because of their weakness. By saying humility is voluntary, slave morality avoids admitting that their humility was in the beginning forced upon them by a master. Biblical principles of turning the other cheek, humility, charity, and pity are the result of universalizing the plight of the slave onto all humankind, and thus enslaving the masters as well. 'The democratic movement is the heir to Christianity.' - the political manifestation of slave morality because of its obsession with freedom and equality."

Nazi atrocities, wars and genocides were inspired by Nietzsche's ideas, as well as those of the Eugenics and Social Darwinist movements.

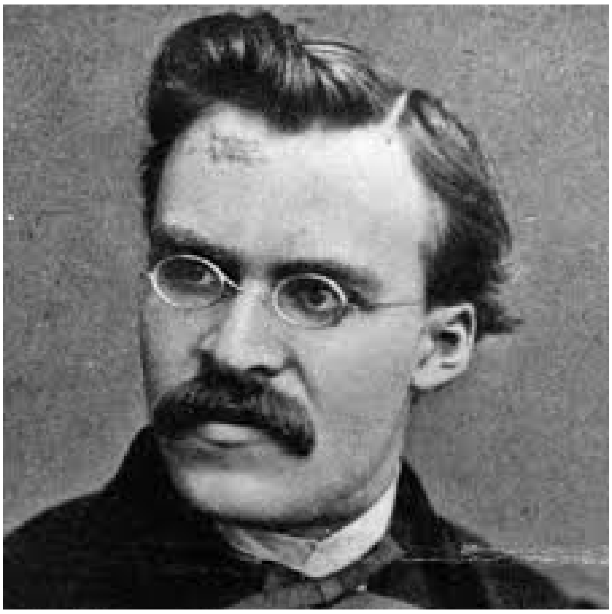

Figure 7.8: *Frederich Nietzsche (1844-1900). The posthumous editions of his works, edited by his racist sister, made his ideas even worse than they were in his original publications.*

Eugenics in Scandinavia

During the first part of the 20th century, the eugenics movement flourished in Europe and elsewhere in the world. Sweden was the first country where a government-funded eugenics (or "race biological") institute was created, and this has been considered a stain on the reputation of the emerging welfare state, made worse by the fact that a law that legitimized the forced sterilization of thousands was enacted in the 1930s.

According to the Wikipedia article on Swedish sterilizations, , "Originally the aim of the sterilization policy was explained as protection of society. The law targeted the so-called feeble-minded individuals or other people who were considered 'unfit for the society'. This practice peaked in the mid-1940s. In 1944, 85% of the sterilizations were performed on eugenic grounds. From the 1950s and onwards the law came to be used mostly for social or medical reasons, under varying degrees of pressure from doctors and social workers.

"According to the 2000 governmental report, 21,000 were estimated to have been forcibly sterilized, 6,000 were coerced into a 'voluntary' sterilization while the nature of a further 4,000 cases could not be determined."

Similar forced sterilizations were also carried out in Denmark. In addition, between 1923 and 1959, unmarried Danish women with several children were

Figure 7.9: *Many thousands of forced sterilizations were performed in the Scandinavian countries. Eugenic and racist ideas were also used by Denmark to justify colonial rule over Greenland.*

labeled as "pathologically promiscuous". They were forcibly sent for isolation on the island of Sprogø The idea behind this was that on the island there were no men, and therefore no more pregnancies would occur. However, local fishermen soon discovered that if they landed quietly on the island at night, they could find willing partners to fulfill their romantic desires.

Nazi atrocities and genocides

The Eugenics movement and the ideas of Nietzsche, Galton and Spengler must bear at least part of the blame for Nazi atrocities and genocides. During the World War II Holocaust, six million Jews were systematically murdered. This amounted to two thirds of the Jewish population of Europe. A broader definition of the Holocaust includes the murder of the Roma and the "incurably sick". as well as ethnic Poles, other Slavic groups, Soviet citizens and prisoners of war, homosexuals, Jehovah's Witnesses, black people, and political opponents.

At least three million Soviet prisoners of war died in German custody, but this figure is small compared with the total number of lives lost in the Soviet Union during World War II. Depending on which historian you believe, the USSR lost at least 11,000,000 soldiers (killed and missing) as well as somewhere between 7,000,000 and 20,000,000 million of its civilians. The total number of people killed in World War II is approximately 60,000,000. If deaths from war-related disease and famine are included, this figure becomes an estimated 80,000,000.

Figure 7.10: *Nazi genocides: A pile of corpses in the Buchenwald extermination camp.*

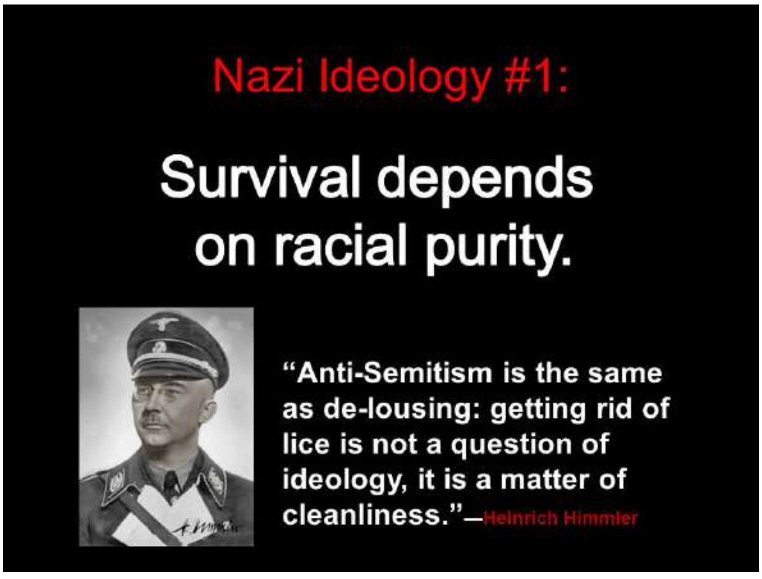

Figure 7.11: *The idea of the superiority of one race over another was at the root of Nazi atrocities.*

Figure 7.12: *Nazi racism was built on the idea that Aryans are superior to all other races. But who is to decide? Will not each ethnic group or nation always decide that they themselves are the "chosen people", loved by God and superior to all others?*

Figure 7.13: *Baba Yar.*

Ayn Rand

Alisa Zinov'yevna Rosenbaum, who later renamed herself "Ayn Rand", was born in St. Petersburg in 1905. After her education in Russia, she moved to the United States in 1926.

Two of her early novels were unsuccessful in the United States, but in 1943 she achieved fame with her third novel, *The Fountainhead*. Later, in 1957, she published another highly successful novel, *Atlas Struggled*. After these two novels, Rand abandoned fiction and began to publish a magazine to promote her personal philosophy. She also published collections of essays until her death in 1982.

The philosophy which she promoted in her books, magazine and essays is close to the "Will To Power" ideas of Nietzsche, which lie behind Nazi ideology and genocides. Rand's ideas are also closely related to the neoliberal philosophy of military world dominance that we see in the Project for a New American Century.

The hero of *The Fountainhead*, is an individualistic young architect named Howard Roark, who designs uncompromisingly modernistic buildings despite the opposition of the majority of architects, who are unwilling to accept innovation. Rand presents her hero as the embodiment of the ideal man. He personifies her belief that individualism is superior to collectivism.

In *Atlas Struggled*, which Ayn Rand regarded as her *magnum opus*, she presents us with a picture of a dystopian American society in which the efficiency of private businesses is undermined by government regulations and by "looting". As the novel ends, a new hyper-capitalist society is being planned.

Three films based on *Atlas Struggled* were produced as a series, Part I in 2011, Part II in 2012, and Part III in 2014, but they achieved neither critical nor box-office success. By contrast, the novel itself was translated into many languages, and by 1984 its sales had exceeded 5 million copies. The book continues to sell very well, especially in times of financial crisis. In 2011 it sold 445,000 copies.

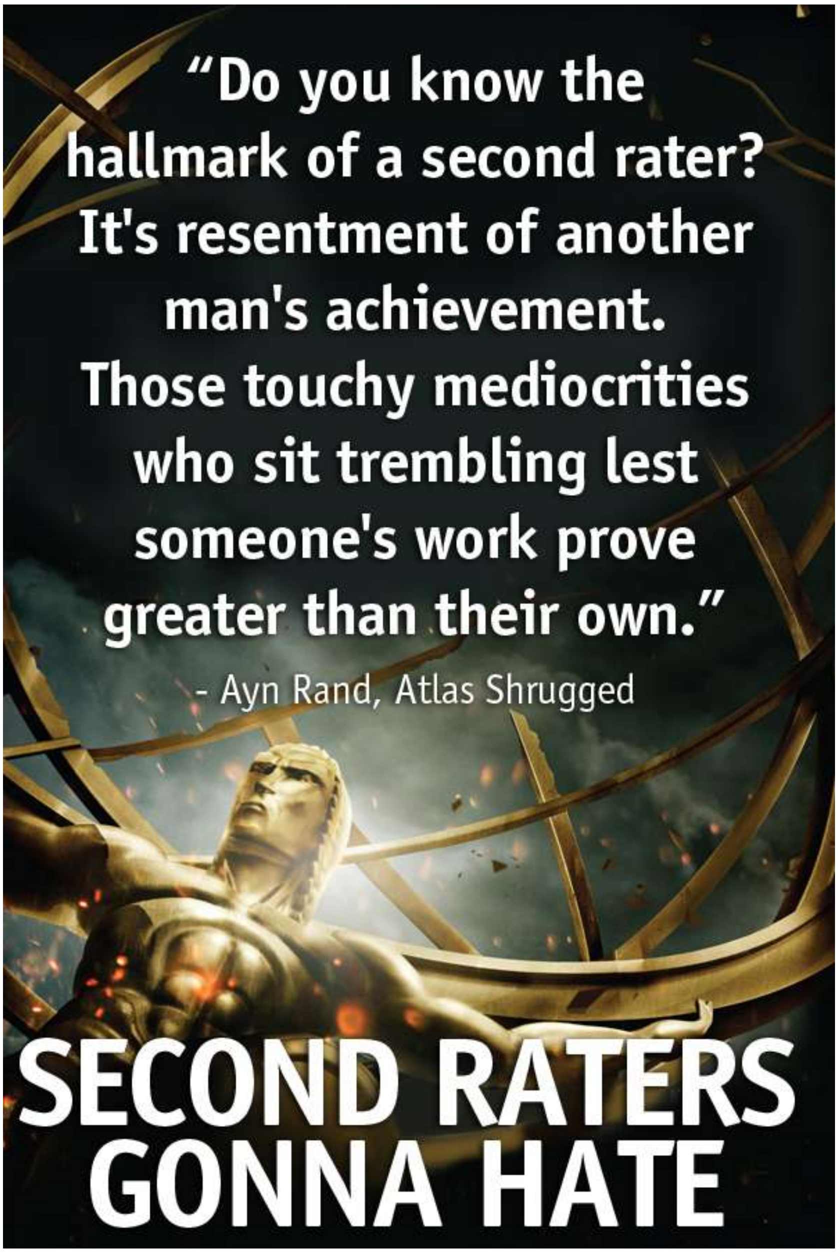

Figure 7.14: *Ayn Rand's version of the "Great Man Theory" has many followers today.*

Figure 7.15: *Neoliberalism: Economic inequality is increasing today, both within nations and between nations. One of the worst consequences is the control of governments by small oligarchies and the decay of true democracy.*

Figure 7.16: *Neoliberalism: A map of the world.*

Figure 7.17: *General Wesley Clark became aware of a Pentagon plan to destroy seven countries in five years. He felt that it was his duty to warn the public about this plan.*

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Chapter 8

RACISM, COLONIALISM, AND EXCEPTIONALISM

It seems to be possible for nations, and the majority of their citizens, to commit the worst imaginable atrocities, including torture, murder and genocide, while feeling that what they are doing is both noble and good. Some understanding of how this is possible can be gained by watching the 3-part BBC documentary, "The History of Racism".

The series was broadcast by BBC Four in March 2007. and videos of the broadcasts are available on the Internet. Watching this eye-opening documentary can give us much insight into the link between racism and colonialism. We can also begin to see how both racism and colonialism are linked to US exceptionalism and neocolonialism.

Looking at the BBC documentary we can see how often in human history economic greed and colonial exploitation have been justified by racist theories. The documentary describes almost unbelievable cruelties committed against the peoples of the Americas and Africa by Europeans. For example, in the Congo, a vast region which King Leopold II of Belgium claimed as his private property, the women of villages were held as hostages while the men were forced to gather rubber in the forests. Since neither the men nor the women could produce food under these circumstances, starvation was the result.

Leopold's private army of 90,000 men were issued ammunition, and to make sure that they used it in the proper way, the army was ordered to cut off the hands of their victims and send them back as proof that the bullets had not been wasted. Human hands became a kind of currency, and hands were cut off from men, women and children when rubber quotas were not fulfilled. Sometimes more than a thousand human hands were gathered in a single day. During the rule of Leopold, roughly 10,000,000 Congolese were killed, which was approximately half the population of the region.

According to the racist theories that supported these atrocities, it was the duty of philanthropic Europeans like Leopold to bring civilization and the Christian religion to Africa. Similar theories were used to justify the genocides committed by Europeans against the native inhabitants of the Americas. Racist theories were also used to justify enormous cruelties committed by the British colonial government in India. For example, during the great famine of 1876-1878, in which ten million people died, the Viceroy, Lord Lytton, oversaw the export from India to England of a record 6.4 million hundredweight of wheat.

Meanwhile, in Europe, almost everyone was proud of the role which they were playing in the world. All that they read in newspapers and in books or heard from the pulpits of their churches supported the idea that they were serving the non-Europeans by bringing them the benefits of civilization and Christianity. Kipling wrote: "Take up the White Man's burden, Send forth the best ye breed, Go bind your sons to exile, To serve your captives' need; To wait in heavy harness, On fluttered folk and wild, Your new-caught, sullen peoples, Half-devil and half-child." On the whole, the mood of Europe during this orgy of external cruelty and exploitation, was self-congratulatory.

Can we not see a parallel with the self-congratulatory mood of the American people and their allies, who export violence, murder, torture and neocolonialism to the whole world, and who justify it by thinking of themselves as "exceptional"?

The world urgently needs a new ethic, in which loyalty to humanity as a whole is fundamental. Racism, colonialism and exceptionalism can have

no place in the future if humanity is to survive in an era of thermonuclear weapons.

The excessive inequality that we can see today, both within countries and between countries, has many harmful effects, and these are experienced by both poor and rich. For example, crime, drug use, and mental illness are much more common in very unequal societies.

On a global scale, the vast chasm of economic inequality between countries blocks efforts to make the United Nations more effective, since rich countries fear that a more effective UN will rob them of their privileged position.

We must also remember that inequality between nations is often maintained by means of military force, regime-change, and interference by powerful nations in the internal affairs of weaker ones.

Oxfam's report on inequality

A recent report by Oxfam[1] has revealed that the wealth of the poorest half of the world's population has fallen by a trillion dollars since 2010, a drop of 38%. Meanwhile, the wealth of the richest 62 people in the world has increased to 1.76 trillion dollars. In fact, the wealthiest 62 individuals now own more than the poorest half of the world's population. Enormous contrasts exist today, not only between nations, but also within nations.

Winnie Byanyima, Oxfam's International Executive Director stated that "It is simply unacceptable that the poorest half of the world's population owns no more than a few dozen super-rich people who could fit onto one bus. World leaders' concern about the escalating inequality has so far not translated into concrete action; the world has become a much more unequal place, and the trend is accelerating. We cannot continue to allow hundreds of millions of people to go hungry while resources that could be used to help them are sucked up by those at the top."

Speaking at the Davos Forum in Switzerland, she continued: "I challenge the governments and elites at Davos to play their part in in ending the era of tax havens, which is fueling economic inequality and preventing hundreds of millions of people from lifting themselves out of poverty. Multinational companies and wealthy elites are playing by different rules than everyone else, refusing to pay the taxes that society needs to function. The fact that 188 of 201 leading companies have a presence in at least one tax haven shows that it it time to act."

Oxfam estimates that globally, 7.6 trillion dollars of individual's wealth sits offshore, and this includes as much as 38% of African financial wealth.

[1]https://www.oxfam.org/en/research/economy-1

Persistent effects of colonialism

Part of the extreme economic inequality that exists in today's world is due to colonial and neocolonial wars.

The Industrial Revolution opened up an enormous gap in military strength between the industrialized nations and the rest of the world. Taking advantage of their superior weaponry, Europe, the United States and Japan rapidly carved up the remainder of the world into colonies, which acted as sources of raw materials and food, and as markets for manufactured goods. Between 1800 and 1914, the percentage of the earth under the domination of colonial powers increased to 85 percent, if former colonies are included.

The English economist and Fabian, John Atkinson Hobson (1858-1940), offered a famous explanation of the colonial era in his book "Imperialism: A Study" (1902). According to Hobson, the basic problem that led to colonial expansion was an excessively unequal distribution of incomes in the industrialized countries. The result of this unequal distribution was that neither the rich nor the poor could buy back the total output of their society. The incomes of the poor were insufficient, and rich were too few in number. The rich had finite needs, and tended to reinvest their money. As Hobson pointed out, reinvestment in new factories only made the situation worse by increasing output.

Hobson had been sent as a reporter by the Manchester Guardian to cover the Second Boer War. His experiences had convinced him that colonial wars have an economic motive. Such wars are fought, he believed, to facilitate investment of the excess money of the rich in African or Asian plantations and mines, and to make possible the overseas sale of excess manufactured goods. Hobson believed imperialism to be immoral, since it entails suffering both among colonial peoples and among the poor of the industrial nations. The cure that he recommended was a more equal distribution of incomes in the manufacturing countries.

The racism of Cecil Rhodes

Cecil Rhodes, who was born in Bishop's Stortford in Hertfordshire, came to South Africa in the late 1800s and made his fortune in the country's diamond mines before moving into politics. He served as prime minister of the Cape Colony and later founded the southern African territory of Rhodesia, which would later become independent Zimbabwe. He was the architect of South Africa's notorious apartheid system, and a rabid advocate of British imperialism. Social Darwinism and the eugenics movement may have contributed to the racism and imperialism of Cecil Rhodes.

Figure 8.1: *A late 19th century French cartoon showing England, Germany, Russia, France and Japan slicing up the pie of China.* (Public domain)

Figure 8.2: *A cartoon showing Cecil Rhodes' colonial ambitions for Africa. The thread in his hands represents a proposed Cape-Town-to-Cairo telegraph line. He wanted to "paint the map British red", and declared, "If I could, I would annex other planets."* (Public domain)

In a December 2015 article in *The Telegraph*, Dalia Gebrial wrote: "Cecil Rhodes was a man responsible for untold, unending devastation and violence. An architect of South African apartheid, he explicitly believed in the existence of an Anglo-Saxon master race - an ideology that drove him to not only steal approximately one [square] million miles of South African land, but to facilitate the deaths of hundreds of thousands of black South Africans.

"His establishment of a paramilitary private army, the British South Africa Company's Police (BSACP) resulted in the systematic murder of approximately 60,000 people; his amendment of the Masters and Servants Act (1890) reintroduced conditions of torture for black labourers; his infamous racist 'land grabs' set up a system in which the unlawful and illegitimate acquisition of land through armed force was routine.

