Life, Biotechnology, and Purposeful Biological Evolution

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Medicine, Magic, and Mayhem

Medicine is magical and
magical is art
The Boy in the Bubble
And the baby with the baboon heart.

Paul Simon

The topic of this chapter is the broad panorama of biological science, biotechnology, medicine, and health in the future. I begin with the question of how future biology and biotechnology will alter human civilization, and it seems quite clear that the effects, even in the immediate future, will be dramatic. Next I look at genetic research and technology and its impact on health, ecology, and the future evolution of life and humanity. This section includes the controversial topics of eugenics, cloning, gene therapy, and bioethics. Bringing together advances in computer science and biological science, I then examine the strange and fascinating reality of artificial life, which is connected to the areas of artificial intelligence and virtual reality, discussed in the previous chapter. Next I turn to artificial body parts and cyborgs, another area where biology and other sciences interact and integrate. In the following section, I examine the future of medicine and health care, which leads into the topics of life-extension, immortality, and the evolutionary transcendence of humanity. I end the chapter with a discussion on contemporary thinking and controversies surrounding the theory of evolution, and draw some general conclusions regarding purposive evolution and the nature and future of life. Across all of these connected areas, we do, indeed, seem to be entering into a time of magic and wonder, yet the potential problems, complications, and mayhem are just as great.

The future of biology, biotechnology, and medicine is one of the most amazing arenas of development in our present world. The main theses of this chapter are:

- Biology will take the lead in providing scientific metaphors and models for describing, organizing, and directing society and civilization. Biotechnology will increasingly infuse itself into all aspects of human life, creating a Neo-Biological Civilization.
- Supported by science and technology, and in particular, genetics, there will be a new level of evolution, a revolutionary jump in the form of change toward purposive biological evolution. We will increasingly guide evolution. We will be able to control biological reproduction. Consequently, the rate of biological change in natural history will accelerate. As a result of this new form of evolution, there will be a biological diversification of life and humanity; many new species of life and types of humans will be created in the next couple of centuries.
- There will be an increasing interactive relationship and interconnectedness between humanity and all of life. Following from the principle of reciprocity, purposive evolution will be co-participatory, involving the influence of numerous creative forms of intelligence and life.
- There will be a progressive physical and functional integration of life and technology. The distinction between the “born” and the “made”, the natural and the artificial, will blur. This general trend in biotechnology dovetails with the corresponding trend in information technology. Artificial intelligence, robotic, and information technologies will integrate with purposive biological evolution. Biological and technological forms will co-evolve and integrate in the future.
- There will be a growing commercialization of medicine and biology. Life, health, and life-enhancements will be for sale and the sales will be big.
- Amazing advances in human life-extension are on the immediate horizon. Relative immortality is becoming a scientific and technological possibility.
- There will be a growing infusion of ethics and values into medicine and biology; some of the great ethical controversies of the next century will come out of biotechnology. Purposive evolution will be directed by the values, visions, and goals of culture and civilization, which will co-evolve with natural and technological systems.
- Our understanding of evolution is still evolving and the implications of evolutionary thinking are only minimally understood within human society. Consequently, there will be a deep philosophical and social struggle in popular culture over evolutionary theory in the future. It is still in conflict with scientifically unsound, though widely accepted, static notions of life, humanity, and existence.

- As we explore and colonize outer space, we will move toward a cosmic perspective on life. Biological and bio-technological diversification will escalate and amplify and life may spread through the entire universe.

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Included in the notes for this chapter is a list of websites on biology, evolutionary theory, medicine, genetics, biotechnology, artificial life, and cyborgization.[1]

Neo-Biological Civilization

***"The past belongs to physics,
but the future belongs to biology."***

Christopher Langton

"Our rapid progress in biotechnology will likely get us into as much trouble as our nuclear-age mechanical technology if we don't make equal progress in understanding life systems and their dynamic ecological balance. Only if it is used with understanding of and respect for living systems can biotechnology offer the possibility of working with life for life."

Elizabet Sahtouris

If during the last few centuries physics was the central and most influential of the sciences, biology promises to be the most significant science to humanity in the immediate centuries to follow. Freeman Dyson predicts that the dominant science of the 21st Century will be biology, with genetics and neuro-physiology presenting an abundance of unsolved problems to be solved with a whole new set of technologies.[2] Both Dyson and Maddox concur that the question of the origin of life is a pivotal and highly significant issue in science that will occupy the attention of numerous scientists in the immediate future.[3] Further, the metaphors and models for nature and human organizations increasingly come from biology rather than physics. As Gregory Stock notes, human civilization is increasingly viewed like a complex living organism, rather than a complex mechanical machine, as during the Industrial Age.[4] Further, the language of physics itself sounds more biological. Open systems theory, which initially developed in the context of biological science[5], has been applied to numerous areas of physical science.[6] To recall one noteworthy example, Smolin has applied self-organizational and feedback principles to describing the dynamics and organization of galaxies.[7] Also, as I described in Chapter 1, much of modern physics and astronomy is becoming organized within an evolutionary framework. Many of the most important contemporary theories of the future emphasize biological and ecological themes.[8] And finally, if any technological development in the coming century will rival computer and information technology in its impact on human society, it will be biotechnology and the genetic manipulation of life.[9]

One classic book that clearly emphasizes the centrality of biology and ecology in future society is Kevin Kelly's *Out of Control: The Rise of Neo-Biological Civilization*.[10] Many of Kelly's ideas contained in this book have been discussed throughout previous chapters. At this point, Kelly's concept of a "**Neo-Biological Civilization**" will be described, since it is relevant to much of the subsequent discussion on the future of biology, biotechnology, and ecology.