" In 1887 he told the House of Assembly in Cape Town: 'The native is to be treated as a child and denied the franchise. We must adopt a system of despotism in our relations with the barbarians of South Africa.' His 1892 Franchise and Ballot Act effectively eliminated African voting rights. He repeatedly reminded his colleagues of the 'extreme caution' they must exercise when it comes to 'granting the franchise to coloured people.

Rhodes wanted to create an international movement to extend British influence. He once said: "Why should we not form a secret society with but one object, the furtherance of the British Empire and the bringing of the whole world under British rule, for the recovery of the United States, for making the Anglo-Saxon race but one Empire?"

Neocolonialism?

In his book, *Neocolonialism, The Last Stage of Imperialism* (Thomas Nielsen, London, 1965), Kwami Nkrumah defined neocolonialism with the following words: "The essence of neocolonialism is that the State which is subject to it is, in theory independent, and has all the outward trappings of international sovereignty. In reality its economic system and thus its political policy is directed from the outside. The methods and form of this direction can take various shapes. For example, in an extreme case, the troops of the imperial power may garrison the territory of the neocolonial State and control the government of it. More often, however, neocolonial control is exercised through monetary means... The struggle against neocolonialism is not aimed at excluding the capital of the developed world from operating in less developed countries. It is aimed at preventing the financial power of the developed countries from being used in such a way as to impoverish the less developed."

The resource curse

The way in which the industrialized countries maintain their control over less developed nations can be illustrated by the "resource curse", i.e. the fact that resource-rich developing countries are no better off economically than those that lack resources, but are cursed with corrupt and undemocratic governments. This is because foreign corporations extracting local resources under unfair agreements exist in a symbiotic relationship with corrupt local officials.

One might think that taxation of foreign resource-extracting firms would provide developing countries with large incomes. However, there is at present no international law governing multinational tax arrangements. These are usually agreed to on a bilateral basis, and the industrialized countries have stronger bargaining powers in arranging the bilateral agreements.

Manufacture and export of small arms

Another important poverty-generating factor in the developing countries is war - often civil war. The five permanent members of the U.N. Security Council are, ironically, the five largest exporters of small arms. Small arms have a long life. The weapons poured into Africa by both sides during the Cold War are still there, and they contribute to political chaos and civil wars that block development and cause enormous human suffering.

The United Nations website on Peace and Security through Disarmament states that "Small arms and light weapons destabilize regions; spark, fuel and prolong conflicts; obstruct relief programmes; undermine peace initiatives; exacerbate human rights abuses; hamper development; and foster a 'culture of violence'."

An estimated 639 million small arms and light weapons are in circulation worldwide, one for every ten people. Approximately 300,000 people are killed every year by these weapons, many of them women and children.

Examples of endemic conflict

In several regions of Africa, long-lasting conflicts have prevented development and caused enormous human misery. These regions include Ethiopia, Eritiria, Somalia (Darfur), Chad, Zimbabwe and the Democratic Republic of Congo. In the Congo, the death toll reached 5.4 million in 2008, with most of the victims dying of disease and starvation, but with war as the root cause. In view of these statistics, the international community can be seen to have a strong responsibility to stop supplying small arms and ammunition to regions of conflict. There is absolutely no excuse for the large-scale manufacture and international sale of small arms that exists today.

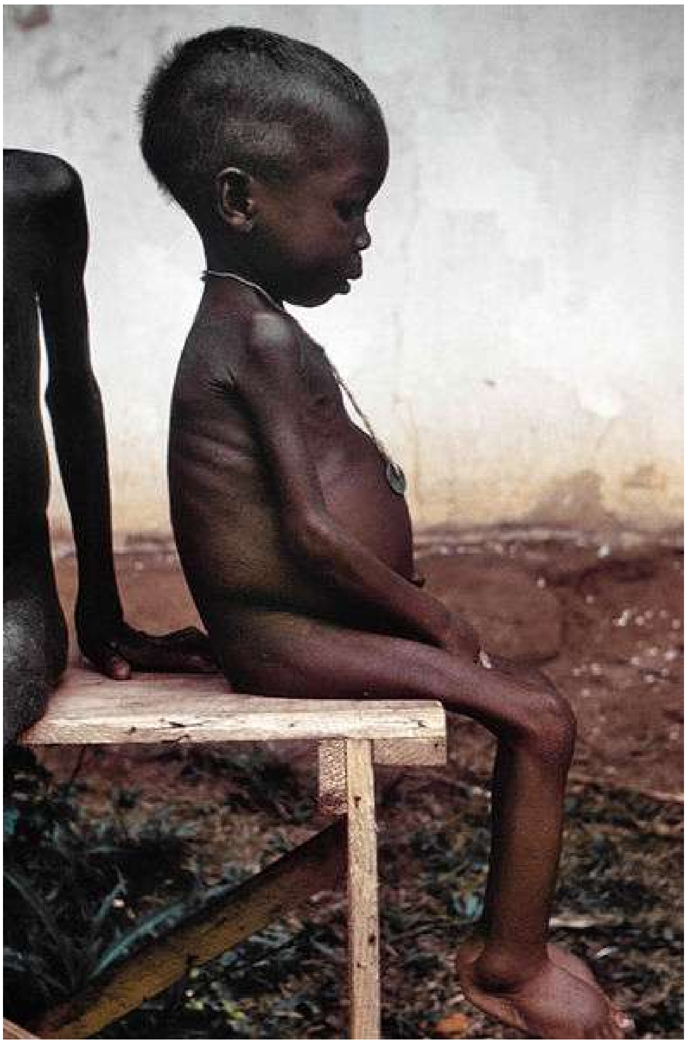

Figure 8.3: *20,000 children die each day from starvation.* (Public domain)

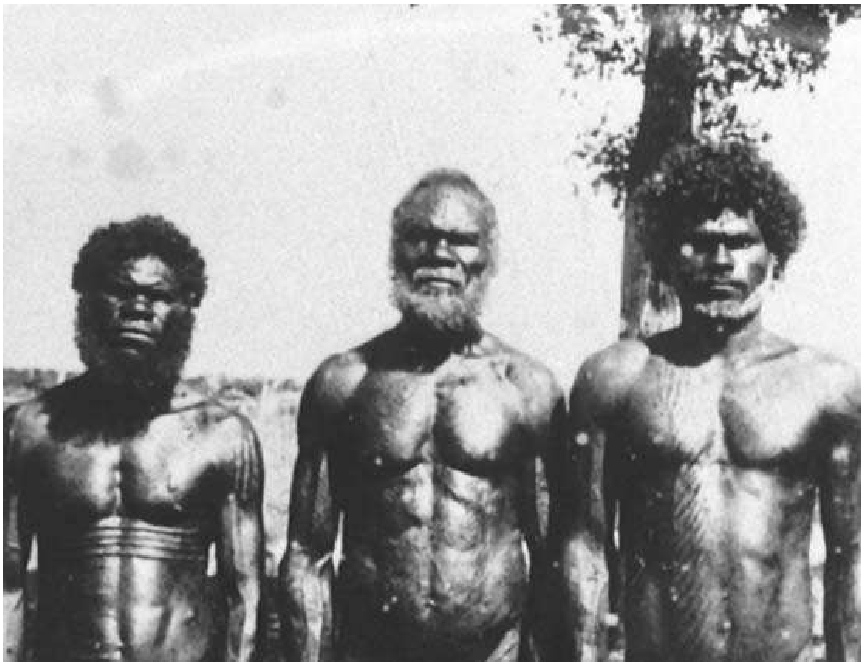

Figure 8.4: *Men from Bathurst Island in Australia's Northern Territories. Indigenous people everywhere in the world are under great pressure from those who desire their land. Indigenous cultures and languages are in danger of being lost.* (Wikipedia)

The plight of indigenous peoples

Readers of Charles Darwin's book describing *The Voyage of the Beagle* will remember his horrifying account of General Rosas' genocidal war against the Amerind population of Argentina. Similar genocidal violence has been experienced by indigenous peoples throughout South and Central America, and indeed throughout the world. In general, the cultures of indigenous peoples require much land, and greed for this land is the motive for violence against them. However, the genetic and cultural heritage of indigenous peoples can potentially be of enormous value to humanity, and great efforts should be made to protect them.

The resurgence of infectious disease

Tropical diseases

Endemic disease is strongly linked to poverty. Great improvements in reducing the effects of diseases like HIV/AIDS, malaria, schistosomiasis, trichoniosis, and river blindness could be made if pharmaceutical companies could be induced to do more research on tropical diseases and to provide drugs to developing countries at affordable prices. Other important measures would be universal vaccination programs, and the provision of safe water to all. It is in the interests of developed countries to promote health in the developing world, because air travel can quickly spread epidemics from one region to another.

HIV/AIDS

In 2004, there were approximately 39.4 million people living with HIV, 4.9 million new HIV infections, and 3.1 million deaths due to AIDS. It is estimated that in five populous countries, Nigeria, Ethiopia, Russia, India and China, the number of people infected with HIV/AIDS will grow from 14-23 million currently to 50-75 million by 2010. 95% of those living with HIV/AIDS do not know that they are infected with the disease.

Tuberculosis

Approximately 2 billion people (one third of the world's population!) are infected with TB, often in a latent form. 90% of the burden of TB falls on the developing countries; on India alone, 30%. Roughly 2 million people die from TB each year. It is the number one killer of women of childbearing age.

Malaria

Every year there are 300 million cases of malaria, and it causes about one million deaths. There are roughly 10 new cases of malaria every second, 90% of which are in Africa. A quarter of all childhood deaths in Africa are due to malaria.

Slavery

Debt slavery

At the moment, the issue of debt slavery is very topical because of the case of Greece; but it is an issue that has a far more general significance.

Usury, the charging of interest on loans, has a history of being forbidden by several major religions, including not only the three Abrahamic religions, Judaism, Christianity and Islam, but also the ancient Vedic Scriptures of India.

Perhaps the reason for these religious traditions can be found in the remarkable properties of exponential growth. If any quantity, for example indebtedness, is growing at the rate of 3% per year, it will double in 23.1 years; if it is growing at the rate of 4% per year, the doubling time is 17.3 years. For a 5% growth rate, the doubling time is 13.9 years, if the growth rate is 7%, the doubling time is only 9.9 years. It follows that if a debt remains unpaid for a few years, most of the repayments will go for interest, rather than for reducing the amount of the debt.

In the case of the debts of third world countries to private banks in the industrialized parts of the world and to the IMF, many of the debts were incurred in the 1970's for purposes which were of no benefit to local populations, for example purchase of military hardware. Today the debts remain, although the amount paid over the years by the developing countries is very many times the amount originally borrowed. Third world debt can be regarded as a means by which the industrialized nations extract raw materials from developing countries without any repayment whatever. In fact, besides extracting raw materials, they extract money.

Child labour and child slavery

The reform movement's efforts, especially those of the Fabians, overcame the worst horrors of early 19th century industrialism, but today their hard-won achievements are being undermined and lost because of uncritical and unregulated globalization. Today, a factory owner or CEO, anxious to avoid high labor costs, and anxious to violate environmental regulations merely moves his factory to a country where laws against child labor and rape of the environment do not exist or are poorly enforced. In fact, he must do so or be fired, since the only thing that matters to the stockholders is the bottom line. One might say (as someone has done), that Adam Smith's invisible hand is at the throat of the world's peoples and at the throat of the global environment.

The movement of a factory from Europe or North America to a country with poorly enforced laws against environmental destruction, child labor and slavery puts workers into unfair competition. Unless they are willing to accept revival of the unspeakable conditions of the early Industrial Revolution, they are unable to compete.

Today, child labor accounts for 22% of the workforce in Asia, 32% in Africa, and 17% in Latin America. Large-scale slavery also exists today, although there are formal laws against it in every country. There are more slaves now than ever before. Their number is estimated to be between 12 million and 27 million. Besides outright slaves, who are bought and sold for as little as 100 dollars, there many millions of workers whose lack of options and dreadful working conditions must be described as slavelike.

Enforcement, in all countries, of laws against child labor would help to stabilize the world's rapidly growing population. When children are regarded as a source of income, or are sold into slavery or prostitution, parents aim for very large families. Thus, slavery or slavelike exploitation of children is a factor behind the global population explosion.

Political and geopolitical consequences of inequality

The intolerable economic inequality of today's world is closely linked with the problem of war:

- Military force is used to maintain neocolonialism and unfair trade relationships between countries.
- Billionaires and corporations use their enormous wealth to dominate governments and media. When this happens, democracy is replaced by oligarchy, and motives of profit take the place of social and ecological goals. The military-industrial complex also gains control of governmental budgets.
- The enormous amounts of money used for war could have been used for education, infrastructure, public health (including information and materials for family planning), sanitary drinking water, and social services.
- An effective system of international law is needed for the abolition of war. But at present, economic inequality between countries is so great that rich countries fear effective global governance because they fear taxation.

Benefits of equality

Interestingly, TED Talks (ideas worth spreading) was recently under fire from many progressive groups for censoring a short talk by the adventure capitalist, Nick Hanauer, entitled "Income Inequality". In this talk, Hanauer says exactly the same thing as John Hobson, but he applies the ideas, not to colonialism, but to current unemployment in the United States. Hanauer says that the rich are unable to consume the products of society because they are too few in number. To make an economy work, demand must be increased, and for this to happen, the distribution of incomes must become much more equal than it is today in the United States.

TED has now posted Hanauer's talk, and the interested reader can find another wonderful TED talk dealing with the same issues from the standpoint of health and social problems. In a splendid lecture entitled "How economic inequality harms societies", Richard Wilkinson demonstrates that there is almost no correlation between gross national product and a number of indicators of the quality of life, such as physical health, mental health, drug abuse, education, imprisonment, obesity, social mobility, trust, violence, teenage pregnancies and child well-being. On the other hand he offers comprehensive statistical evidence that these indicators are strongly correlated with the degree of inequality within countries, the outcomes being uniformly much better in nations where income is more equally distributed.

Warren Buffet famously remarked, "There's class warfare, all right. But it's my class, the rich class, that's making war, and we're winning." However, the evidence presented by Hobson, Hanauer and Wilkinson shows conclusively that no one wins in a society where inequality is too great, and everyone wins when incomes are more evenly distributed.

We must decrease economic inequality

In his Apostolic Exhortation, "Evangelii Gaudium", Pope Francis said:

"In our time humanity is experiencing a turning-point in its history, as we can see from the advances being made in so many fields. We can only praise the steps being taken to improve peoples welfare in areas such as health care, education and communications. At the same time we have to remember that the majority of our contemporaries are barely living from day to day, with dire consequences. A number of diseases are spreading. The hearts of many people are gripped by fear and desperation, even in the so-called rich countries. The joy of living frequently fades, lack of respect for others and violence are on the rise, and inequality is increasingly evident. It is a struggle to live and, often, to live with precious little dignity."

"This epochal change has been set in motion by the enormous qualitative, quantitative, rapid and cumulative advances occurring in the sciences and in technology, and by their instant application in different areas of nature and of life. We are in an age of knowledge and information, which has led to new and often anonymous kinds of power."

"Just as the commandment 'Thou shalt not kill' sets a clear limit in order to safeguard the value of human life, today we also have to say 'thou shalt not' to an economy of exclusion and inequality. Such an economy kills. How can it be that it is not a news item when an elderly homeless person dies of exposure, but it is news when the stock market loses two points? This is a case of exclusion. Can we continue to stand by when food is thrown away while people are starving? This is a case of inequality. Today everything comes under the laws of competition and the survival of the fittest, where the powerful feed upon the powerless. As a consequence, masses of people find themselves excluded and marginalized: without work, without possibilities, without any means of escape."

"In this context, some people continue to defend trickle-down theories which assume that economic growth, encouraged by a free market, will inevitably succeed in bringing about greater justice and inclusiveness in the world. This opinion, which has never been confirmed by the facts, expresses a crude and naive trust in the goodness of those wielding economic power and in the sacralized workings of the prevailing economic system. Meanwhile, the excluded are still waiting."

In a recent speech, Senator Bernie Sanders quoted Pope Francis extensively and added: "We have a situation today, Mr. President, incredible as it may sound, where the wealthiest 85 people in the world own more wealth than the bottom half of the world's population."[2]

The social epidemiologist Prof. Richard Wilkinson, has documented the ways in which societies with less economic inequality do better than more unequal societies in a number of areas, including increased rates of life expectancy, mathematical performance, literacy, trust, social mobility, together with decreased rates of infant mortality, homicides, imprisonment, teenage births, obesity and mental illness, including drug and alcohol addiction.[3] We must also remember that according to the economist John A. Hobson, the basic problem that led to imperialism was an excessively unequal distribution of incomes in the industrialized countries. The result of this unequal distribution was that neither the rich nor the poor could buy back the total output of their society. The incomes of the poor were insufficient, and rich were too few in number.

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[3]https://www.youtube.com/watch?v=cZ7LzE3u7Bw
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Figure 8.5: *Zaatari refugee camp for Syrian refugees in Jordan which only contains a population of 80,000 out of the 1.3 million in the country. It is expected that climate change will contribute to the refugee crisis and the problem of famine. International cooperation is needed to meet this emergency.* (Public domain)

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Chapter 9

RELIGION: PROBLEM OR ANSWER?

From tribalism to universal brotherhood

Early religions tended to be centered on particular tribes, and the ethics associated with them were usually tribal in nature. However, as was mentioned in Chapter 2, the more cosmopolitan societies that began to form after the neolithic agricultural revolution required a more universal code of ethics.

In the 6th century B.C., Prince Gautama Buddha founded a new religion in India, with a universal (non-tribal) code of ethics. Among the sayings of the Buddha are the following:

"Hatred does not cease by hatred at any time; hatred ceases by love."

"Let a man overcome anger by love; let him overcome evil by good."

"All men tremble at punishment. All men love life. Remember that you are like them, and do not cause slaughter."

One of the early converts to Buddhism was the emperor Ashoka Maurya, who reigned in India between 273 B.C. and 232 B.C. After his conversion, he resolved never again to use war as an instrument of policy. He became one of the most humane rulers in history, and he also did much to promote the spread of Buddhism throughout Asia.

In Christianity, which is built on the foundations of Judaism, the concept of universal human brotherhood replaces narrow loyalty to the tribe. The universality of Christian ethical principles, which we see especially in the Parable of the Good Samaritan, make them especially relevant to our own times. Today, in a world of thermonuclear weapons, the continued existence of civilization depends on whether or not we are able to look on all of humanity as a single family.

In the Christian Gospel According to Mathew, the following passage occurs:

Figure 9.1: *A statue of the Buddha*

"You have heard it said: Thou shalt love thy neighbor and hate thy enemy. But I say unto you: Love your enemies, bless them that curse you, do good to them that hate you, and pray for them that spitefully use you and persecute you." This echos the sayings of Buddha, "Hatred does not cease by hatred at any time; hatred ceases by love", and "Let a man overcome anger by love; let him overcome evil by good."

The seemingly impractical advice given to us by both Jesus and Buddha - that we should love our enemies and return good for evil - is in fact of the greatest practicality, since acts of unilateral kindness and generosity can stop escalatory cycles of revenge and counter-revenge such as those which characterize the present conflict in the Middle East and the recent troubles in Northern Ireland. Amazingly, Christian nations, while claiming to adhere to the ethic of love and forgiveness, have adopted a policy of "massive retaliation", involving systems of thermonuclear missiles whose purpose is to destroy as much as possible of the country at which retaliation is aimed. It is planned that entire populations shall be killed in a "massive retaliation", innocent children along with guilty politicians. The startling contradiction between what Christian nations profess and what they do was obvious even before the advent of nuclear weapons, at the time when Leo Tolstoy, during his last years, was exchanging letters with a young Indian lawyer in South Africa.