Recall the distinction between centralized-hierarchical organizations and distributed-network organizations. Hierarchies are top-down organizations, whereas networks are bottom-up.[11] The Newtonian notion that laws were imposed upon nature from some transcendent source of order, which in fact goes back to Plato's theory of reality, is a top-down theory of how nature is organized. Kelly's view is that biological systems, whether an individual cell, a multi-cellular organism, or an ecosystem, actually exhibit a network organization. Control is not localized in one spot in the system, but rather control is distributed. A central command station does not dictate the holistic properties of the organization; rather the holistic properties emerge through the interaction of multiple units in the network. Consequently, the behavior of the whole cannot be predicted by looking at any one of its parts, since there is no one part that controls the whole. The behavior of the organization is an interaction effect essentially involving all parts. This interactive explanation of order within a system, as I pointed out earlier, is a central tenet of self-organization theorists, such as Smolin, Sahtouris, and Goerner.[12]

For any complex system, such as a living cell or a swarm of bees, the number of ongoing and continually changing interactions among its myriad parts is so vast that it is exceedingly difficult to predict the behavior of the total system. This is a basic implication of chaos and complexity theory.[13] Because the behavior of a complex distributed network is difficult to predict, according to Kelly, it is also difficult to control. There is no one place from within or outside the system, where the entire system can be controlled; control is distributed. There are limits to this philosophy of indeterminism. There is a degree of order and predictability in the chaos,[14] but, as Kelly argues if we start altering living systems, it is important to keep in mind that humans will not be totally in control of the ramifications. Kelly uses expressions such as a "**hive mind**" and a "**swarm system**" to capture the feeling, meaning, and somewhat helter-skelter quality of a complex, distributed network.[15]

We should note that during the Newtonian Industrial Era, which operated from a philosophy of natural determinism and a top-down view of the origins of order, we only thought that we were in control. We may have been able to control simple machines or hierarchical human organizations to a degree, but all the various consequences of these localized pockets of control rippled out into our environment and our civilization, leading to numerous unanticipated effects.[16] We may have been able to build cars, but we didn't anticipate traffic jams, the exodus to the suburbs, pollution, and mass biological extinctions, all generally unforeseen consequences of our efforts to control our world. These various unanticipated effects occurred because our reality is a distributed network system filled with many different social, technological, and natural sub-systems, producing among themselves numerous interaction effects. This is in stark contrast to how people of the Industrial Era saw their creations as closed systems that could be individually manipulated from central command points.

Humans have also, in numerous ways throughout history, manipulated and influenced both biological and ecological variables and factors in the world, e.g., selective breeding, agriculture, and hunting.[17] Sometimes our influence has been intentional, sometimes unintentional. We have not always correctly anticipated the effects of our actions. We have though instigated many positive changes in living forms and living populations, especially regarding improvements in agricultural and food products[18], though there is significant debate over the overall effects of our efforts.[19] It would be highly counterproductive, regressive and, in fact, next to impossible to back out of efforts to control and alter life. Following from the principle of reciprocity, it is impossible for any living creature to avoid influencing its environment. Any living form by its very presence affects other living forms. Further, as I discussed in the previous two chapters, humans are integrally tied to their technologies, which are instruments for manipulating the environment. But we are entering a period where our biological knowledge and technological and practical capabilities are vastly accelerating. A quantum leap in theoretical biology and biotechnology is taking place. We will not only be able to instigate much bigger and more profound effects on life on the earth, we will be able to create technologies out of life.

Kelly proposes that, as we enter into this new era of biotechnology, we adopt a different philosophy and attitude regarding our relationship to technology and the world and develop an evolutionary strategy in creating technologies. This new strategy for biotechnology is already emerging and involves a shift from designing our new technologies to evolving them. Instead of trying to specify and construct in complete detail a new biological system that will serve some instrumental end, we place living forms within the test environment and allow them to evolve a way of solving the test problem. For example, if you want an organism that will eat pollution or combat a disease, you place viable candidates in a test environment, containing the pollutant or disease, and selectively guide them in appropriate directions as they reproduce and change. In a process analogous to natural selection, where survival depends upon approximating toward the desired consequence, we selectively “breed” a living form that will accomplish the goal we have identified. In essence, you allow the biotechnology to figure out a solution. Note that this is a clear example of an intelligent technology. The technological system, to a degree, is showing flexibility and learning.[20]

This change in technological approach reflects the complexity and level of autonomy of biological systems. Bio-technical systems are fluid and changing.

They are not inert hunks of metal like Newtonian machines; they are alive. Further, they are much more complex than Newtonian machines and they possess an inherent set of survival and evolutionary mechanisms. They do not simply sit there waiting for their buttons to be pushed. Kelly thinks that because they continuously reproduce, mutate, and experiment with their environment on a mass scale, they will probably hit upon a solution to the problem (with our guidance) more quickly than we could figure one out alone. Given all of these fundamental differences, they cannot be controlled in the manner that Newtonian machines can be controlled.

This new technological strategy moves from a top-down approach, where the new mechanism is made, designed, molded and put together, to a **partnership approach**, where the new mechanism emerges from an interaction of our goals and the biological inventiveness of the living forms. Instead of treating the units of the system as if they were passive and would simply follow whatever directions you gave them, (a top-down approach) you acknowledge and use their creativity, complexity, autonomy, and intelligence, and allow them to work out solutions. We take advantage of the skills and capabilities that the system possesses. In working with life we are interacting with systems that are flexible, intelligent, and inherently autonomous; they self-organize and evolve. They cannot simply be pushed around.

Kelly points out that a centralized system that attempts to rigidly control its parts shows little flexibility and creativity. Distributed and interactive network systems allow much more flexibility and are not locked into a single approach directed from above. Life is a partnership, a distributed system, and the directions biotechnology will take are open-ended, creative, and, to re-emphasize, not in complete control from any one point within the network. As Kelly underscores in the title of his book, an expression he apparently took from Rodney Brooks' well-known article on robotics,[21] our emerging Neo-Biological Civilization will be "**out of control**".

With simple physical machines rigidly coordinated via hierarchical chains of command, such as existed in the Newtonian-Industrial Age, control to some degree was possible, as least regarding the workings of the machines. But, the philosophy of this era was to control and dominate nature, for nature was seen as one huge clocklike mechanism that could be manipulated by the human mind and appropriate technology.[22] Consequently, the philosophy of the future during this era assumed that the future could be rationally planned and directed. But a single living cell, let alone an ecosystem, is more complex than any industrial factory, and there is no master control room from which all of the individual functions can be perfectly manipulated. Consequently, as we enter the age of biotechnology, we can no longer operate from a philosophy of total control. What we are going to encounter is more of an adventure, an odyssey, and the multiple possible trajectories or probability distributions of such a Neo-biological civilization will be, to some degree, full of surprises. It will be, in essence, a partnership instead of a tyranny.

But how do humans feel about not being in control? Aside from the fact that we have inherited a philosophy of control over nature from the Newtonian-

Industrial Age, the feeling of being in control gives us a sense of security and individual power. Not being in control would conflict with our domineering mindset, generating cognitive dissonance, and, emotionally, we would feel insecure, threatened, and stressed. A world out of our control would seem risky and dangerous. All told, relinquishing the idea and the need for control would embody a fundamental paradigm shift in many people's philosophy, psychology, and way of life.

Kelly's ideas on control and future human civilization lead us back to several important themes in this book. For one thing, Kelly's general philosophy and attitude regarding biotechnology and future society reconfirm the idea that the future should be seen as an adventure of possibilities, an odyssey, rather than a destined or determined path. More so than the mechanistic theory of physics that dominated the Industrial Age, our contemporary understanding of life, open systems, and self-organization underscores and emphasizes the uncertainty of the future. Second, when we examine Kelly's concept of networks, we see that he believes that the uncertainty of their behavior is a function of the interactivity and interconnectedness among their parts. Not only are networks holistic realities, they are built upon reciprocities of interdependencies. The dualist image of order depicted reality as consisting of a higher and separate realm that imposed order on a lower realm. Within this traditional image, the future seems easier to predict, since future events seem to follow from the directions and controls of the higher realm. Yet if future events follow from interactions among various systems, then the future always goes beyond the dictates of any one element within the network. Uncertainties and possibilities follow from reciprocities. Next we should note that, following Kelly's distinction between rigid hierarchies and flexible networks, creativity and novelty arise more naturally in networks than in hierarchies. The theory of evolution assumes novelty within the passage of time. New things emerge over time, if not what is the sense of the term "evolution"? A theory of the future based on either destiny or determinism does not see the passage of time as generating anything new. In determinism, the future follows from the present. In a destiny view, the future is already defined. The idea of networks fits with the open-ended vision of the evolutionary perspective.

Kelly's vision of a Neo-Biological Civilization is a strong example of a biological perspective or theory on the future; biology and biological concepts will transform the totality of human society. Another strong advocate for a biological view of the future is Hazel Henderson. Henderson thinks that the contemporary world transformation should be described in terms of open systems concepts. She correctly identifies that the origin and inspiration of open systems theory goes back to the study of life. Henderson sees open systems theory and contemporary biology as clashing with Newtonian and Industrial Age ideas, which Kelly also notes, and she believes that our future society should be structured on biological and open systems concepts rather than the linear, hierarchical and dualistic notions of the Industrial Age. Similar to Kelly, she sees this new society as emphasizing creativity, interactivity, and a partnership or co-creative approach with the earth's living systems.[23] Elizabet Sahtouris,[24] whom I discussed earlier when I reviewed the differences between open systems theory and Newtonian physics,[25] is another clear example of a theorist who emphasizes contemporary biological thinking in her vision of the future. I will further examine her ideas throughout this chapter and the next chapter on ecology. Fritjof Capra also falls into this theoretical perspective, again highlighting the differences between Newtonian and Industrial thinking and contemporary open systems and biological-ecological views.[26] The **biological perspective** is a current and very popular approach to understanding the future.