Tolstoy, Gandhi, and Martin Luther King; Nonviolence

One of the functions of good literature is to help us to put ourselves imaginatively into the skin of another person. Good literature (and for that matter, good cinema and television) ought to broaden the range of human sympathy, allowing us to share the feelings of other people who are very different from ourselves.

It is an interesting fact that Leo Tolstoy, who is generally considered to have been one of the greatest novelists of all time, was deeply aware of ethical problems. Leo Tolstoy was born in 1828. While he was still a child, his parents died, and he became Count Tolstoy, with responsibility for the family estate at Yasnaya Polyana. As a young man, he was attracted to the gay and worldly social life of Moscow, but his diary during this period shows remorse over his pursuit of sensual pleasures. Disgusted with himself, he entered the army, and during idle periods he began his career as a writer. While still a soldier, he published a beautiful nostalgic work entitled "Childhood" as well as a number of skillful stories describing army life.

At the age of 28, Tolstoy left the army and spent a brief period as a literary idol in St. Petersburg. He then became concerned about lack of education among Russian peasants, and he travelled widely in Europe, studying edu-

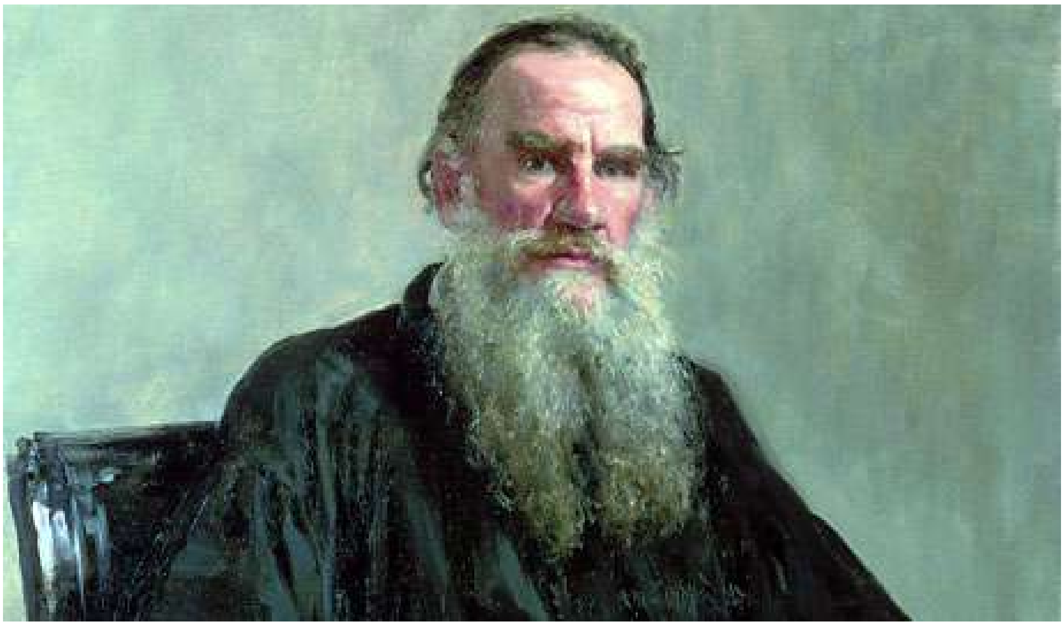

Figure 9.2: *Tolstoy as an old man*

cational theory and methods. Returning to Yasnaya Polyana, he established schools for the peasants, published an educational magazine and compiled a number of textbooks whose simplicity and attractiveness anticipated modern teaching methods.

Tolstoy married in 1862 at the age of 34. His wife, Sonya Bers, shared his wide intellectual interests, and they had a happy family life with thirteen children. During this period, Tolstoy managed his estate with much success, and he produced his great literary masterpieces "War and Peace" and "Anna Karenina". He modeled the characters in "War and Peace" after members of his own family. For example, Tolstoy's famous heroine, Natassia, is modeled after his sister-in-law, Tanya Bers. Pierre in "War and Peace" and Levin in "Anna Karenina" reflect Tolstoy's own efforts to understand the meaning of life, his concern with the misery of the Russian peasants, and his ultimate conclusion that true happiness and peace of mind can only be found in a simple life devoted to the service of others.

By the time Tolstoy had finished "Anna Karenina", he had become very dissatisfied with the life that he was leading. Despite having achieved in great measure all of the goals for which humans usually strive, he felt that his existence lacked meaning; and in 1879 he even contemplated suicide. He looked for life's purpose by systematically studying the writings of scientists and philosophers, but he could not find an answer there that satisfied him.

Finally Tolstoy found inspiration in the humble and devout lives of the peasants. He decided that the teachings of Jesus, as recorded in the New Testament, could provide the answer for which he was searching. Tolstoy published an account of his spiritual crisis in a book entitled "A Confession", in which he says:

"I searched for enlightenment everywhere in the hard-won accumulated knowledge of mankind. I searched passionately and long, not in a lazy way, but with my whole soul, day and night - I searched like a drowning man looking for safety - and found nothing."

"I searched all the sciences, and not only did I find nothing, but I also came to the conclusion that everyone who, like myself, had searched in the sciences for life's meaning had also found nothing."

"I then diligently studied the teachings of Buddhism and Islam in the holy books of those religions; but most of all I studied Christianity as I met it in the holy Scriptures and in the living Christians around me..."

"I began to approach the believers among the poor, simple ignorant people - pilgrims, monks and peasants... The whole life of Christians of our own circle seemed to be a contradiction of their faith. By contrast, the whole life of Christians of the peasant class was an affirmation of the view of life which their religious faith gave to them. I looked more and more deeply into the faith of these people, and the more deep my insight became, the more I became convinced that they had a genuine belief, that their faith was essential to them, and that it was their faith alone which gave their life a meaning and made it possible for them to live... I developed a love for these simple people."

Moved by the misery of the urban poor whom he encountered in the slums of Moscow, Tolstoy wrote: "Between us, the rich and the poor, there is a wall of false education, and before we can help the poor, we must first tear down that wall. I was forced to the conclusion that our own wealth is the true cause of the misery of the poor."

Tolstoy's book, "What Then Must We Do?", tells of his experiences in the slums and analyses the causes of poverty. Tolstoy felt that the professed Christian belief of the Czarist state was a thin cosmetic layer covering a structure that was fundamentally built on violence. Violence was used to maintain a huge gap between the rich and the poor, and violence was used in international relations. Tolstoy felt especially keenly the contradiction between Christianity and war. In a small book entitled "The Kingdom of God is Within Us" he wrote:

"All other contradictions are insignificant compared with the contradiction which now faces humankind in international relations. and which cries out for a solution, since it brings the very existence of civilization into danger. This is the contradiction between the Christian conscience and war."

"All of the Christian peoples of the world, who all follow one and the same spiritual life, so that any good and fruitful thought which is put forward in any corner of the world is immediately communicated to all of Christiandom, where it arouses feelings of pride and happiness in us regardless of our nationality; we who simply love the thinkers, humanitarians, and poets of other countries; we who not only admire their achievements, but also feel delight in meeting them and greet them with friendly smiles - we will all be forced by the state to participate in a murderous war against these same people - a war which if it does not break out today will do so tomorrow."

"...The sharpest of all contradictions can be seen between the government's professed faith in the Christian law of the brotherhood of all humankind, and the military laws of the state, which force each young man to prepare himself for enmity and murder, so that each must be simultaneously a Christian and a gladiator."

Tolstoy's writings on Christianity and on social questions were banned by the public censor, and he was excommunicated from the Russian Orthodox Church. However, his universally recognized stature as one of the world's greatest writers was undiminished, and his beliefs attracted many followers, both inside and outside of Russia.

In 1894, the young Indian lawyer, Mohandas K. Gandhi, (who was then working for the civil rights of Indians in South Africa), read Tolstoy's books on Christianity and was greatly influenced by them. Gandhi wrote a review of "The Kingdom of God is Within Us", and in 1909 he sent Tolstoy an account of the activities of the civil rights movement in South Africa. He received a reply in which Tolstoy said:

"...The longer I live, and especially now, when I vividly feel the nearness of death, the more I want to tell others what I feel so particularly clearly and what to my mind is of great importance - namely that which is called passive resistance, but which is in reality nothing else but the teaching of love, uncorrupted by false interpretations. That love - i.e. the striving for the union of human souls and the activity derived from that striving - is the highest and only law of human life, and in the depth of his soul every human being knows this (as we most clearly see in children); he knows this until he is entangled in the false teachings of the world. This law was proclaimed by all - by the Indian as by the Chinese, Hebrew, Greek and Roman sages of the world. I think that this law was most clearly expressed by Christ, who plainly said that 'in this alone is all the law and the prophets'..."

"...The peoples of the Christian world have solemnly accepted this law, while at the same time they have permitted violence and built their lives on violence; and that is why the whole life of the Christian peoples is a continuous contradiction between what they profess, and the principles on which they order their lives - a contradiction between love accepted as the law of life, and violence which is recognized and praised, acknowledged even as a necessity in different phases of life, such as the power of rulers, courts, and armies..."

"This year, in the spring, at a Scripture examination in a girls' high school in Moscow, the teacher and the bishop present asked the girls questions on the Commandments, and especially on the sixth. After a correct answer, the bishop generally put another question, whether murder was always in all cases forbidden by God's law; and the unhappy young ladies were forced by previous instruction to answer 'not always' - that murder was permitted in war and in the execution of criminals. Still, when one of these unfortunate young ladies (what I am telling is not an invention, but a fact told to me by an eye witness) after her first answer, was asked the usual question, if killing was always sinful, she, agitated and blushing, decisively answered 'Always', and to all the usual sophisms of the bishop, she answered with decided conviction that killing always was forbidden in the Old Testament and forbidden by Christ, not only killing, but every wrong against a brother. Notwithstanding all his grandeur and arts of speech, the bishop became silent and the girl remained victorious."

Tolstoy believed that violence can never under any circumstances be justified, and that therefore an individual's resistance to governmental violence must be passive and non-violent. He also believed that each individual ought to reduce his needs to a minimum in order to avoid exploiting the labor of others.

Tolstoy gave up meat, alcohol, tobacco, and hunting. He began to clean his own room, wore simple peasant clothes, worked in the fields, and made his own boots. He participated in famine relief, and he would have liked to give away all of his great wealth to feed the poor, but bowing to the protests of his family, he gave his wealth to them instead.

Because he had been unable to convert his family to his beliefs, Tolstoy left home secretly on a November night in 1910, accompanied, like King Lear, by his youngest daughter. He died of pneumonia a few days later at a remote railway junction.

In the hands of Gandhi, non-violent passive resistance became a practical political force. Mohandas Karamchand Gandhi was born in 1869 in Porbandar, India. His family belonged to the Hindu caste of shopkeepers. (In Gujarati "Gandhi" means "grocer".) However, the family had risen in status, and Gandhi's father, grandfather, and uncle had all served as prime ministers of small principalities in western India.

In 1888, Gandhi sailed for England, where he spent three years studying law at the Inner Temple in London. Before he left India, his mother had made him take a solemn oath not to touch women, wine, or meat. He thus came into contact with the English vegetarians, who included Sir Edward Arnold

Figure 9.3: *Gandhi and his wife Kasturbai in 1902*

(translator of the Bhagavadgita), the Theosophists Madame Blavatsky and Annie Besant, and the Fabians. Contact with this idealistic group of social critics and experimenters helped to cure Gandhi of his painful shyness, and it also developed his taste for social reform and experimentation.

Gandhi's exceptionally sweet and honest character won him many friends in England, and he encountered no racial prejudice at all. However, when he travelled to Pretoria in South Africa a few years later, he experienced racism in its worst form. Although he was meticulously well dressed in an English frock coat, and in possession of a first-class ticket, Gandhi was given the choice between travelling third class or being thrown off the train. (He chose the second alternative.) Later in the journey he was beaten by a coach driver because he insisted on his right to sit as a passenger rather than taking a humiliating position on the footboard of the coach.

The legal case which had brought Gandhi to South Africa was a dispute between a wealthy Indian merchant, Dada Abdullah Seth, and his relative, Seth Tyeb (who had refused to pay a debt of 40,000 pounds, in those days a huge sum). Gandhi succeeded in reconciling these two relatives, and he persuaded them to settle their differences out of court. Later he wrote about this experience:

"Both were happy with this result, and both rose in public estimation. My joy was boundless. I had learnt the true practice of law. I had learnt to find out the better side of human nature and to enter men's hearts. I realized that the true function of a lawyer was to unite parties riven asunder. The lesson was so indelibly burnt into me that a large part of my time during my twenty years of practice as a lawyer was occupied in bringing about compromises of hundreds of cases. I lost nothing thereby - not even money, certainly not my soul."

Gandhi was about to return to India after the settlement of the case, but at a farewell party given by Abdullah Seth, he learned of a bill before the legislature which would deprive Indians in South Africa of their right to vote. He decided to stay and fight against the bill.

Gandhi spent the next twenty years in South Africa, becoming the leader of a struggle for the civil rights of the Indian community. In this struggle he tried "...to find the better side of human nature and to enter men's hearts". Gandhi's stay in England had given him a glimpse of English liberalism and English faith in just laws. He felt confident that if the general public in England could be made aware of gross injustices in any part of the British Empire, reform would follow. He therefore organized non-violent protests in which the protesters sacrificed themselves so as to show as vividly as possible the injustice of an existing law. For example, when the government ruled that Hindu, Muslim and Parsi marriages had no legal standing, Gandhi and his followers voluntarily went to prison for ignoring the ruling.

Gandhi used two words to describe this form of protest: "satyagraha" (the force of truth) and "ahimsa" (non-violence). Of these he later wrote: "I have nothing new to teach the world. Truth and non-violence are as old as the hills. All that I have done is to try experiments in both on as vast a scale as I could. In so doing, I sometimes erred and learnt by my errors. Life and its problems have thus become to me so many experiments in the practice of truth and non-violence."

In his autobiography, Gandhi says: "Three moderns have left a deep impression on my life and captivated me: Raychandbhai (the Indian philosopher and poet) by his living contact; Tolstoy by his book 'The Kingdom of God is Within You'; and Ruskin by his book 'Unto the Last'."

Ruskin's book, "Unto This Last", which Gandhi read in 1904, is a criticism of modern industrial society. Ruskin believed that friendships and warm interpersonal relationships are a form of wealth that economists have failed to consider. He felt that warm human contacts are most easily achieved in small agricultural communities, and that therefore the modern tendency towards centralization and industrialization may be a step backward in terms of human happiness. While still in South Africa, Gandhi founded two religious utopian communities based on the ideas of Tolstoy and Ruskin. Phoenix Farm

(1904) and Tolstoy Farm (1910). At this time he also took an oath of chastity ("bramacharya"), partly because his wife was unwell and he wished to protect her from further pregnancies, and partly in order to devote himself more completely to the struggle for civil rights.

Because of his growing fame as the leader of the Indian civil rights movement in South Africa, Gandhi was persuaded to return to India in 1914 and to take up the cause of Indian home rule. In order to reacquaint himself with conditions in India, he travelled tirelessly, now always going third class as a matter of principle.

During the next few years, Gandhi worked to reshape the Congress Party into an organization which represented not only India's Anglicized upper middle class but also the millions of uneducated villagers who were suffering under an almost intolerable burden of poverty and disease. In order to identify himself with the poorest of India's people, Gandhi began to wear only a white loincloth made of rough homespun cotton. He travelled to the remotest villages, recruiting new members for the Congress Party, preaching non-violence and "firmness in the truth", and becoming known for his voluntary poverty and humility. The villagers who flocked to see him began to call him "Mahatma" (Great Soul).

Gandhi organized demonstrations whose purpose was to show the British public that although the British raj gave India many benefits, the toll exacted was too high, not only in terms of money, but also in terms of India's self-respect and self-sufficiency. All of Gandhi's demonstrations were designed to underline this fact. For example, in 1930 Gandhi organized a civil-disobedience campaign against the salt laws. The salt laws gave the Imperial government a monopoly and prevented Indians from making their own salt by evaporating sea water. The majority of Indians were poor farmers who worked long hours in extreme heat, and salt was as much a necessity to them as bread. The tax on salt was essentially a tax on the sweat of the farmers.

Before launching his campaign, Gandhi sent a polite letter to the Viceroy, Lord Irwin, explaining his reasons for believing that the salt laws were unjust, and announcing his intention of disregarding them unless they were repealed. Then, on March 12 1930, Gandhi and many of his followers, accompanied by several press correspondents, started on a march to the sea to carry out their intention of turning themselves into criminals by making salt. Every day, Gandhi led the procession about 12 miles, stopping at villages in the evenings to hold prayer meetings. Many of the villagers joined the march, while others cast flower petals in Gandhi's path or sprinkled water on his path to settle the dust.

On April 5, the marchers arrived at the sea, where they spent the night in prayer on the beach. In the morning they began to make salt by wading into the sea, filling pans with water, and letting it evaporate in the sun. Not much salt was made in this way, but Gandhi's action had a strong symbolic power. A wave of non-violent civil disobedience demonstrations swept over India, so extensive and widespread that the Imperial government, in danger of losing control of the country, decided to arrest as many of the demonstrators as possible. By midsummer, Gandhi and a hundred thousand of his followers were in prison, but nevertheless the civil disobedience demonstrations continued.

In January, 1931, Gandhi was released from prison and invited to the Viceroy's palace to talk with Lord Irwin. They reached a compromise agreement: Gandhi was to call off the demonstrations and would attend a Round Table Conference in London to discuss Indian home rule, while Lord Irwin agreed to release the prisoners and would change the salt laws so that Indians living near to the coast could make their own salt.

The salt march was typical of Gandhi's non-violent methods. Throughout the demonstrations he tried to maintain a friendly attitude towards his opponents, avoiding escalation of the conflict. Thus at the end of the demonstrations, the atmosphere was one in which a fair compromise solution could be reached. Whenever he was in prison, Gandhi regarded his jailers as his hosts. Once, when he was imprisoned in South Africa, he used the time to make a pair of sandals, which he sent to General Smuts, the leader of the South African government. Thus Gandhi put into practice the Christian principle, "Love your enemies; do good to them that hate you."

Gandhi's importance lies in the fact that he was a major political leader who sincerely tried to put into practice the ethical principles of religion. In his autobiography Gandhi says: "I can say without the slightest hesitation, and yet with all humility, that those who say that religion has nothing to do with politics do not know what religion means."

Gandhi believed that human nature is essentially good, and that it is our task to find and encourage whatever is good in the character of others. During the period when he practiced as a lawyer, Gandhi's aim was "to unite parties riven asunder", and this was also his aim as a politician. In order for reconciliation to be possible in politics, it is necessary to avoid escalation of conflicts. Therefore Gandhi used non-violent methods, relying only on the force of truth. "It is my firm conviction", he wrote, "that nothing can be built on violence."