As Francis Fukuyama points out, since the time of Darwin many scientists and social thinkers have tried to model human society on biological ideas.[27] These efforts have been criticized as being inappropriate, biased, self-serving, and simplistic. Critics question whether human society is really like a living organism or ecosystem. Yet as I have noted, science continually provides metaphors and models that people use in creating and describing human society. The model of human society created in the Industrial Era is a perfect example of taking scientific ideas and applying them to human affairs. Newton's mechanistic and clocklike model of machines was applied to society, industry, and business. What Kelly, Henderson, and others are advocating is that a much more valid and richer set of scientific ideas for modeling society can be found in contemporary thinking on open systems, biology, and biotechnology.

As Newtonians and dualists, we did not see ourselves in a partnership relationship with nature. We saw ourselves standing above nature, pulling the strings. But the human need for control, carried to the extreme, is unhealthy and counterproductive. Risk taking is necessary for psychological growth, and a strong need for control and certainty is reflective of psychological insecurity. And isn't it a form of supreme arrogance to think that we can unilaterally determine the future of the earth? In any healthy social relationship there needs to be a partnership rather than a dictatorship, and throughout history unequal distributions of power and wealth appear to inevitably backfire.[28]

The idea of a creative partnership in social and ecological evolution, a concept distinctly different from 19th Century social Darwinism, which emphasized competition and survival of the fittest, is philosophically and psychologically quite appealing to many futurists. The philosophy of partnership is clearly founded upon the idea of reciprocity. Open systems theory points out that everything in nature is in a dynamic interdependent relationship with other things in nature.[29] Goerner, to recall, describes the entire universe as ecological, underscoring the theme of interactive interdependency. Both Kelly, in his emphasis on networks, distributed power, and interactivity, and Henderson and Sahtouris, in their similar advocacy for open systems thinking, assume a logic of reciprocity as opposed to dualism in describing the nature of biological systems. All apply this way of thinking to the evolution of human society. For Henderson, Sahtouris, and Kelly, it is time that humanity sees that the future needs to be approached as a **co-creative** partnership with the other living systems of the earth. In a partnership we acknowledge that we cannot control or predict everything, and this uncertainty and lack of complete control is a positive feature of the relationship.

Walter Truett Anderson has also written extensively on the significance of biology and biotechnology and its effect upon future human society. His highly regarded *Evolution Isn't What It Used To Be: The Augmented Animal and the Whole Wired World* reinforces many of the ideas contained in Kelly's thinking, such as the blurring distinction between nature and technology. Anderson also adds some important new themes to the discussion of the future of biology and biotechnology.[30] One central idea in Anderson is that he strongly connects the evolution of information technology with biology and biotechnology; many of the advances in our understanding of life have been facilitated by the computing and research capabilities of information technology, and many of the present and future developments within biotechnology will involve the integration of biological systems with information technological systems. Recall in the previous chapter the various predictions regarding the augmentation of neural and biological systems with information technology, e.g., brain implants. Also note that Anderson's perspective reinforces Kaku's thesis that biotechnology and information technology are reciprocally supporting advances.[31] Anderson, based on the strong relationship he identifies between information technology and biotechnology and their mutual impact on human society, refers to our emerging new era as the **Bio-Information Age**. Like Kelly and other futurists who emphasize the growing importance of biological and bio-technical themes, he thinks that our whole social order will need to be re-structured as a consequence of what is happening in these fields.

Another central theme in Anderson, which also resonates with Kelly and open systems thinking, is the **interconnectivity** of all life. But where I have thus far described this idea of interconnectivity as applying to the natural interdependency of all life, Anderson wants to highlight how advances in biotechnology will, in fact, further intertwine the web of life on the earth. Fundamentally, biotechnology in the future will increasingly involve the exchange and interweaving of biological material from different species into one other. We already implant organs and genetic material from one species into another, but these trends, according to Anderson, will accelerate and advance in the coming decades. John Naisbitt has also emphasized this growing trend, referring to the technology as "**transgenic technology**". As Naisbitt notes, all of life has a common foundation within the DNA molecular system, which provides the genetic code for all living creatures on the earth.[32] For Naisbitt, this universal genetic code for all life on earth suggests that ultimately all life is one. Exchanging and combining pieces of DNA is an ongoing normal process within bacteria, and, in fact, is the essence of sexual reproduction within species.[33] Lynn Margulis has argued that the combining of DNA sequences from different species, in particular in the evolution of more complex organisms from simpler organisms, has been a highly important factor in the evolution of life on earth.[34] What Anderson wishes to emphasize is that with advances in our understanding of genetics and biotechnology, we will be able to orchestrate this inter-exchanging of DNA and other biological materials far more extensively in the future. According to Anderson, no other life form on earth uses other life forms to the extent that humans do, but, in what amounts to an evolutionary leap, we will be able to systematically and technologically mix together the living components of species to create entirely new forms of life. We will create organ and animal farms to provide a whole host of parts and ingredients for humans who require new or rejuvenated bio-substances and systems within their bodies. All told, even as we distance ourselves further from nature with our technology and civilization, we are becoming, paradoxically, through the development of biotechnological relations, more entangled with all of life.[35]

The theme of interconnectivity, as I noted above, is a central idea in open systems and biological thinking. As I discuss in more depth in the next chapter, it is also the foundation of ecological theory. Kelly's emphasis on network organizations in nature, the partnership and co-participatory ideas in Kelly, Henderson, and Sahtouris, and the relationship of all these ideas to the principle of reciprocity, also highlights the importance of interconnectivity in life and nature as a whole. Kelly makes a strong argument that networks better capture the organization of life than hierarchies, yet Anderson, in his discussion of how humans are directing the further evolution of the web of life, brings into question whether the distribution of power among interdependent living systems is equal. In point of fact, if we look at the organization of different living systems, we find relative centralizations of control and guidance within their make-up. Though a living cell, for example, is a complex net of processes and structures that mutually influence each other, the nucleus provides a convergence and divergence point that appears to coordinate the workings of the entire cell. At the level of a multi-cellular animal, the nervous system has evolved as a coordinating structure within the body. Such **coordinating structures** are clearly not transcendent or isolated systems that issue commands, impervious to the activities and effects of other components within the biological system, but they do serve the function of organizing the total operations of the system. As numerous scientists, such as Murray Gell-Mann, have pointed out, nature appears to be organized as a set of nested or embedded hierarchies, building from sub-atomic to atomic to molecular to supra-molecular systems.[36] Further, this hierarchical progression of systems within systems brings with it **central-surround configurations**, where at any given level of complexity and organization, there will be an integrative component surrounded by a peripheral component. Again, the coordinating center is quite interactive with the surrounding area, thus demonstrating a high level of reciprocal interdependency, but the reciprocity, to use an expression coined by the philosopher, scientist, and practicing psychiatrist, Hector Sabelli, is an "**asymmetrical reciprocity**".[37]

Referring back to my discussion of Smolin and his critique of "unexplained explainers", where some principle or entity stands independent of any effects upon it by any other factor in nature, and the Newtonian-Industrial concept of absolute top-down determinism,[38] Kelly seems quite correct in arguing that all of life has a network configuration where there is interactivity among its members, but there are still dimensions of both hierarchical order and centralization within the organization of the universe. Nature appears to be a synthesis of both networks and hierarchies, of centralization and distribution of functions. Even something like the Internet, a technological system, appears to be evolving both central convergent points that integrate huge amounts of data and lines of communication and connection, and network properties where all the components of the system are interwoven into a vast web of mutual interconnections. This same type of organization is apparent in the nervous system where ganglia, as localized integrations of neural lines, provide a multi-level coordination of activity in the nervous system all the way up to the brain, which in essence is just a master ganglia enveloping many smaller ganglia.

Given this more balanced understanding of natural order, if we look at the significance of humanity and human technology, in the overall organization of life on the earth, there is clearly a growing interconnectivity arising between humans and the rest of life, where we depend more and more upon the elements of life to support our civilization. Biotechnology brings in new capacities for the development of further relationships with life. As Anderson states, we are becoming more entangled. Yet this growing interdependency is being instigated and coordinated by humans. As the Internet is perhaps an emerging nervous system for the earth, linking together the myriad activities across the globe, it is providing a coordinating function under the guidance and direction of humans. Paradoxically, whatever level of control (e.g., guidance, coordination, or direction) we achieve within the world, we achieve it not standing outside of or above the vast system of nature, but by becoming more interconnected and entangled into its workings.

There are different philosophical views of our relationship with nature and life, from Elizabet Sahtouris, who wishes to emphasize how we should look to nature for guidance and direction, to the other extreme of Michael Zey, who believes that humans should take the leadership role of determining the future evolution of life on earth.[39] This difference could be described as the clash of partnership (or even submission) versus dominance models of humanity and nature. Yet, what the sudden accelerative growth of biotechnology is teaching us is that it is our rapidly increasing knowledge of life, from which we gain much guidance and understanding that is fueling the technological capacities to direct the manipulation and evolution of life. In particular, contemporary scientific advances in genetics, ecology, evolution, and molecular biology are having a powerfully stimulating effect on the growth of biotechnology. As Daniel Bell has noted, in the Information Age, technology is increasingly guided by scientific principles and understanding.[40] Expanding on this point, for Anderson, it is the vastly enhanced capacities to collect, distribute, and integrate scientific and technological knowledge and data, facilitated by information and communication technologies, that is allowing for the rapid growth of biotechnology.[41] As the central convergent point for incoming information on the nature of life and the central coordinating divergent point to influence the flow of events within the biosphere, humans are both master students and teachers in the ongoing evolution of life on earth.