To the insidious argument that "the end justifies the means", Gandhi answered firmly: "They say 'means are after all means'. I would say 'means are after all everything'. As the means, so the end. Indeed the Creator has given us control (and that very limited) over means, none over end... The means may be likened to a seed, and the end to a tree; and there is the same inviolable connection between the means and the end as there is between the seed and the tree. Means and end are convertible terms in my philosophy of

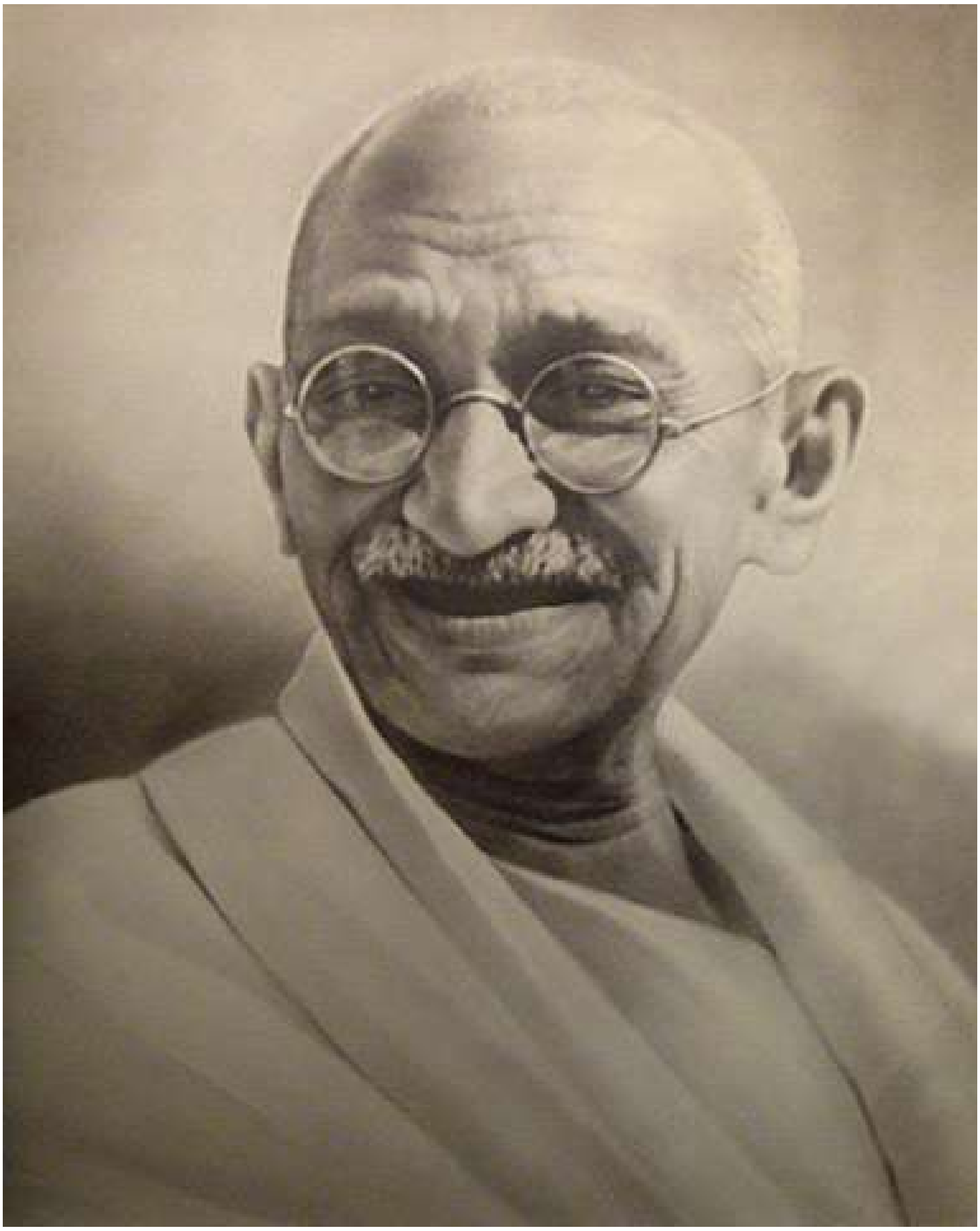

Figure 9.4: *Gandhi said, "The means may be likened to a seed, and the end to a tree; and there is the same inviolable connection between means and end as there is between the seed and the tree. Means and end are convertible terms in my philosophy of life."*

life." In other words, a dirty method produces a dirty result; killing produces more killing; hate leads to more hate. But there are positive feedback loops as well as negative ones. A kind act produces a kind response; a generous gesture is returned; hospitality results in reflected hospitality. Hindus and Buddhists call this principle "the law of karma".

Gandhi believed that the use of violent means must inevitable contaminate the end achieved. Because Gandhi's methods were based on love, understanding, forgiveness and reconciliation, the non-violent revolution which he led left very little enmity in its wake. When India finally achieved its independence from England, the two countries parted company without excessive bitterness. India retained many of the good ideas which the English had brought - for example the tradition of parliamentary democracy; and the two countries continued to have close cultural and economic ties.

Another example of a successful non-violent revolution is the black civil rights movement in America, led by Martin Luther King, Jr. The son of a southern Baptist minister, King received his Ph.D. in theology from Boston University in 1955. During his studies, he had admired Thoreau's essay "On the Duty of Civil Disobedience", and he had also been greatly moved by the life and teachings of Mahatma Gandhi.

Martin Luther King Jr. had been pastor of the Dexter Avenue Baptist Church in Montgomery Alabama for only a year when he was chosen to lead a boycott protesting segregation in the Montgomery busses. Suddenly thrust into this situation of intense conflict, he remembered both the Christian principle of loving one's enemies and Gandhi's methods of non-violent protest. In his first speech as President of the Montgomery Improvement Association (a speech which the rapid pace of events had forced him to prepare in only twenty minutes, five of which he spent in prayer), he said:

"Our method will be that of persuasion, not coercion. We will only say to people, 'Let your conscience be your guide'. Our actions must be guided by the deepest principles of our Christian faith. Love must be our regulating ideal. Once again we must hear the words of Jesus echoing across the centuries: 'Love your enemies, bless them that curse you, and pray for them that despitefully use you.' If we fail to do this, our protest will end up as a meaningless drama on the stage of history, and its memory will be shrouded by the ugly garments of shame. In spite of the mistreatment that we have confronted, we must not become bitter and end up by hating our white brothers. As Booker T. Washington said, 'Let no man pull you down so low as to make you hate him.'"

"If you will protest courageously, and yet with dignity and Christian love, when the history books are written in future generations, the historians will have to pause and say, 'There lived a great people - a black people - who injected new meaning and dignity into the veins of civilization.' This is our challenge and our overwhelming responsibility."

This speech, which Dr. King made in December 1955, set the tone of the black civil rights movement. Although the protesters against racialism were often faced with brutality and violence; although many of them, including Dr. King were unjustly jailed; although the homes of the leaders were bombed; although they constantly received telephone calls threatening their lives; although many civil rights workers were severely beaten, and several of them killed, they never resorted to violence in their protests against racial discrimination. Because of this adherence to Christian ethics, public opinion shifted to the side of the civil rights movement, and the United States Supreme Court ruled bus segregation to be unconstitutional.

In 1959, while recovering from an almost-fatal stabbing, Martin Luther King Jr. visited India at the invitation of Prime Minister Jawaharlal Nehru. Dr. King and his wife Coretta were warmly welcomed by Nehru, who changed his schedule in order to meet them. They had an opportunity to visit a religious community or "ashram" that Gandhi had founded, and they discussed non-violence with many of Gandhi's disciples.

In 1964, the change in public opinion produced by the non-violent black civil rights movement resulted in the passage of the civil rights act. In the same year, Dr. King was awarded the Nobel Peace Prize. He accepted it, not as an individual, but on behalf of all civil rights workers; and he immediately gave all the prize money to the movement.

In 1967, a year before his assassination, Dr. King forcefully condemned the Viet Nam war in an address at a massive peace rally in New York City. He felt that opposition to war followed naturally from his advocacy of non-violence. In his book, "Strength to Love", Dr. King wrote: "Wisdom born of experience should tell us that war is obsolete. There may have been a time when war served a negative good by preventing the spread of an evil force, but the power of modern weapons eliminates even the possibility that war may serve as a negative good. If we assume that life is worth living, and that man has a right to survival, then we must find an alternative to war... I am convinced that the Church cannot be silent while mankind faces the threat of nuclear annihilation. If the church is true to her mission, she must call for an end to the nuclear arms race."

Concerning the Christian principle of loving one's enemies, Dr. King wrote: "Why should we love our enemies? Returning hate for hate multiplies hate, adding deeper darkness to a night already devoid of stars. Darkness cannot drive out darkness; only light can do that. Hate cannot drive out hate. Only love can do that... Love is the only force capable of transforming an enemy into a friend. We never get rid of an enemy by meeting hate with hate; we get rid

Figure 9.5: *Dr. Martin Luther King Jr. speaking in Washington D.C.*

of an enemy by getting rid of enmity... It is this attitude that made it possible for Lincoln to speak a kind word about the South during the Civil War, when feeling was most bitter. Asked by a shocked bystander how he could do this, Lincoln said, 'Madam, do I not destroy my enemies when I make them my friends?' This is the power of redemptive love."

To a large extent, the black civil rights movement of the '50's and '60's succeeded in ending racial discrimination in America. If the methods used had been violent, the movement could easily have degenerated into a nightmare of interracial hatred; but by remembering the Christian message, "Love your enemy; do good to them that despitefully use you", Martin Luther King Jr. raised the ethical level of the civil rights movement; and the final result was harmony and understanding between the black and white communities. Later the nonviolent methods of Gandhi and King were successfully applied to the South African struggle against Apartheid.

The examples that we have considered here - the Indian civil rights movement in South Africa, the Indian independence movement, and the black civil rights movement in the United States - all show that non-violent protest can sometimes be a very effective method for resisting governmental violence and for changing unjust laws. As Gandhi pointed out, the end achieved inevitably reflects the means used. Therefore, if harmony and understanding are to be the end result of a political movement, then non-violent methods must be used.

There is, however, another question that we should try to answer: To what extent can violence be eliminated altogether from a society and replaced by the rule of love? Tolstoy was completely uncompromising in his condemnation of violence; and he even went so far as to maintain that there are no circumstances whatever under which violence can be justified, even in law-enforcement. Tolstoy's arguments are logically consistent, and consistent also with the words and spirit of the Sermon on the Mount. However, one feels that he may be exaggerating for the sake of clarity.

Tolstoy tells us that the only thing needed for a new order - "the Kingdom of God" - to be established on Earth is for all men and women to abandon violence and to follow the rule of love. He is right, of course, but when we read his words, we cannot help noticing the word "all". If *all* humans abandon violence and follow the rule of love, a new order will come; but what if some of us become as gentle as lambs, while others remain unregenerate wolves? Will not the wolves eat the lambs? This is the difficulty that has always blocked progress towards a non-violent society. It is the problem that lies at the root of the arms race. It is the riddle that we somehow must solve if we are to save civilization from a third world war.

Although no real society is completely free from violence, some societies are much less violent than others. For example, feudal Japan was a very violent society, as was the American west in the days when everyone carried a gun. Scandinavia, as it is described in the Sagas, was also extremely violent. By contrast, one can also think of societies where the level of violence is very low, for example Bhutan, Tibet or Nepal (until recently), modern Scandinavia, modern Switzerland, or the Arapesh society described by Margaret Mead, to name only a few.

Many of the world's nations have reduced their level of internal violence considerably during the last few hundred years. A few centuries ago, a gentleman in France or England carried a sword, and a child could be hanged for stealing a handkerchief. Today it is usually no longer necessary for citizens to carry personal weapons, and in many countries both torture and the death penalty have been abolished. On the other hand, very little progress has been made towards solving the problem of international violence.

While the level of violence *within* many nations has decreased, the level of international violence has greatly increased because of modern weapons: The two world wars that have taken place during this century have produced destruction and death on a scale previously unknown; and humanity is threatened with the possibility of a third world war that could dwarf the other two. Thus it is imperative that we achieve at an international level the same degree of order and good government that has been achieved locally in such places as (for example) Scandinavia.

In the Sagas, one can hardly find a page that is free from violence, and yet in modern Scandinavia the citizens are so law-abiding that they will not cross a street against a red light, even if there is neither an automobile nor a policeman anywhere in sight. This obedience to laws is not derived from fear, but from a belief that the laws are beneficial. The fact that it has been possible to achieve such a degree of internal peace and order in what was once one of the world's most violent societies can make us optimistic as we work to make the same transition at the international level.

Violence within a society is a symptom that something is wrong, just as violence within a family is a symptom that something is wrong. A good government does not need torture or the death penalty or an excessively numerous police force in order to govern, just as good parents do not need the threat of physical violence in order to control their children. The power of a good government rests on the consent of the governed, just as the authority of good parents rests on the love and respect that their children feel for them.

The achievement of good government is not a trivial problem. In those places in the world where it exists today, it has been built up only through much effort and thought. Nevertheless, the fact that there are countries where a great measure of peace and happiness have been achieved locally shows that the problem is not insoluble.

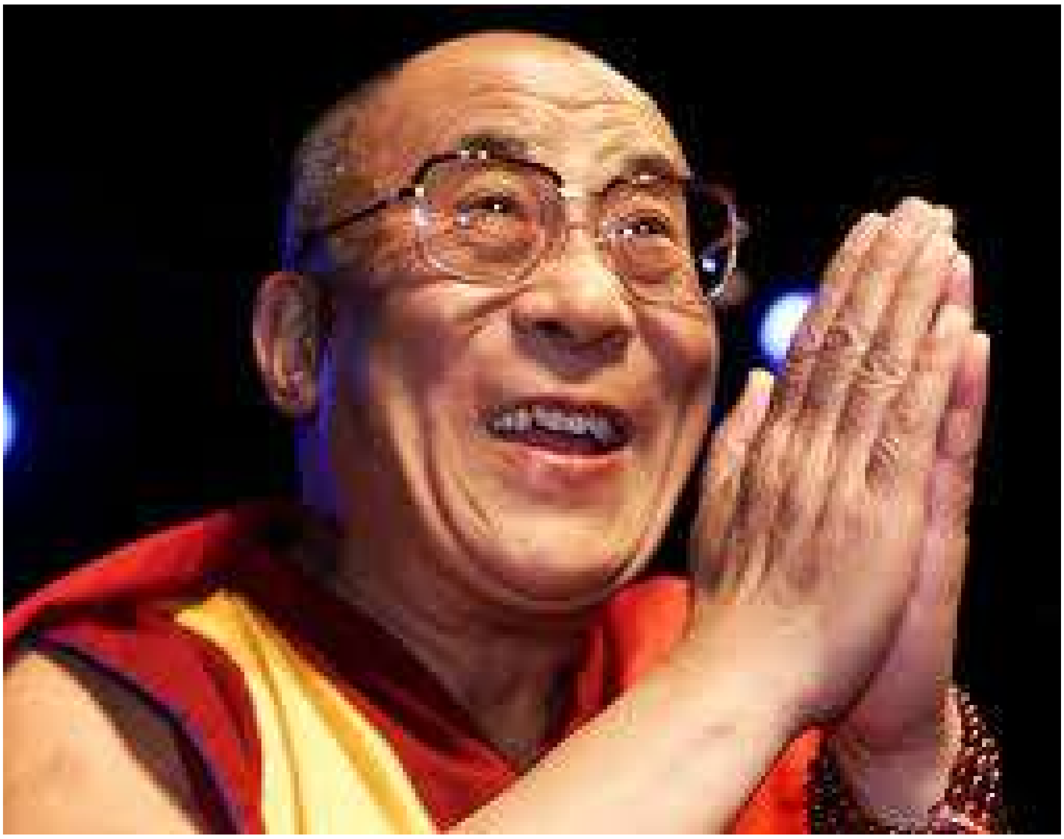

Figure 9.6: *His Holiness the 14th Dalai Lama of Tibet*

What we need to do is to concentrate more effort and intelligence on the problem of achieving good government globally. This problem should not really be beyond the ability of mankind to solve. Humans are, after all, very intelligent. In fact, the acuteness of the present crisis is due to the rapid technological development that human ingenuity has produced. The intelligence of mankind has seen very deeply into the secrets of nature. Can we not use the same intelligence to achieve good government at a global level?

In his excellent and highly readable book, *Ancient Wisdom, Modern World: Ethics for the New Millennium*, the Dalai Lama writes:

"..At present and for the conceivable future, the UN is the only global institution capable of influencing and formulating policy on behalf of the international community. Of course, many people criticize it on the grounds that it is ineffective, and it is true that time and again we have seen its resolutions ignored, abandoned and forgotten. Nevertheless, in spite of its shortcomings, I for one continue to have the highest regard not only for the principles on which it was founded but also for the great deal that it has achieved since its inception in 1945. We need only ask ourselves whether or not it has helped to save lives by defusing potentially dangerous situations to see that it is more than the toothless bureaucracy some people say it is. We should also consider the great work of its subsidiary organizations, such as UNICEF, United Nations High Commission for Refugees, UNESCO and the World Health Organization..."

"I see the UN, developed to its full potential, as being the proper vehicle for carrying out the wishes of humanity as a whole. As yet it is not able to do this very effectively, but we are only just beginning to see the emergence of a global consciousness (which is made possible by the communications revolution). And in spite of tremendous difficulties, we have seen it in action in numerous parts of the world, even though at the moment there may be only one or two nations spearheading these initiatives. The fact that they are seeking the legitimacy conferred by a United Nations mandate suggests a felt need for justification through collective approbation. This, in turn, I believe to be indicative of a growing sense of a single, mutually dependent, human community."

Another example of religious leadership in addressing global problems was given by H.H. Pope John Paul II. In his Christmas address on 25 December, 2002, the Pope said that efforts for peace were urgently needed "in the Middle East, to extinguish the ominous smouldering of a conflict which, with the joint efforts of all, can be avoided." Although he did not specifically name the countries involved, it was clear that his remarks referred to the threatened invasion of Iraq by the United States and England. This interpretation was strengthened by senior Vatican officials who reiterated Catholic teaching that "preventative" war is unjustifiable. In an interview with Rome's La Republica, Archbishop Renato Martino, prefect of the Council for Justice and Peace, stated that "unilateralism is not acceptable".

Pope John Paul II was not an exception among the Roman Catholic Popes of the 20th century. All of them have spoken strongly against the institution of war. Especially notable are H.H. Pope Paul IV who made a one-day visit to the United Nations where his speech included the words "no more war, war never again", and H.H. Pope John XXIII, author of the eloquent encyclical, *Pacem in Terris*. One can think also of the Ecumenical Council *Vatican II*, which denounced the arms race as an "utterly treacherous trap for humanity", questioned the method of deterrence as a safe way to preserve a steady peace, and condemned war as a "crime against God and man himself".

Other powerful voices have been raised by the World Conference of Religions for Peace, which met for the first time in October 1970 in Kyoto Japan.[1] At this meeting, more than 1000 religious leaders gathered to discuss the grave

[1]Subsequent World Assemblies of the WCRP have been held in Louvain, Belgium, (1974); Princeton New Jersey, (1979); Nairobi, Kenya, (1984); Melbourne, Australia, (1989); Riva del Garde, Italy, (1994); and Amman, Jordan, (1999).

dangers posed by modern war. Among them were representatives of the Baha'i, Mahayana and Trevada Buddhists, Protestants, Roman Catholics, and Orthodox Christians, Confucianists, representatives of several streams of Hinduism, a number of communities of Indigenous faith, Shiite and Sunni Muslims, Jainists, Reform Jews, Shintos, Sikhs, Zoroastrians, and representatives of a number of new religions.

The WCRP sponsors many projects related to conflict resolution, the world's children, development, disarmament and security, human rights, and peace education. For example, in the field of peace education, WCRP sponsors a project in Israel called "Common Values/Different Sources" which brings together Jews, Muslims and Christians to study sacred texts together in search of shared values, eventually resulting in a book for classroom use. In England and Germany, another WCRP project analyzes school textbooks' treatment of religious traditions that are foreign to the books' intended audiences.

Dr. Edy Korthals Altes, a former Ambassador of the Netherlands to Poland and Spain and an Honorary President of the World Conference of Religions for Peace, has expressed his vision of our current global situation in the following words: "We need a new concept of security. The old concept dates back to the Romans who said 'If you want peace, prepare for war'. The new concept I would propose is exactly the opposite, 'If you want peace, prepare for peace'. While this may sound simplistic, it is difficult to put into practice since the application of justice and solidarity in international political and economic relations require sacrifices from 'those who have'. I would give three reasons why the old concept of 'security' is no longer valid: a) The extreme vulnerability of modern society; b) The tremendous destructive power of modern arms and terrorism; c) The interdependence between nations. These three elements are closely interconnected. It is therefore imperative to apply justice and solidarity in our international relations. If not, disaster looms!"

Dr. Altes feels that economic reforms are needed if global peace is to be achieved. "Not only economic justice is involved", he writes, "but also political justice. A clear example of which is the current situation in the Middle East. There must also be justice in the economic world situation where 1/5 of the world population enjoys a high standard of living while 1/5 lives in terrible poverty, millions dying every year from hunger. This 'North South gap' is increasing!"

Discussing "myths that underlie our present economic system", he points to

1. "The notion that each person has unlimited material needs. We are told to 'consume more' which is totally contra to any religion. What is more, it is a self-defeating program that is contrary to humanity in general.

The New Testament is clear 'you shall not live on bread alone.' Our deeper needs are not for material goods but for inner growth."

2. "Unlimited growth. The economy, my firm, my salary should all grow. In a finite planet, this is total nonsense. This maxim of growth has brought about great ecological damage."
3. Idolatry of the Free Market. I am in favor of a free market, but one that is set in the context of social and human conditions. We need to apply means to avoid the 'law of the jungle' in the market place."

No enumeration of religious voices raised in the cause of peace would be complete without mention of the Religious Society of Friends (Quakers), all of whom refuse to give any support whatever to the institution of war. Although they are fundamentally opposed to war as being completely contrary to Christian ethics, the Quakers are active in caring for the victims of war, and in 1947 the American Friends Service Committee and the Friends Service Council were jointly awarded the Nobel Peace Prize.

The Non-violence of Mahatma Gandhi, Martin Luther King and Nelson Mandela, the writings of the Dalai Lama, the messages of Pope John Paul II and other Popes, the anti-war convictions of the Quakers, and the many projects of the World Conference of Religions for Peace all illustrate the potentialities of the world's religions as powerful forces for mobilizing public opinion in the cause of peace. One hopes that the voice of religion in this cause will become still more powerful in the future. Each week, all over the world, congregations assemble and are addressed by their leaders on ethical issues. But all too often there is no mention of the astonishing and shameful contradiction between the institution of war (especially the doctrine of "massive retaliation"), and the principle of universal human brotherhood, loving and forgiving one's enemies, and returning good for evil. At a moment of history when the continued survival of civilization is in doubt because of the incompatibility of war with the existence of thermonuclear weapons, our religious leaders ought to use their enormous influence to help to solve the problem of war, which is after all an ethical problem.

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Chapter 10

THE NEED FOR HUMAN SOLIDARITY

"Man lives in a new cosmic world for which he was not made. His survival depends on how well and how fast he can adapt himself to it, rebuilding all his ideas, all his social and political institutions. ...Modern science has abolished time and distance as factors separating nations. On our shrunken globe today, there is room for one group only - the family of man."

Albert Szent-Györgyi

"There lies before us, if we choose, continual progress in happiness, knowledge, and wisdom. Shall we, instead, choose death, because we cannot forget our quarrels? We appeal as human beings to human beings: Remember your humanity, and forget the rest. "

Bertrand Russell and Albert Einstein

Why is human solidarity needed so urgently?

Today the world is faced by three extremely serious dangers. We cannot be at all sure that we will get through the 21st century without a catastrophe. The three greatest threats will be discussed in more detail below, but briefly they are as follows:

- The threat of an all-destroying thermonuclear war
- The threat of catastrophic climate change
- The threat of a global famine leading to as many as a billion human deaths

In order to avert these threats and to pass safely through the next short period of history, we urgently need human solidarity.

The ideas of Social Darwinism and the Eugenics Movement undermine human solidarity. This is not the moment for genetic improvement of the human race! Genetic evolution proceeds extremely slowly, but today technological and political change are moving with blinding speed - constantly accelerating speed. So fast, indeed, is the speed of change, that it threatens to shake human civilization to pieces.

For the sake of survival in a desperately precarious time, we can afford to allow humans to lose a percentage or two of their IQ's or to become very slightly less athletic, if that is the consequence of failing to breed humans as though they were farm animals. In any case, the horrors committed by the Nazi's during World War II in the name of "improving the race" should serve as a warning.

The rapid growth of knowledge

Cultural evolution depends on the non-genetic storage, transmission, diffusion and utilization of information. The development of human speech, the invention of writing, the development of paper and printing, and finally, in modern times, mass media, computers and the Internet: all these have been crucial steps in society's explosive accumulation of information and knowledge. Human cultural evolution proceeds at a constantly-accelerating speed, so great in fact that it threatens to shake society to pieces.

In many respects, our cultural evolution can be regarded as an enormous success. However, at the start of the 21st century, most thoughtful observers agree that civilization is entering a period of crisis. As all curves move exponentially upward, population, production, consumption, rates of scientific discovery, and so on, one can observe signs of increasing environmental stress, while the continued existence and spread of nuclear weapons threaten civilization with destruction. Thus, while the explosive growth of knowledge has brought many benefits, the problem of achieving a stable, peaceful and sustainable world remains serious, challenging and unsolved.

The threat of nuclear war

Today, because of the possibility that U.S. President Donald Trump will initiate a nuclear war against Iran or North Korea, or even Russia, the issue of nuclear weapons is at the center of the global stage. I strongly believe that the time has come for all countries to take a united stance on this issue. Most of the world's nations live in nuclear weapon free zones. This does not give them any real protection, since the catastrophic environmental effects of nuclear war would be global, not sparing any nation. However, by supporting the Nuclear Weapons Convention and by becoming members of NWFZ's, nations can state that they consider nuclear weapons to be morally unacceptable, a view that must soon become worldwide if human civilization is to survive.

We must take a stand, and state clearly that nuclear weapons are an absolute evil; that their possession does not increase anyone's security; that their continued existence is a threat to the life of every person on the planet; and that these genocidal and potentially omnicidal weapons have no place in a civilized society.

Nuclear warfare as genocide

On December 9, 1948, the United Nations General Assembly adopted a convention prohibiting genocide. It seems appropriate to discuss nuclear warfare against the background of this important standard of international law.

Cannot nuclear warfare be seen as an example of genocide? It is capable of killing entire populations, including babies, young children, adults in their prime and old people, without any regard for guilt or innocence. The retention of nuclear weapons, with the intent to use them under some circumstances, must be seen as the intent to commit genocide. Is it not morally degrading to see our leaders announce their intention to commit the "crime of crimes" in our names?

The use of nuclear weapons potentially involves not only genocide, but also omnicide, the death of all, since a large-scale thermonuclear war would destroy human civilization and much of the biosphere.

If humanity is to survive, we must develop an advanced ethic to match our advanced technology. We must regard all humans as our brothers and sisters, More than that, we must actively feel our kinship with all living things, and accept and act upon our duty to protect both animate and inanimate nature.

Science is double-edged

Modern science has, for the first time in history, offered humankind the possibility of a life of comfort, free from hunger and cold, and free from the constant threat of death through infectious disease. At the same time,science has given humans the power to obliterate their civilization with nuclear weapons, or to make the earth uninhabitable through overpopulation and pollution. The question of which of these paths we choose is literally a matter of life or death for ourselves and our children.

Will we use the discoveries of modern science constructively, and thus choose the path leading towards life? Or will we use science to produce more and more lethal weapons, which sooner or later, through a technical or human failure, may result in a catastrophic nuclear war? Will we thoughtlessly destroy our beautiful planet through unlimited growth of population and industry? The choice among these alternatives is ours to make. We live at a critical moment of history - a moment of crisis for civilization.

No one living today asked to be born at such a moment, But history has given our generation an enormous responsibility, and two daunting tasks: We must abolish nuclear weapons and we must abolish institution of war.

The continuity of life is sacred

In 1985, International Physicians for the Prevention of Nuclear War received the Nobel Peace Prize. IPPNW had been founded in 1980 by six physicians, three from the Soviet Union and three from the United States. Today, the organization has wide membership among the world's physicians. Professor Bernard Lowen of the Harvard School of Public Health, one of the founders of IPPNW, said in a recent speech:

"...No public health hazard ever faced by humankind equals the threat of nuclear war. Never before has man possessed the destructive resources to make this planet uninhabitable... Modern medicine has nothing to offer, not even a token benefit, in the event of nuclear war..."

"We are but transient passengers on this planet Earth. It does not belong to us. We are not free to doom generations yet unborn. We are not at liberty to erase humanity's past or dim its future. Social systems do not endure for eternity. Only life can lay claim to uninterrupted continuity. This continuity is sacred."

Mr. Javier Pérez de Cuéllar , former Secretary-General of the United Nations, emphasized the same point in one of his speeches: "I feel", he said, "that the question may justifiably be put to the leading nuclear powers: by what right do they decide the fate of humanity? From Scandinavia to Latin America, from Europe and Africa to the Far East, the destiny of every man and woman is affected by their actions. No one can expect to escape from the catastrophic consequences of a nuclear war on the fragile structure of this planet. ..."

"No ideological confrontation can be allowed to jeopardize the future of humanity. Nothing less is at stake: todays decisions affect not only the present; they also put at risk succeeding generations. Like supreme arbiters, with our disputes of the moment, we threaten to cut off the future and to extinguish the lives of innocent millions yet unborn. There can be no greater arrogance. At the same time, the lives of all those who lived before us may be rendered meaningless; for we have the power to dissolve in a conflict of hours or minutes the entire work of civilization, with all the brilliant cultural heritage of humankind.

"...In a nuclear age, decisions affecting war and peace cannot be left to military strategists or even to governments. They are indeed the responsibility of every man and woman. And it is therefore the responsibility of all of us... to break the cycle of mistrust and insecurity and to respond to humanity's yearning for peace."

Nuclear war is uniquely dangerous

As bad as conventional arms and conventional weapons may be, it is the possibility of a catastrophic nuclear war that poses the greatest threat to humanity. There are today roughly 16,000 nuclear warheads in the world. The total explosive power of the warheads that exist or that could be made on short notice is approximately equal to 500,000 Hiroshima bombs.

To multiply the tragedy of Hiroshima by a factor of half a million makes an enormous difference, not only quantitatively, but also qualitatively. Those who have studied the question believe that a nuclear catastrophe today would inflict irreversible damage on our civilization, genetic pool and environment.

Thermonuclear weapons consist of an inner core where the fission of uranium-235 or plutonium takes place. The fission reaction in the core is able to start a fusion reaction in the next layer, which contains isotopes of hydrogen. It is possible to add a casing of ordinary uranium outside the hydrogen layer, and under the extreme conditions produced by the fusion reaction, this ordinary uranium can undergo fission. In this way, a fission-fusion-fission bomb of almost limitless power can be produced.

The danger of a catastrophic nuclear war casts a dark shadow over the future of our species. It also casts a very black shadow over the future of the global environment. The environmental consequences of a massive exchange of nuclear weapons have been treated in a number of studies by meteorologists and other experts from both East and West. They predict that a large-scale use of nuclear weapons would result in fire storms with very high winds and high temperatures, which would burn a large proportion of the wild land fuels in the affected nations. The resulting smoke and dust would block out sunlight for a period of many months, at first only in the northern hemisphere but later also in the southern hemisphere.

Temperatures in many places would fall far below freezing, and much of the earth's plant life would be killed. Animals and humans would then die of starvation. The nuclear winter effect was first discovered as a result of the Mariner 9 spacecraft exploration of Mars in 1971. The spacecraft arrived in the middle of an enormous dust-storm on Mars, and measured a large temperature drop at the surface of the planet, accompanied by a heating of the upper atmosphere. These measurements allowed scientists to check their theoretical models for predicting the effect of dust and other pollutants distributed in planetary atmospheres.

Flaws in the concept of nuclear deterrence

A number of prominent political and military figures (many of whom have ample knowledge of the system of deterrence, having been part of it) have expressed concern about the danger of accidental nuclear war. Colin S. Gray, Chairman, National Institute for Public Policy, expressed this concern as follows: "The problem, indeed the enduring problem, is that we are resting our future upon a nuclear deterrence system concerning which we cannot tolerate even a single malfunction". General Curtis E. LeMay, Founder and former Commander in Chief of the United States Strategic Air Command, has written, "In my opinion a general war will grow through a series of political miscalculations and accidents rather than through any deliberate attack by either side". Bruce G. Blair (Brookings Institute) has remarked that "It is obvious that the rushed nature of the process, from warning to decision to action, risks causing a catastrophic mistake... This system is an accident waiting to happen."

Fred Ikle of the Rand Corporation has written, "Given the huge and far-flung missile forces, ready to be launched from land and sea on both sides, the scope for disaster by accident is immense... In a matter of seconds - through technical accident or human failure - mutual deterrence might thus collapse."

Another serious failure of the concept of nuclear deterrence is that it does not take into account the possibility that atomic bombs may be used by terrorists. Indeed, the threat of nuclear terrorism has today become one of the most pressing dangers that the world faces, a danger that is particularly acute in the United States.

Since 1945, more than 3,000 metric tons (3,000,000 kilograms) of highly enriched uranium and plutonium have been produced - enough for several hundred thousand nuclear weapons. Of this, roughly a million kilograms are in Russia, inadequately guarded, in establishments where the technicians are poorly paid and vulnerable to the temptations of bribery. There is a continuing danger that these fissile materials will fall into the hands of terrorists, or organized criminals, or irresponsible governments. Also, an extensive black market for fissile materials, nuclear weapons components etc. has recently been revealed in connection with the confessions of Pakistan's bomb-maker, Dr. A.Q. Khan. Furthermore, if Pakistan's less-than-stable government should be overthrown, complete nuclear weapons could fall into the hands of terrorists.

Finally, the doctrine of nuclear deterrence rests on the assumption that political leaders have sound judgement. But what if the leaders are not entirely sane? We must ask this question in the context of the present conflict between the United States and North Korea.

Nuclear weapons are criminal! Every war is a crime!

War was always madness, always immoral, always the cause of unspeakable suffering, economic waste and widespread destruction, and always a source of poverty, hate, barbarism and endless cycles of revenge and counter-revenge. It has always been a crime for soldiers to kill people, just as it is a crime for murderers in civil society to kill people. No flag has ever been wide enough to cover up atrocities.

But today, the development of all-destroying modern weapons has put war completely beyond the bounds of sanity and elementary humanity.

Today, war is not only insane, but also a violation of international law. Both the United Nations Charter and the Nuremberg Principles make it a crime to launch an aggressive war. According to the Nuremberg Principles, every soldier is responsible for the crimes that he or she commits, even while acting under the orders of a superior officer.

Nuclear weapons are not only insane, immoral and potentially omnicidal, but also criminal under international law. In response to questions put to it by WHO and the UN General Assembly, the International Court of Justice ruled in 1996 that "the threat and use of nuclear weapons would generally be contrary to the rules of international law applicable in armed conflict, and particularly the principles and rules of humanitarian law." The only possible exception to this general rule might be "an extreme circumstance of self-defense, in which the very survival of a state would be at stake". But the Court refused to say that even in this extreme circumstance the threat or use of nuclear weapons would be legal. It left the exceptional case undecided. In addition, the Court added unanimously that "there exists an obligation to pursue in good faith and bring to a conclusion negotiations leading to nuclear disarmament in all its aspects under strict and effective international control."

Can we not rid ourselves of both nuclear weapons and the institution of war itself? We must act quickly and resolutely before everything that we love in our beautiful world is reduced to radioactive ashes.

The threat of catastrophic climate change

Quick change is needed to save the long-term future.

The central problem which the world faces in its attempts to avoid catastrophic climate change is a contrast of time scales. In order to save human civilization and the biosphere from the most catastrophic effects of climate change we need to act immediately, Fossil fuels must be left in the ground. Forests must be saved from destruction by beef or palm oil production.

These vitally necessary actions are opposed by powerful economic interests, by powerful fossil fuel corporations desperate to monetize their underground "assets", and by corrupt politicians receiving money from the beef or palm oil industries.

However, although some disastrous effects climate change are already visible, the worst of these calamities lie in the distant future. Therefor it is difficult to mobilize the political will for quick action. We need to act immediately, because of the danger of passing tipping points beyond which climate change will become irreversible despite human efforts to control it.

Tipping points are associated with feedback loops, such as the albedo effect and the methane hydrate feedback loop. The albedo effect is important in connection with whether the sunlight falling on polar seas is reflected or absorbed. While ice remains, most of the sunlight is reflected, but as areas of sea surface become ice-free, more sunlight is absorbed, leading to rising temperatures and further melting of sea ice, and so on, in a loop.

The methane hydrate feedback loop involves vast quantities of the powerful greenhouse gas methane, CH_4, frozen in a crystalline form surrounded by water molecules. 10,000 gigatons of methane hydrates are at present locked in Arctic tundra or the continental shelves of the world's oceans. Although oceans warm very slowly because of thermal inertia, the long-term dangers from the initiation of a methane-hydrate feedback loop are very great. There is a danger that a very large-scale anthropogenic extinction event could be initiated unless immediate steps are taken to drastically reduce the release of greenhouse gases.

Scientists have long been aware of the dangers

Scientists have long been aware that CO_2 and other greenhouse gases released into the earth's atmosphere through human activities can cause dangerous climate change. László Szombatfalvy's important book. "The Greatest Challenges of Our Time", (Ekerlids, 2010), gives the following history of our knowledge of the link between greenhouse gases and climate change:

"As far back as 100 years ago, Swedish scientists observed that human activities could affect the climate. Arvid Högbom, professor of geology in Stockholm, warned in 1895 that anthracite burning would increase carbon dioxide content in the air. The following year, Svante Arrhenius, professor of physics and Nobel Prize Laureate, estimated that doubling of the content of carbon dioxide in the atmosphere would lead to an increase of the earth's average temperature by 5-6 degrees C. However, with the low emissions at that time, the process would take several thousand years.

"In 1938, measurements by Guy S. Callendar, an English researcher, confirmed theories that the amount of carbon dioxide in the atmosphere had actually increased since the previous century. His report made little impact since attention at that time was focused on the outbreak of World War II.

"During the 1950s and 1960s, several research reports were published supporting Svante Arrhenius's calculation of carbon dioxide emissions' warming effects. But the time perspective in these reports has been reduced considerably.

"In the 1970s, it was discovered that emissions of several other greenhouse gases from human activities heightened carbon dioxide's effects.