As the development of both industrial technology, and later information technology have supported the emergence of biotechnology, biotechnology in the future will increasingly turn the tables around, infusing its creations into the world of industry and technology. Technologically modified biological materials and forms will permeate out into human society. This critical development is another central theme in Anderson's thinking, and another significant dimension of the emerging Neo-Biological Age. Anderson discusses the rapidly growing bio-information industries, which synthesize biology and information science, into new products for research and commercial purchase. Also, he highlights the theme of the "**greening of industry**", where biotechnological substances and devices are used instead of mechanical and chemical components. Anderson foresees the growing production of biomaterials, bio-energy sources, bio-mechanisms, and bio-computers working there way into all aspects of our technology. Our environment will be cleaned and rejuvenated through bio-remediation. Just as physics and chemistry provided the knowledge to manipulate physical matter and energy in earlier centuries to support the creation of modern industry and manufacturing, biology is going to provide the necessary knowledge to utilize life in the further evolution of technology. To recall from the previous discussion of Kelly, living forms are much more complex, inventive, and versatile than those materials used in the construction of Industrial Age machines, and assuming we can constructively utilize such living forms and materials, our whole technological infrastructure could jump to a whole new level of sophistication and power. Further, Anderson, and Naisbitt also see genetically engineered biotechnologies and physically engineered technologies integrating and even merging during this century, producing various amalgams of the living and the non-living in our machinery and industries.[42] This mixing of living and non-living technologies is but a further example of the blurring of the distinction between the natural and the artificial, or the "born" and the "made".[43]

The use of animals and other living forms in biotechnology raises again the continuing issue of the exploitation of animals. Anderson, given the fact that he sees biotechnology as a powerful and promising force in the future, considers whether there will be further and more pervasive exploitation in the decades ahead, or whether humans will develop sufficient knowledge of biochemistry and theoretical biology to simply construct from the ground up whatever type of biological materials and structures are needed without having to use animals as hosts or suppliers for biotechnological creations. The distinction though between these two approaches is fuzzy at best, since we are experimenting with and manipulating living systems in both situations.

Because we are altering biological systems and material in biotechnology, we run the continued risk, to return to Kelly's main point, of causing surprising if not uncontrollable effects. Futurists such as Kaku express the worry of introducing new plants or species that will uncontrollably spread and disrupt the earth's ecosystems.[44] Bill Joy has stated similar and even more unsettling concerns, for new biological forms could spell the end of humanity.[45] Cornish discusses the related issue of accidentally instigating the evolution of new types of life forms and the emergence of "super-bugs" which are resistant to our antibiotics and other medical interventions.[46] The possibilities of "unintended consequences" multiply significantly once we enter into the arena of the technological manipulation of life.

The history of worries, nightmares, and terrifying visions associated with the scientific and technological manipulation of life runs back to Mary Shelly's *Frankenstein* and H.G. Wells' *The Island of Dr. Moreau*. The theme of biotechnology gone wild is one of the classic fears we harbor concerning the dangers of future technologies, and it is a topic that numerous science fiction writers since Shelly and Wells have addressed. One contemporary treatment of the theme is Greg Bear's well-known novel *Blood Music*.[47]

Although in the past humans have manipulated and influenced life toward various ends, the methods employed, for example, selective breeding and agriculture, worked relatively slowly and without a great deal of freedom in possible directions. But what if living forms could be more powerfully and swiftly altered? What kinds of biological systems might we create and what could be the catastrophic consequences of such new forms of life? Further, what types of bacteria or virus might political or social adversaries try to unleash upon each other and how might these efforts backfire? The popular movies *Outbreak* and *Twelve Monkeys* considered such possibilities.

Eric Rodenbeck, in his speculative futuristic scenario "Savior of the Plague Years", considers the possible consequences of losing control of our biotechnological creations.[48] Rodenbeck envisions a hypothetical scenario in which a worldwide plague wipes out the majority of the world's human population. Rumor has it that this plague may have been caused by genetic engineering research that got "out of control". Human society is fast disintegrating and the human species is threatened with eventual extinction. The story line follows a group of scientists who are working on a cure for the plague and as the story unfolds they do find a cure. What is interesting is that it is genetic engineering and the computer-communication network that eventually come up with a solution. The human immune system is genetically modified via the collaborative efforts of biological scientists and computer and virtual reality experts working across the electronic network. Hence, the same system, the Bio-Information system that creates the problem, solves it. In fact, it is only the scientific and technological community that can solve it. Advances being made in biotechnology run the risk of creating significant problems, but it will only be this type of technology and its knowledge base that can solve the potential problems it creates. The moral of the story is that biotechnology is a double-edged sword, a Yin-Yang generating new order and new chaos, new problems and new solutions.

Lest we fool ourselves, we need to keep in mind that the genie is already out of the bottle. There are numerous arguments being made regarding why we should not get into biotechnology.[49] Yet, we are already deep into biotechnology as Anderson so strongly documents, and to recall, we have since the time of the agricultural revolution, been significantly influencing the direction of life. Again, can we try to stop the advance of any technology? Can we try to stop human efforts to better understand, manipulate, and influence nature? Should we stop agriculture and selective breeding? Should we stop medicine? These questions, as posed, sound ridiculous and nonsensical. It is better to try to understand what we are doing than to try to deny it or repress it. Further, what are the potential benefits to this line of research? Human actions invariably have both possible negative and positive consequences. It is no different with biotechnological efforts. As we will see below, the possible benefits associated with biotechnology are enormous.