"In 1988, the International Panel on Climate Control, IPCC, was organized. Every fourth or fifth year since 1990, the IPCC has published climate change reports that are increasingly more extensive and ominous.

"In December 1997, the first international agreement to limit emissions of greenhouse gases was signed in Japan. Known as the Kyoto Protocol, the agreement's goal is that industrialized nations reduce emissions of greenhouse gases by 5.2 percent by 2012, compared with 1990 levels. The Protocol has been hitherto ratified by 176 countries, but unfortunately not by the most important country in this matter: USA."

More recently, on December 12, 2015, the Paris Agreement was adopted by consensus by the 196 parties of the United Nations Framework Convention on Climate Change. As of June, 2017, 195 UNFCC members have signed the Agreement, and 153 nations have ratified it.

The Paris Agreement aims at "Holding the increase in the global average temperature to well below 2^oC above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5^oC above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change."

Unchanged life-styles are not an option. Business as usual is not an option. Inaction is not an option. Public education is needed. Votes for environmentally friendly politicians are needed. A carbon tax is needed. Subsidies to fossil fuel giants must stop. Extraction of fossil fuels must stop. Renewable energy infrastructure must quickly be constructed.

Renewable energy infrastructure represents an unprecedented investment opportunity, and new renewable energy jobs far outnumber those that will be lost in the fossil fuel sector.

There is reason for optimism because of the economic tipping point mentioned in Chapter 1. Renewables are now cheaper than fossil fuels. With the help of renewable-friendly governmental policies, the transition that we so urgently need can be driven by economic forces alone.

We give loving care to our children and grandchildren, but it makes no sense to do so unless we leave them a world in which they and all future generations will be able to survive.

The threat of a large-scale global famine by the middle of the 21st century

Unless efforts are made to stabilize and ultimately reduce global population, there is a serious threat that climate change, population growth, and the end of the fossil fuel era could combine to produce a large-scale famine by the middle of the 21st century.

As glaciers melt in the Himalayas and the Andes, depriving India, China and South America of summer water supplies; as sea levels rise, drowning fertile rice-growing regions of Southeast Asia; as droughts reduce the food production of North America and Southern Europe; as groundwater levels fall in China, India, the Middle East and the United States; and as high-yield modern agriculture becomes less possible because fossil fuel inputs are lacking, the 800 million people who are currently undernourished may not survive at all.

Energy inputs of agriculture

Modern agriculture has become highly dependent on fossil fuels, especially on petroleum and natural gas. This is especially true of production of the high-yield grain varieties introduced in the Green Revolution, since these require especially large inputs of fertilizers, pesticides and irrigation. Today, fertilizers are produced using oil and natural gas, while pesticides are synthesized from petroleum feedstocks, and irrigation is driven by fossil fuel energy. Thus agriculture in the developed countries has become a process where inputs of fossil fuel energy are converted into food calories.

Predictions of drought in the Stern Review

According to a report presented to the Oxford Institute of Economic Policy by Sir Nicholas Stern on 31 January, 2006, areas likely to lose up to 30% of their rainfall by the 2050's because of climate change include much of the United States, Brazil, the Mediterranean region, Eastern Russia and Belarus, the Middle East, Southern Africa and Southern Australia. Meanwhile rainfall is predicted to increase up to 30% in Central Africa, Pakistan, India, Bangladesh, Siberia, and much of China.

Stern and his team point out that "We can... expect to see changes in the Indian monsoon, which could have a huge impact on the lives of hundreds of millions of people in India, Pakistan and Bangladesh. Most climate models suggest that the monsoon will change, although there is still uncertainty about exactly how. Nevertheless, small changes in the monsoon could have a huge impact. Today, a fluctuation of just 10% in either direction from average monsoon rainfall is known to cause either severe flooding or drought. A weak summer monsoon, for example, can lead to poor harvests and food shortages among the rural population - two-thirds of India's almost 1.1 billion people. Heavier-than-usual monsoon downpours can also have devastating consequences..."

In some regions, melting of glaciers can be serious from the standpoint of dry-season water supplies. For example, melts from glaciers in the Hindu Kush and the Himalayas now supply much of Asia, including China and India, with a dry-season water supply. Complete melting of these glacial systems would cause an exaggerated runoff for a few decades, after which there would be a drying out of some of the most densely populated regions of the world.

Ocean current changes and failure of monsoons

It is expected that climate change will affect ocean currents, and hence also affect monsoon rainfall. We are already experiencing a diversion of the Gulf Stream due to southward currents of cold water from melting ice in the Arctic. This has caused what is known as the *North Atlantic Anomaly.* While most regions of the world are experiencing rising temperatures, the North Atlantic and several northern European countries are exceptions to this rule, and have cooled. Complete failure of the Gulf Stream would lead to much colder temperatures in Europe.

Changes in ocean currents have already lead to the failure of the West African Monsoon, and this has already produced severe food insecurity in West Africa.

In the future, climate-changed ocean currents may lead to failures of monsoons in South-east Asia, and thus damage the food supply of almost two billion people.

Falling water tables around the world

Under many desert areas of the world are deeply buried water tables formed during glacial periods when the climate of these regions was wetter. These regions include the Middle East and large parts of Africa. Water can be withdrawn from such ancient reservoirs by deep wells and pumping, but only for a limited amount of time.

In oil-rich Saudi Arabia, petroenergy is used to drill wells for ancient water and to bring it to the surface. Much of this water is used to irrigate wheat fields, and this is done to such an extent that Saudi Arabia exports wheat. The country is, in effect, exporting its ancient heritage of water, a policy that it may, in time, regret. A similarly short-sighted project is Muammar Qaddafi's enormous pipeline, which will bring water from ancient sub-desert reservoirs to coastal cities.

In the United States, the great Ogallala aquifer is being overdrawn. This aquifer is an enormous stratum of water-saturated sand and gravel under-lying parts of northern Texas, Oklahoma, New Mexico, Kansas, Colorado, Nebraska, Wyoming and South Dakota. The average thickness of the aquifer is about 70 meters. The rate of water withdrawal from the aquifer exceeds the rate of recharge by a factor of eight.

Thus we can see that in many regions, the earth's present population is living on its inheritance of water, rather than its income. This fact, coupled with rapidly increasing populations and climate change, may contribute to a very serious food crisis partway through the 21st century.

Populations displaced by drought and famine

Climate change could produce a refugee crisis that is "unprecedented in human history", Barack Obama has warned as he stressed global warming was the most pressing issue of the age.

Speaking at an international food conference in Milan, the former US President said rising temperatures were already making it more difficult to grow crops and rising food prices were "leading to political instability".

If world leaders put aside "parochial interests" and took action to reduce greenhouse gas emissions by enough to restrict the rise to one or two degrees Celsius, then humanity would probably be able to cope.

Failing to do this, Mr Obama warned, increased the risk of "catastrophic" effects in the future, "not only real threats to food security, but also increases in conflict as a consequence of scarcity and greater refugee and migration patterns".

"If you think about monsoon patterns in the Indian subcontinent, maybe half a billion people rely on traditional rain patterns in those areas,"

Populations displaced by rising temperatures

A new study published in Nature: Climate Change has warned that up to 75% of the world's population could face deadly heat waves by 2100 unless greenhouse gas emissions are rapidly controlled.[1]. The following is an excerpt from the article:

"Here we conducted a global analysis of documented lethal heat events to identify the climatic conditions associated with human death and then quantified the current and projected occurrence of such deadly climatic conditions worldwide. We reviewed papers published between 1980 and 2014, and found 783 cases of excess human mortality associated with heat from 164 cities in 36 countries.

"Based on the climatic conditions of those lethal heat events, we identified a global threshold beyond which daily mean surface air temperature and relative humidity become deadly. Around 30% of the world's population is currently exposed to climatic conditions exceeding this deadly threshold for at least 20 days a year.

"By 2100, this percentage is projected to increase to 48% under a scenario with drastic reductions of greenhouse gas emissions and 74% under a scenario of growing emissions. An increasing threat to human life from excess heat now seems almost inevitable, but will be greatly aggravated if greenhouse gases are not considerably reduced." [2]

Conclusions

The subject of population stabilization is a highly sensitive and controversial one. Nevertheless it is an issue that must be confronted if a catastrophic global famine is to be avoided. The three terrible Malthusian forces, famine, disease

[1]Mora, C. et al., *Global risk of deadly heat*, Nature: Climate Change, 19 June 2017

[2]See also https://phys.org/news/2017-08-deadly-south-asia-century.html and https://cleantechnica.com/2017/09/28/extreme-heatwaves-like-recent-lucifer-heatwave-become-normal-europe-2050s/

and war. in the end will cut down any population that exceeds its means of support.

In the first edition of his book on population, Malthus wrote: "That population cannot increase without the means of subsistence is a proposition so evident that it needs no illustration. That population does invariably increase, where there are means of subsistence, the history of every people who have ever existed will abundantly prove. And that the superior power cannot be checked without producing misery and vice, the ample portion of these two bitter ingredients in the cup of human life, and the continuance of the physical causes that seem to have produced them, bear too convincing a testimony."

In later editions, he modified this opinion and made it less pessimistic by allowing for the effect of preventive checks such as late marriage. Malthus considered birth control to be a form of vice, but today it is accepted as the most humane method of avoiding the grim Malthusian forces, famine, disease and war.

If we examine them in the light of current history, we can see that famine, disease and war are interlinked. War produces famine, and indeed famine has been used as an instrument of war, as we see in the conflicts now taking place in Somalia. Another link is the almost unbelievable economic cost of war. An estimated 1.7 trillion U.S. dollars were spent on armaments in 2017. Part of this collossal sum could instead have been used to provide primary health care to all the peoples of the world, and with it, access to the information and materials needed for family planning.

Let us work together to avoid the enormous suffering that would be involved if climate change and population growth combine to produce a catastrophic global famine.

Culture and solidarity

Our modern civilization has been built up by means of a worldwide exchange of ideas and inventions. It is built on the achievements of many ancient cultures. China, Japan, India, Mesopotamia, Egypt, Greece, the Islamic world, Christian Europe, and the Jewish intellectual traditions, all have contributed. Potatoes, corn, squash, vanilla, chocolate, chili peppers, and quinine are gifts from the American Indians.

The sharing of scientific and technological knowledge is essential to modern civilization. The great power of science is derived from an enormous concentration of attention and resources on the understanding of a tiny fragment of nature. It would make no sense to proceed in this way if knowledge were not permanent, and if it were not shared by the entire world.

Science is not competitive. It is cooperative. It is a great monument built by many thousands of hands, each adding a stone to the cairn. This is true not only of scientific knowledge but also of every aspect of our culture, history, art and literature, as well as the skills that produce everyday objects upon which our lives depend. Civilization is cooperative. It is not competitive.

Our cultural heritage is not only immensely valuable; it is also so great that no individual comprehends all of it. We are all specialists, who understand only a tiny fragment of the enormous edifice. No scientist understands all of science. Perhaps Leonardo da Vinci could come close in his day, but today it is impossible. Nor do the vast majority people who use cell phones, personal computers and television sets every day understand in detail how they work. Our health is preserved by medicines, which are made by processes that most of us do not understand, and we travel to work in automobiles and buses that we would be completely unable to construct.

The fragility of modern society

As our civilization has become more and more complex, it has become increasingly vulnerable to disasters. We see this whenever there are power cuts or transportation failures due to severe storms. If electricity should fail for a very long period of time, our complex society would cease to function. The population of the world is now so large that it is completely dependent on the high efficiency of modern agriculture. We are also very dependent on the stability of our economic system.

The fragility of modern society is particularly worrying, because, with a little thought, we can predict several future threats which will stress our civilization very severely. We will need much wisdom and solidarity to get safely through the difficulties that now loom ahead of us.

We can already see the the problem of famine in vulnerable parts of the world. Climate change will make this problem more severe by bringing aridity to parts of the world that are now large producers of grain, for example the Middle West of the United States. Climate change has caused the melting of glaciers in the Himalayas and the Andes. When these glaciers are completely melted, China, India and several countries in South America will be deprived of their summer water supply. Water for irrigation will also become increasingly problematic because of falling water tables. Rising sea levels will drown many rice-growing areas in South-East Asia. Finally, modern agriculture is very dependent on fossil fuels for the production of fertilizer and for driving farm machinery. In the future, high-yield agriculture will be dealt a severe blow by the rising price of fossil fuels.

Economic collapse is another threat that we will have to face in the future. Our present fractional reserve banking system is dependent on economic growth. But perpetual growth of industry on a finite planet is a logical impossibility. Thus we are faced with a period of stress, where reform of our growth-based economic system and great changes of lifestyle will both become necessary.

How will we get through the difficult period ahead? I believe that solutions to the difficult problems of the future are possible, but only if we face the problems honestly and make the adjustments which they demand. Above all, we must maintain our human solidarity.

Who is my neighbor?

Are we losing the human solidarity that will be needed if our global society is to solve the pressing problems that are facing us today? Among the symptoms of loss of solidarity is the drift towards violence, racism and war that can be seen in some countries.[3] To worried observers it seems reminiscent of Germany and Italy in the 1930's. Another warning symptom is the inhospitable reception that refugees have received in Europe and elsewhere.[4]

Tribalism

Human emotional nature evolved over the long prehistory of our species, when our remote ancestors lived small tribes, competing for territory on the grasslands of Africa. Since marriage within a tribe was much more frequent than marriage outside it, each tribe was genetically homogeneous, and the tribe itself, rather than the individual, was the unit upon which the forces of natural selection acted. Those tribes that exhibited internal solidarity, combined with aggression towards competing tribes, survived best. Over a long period of time, tribalism became a hard-wired part of human nature. We can see

[3]http://www.commondreams.org/news/2016/03/01/after-latest-display-bigotry-trump-again-faces-charges-racism http://www.truth-out.org/opinion/item/35053-an-open-letter-to-evangelical-trump-voters
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[4]http://www.commondreams.org/news/2016/03/01/new-low-europe-police-bulldoze-camps-tear-gas-asylum-seekers-and-shutter-borders

tribalism today in the emotions involved in football matches, in nationalism, and in war.

The birth of ethics

When humans began to live in larger and more cosmopolitan groups, it was necessary to overwrite some elements of raw human emotional nature. Tribalism became especially inappropriate, unless the scope of the perceived tribe could be extended to include everyone in the enlarged societies. Thus ethical principles were born. It is not just a coincidence that the greatest ethical teachers of history lived at a time when the size of cooperating human societies was being enlarged.

All of the major religions of humanity contain some form of the Golden Rule. Christianity offers an especially clear statement of this central ethical principle: According to the Gospel of Luke, after being told that he must love his neighbor as much as he loves himself, a man asks Jesus, "Who is my neighbor?". Jesus then replies with the Parable of the Good Samaritan, in which we are told that our neighbor need not be a member of our own tribe, but can live far away and can belong to a completely different nation or ethnic group. Nevertheless, that person is still our neighbor, and deserves our love and care.

The central ethical principle which is stated so clearly in the Parable of the Good Samaritan is exactly what we need today to avoid disaster. We must enlarge our loyalties to include the whole of humanity. We must develop a global ethic of comprehensive human solidarity, or else perish from a combination of advanced technology combined with primitive tribalism. Space-age science is exceedingly dangerous when it is combined with stone-age politics.[5]

The need for global solidarity comes from the instantaneous worldwide communication and economic interdependence that has resulted from advanced science and technology. Advanced technology, our almost miraculous ability to communicate through the Internet, Skype and smartphones, could weld the world into a single peaceful and cooperative unit. But we must learn to use global communication as a tool for developing worldwide human solidarity.

Each week, all over the world, congregations assemble and are addressed by their religious leaders on ethical issues. But all too often there is no mention of the astonishing and shameful contradiction between the institution of war (especially the doctrine of "massive retaliation"), and the principle of universal human brotherhood, loving and forgiving one's enemies, and returning good for evil.

[5]http://www.learndev.org/dl/SpaceAgeScienceStoneAgePolitics-Avery.pdf

Figure 10.1: *Who is my neighbor? The Parable of the Good Samaritan tells us that our neighbor may belong to an entirely different ethnic group. Nevertheless, he or she deserves our love and care.* (Wikipedia)

At a moment of history, when the continued survival of civilization is in doubt because of the incompatibility of war with the existence of thermonuclear weapons, our religious leaders ought to use their enormous influence to help to solve the problem of war, which is after all an ethical problem.

This is how Bertrand Russell expressed the need for human solidarity: *All who are not lunatics agree about certain things. That it is better to be alive than dead, better to be adequately fed than starved, better to be free than a slave. Many people desire those things only for themselves and their friends; they are quite content that their enemies should suffer. These people can be refuted by science: Humankind has become so much one family that we cannot insure our own prosperity except by insuring that of everyone else. If you wish to be happy yourself, you must resign yourself to seeing others also happy.*

New ethics to match new technology

Modern science has, for the first time in history, offered humankind the possibility of a life of comfort, free from hunger and cold, and free from the constant threat of death through infectious disease. At the same time, science has given humans the power to obliterate their civilization with nuclear weapons, or to make the earth uninhabitable through overpopulation and pollution. The question of which of these paths we choose is literally a matter of life or death for ourselves and our children.

Will we use the discoveries of modern science constructively, and thus choose the path leading towards life? Or will we use science to produce more and more lethal weapons, which sooner or later, through a technical or human failure, may result in a catastrophic nuclear war? Will we thoughtlessly destroy our beautiful planet through unlimited growth of population and industry? The choice among these alternatives is ours to make. We live at a critical moment of history - a moment of crisis for civilization.

No one living today asked to be born at such a moment, but by an accident of birth, history has given us an enormous responsibility, and two daunting tasks: If civilization is to survive, we must not only stabilize the global population but also, even more importantly, we must eliminate the institution of war. We face these difficult tasks with an inherited emotional nature that has not changed much during the last 40,000 years. Furthermore, we face the challenges of the 21st century with an international political system based on the anachronistic concept of the absolutely sovereign nation-state. However, the human brain has shown itself to be capable of solving even the most profound and complex problems. The mind that has seen into the heart of the atom must not fail when confronted with paradoxes of the human heart.

The problem of building a stable, just, and war-free world is difficult, but it is not impossible. The large regions of our present-day world within which war has been eliminated can serve as models. There are a number of large countries with heterogeneous populations within which it has been possible to achieve internal peace and social cohesion, and if this is possible within such extremely large regions, it must also be possible globally.

We must replace the old world of international anarchy, chronic war and institutionalized injustice, by a new world of law. The United Nations Charter, the Universal Declaration of Human Rights and the International Criminal Court are steps in the right direction, but these institutions need to be greatly strengthened and reformed.

We also need a new global ethic, where loyalty to one's family and nation will be supplemented by a higher loyalty to humanity as a whole.

Creating the future

The chorus of a popular song repeats a message of comforting (but irresponsible) fatalism: *Que Sera Sera. Whatever will be, will be. The future's not ours to see. Que Sera Sera. What will be will be.* But can we allow ourselves the luxury of fatalism, especially today, when our future is darkened by the twin threats of catastrophic climate change and thermonuclear war.?

Must we not accept our responsibility for both the near future and the distant future. We must do all that is within our power to make our world one in which our children and their descendants can survive? We must save the environment. We must save plants and animals from extinction.

What has happened to the global environment is a human creation. Its very name, the anthhropocene, indicates that we made it. What will happen in the future will also be our creation, the sum of the choices that we make.

War is a human creation. Just as we abolished slavery, we can also abolish the institution of war. It is our responsibility to do so.

The tribal tendencies of human nature are not inevitable. Racism is not inevitable. Nationalist Chauvinism is not inevitable. The dark side of human nature can be overwritten by education and ethics. It is our responsibility to create a global ethical system that matches our advanced technology. We must create an ethic of universal human solidarity.

Global anarchy is not inevitable. We can extend the methods used to avoid war within nations to the entire world. We can reform the United Nations and create a global federation capable of effectively achieving the goals that we desire.

Our economic system is a human creation. The laws of the market are not really laws: They are choices. If we choose we could maximize human happiness, rather than maximizing production and profits.

The population explosion is not inevitable. It is a result of human choices. The threat of an extremely severe worldwide famine resulting from climate change, exploding populations and end of the fossil fuel era is not inevitable. If such a famine comes, it will be the result of human choices.

The decay of democracy is not inevitable. Oligarchy is not inevitable. These evils are the result of neglect and political irresponsibility. As citizens, we must have the courage to restore democracy in countries where it has disappeared, and to create it in countries where it never existed.

We live in a special time, a time of crisis. Here are the responsibilities that history has given to our generation:

- We need system change, not climate change!
- We need a new economic system, a new society, a new social contract, a new way of life.
- We must achieve a steady-state economic system. Limitless growth on a finite planet is a logical absurdity.
- We must restore democracy in countries where it has decayed, and create it in countries where it never existed.

- We must decrease economic inequality.
- We must break the power of corporate greed.
- We must leave fossil fuels in the ground.
- We must stabilize and ultimately reduce global population to a level that can be supported by sustainable agriculture.
- We must abolish the institution of war before modern weapons destroy us.
- And finally, we must develop a mature ethical system to match our new technology.

No one is exempt from these responsibilities. No one can achieve these goals alone; but together we can create the future that we choose.

The Nobel laureate biochemist Albert Szent-Györgyi once wrote:

"The story of man consists of two parts, divided by the appearance of modern science.... In the first period, man lived in the world in which his species was born and to which his senses were adapted. In the second, man stepped into a new, cosmic world to which he was a complete stranger.... The forces at man's disposal were no longer terrestrial forces, of human dimension, but were cosmic forces, the forces which shaped the universe. The few hundred Fahrenheit degrees of our flimsy terrestrial fires were exchanged for the ten million degrees of the atomic reactions which heat the sun."

"This is but a beginning, with endless possibilities in both directions - a building of a human life of undreamt of wealth and dignity, or a sudden end in utmost misery. Man lives in a new cosmic world for which he was not made. His survival depends on how well and how fast he can adapt himself to it, rebuilding all his ideas, all his social and political institutions."

"...Modern science has abolished time and distance as factors separating nations. On our shrunken globe today, there is room for one group only - the family of man."

Figure 10.2: *Cultural activities strengthen internationalism, use very few resources, and produce almost no waste.* (Wikipedia)

Compassion and Greed: Two sides of Human Nature

Humans are capable of great compassion and unselfishness. Mothers and fathers make many sacrifices for the sake of their families. Kind teachers help us through childhood, and show us the right path. Doctors and nurses devote themselves to the welfare of their patients.

Sadly there is another, side to human nature, a darker side. Human history is stained with the blood of wars and genocides. Today, this dark, aggressive side of human nature threatens to plunge our civilization into an all-destroying thermonuclear war.

Humans often exhibit kindness to those who are closest to themselves, to their families and friends, to their own social group or nation. By contrast, the terrible aggression seen in wars and genocides is directed towards outsiders. Human nature seems to exhibit what might be called "tribalism": altruism towards one's own group; aggression towards outsiders. Today this tendency towards tribalism threatens both human civilization and the biosphere.

Greed, in particular the greed of corporations and billionaire oligarchs, is driving human civilization and the biosphere towards disaster.

The greed of giant fossil fuel corporations is driving us towards a tipping point after which human efforts to control climate change will be futile because feedback loops will have taken over. The greed of the military industrial complex is driving us towards a Third World War that might develop into a catastrophic thermonuclear war. The greed of our financial institutions is also driving us towards economic collapse, as we see in the case of Greece.

Until the start of the Industrial Revolution in the 18th and 19th centuries,

Figure 10.3: *Greed is driving us towards disaster.*

human society maintained a more or less sustainable relationship with nature. However, with the beginning of the industrial era, traditional ways of life, containing elements of both social and environmental ethics, were replaced by the money-centered, growth-oriented life of today, from which these vital elements are missing.

According to the followers of Adam Smith (1723-1790), self-interest (even greed) is a sufficient guide to human economic actions. The passage of time has shown that Smith was right in many respects. The free market, which he advocated, has turned out to be the optimum prescription for economic growth. However, history has also shown that there is something horribly wrong or incomplete about the idea that self-interest alone, uninfluenced by ethical and ecological considerations, and totally free from governmental intervention, can be the main motivating force of a happy and just society. There has also proved to be something terribly wrong with the concept of unlimited economic growth.

The Industrial Revolution marked the start of massive human use of fossil

Figure 10.4: *... but compassion can save us.*

fuels. The stored energy from several hundred million years of plant growth began to be used at roughly a million times the rate at which it had been formed. The effect on human society was like that of a narcotic. There was a euphoric (and totally unsustainable) surge of growth of both population and industrial production. Meanwhile, the carbon released into the atmosphere from the burning of fossil fuels began to duplicate the conditions which led to the 5 geologically-observed mass extinctions, during each of which more than half of all living species disappeared forever.

The Stern Review Discussion Paper of 2006 stated that "Melting of permafrost in the Arctic could lead to the release of huge quantities of methane. Dieback of the Amazon forest could mean that the region starts to emit rather than to absorb greenhouse gases. These feedbacks could lead to warming that is at least twice as fast as current high-emission projections, leading to temperatures higher than seen in the last 50 million years."

The greed of giant fossil fuel corporations has recently led them to conduct large-scale advertising campaigns to convince the public that anthropogenic climate change is not real. These corporations own vast oil, coal and gas reserves that must be kept in the ground if we are to avoid catastrophic global warming. It does not seem to bother the fossil fuel giants that if the earth is made uninhabitable, future generations of both humans and animals will perish.

When the United Nations was established in 1945, the purpose of the organization was to abolish the institution of war. This goal was built into many of the articles of the UN Charter. Accordingly, throughout the world, many War Departments were renamed and became Departments of Defense. But the very name is a lie. In an age of nuclear threats and counter-threats, populations are by no means protected. Ordinary citizens are just hostages in a game for power and money. It is all about greed.

Why is war continually threatened? Why is Russia threatened? Why is war with Iran threatened? Why fan the flames of conflict with China? Is it to "protect" civilians? Absolutely not! In a thermonuclear war, hundreds of millions of civilians would die horribly everywhere in the world, also in neutral countries. What is really being protected are the profits of arms manufacturers. As long as there are tensions; as long as there is a threat of war, military budgets are safe; and the profits of arms makers are safe. The people in several "democracies", for example the United States, do not rule at the moment. Greed rules.

Greed and lack of ethics are built into the structure of corporations. By law, the Chief Executive Officer of a corporation must be entirely motivated by the collective greed of the stockholders. He must maximize profits. Nothing must count except the bottom line. If the CEO abandons this single-minded chase after corporate profits for ethical reasons, or for the sake of humanity or the biosphere or the future, he (or she) must, by law, be fired and replaced.

Occasionally, for the sake of their public image, corporations seem to do something for other motives than their own bottom line, but it is usually window dressing. For example, Shell claims to be supporting research on renewable energy. Perhaps there is indeed a small renewable energy laboratory somewhere in that vast corporation; but the real interest of the organization is somewhere else. Shell is sending equipment on a large scale to drill for more and more environment-destroying oil in the Arctic.

What does Christianity say about greed? Wikipedia states that "The seven deadly sins, also known as capital vices or cardinal sins, is a classification of vices (part of Christian ethics) that has been used since early Christian times to educate and instruct Christians concerning fallen humanity's tendency to sin. In the currently recognized version, the sins are usually given as wrath, greed, sloth, pride, lust, envy and gluttony. Each is a form of Idolatry-of-Self wherein the subjective reigns over the objective."

Saint Thomas Aquinas wrote: "Greed is a sin against God, just as all mortal sins, in as much as man condemns things eternal for the sake of temporal things".

In the New Testament, we can find many passages condemning greed, for example:

"For the love of money is the root of all evil: which while some coveted after, they have erred from the faith, and pierced themselves through with many sorrows." Timothy 6:10

"Lay not up for yourselves treasures upon earth, where moth and rust doth corrupt, and where thieves break through and steal." Mathew 6:19

In his encyclical Laudato Si', and on his recent visit to South America, Pope Francis has spoken strongly against economic activity that lacks both social and environmental ethics.

Much depends on whether we are able to break the power that corporations and extremely rich oligarchs now hold over our governments and our mass media. Pope Francis has shown by example what a world leader of courage and honesty can do. Most of us are not in such a position, but each person can do his or her best to restore democracy where it has been lost to corporate money and greed. If the mass media have sold themselves to the highest bidder, we can make our own media. If most politicians are corrupt, we can make our own political movements. As Shelly said, "We are many, they are few".

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Appendix A

AN INTERVIEW WITH BINU MATHEW

In 2017 Binu Mathew, the Indian Editor of the Internet news website "Countercurrents", came to Snebærhaven to interview me. Here is an exerpt from the interview:[1]

Binu: I have a fascination to know how life evolved on this earth, and what's it's future. Your wonderful book, "Information Theory and Evolution" answers almost all these questions. What prompted you to write the book?

John: During the summers of 1960 and 1961, while I was still a post-graduate student in theoretical physics at the University of Chicago, I had the privilege of spending two summers working in the laboratory of the great Hungarian-American physiologist and biochemist, Albert Szent-Györgyi. He was famous for isolating vitimin C and for discovering the molecular memchanism of muscle contraction. But more importantly, he founded a new field of study: Bioenergetics.

Szent-Györgyi wondered how the chemical energy from food is harnesed to do mechanical work or to drive our metabolisms. He reasoned that there must be structures in living organisms which are analogous to the structures of engines. If you pour gasoline onto the street and set fire to it, no useful work results, only heat But if you burn it inside an engine, the chemical energy of the gasoline can be converted into useful mechanical work. Following this line of thought, Szent-Györgyi looked for energy-transducing structures in the

[1] http://www.countercurrents.org/2017/03/15/interview-with-john-scales-avery-one-of-the-greatest-living-intellectuals-on-earth/

tissues of living organisms. Among the structures that caught Szent-Györgyi's attention were mitochondria, which power the metabolism of all animals, and he also studied the microscopic photosynthetic unit (thylakoids) in plants. After some years of work, he became convinced that quantum theory was needed in order to gain a complete understanding of how these microscopic engines work. Therefore he spent a year at the Institute for Advanced Study in Princeton, where he learned quite a lot of quantum theory.

Although he knew enough quantum theory to understand what physicists were talking about, he nevertheless thought that for the research which he wanted to undertake, he needed to collaborate with people whose whole education was in that field, and he brought some theoretical physicists (including me) to his laboratory. During the time that I was there, we worked to obtain a quantum theoretical understannding of the mechanism of the primary process in photosynthesis, where the energy of a photon nis stabilized and trapped, ready to drive the synthests of sugars.

In 1969, after I had obtained a Ph.D. in theoretical chemistry from Imperial College, University of London, and was teaching there, Plenum Press invited me to start a new journal and to become its first Managing Editor: It was called "The Journal of Bioenergetics and Biomembranes". (I think that Szent-Györgyi must have recommended me for this task). I served as editor until 1980. During that time, I am proud to say, our authors included Peter Mitchell and Jens C. Skou, whose papers were being refused by other journals at the time, but who each later won a Nobel Prize.

In 1973, for family reasons, I moved permanently to the University of Copenhagen, One of the courses I helped to teach there was on "Statistical Mechanics From the Standpoint of Information Theory". What a title! My Copenhagen colleague, Dr. Knud Andersen, who had initiated this course, was really ahead of his time! I learned a great deal from helping him to teach the course.

Also, for many years, I taught physical chemistry to biologists. In this field, the concept of Gibbs free energy is very central. In a chemical reaction, the entropy (i.e. disorder) of the universe must always increase, as is required by the secon law of thermodynamics. Entropy is a measure of disorder, and the universe always moves towards a state of greater disorder. To say this is the same as saying that the universe always moves from less probable configurations to states of greater and greater probability. We can create local order, but only by exporting disorder to the universe as a whole. In chemical thermodynamics, the requirement that Gibbs free energy must always decrease in a sponoeous chemical reaction is equivalent to saying that the entropy of the universe must always increase, but it allows us to take into account the fact that chemical reactions usually occur at constant temperature and pressure.

In addition to teaching courses in chemistry and physics, I also taught a course on "Science and Society". This was a history of science and its enormous social impact. An enlarged and updated version of the book that I wrote for this course has recently been published by World Scientific. One of the features of my Science and Society course was that we had many exciting guest lecturers. Among these were Dr. Claus Emmeche and Dr. Luis Emilio Bruni, both of whom were experts in the new field of Biosemiotics, which regards information as the central feature of living organisms. Listening to their wonderful lectures, I found a criticism forming in my mind: They did not distinguish between cybernetic information and thermodynamic information. In other words, they did not distinguish between the information contained in messages, and the information content of Gibbs free energy. I decided that I would try to write a book which would make this distinction clear, but the project was left "on the back burner", and I too no steps towards starting it.

However, a few years later, when I was visiting the Harvard laboratory of the famous chemical physicist Professor Dudley R. Herschbach, he took me to lunch with his postgraduate student, Anita Goel. She was in a special Harvard-MIT program where she was simultaneously obtaining both her Ph.D. in chemical physics and her M.D..

After lunch, I spent the afternoon talking with Anita, and I told her about the information theory book that I was vaguely planning to write. Listening to her reaction, I realized that this was an extremely hot topic. Anita told me that there were many other people working hard on these questions, although they perhaps did not have exactly my angle of approach. I decided to start writing immediately.

Anita was very good at asking questions, and during the whole afternoon she asked me more and more about how my planned book would be organized. How would I explain this, and how that? Which topics should come first and which afterwards? Her excellent questions forced me to find answers. At the end of the afternoon, I returned to my lodgings and wrote down in detail my whole conversation with Anita.

By a coincidence, when I returned to Copenhagen, I found on my desk a letter from the World Scientific Publishing Company asking whether I had any writing plans in which they might be interested. I immediately formalized the outline that I had written at Harvard, and sent it to them; but I did not think that they could find a reviewer who had a background both in information theory and in biology.

To my amazment, World Scientific found a Swedish professor with a background in both fields. He wrote an extremely long review of my book proposal, many times the usual length, criticizing some aspects of my proposed outline, suggesting improvements, and finally recommending publication.

When the book came out, I expected some harsh criticism from the Biosemiotics experts like Claus and Luis, but in fact they liked what I had written. Recently World Scientific asked me to produce a new edition, incorporatingthe latest research. Today, if one includes topics like artificial life and computer technology inspired by mechanisms of the brain, the field is developing with great speed. MIT, where I graduated with a B.Sc. in 1954, now has a Department of Cognative Science, in which half the researchers are looking more and more deeply at how the brain works, while the other half are producing hardware and software that mimic the functions of the brain, including learning and intuition.

Binu: I also have a fascination for the second law of thermodynamics, and how it affects every aspect of our life. You've wonderfully connected the evolution of life and the second law of thermodynamics. Can you explain briefly for CC readers how both these phenomina are connected?

John: The second law of thermodynamics states the the entropy (disorder) of the universe constantly increases. This follows from the fact that disorder is more statistically probable than order. For example, if we put a completed jigsaw puzzel into the bottom of a box, and shake the box, a disordered jumble of pieces results. The reverse process is virtually impossible. We could never, or almost never, put disordered pieces of a puzzel into a box, shake it, and then to find the completed puzzle in the bottom,

Since disorder (entropy) always increases, how is it possible that the world we see around us so highly ordered? How is life possible? How is the Taj Mahal possible? How is the Internet possible? The answer is that the earth is not a closed system. A flood of information-containing free energy reaches the earth's biosphere in the form of sunlight. Passing through the metabolic pathways of living organisms, this information keeps the organisms far away from thermodynamic equilibrium, which is death. As the thermodynamic information flows through the biosphere, much of it is degraded to heat, but part is converted into cybernetic information and preserved in the intricate structures which are characteristic of life. The principle of natural selection ensures that when this happens, the configurations of matter in living organisms constantly increase in complexity, refinement and statistical improbability. This is the process which we call evolution, or in the case of human society, progress.

In his 1944 book "What is Life" Erwin Schrödinger (one of the main founders of quantum theory) showed that, even at that early date, he was already aware of how life and entropy are related. He wrote: "What is that precious something contained in our food which keeps us from death? That is easily answered. Every process, event, happening, call it what you will; in a word, everything that is going on in Nature means an increase of the entropy of the part of the world where it is going on. Thus a living organism continually increases its entropy, or if you will, produces poositive entropy., which is death. It can only keep aloof from it, i.e. alive, by continually drawing from its environment negative entropy..."

"Entropy, taken with a negative sign, is itself a measure of order. Thus the device by which an organism maintains itself at a fairly high level of orderliness (= a fairly low level of entropy) really consists in sucking orderliness from its environment."

Binu: The information revolution has made life easier for many of us humans, even helping us to be born. But it has also destroyed our ecosystems, putting our own life, and the life of our fellow species, into peril. Can we use the information revolution to our advantage to save the planet?

John: Cultural evolution depends on the non-genetic storage and transmission, diffusion and utilization of information. The development of human speech, the invention of writing, the development of paper and printing, and finally in modern times, mass media, computers and the Internet: all these have been crucial steps in society's explosive accumulation of information and knowledge. Human cultural evolution proceeds at a constantly accelerating speed; so great in fact that it threatens to shake society to pieces.

Within rapidly-moving cultural evolution, we can observe that technical change now moves with such astonishing rapidity that neither social institutions, nor political structures, nor education, nor public opinion can keep pace. The lightning-like pace of technical progress has made many of our ideas and institutions obsolete. For example, the absolutely sovereign nation-state and the institution of war have both become dangerous anachronisms in an era of instantaneous communication, global interdependence and all-destroying weapons.

In many respects, human cultural evolution can be regarded as an enormous success. However, at the start of the 21st century, most thoughtful observers agree that civilization is entering a period of crisis. As all curves move exponentially upward, population, production, consumption, rates of scientific discovery, and so on, one can observe signs of increasing environmental stress, while the continued existence and spread of nuclear weapons threaten civilization with destruction. Thus, while the explosive growth of knowledge has brought many benefits, the problem of achieving a stable, peaceful and sustainable world remains serious, challenging and unsolved.

The achievements of modern society are achievements of cooperation. We can fly, but no one builds an airplane alone. We can cure diseases, but only through the cooperative efforts of researchers, doctors and medicinal firms. We can photograph and understand distant galaxies, but the ability to do so is built on the efforts of many cooperating individuals.

Looking at human nature, both from the standpoint of evolution and from that of everyday experience, we see the two faces of Janus: one face shines radiantly; the other is dark and menacing. Two souls occupy the human breast, one warm and friendly, the other, murderous. Humans have developed a genius for cooperation, the basis for culture and civilization; but they are also capable of genocide; they were capable of massacres during the Crusades, capable of genocidal wars against the Amerinds, capable of the Holocaust, of Hiroshima, of the killing-fields of Cambodia, of Rwanda, and of Darfur.