As Kaku notes, **genetic biotechnology**, along with computer and quantum technology, is one of the three main thrusts of technological development in our contemporary times. Wherever there is technological and industrial development, there will also be significant commercialization. Another main feature of the Neo-Biological Age is that biotechnology will become a huge element of the overall economy, as information technology has over the last few decades. Biotechnology is attracting increasing amounts of investment, becoming a 13 billion dollar a year industry,[50] and there is both corporate and national competition around the world to see who will stay ahead in the game. The economic bet is on that genetic biotechnology is quickly going to emerge as a powerful force in our society.[51] Not only will forms of life be sold or rented for industrial, commercial, or environmental use but genetic treatments and biotechnological implantations will become a lucrative area of medicine and health care. Life is going to be increasingly commercialized and this raises ethical and social issues. As Henderson notes, there is a battle today over the idea that life and life patterns can be copyrighted and owned, or patented and privatized.[52] Jeremy Rifkin has fought various battles over this issue and lost to those who want to commercialize life.[53] Yet should any individual or business own a particular form of life? Is a DNA sequence the same as a computer software program?

Thus we come to the major feature of the emerging Neo-Biological Age, which brings with it both wonder and potential benefit, as well as possible mayhem if not disaster. Biotechnology is based upon the simple idea that living forms can be manipulated and influenced through scientific understanding and technological know-how, hopefully toward desirable ends. The present biological and ecological make-up of our planet is a consequence of evolution, and in entering into the arena of modifying life, we are entering into the arena of directing evolution. I have referred to this process as "**purposive evolution**" for it involves the introduction of conscious purpose into the evolutionary process. Purposive evolution though covers the controversial field of **eugenics**, the intentional effort to selectively direct the creation and evolution of humans. Aside from whatever natural disruptive consequences may occur as a result of biotechnology, efforts to modify and control the biological make-up of humans are also going to instigate social turmoil and dispute in the future. But again, the genie is already out of the bottle, and as Anderson argues, we might as well understand and get used to the fact that eugenics and the purposive evolution of humans are coming.[54] In subsequent sections of this chapter and the next, I discuss the controversies surrounding the purposive manipulation of life, including human life. As we will see these issues often involve a strong disagreement concerning the whole idea of evolution as a framework for understanding the nature of life.

Biotechnology, Genetics, and the Purposive Evolution of Life

"I think something's happening now…which is incomprehensible to us, and I find that both frightening and exciting."

W. Daniel Hillis

Biotechnology includes a variety of different technologies, aside from the instrumental use of bio-systems and materials in industry, environment management, and physical technologies.[55] Biotechnology also includes various approaches to altering, enhancing, or even creating life. One extremely important area of biotechnology is **genetic engineering**, the application of the science of genetics to modification and improvement of life. It is one of the most controversial areas because it is through genetics that the promise of purposive evolution will be realized.

Genetics is the study of the inherited molecular code within life, passed on through successive generations, that significantly determines the biological structure and functions of each particular form of life. As James Watson and Francis Crick discovered in the 1950's, the molecular code for all life on earth is embodied within the same complex molecule, **DNA**.[56] Differences among species are due to variations within the DNA code. The code is contained in the particular sequencing of four nucleic acids, abbreviated as A, C, T, and H. DNA molecules are structured like a double-helix, a twisting double string of nucleic acids. Each nucleic acid in one line of the double string is connected to another of the nucleic acids in the second string, with each pair of nucleic acids referred to as a "base pair". There are different numbers of base pairs for different species, roughly depending upon the complexity of the life form. Yeast has 12 million base pairs, a fruit fly has 180 million, and a human (as well as a mouse) has 3 billion. Sequences of base pairs form into "**genes**" which determine the production of different proteins in the body. The entire genetic code of a species is referred to as the "**genome**" for a species. It has been estimated that the human genome has fifty to a hundred thousand genes; again, other species, depending on their genotypic complexity, have different numbers of genes.[57]

Although genetic structure stays relatively constant across generations, insuring for a high level of stability within a species, there is a degree of variation across generations, as well as among siblings of the same generation. For example, the genetic structure between a human parent and the parent's child is approximately 99.95 % the same; two human siblings produced from the same parents also show about 99.95% genetic overlap, whereas any two humans average around 99.9% overlap.[58] To provide points of comparison for these degrees of genetic overlap, chimpanzees show 98.4 % genetic overlap with humans, the mouse genome shows 75% overlap, and a worm shows 40%

overlap. Although Darwin did not understand modern genetics, he did believe that life evolved through the natural selection of random mutations within their inherited biological make-up. Whatever the causes of genetic change across generations, and there is significant debate on this question,[59] the particular sequence and make-up of genes within a life form could not be directly altered through human intervention. Humans, of course, have for thousands of years selectively bred certain variations of animals and plants, but there was no direct manipulation, or for that matter knowledge, of the genes. We could even say that humans have selectively bred themselves through their collective selection of preferred mates for reproduction.