This being so, there are strong reasons to enlist the help of education and religion to make the bright side of human nature win over the dark side. Today, the mass media are an important component of education, and thus the mass media have a great responsibility for encouraging the cooperative and constructive side of human nature rather than the dark and destructive side. Our almost miraculous means of communication, if properly used, offer us the possibility of welding humanity into a single cooperative society.

Binu: Like every activity on earth, economic activity also is a

dissipative form of energy flow. Why is so much income disparity taking place? According to a recent Oxfam report, eight people own as much wealth as the poorest half of humanity. How do you explain it? Do you think that the second law of thermodynamics should be made an essential part of our educational system, especially in economics?

John: With your permission, I will try to answer your last question first. I absolutely agree with you that the concept of entropy and the second law of thermodynamics ought to be made an essential part of our educational system, especially in economics. Although classical economic theory leaves it out entirely, a few pioneers of economic thought have realized that entropy and dissipation need to play an a central role in any correct theory.

One of the first people to call attention to the relationship between entropy and economics was the English radiochemist Frederick Soddy (1877-1956). Soddy won the Nobel Prize for Chemistry in 1926 for his work with Ernest Rutherford, demonstrating the transmutation of elements in radioactive decay processes. His concern for social problems then led him to a critical study of the assumptions of classical economics. Soddy believed that there is a close connection between free energy and wealth, but only a very tenuous connection between wealth and money. He was working on these problems during the period after World War I, when England left the gold standard, and he advocated an index system to replace it. In this system, the Bank of England would print more money and lend it to private banks whenever the cost of standard items indicated that too little money was in circulation, or conversely destroy printed money if the index showed the money supply to be too large.

Soddy was extremely critical of the system of "fractional reserve banking" whereby private banks keep only a small fraction of the money that is entrusted to them by their depositors and lend out the remaining amount. He pointed out that, in this system, the money supply is controlled by the private banks rather than by the government, and that profits made from any expansion of the money supply go to private corporations instead of being used to provide social services. When the economy is expanding, this system is unjust but not disastrous. However, when the economy contracts, depositors ask for their money; but it is not there, having been lent out; and the banks crash. Fractional reserve banking exists today, not only in England but also in many other countries. Soddy's criticisms of this practice casts light on the subprime mortgage crisis of 2008 and the debt crisis of 2011.

As Soddy pointed out, real wealth is subject to the second law of thermodynamics. As entropy increases, real wealth decays. He contrasted this with the behavior of debt at compound interest, which increases exponentially without any limit, and he remarked: “You cannot permanently pit an absurd human convention, such as the spontaneous increment of debt [compound interest] against the natural law of the spontaneous decrement of wealth [entropy]”.

Thus, in Soddy’s view, it is a fiction to maintain that being owed a large amount of money is a form of real wealth.Frederick Soddy’s book, “Wealth, virtual wealth and debt: The solution of the economic paradox”, published in 1926 by Allen and Unwin, was received by the professional economists of the time as the quixotic work of an outsider. Today, however, Soddy’s commonsense economic analysis is increasingly valued for the light that it throws on the instability of our fractional reserve banking system as economic growth falters.

The incorporation of the idea of entropy into economic thought also owes much to the mathematician and economist Nicholas Georgescu-Roegen (1906-1994), the son of a Romanian army officer. Georgescu-Roegen’s talents were soon recognized by the Romanian school system, and he was given an outstanding education in Mathematics, which later contributed to his success and originality as an economist.

In Georgescu-Roegen’s words, “The idea that the economic process is not a mechanical analogue, but an entropic, unidirectional transformation began to turn over in my mind long ago, as I witnessed the oil wells of the Plosti field of both World Wars’ fame becoming dry one by one, and as I grew aware of the Romanian peasants’ struggle against the deterioration of their farming soil by continuous use and by rains as well. However it was the new representation of a process that enabled me to crystallize my thoughts in describing the economic process as the entropic transformation of valuable natural resources (low entropy) into valueless waste (high entropy).”

After making many technical contributions to economic theory, Georgescu-Roegen returned to this insight in his important 1971 book, The Entropy Law and the Economic Process (Harvard University Press, Cambridge, 1971), where he outlines his concept of bioeconomics.

Nicholas Georgescu-Roegen’s influence continues to be felt today, not only through his own books and papers but also through those of his student, the distinguished economist Herman E. Daly, who for many years has been advocating a steady-state economy. As Daly points out in his books and papers, it is becoming increasingly apparent that unlimited economic growth on a finite planet is a logical impossibility. However, it is important to distinguish between knowledge, wisdom and culture, which can and should continue to grow, and growth in the sense of an increase in the volume of material goods produced, which is reaching its limits.

Daly describes our current situation as follows: "The most important change in recent times has been the growth of one subsystem of the Earth, namely the economy, relative to the total system, the ecosphere. This huge shift from an "empty" to a "full" world is truly something new under the sun... The closer the economy approaches the scale of the whole Earth, the more it will have to conform to the physical behavior mode of the Earth... The remaining natural world is no longer able to provide the sources and sinks for the metabolic throughput necessary to sustain the existing oversized economy - much less a growing one. Economists have focused too much on the economy's circulatory system and have neglected to study its digestive tract."

Let me now turn to your question about enormous economic inequality. This exists today both within nations and between nations. Part of the explanation for this intolerable ecomomic inequality can be found in the remarkable properties of exponential growth. If any quantity, for example indebtedness, is growing at the rate of 3% per year, it will double in 23.1 years; if it is growing at the rate of 4% per year, the doubling time is 17.3 years. For a 5% growth rate, the doubling time is 13.9 years, if the growth rate is 7%, the doubling time is only 9.9 years. It follows that if a debt remains unpaid for a few years, most of the repayments will go for interest, rather than for reducing the amount of the debt.

In the case of the debts of third world countries to private banks in the industrialized parts of the world and to the IMF, many of the debts were incurred in the 1970's for purposes which were of no benefit to local populations, for example purchase of military hardware. Today the debts remain, although the amount paid over the years by the developing countries is very many times the amount originally borrowed. Third world debt can be regarded as a means by which the industrialized nations extract raw materials from developing countries without any repayment whatever. In fact, besides extracting raw materials, they extract money. The injustice of this arrangement was emphasized recently by Pope Francis in his wonderful encyclical "Laudato Si' "

Another part of the explanation lies in "resource wars", conducted by militarily powerful countries to put in place or maintain unfair trade relationships with resource-rich nations in the third world. Finally, our present economic system favors concentration of wealth. "The rich get richer, and the poor get poorer", or "To him who hath, it shall be given, but from him who hath not, even that which he hath shall be taken away". At present, powerful oligarchs use their wealth to control governments. Democracy decays, tax loopholes are found for the rich, and inequality increases. This situation, and the impossibility of perpetual growth on a finite planet, point to the need for a new economic system, a system where cooperation plays a greater role; a system with both a social conscience and an ecological conscience.

Binu: The nuclear bomb is the greatest concentration of man-made energy on earth. Why is it that peace is the only software capable of diffusing this dangerous concentration of energy?

John: Let me begin to try to answer you question by quoting Albert Szent Györgyi: I have always found these words very enlightening and inspiring: "The story of man consists of two parts, divided by the appearance of modern science...In the first period, man lived in the world in which his species was born and to which his senses were adapted. In the second, man stepped into a new, cosmic world to which he was a complete stranger.... The forces at man's disposal were no onger terrestrial forces, of human dimension, but were cosmic forces, the forces which shaped the universe. The few hundred Fahrenheit degrees of our flimsy terrestrial fires were exchaned for the ten million degrees of the atomic reactions which heat the sun."

"This is but a beginning, with endless possibilities in both directions; a building of a human life of undreamt of wealth and dignity, or a sudden end in utmost misery. Man lives in a new cosmic world for which he was not made. His survival depends on how well and how fast he can adapt himself to it, rebuilding all his ideas, all his social and political institutions."

"...Modern science has abolished time and distance as factors separating nations. On our shrunken globe today, there is room for one group only: the family of man".

I would also like to quote from the Russell-Einstein Manifesto of 1955, the founding document of Pugwash Conferences on Science and World Affairs. The Manifesto ends with the words, "Here, then, is the problem which we present to you, stark and dreadful and inescapable. Shall we put an end to the human race, or shall mankind renounce war?... There lies before us, if we choose, continual progress in happiness, knowledhe and wisdom. Shall we instead choose death because we cannot forget our quarrels? .. We appeal as human beings to human beings: Remember your humanity and forget the rest. If you can do so, there lies before you a new Paradise; if you cannot, there lies before you the threat of universal death."

The human tendency towards tribalism evolved when our remote ancestors lived in small, genetically homogeneous tribes, competing for territory on the grasslands of Africa. Because marriage within a tribe was much more common than marriage outside it, genes were shared within the tribe. The tribe as a whole either survived or perished. The tribe, rather than the individual was the unit upon which the Darwinian forces of natural selection acted.

Although it was a survival trait 100,000 years ago, tribalism threatens our human civilization of today with thermonuclear annihilation. As Konrad Lorenz put it, "An impartial visitor from another planet, looking at man as he is today, in his hand the atom bomb, the product of his intelligence, in his heart the aggression drive, inherited from his anthropoid ancestors, which the same intelligence cannot control, such a visitor would not give mankind much chance of survival."

Today, at the start of the 21st century, we live in nation-states to which we feel emotions of loyalty very similar to the tribal emotions of our ancestors. The enlargement of the fundamental political and social unit has been made necessary and possible by improved transportation and communication, and by changes in the techniques of warfare.

The tragedy of our present situation is that the same forces that made the nation-state replace the tribe as the fundamental political and social unit have continued to operate with constantly increasing intensity. For this reason, the totally sovereign nation-state has become a dangerous anachronism.

Although the world now functions as a single unit because of modern technology, its political structure is based on fragments, on absolutely sovereign nation-states . They are large compared to tribes, but too small for present-day technology, since they do not include all of mankind.

The elimination of war, and the elimination of the threat of nuclear annihilation, will require effective governance at the global level. In 1995 the Nobel Peace Prize was awarded jointly to Pugwash Conferences on Science and World Affairs and to its leader, Sir Joseph Rotblat. In his acceptance speech, Sir Joseph said, "We have to extend our loyalty to the whole of the human race... A war-free world will be seen by many as Utopian. It is not Utopian. There already exist in the world large regions, for example the European Union, within which war is inconceivable. What is needed is to extend these."

Binu: How can information theory play a role in peace politics?

Biosemiotics regards information as being the central feature of living organisms- Societies can be regarded as super-organizme. One might think of extending Biosemiotics to the study of the way in which information is the central feature of the development and function of societies. Such a field of study might be called Sociosemiotics. Information theory is certainly essential to an understanding of history and to an unddrstanding of the crisis of civilization that has been produced by the information explosion.

Binu: Do you see any connection between the rise of populist and even fascist leaders around the world and information theory and thermodynamics?

John: When the earth's human population is plotted as a function of time over a period of 10,000 years, the simple mathematical function that best fits the data in not an exponentially increasing curve but a hyperbola, $P=C/(2025-t)$, where P is the population, C is a constant, and t is the time, measured in years. If population continued to follow this curve, it would become infinite in the year 2025, which, of course, is impossible. In fact, global population has already begun to fall below the curve. Why is the emperical curve a hyperbola rather than an exponential? We can understand this if we see the growth of population as being driven by the information explosion. According to Malthus, population always presses against its food supply. As human knowledge and control of nature increased, the food supply also increased, leading to an increase in population. But today, we are facing a crisis. Our global food supply may be hit severely by the end of the fossil fuel era, and by climate change. These factors have already produced a flood of refugees fleeing environmental catastrophes in Africa. Added to this is are millions of refugees from wars in the Middle East.

The result of the refugee crisis has been a loss of human solidarity, and the rise of fascism.In this difficult situation, we need to regain our human solidarity. We need to fight against fascism, and to regain democratic government. We need to end the wars, which are producing many millions of refugees. We eed to avoid catastrophic climate cjhange.

Binu: "Post-truth" was the word of the year of 2016. Why such a word now? Was there a "pre-truth" or "truth" era? Or is there ever truth?

Let me again quote Albert Szent-Györgyi. One of his remarks that I remember from the time that I worked in his laboratory was this: "The human mind was not designed by evolutionary forces for finding truth. It was designed for finding advantage". Napoleon Bonaparte, quoting Fontanelle, said "History is a set of agreed-upon lies". Members of tribelike groups throughout history have marked their identity by adhering to irrational systems of belief. Like the ritual scarification which is sometimes used by primitive tribes as a mark of identity, irrational systems of belief also mark the boundaries of groups. We parade these beliefs to demonstrate that we belong a special group and that we are proud of it. The more irrational the belief is, the better it serves this purpose. When people tell each other that they believe the same nonsense, a bond is forged between them. The worse the nonsense, the stronger the bond.

Sometimes motives of advantage are mixed in. As Szent-Györgyi observed, evolution designed the human mind, not for finding truth, but for finding advantage. Within the Orwellian framework of many modern nations, it is extremely disadvantageous to hold the wrong opinions. The wiretappers know what you are thinking.

But truth has the great virtue that it allows us to accurately predict the future. If we ignore truth because it is unfashionable, or painful, or heretical, the future will catch us unprepared. What do you think of fake news, and the discussions going on the mechanisms to control it? Throughout history, art was commissioned by rulers to communicate, and exagerate their power, glory, absolute rightness, etc. to the population. Modern powerholders are also aware of the imporatnce of propaganda. Thus the media are a battleground, where reformers struggle for attention, but are defeated with great regulatity by the wealth and power of the establishment. This is a tragedy, because today, there is an urgent need to make public opinion aware of the serious threats that are facing civilization, and the steps that are needed to solve these problems. The mass media could potentially be a great force for public education, but in general, their role is not only unhelpful: it is often negative. Today we are faced with the task of creating a new global ethic in which loyalty to family, religion and nation will be supplemented by a higher loyalty to humanity as a whole.

In addition, our present culture of violence must be replaced by a culture of peace. To achieve these essential goals, we urgently need the cooperation of the mass media.

How do the media fulfil this life-or-death responsibility? Do they give us insight? No, they give us pop music. Do they give us an understanding of the sweep of evolution and history? No, they give us sport. Do they give us an understanding of need for strengthening the United Nations, and the ways that it could be strengthened? No, they give us sit-coms and soap operas. Do they give us unbiased news? No, they give us news that has been edited to conform with the interests of the military-industrial complex and other powerful lobbys. Do they present us with the need for a just system of international law that acts on individuals? On the whole, the subject is neglected. Do they tell of of the essentially genocidal nature of nuclear weapons, and the need for their complete abolition? No, they give us programs about gardening and making food.

In general, the mass media behave as though their role is to prevent the peoples of the world from joining hands and working to save the world from thermonuclear and environmental catastrophes. The television viewer sits slumped in a chair, passive, isolated, disempowered and stupefied. The future of the world hangs in the balance, the fate of children and grandchildren hang in the balance, but the television viewer feels no impulse to work actively to change the world or to save it. The Roman emperors gave their people bread and circuses to numb them into political inactivity. The modern mass media seem to be playing a similar role.

Because the mass media have failed us completely, the work of independent editors like yourself has become enormously important for the future of humanity and the biosphere.

Binu: Do you think that humanity can tackle climate change? Do you have any suggestions?

Solar power and wind energy are already much cheaper than fossil fuels if the enormous subsidies given to fossil fuel corporations are discounted. The main thing that the world needs to do is to abolish these subsidies, or, better yet, shift them to the support of renewable energy infrastructure. If this is done, then economic forces alone will produce the rapid transition to renewable energy which we so urgently need to save the planet.

Oil Change International, an organization devoted to exposing the true costs of fossil fuels, states that "Internationally governments provide at least $775 billion to $1 trillion annually in subsidies, not including other costs of fossil fuels related to climate change, environmental impacts, military conflicts and spending, and health impacts."

Hope that catastrophic climate change can be avoided comes from theexponentially growing world-wide use of renewable energy, and from the fact prominent public figures, such as Pope Francis, Leonardo DiCaprio, Elon Musk, Bill McKibben, Naomi Klein and Al Gore, are making the public increasingly aware of the long-term dangers. This awareness is needed to counter the climate change denial propaganda sponsered by politicians subserviant to the fossil fuel industry.

Short-term disasters due to climate change may also be sufficiently severe to wake us up. We can already see severe effects of global warming in Africa, in parts of India and.in island nations threatened by rising sea levels.

Binu: What do you think of the attitude of people like James Lovelock, who say "enjoy life while you can"?

I believe that this is a betrayal of our responsibility to our children and grandchildren and to all future generations of humans. It is also a betrayal of all the other species with which we share our beautiful planet.

We give our children loving care, but it makes no sense do so and at the same time to neglect to do all that is within our power to ensure that they and their descendants will inherit an earth in which they can survive.

Inaction is not an option. We have to act with courage and dedication, even if the odds are against success, because the stakes are so high.

The mass media could mobilize us to action, but they have failed in their duty. Our educational system could also wake us up and make us act, but it too has failed us. The battle to save the earth from human greed and folly has to be fought in the alternative media.

We need a new economic system, a new society, a new social contract, a new way of life. Here are the great tasks that history has given to our generation: We must achieve a steady-state economic system. We must restore democracy. We must decrease economic inequality. We must break the power of corporate greed. We must leave fossil fuels in the ground. We must stabilize and ultimately reduce the global population. We must eliminate the institution of war. And finally, we must develop a more mature ethical system to match our new technology.

Binu: What do you think of a world 50 years from now?

John: The future looks extremely dark because of human folly, especially the long-term future.Â The greatest threats are catastrophic climate change and thermonuclear war, but a large-scale global famine also has to be considered. Nevertheless, I hope for the best, and I think that it is our collective duty to work for the best. The problems that we face today are severe, but they all have rational solutions.

It is often said that ethical principles cannot be derived from science, and that they must come from somewhere else. However, when nature is viewed through the eyes of modern science, we obtain some insights which seem almost ethical in character. Biology at the molecular level has shown us the complexity and beauty of even the most humble living organisms, and the interrelatedness of all life on earth. Looking through the eyes of contemporary biochemistry, we can see that even the single cell of an amoeba is a structure of miraculous complexity and precision, worthy of our respect and wonder.

Knowledge of the second law of thermodynamics, the statistical law favoring disorder over order, reminds us that life is always balanced like a tight-rope walker over an abyss of chaos and destruction. Living organisms distill their order and complexity from the flood of thermodynamic information which reaches the earth from the sun. In this way, they create local order; but life remains a fugitive from the second law of thermodynamics. Disorder, chaos, and destruction remain statistically favored over order, construction, and complexity.

It is easier to burn down a house than to build one, easier to kill a human than to raise and educate one, easier to force a species into extinction than to replace it once it is gone, easier to burn the Great Library of Alexandria than to accumulate the knowledge that once filled it, and easier to destroy a civilization in a thermonuclear war than to rebuild it from the radioactive ashes.

Knowing this, we can use the second law of thermodynamics to form an almost ethical insight: To be on the side of order, construction, and complexity, is to be on the side of life. To be on the side of destruction, disorder, chaos and war is to be against life, a traitor to life, an ally of death. Knowing the precariousness of life, knowing the statistical laws that favor disorder and chaos, we should resolve to be loyal to the principle of long-continued construction upon which life depends.

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