Yet in the last fifty years, beginning with the work of Crick and Watson, the genetic code or blueprint for life, as embodied within the complex patterns of DNA molecules, is being unraveled and understood. This genetic knowledge, together with the appropriate technology, is providing humanity with the power to manipulate and alter living forms in a totally different way than past practices and methods. By being able to identify and change gene complexes that connect with different biological traits, structures, and functions, the inherited code within a living form can be altered or radically changed.[60]

Reading the base pair sequencing of human DNA accelerated through the last few decades, eventually becoming a highly charged and controversial race to the finish line. Thousands of base pairs had been identified by the end of the 1970's; in the 1980's, facilitated by the introduction of computers into the process, the number jumped to millions and then tens of millions.[61] Under the direction of Dr. Francis Collins, the National Institutes of Health initiated the **Human Genome Project**,[62] further picking up the pace of DNA mapping. The goal of the Human Genome Project was to identify all the base pairs and genes in human DNA and early projections were that the project would be completed by around 2005.[63] With additional technological advances and the introduction of a strong competitive element from J. Craig Ventor and his company Celera Genomics, which was carrying on its own independent gene-mapping project, the sequencing of the entire human genome was completed well ahead of schedule in 2000.[64]

According to Dyson, the race to map the entire human genome as quickly as possible was more a political decision than a scientific one.[65] For Dyson, it would have made more sense to first map the genomes of various simpler organisms, which promised more immediate and far-reaching benefits. Yet as Kaku states based upon a polling of various researches in the field, we should have something approximating an "**Encyclopedia of Life**" by 2020, where thousands of different species' genomes have been mapped.[66] Kaku also predicts that by 2020 we should be able to produce personalized DNA profiles for each individual human, and even earlier, by 2010, we should have identified the genetic profiles for thousands of hereditary diseases, hence being able to predict in a human fetus genetic predispositions for such diseases.

The genetic system is extremely complex and interactive. Although different sets of genes are connected with different organs and systems in the body, and some genes are specifically associated with certain hereditary disorders,[67] most traits in an organism are probably due to the interaction of multiple genes.[68] Such traits are referred to as "**polygenic**". Also, if any one gene is altered to produce some specific effect in the organism, other traits could be affected as well. There also appear to be "master genes" that influence sets of other genes and affect the overall initiation and direction of embryological growth and basic body plan.[69] As Stuart Kauffman describes it, the genetic system is a highly interactive, self-organizing system. Kaku thinks that the main challenge over the next fifty years will be to understand the interactive complexities of the genetic code and identify the genetic make-up of polygenic traits and diseases.

As Dyson states once the genetic code can be read, it can be written or rewritten.[70] Genetic engineering involves the altering of the genetic code of a living organism. Biotechnology, according to Maddox, works on the fact that each biological function is carried out by a distinctive biological structure and these functions can be done more efficiently and effectively.[71] Zey uses the expression "**biogenesis**" to refer to the biological modification and potential enhancement of humans through technology. But as Zey also notes, the promise of genetic engineering is to improve on the biological structures and consequent functions in numerous other species as well.

Genetic engineering, according to Clifton Anderson, has implications for all aspects of human life, including economics, the environment, medicine, society, demography, and government.[72] In particular, it will affect, for better or worse, all major environmental factors including population levels, pollution, erosion, and biodiversity, providing both dangers and opportunities for the future. Naisbitt states that the effects of genetic engineering will overwhelm all other technologies, including computers and information technology.[73] I have already described the general concern over potential dangers associated with introducing technologically altered species into the environment that could unsettle or even kill present biological forms. Yet, as Zey contends, citing a recent issue of *Time* magazine devoted to the topic,[74] the general public is very much interested in the potential benefits associated with biotechnology and supports the idea of genetic enhancement or improvement.[75]

As Edith Weiner points out in "Our Bio-Futures: Exploring the Frontiers of Human Biology",[76] the first gene was reproduced or "cloned' in the year 1972. Today hundreds are produced daily. Kaku reports that the first crossbreeding of species, producing "transgenic animals and plants" through genetic implants, was only achieved in the last twenty years.[77] Currently, animals and plants have non-species genes implanted in them routinely. Humans first had modified genes placed in their bodies in 1990, and soon it will become much more common for humans to receive genetic implants into their bodies.[78] As Weiner notes, genetic manipulation is a growing practice in agriculture, medicine, and the animal sciences. Different genetic sequences from different species are being combined to create new variations of living forms. Vegetables and fruits are being altered, through genetic implants, to produce healthier, heavier, and more nutritious products.[79]

Biotechnologists distinguish between two basic types of genetic engineering or "gene therapy". A new gene can be introduced into the body of an organism, hopefully producing a beneficial change in the species, similar to what is commonly done in agriculture. This type of genetic intervention is called "**somatic gene therapy**". Although the genetic make-up of the animal or plant may be altered, the alteration does not get passed on to succeeding generations. But as a second approach, a different gene can be implanted into the germ or reproductive cell of the organism. This technique is referred to as "**germline therapy**". In germline therapy, the altered genetic code is passed on to succeeding generations. Although somatic gene therapy is a common practice today, many biotechnologists and futurists predict that germline therapy will become much more prevalent in the near future.[80]

As Dyson notes, although there is significant contemporary controversy surrounding cloning, which basically involves the duplication of an already existent genetic code or structure, altering genes within the reproductive cells is a much more important achievement and will have much greater repercussions.[81] Anderson argues that the advantage of germline therapy over somatic therapy is that germline therapy produces a permanent positive effect upon the gene pool of a species, rather than just a quick and temporary fix. Beneficial genetic modifications are passed on in germline therapy.[82] According to the George Washington University forecaster group, by 2007-2008, genetic engineering will routinely produce new genetic strains of both existing animals and plants.[83] Further, germline therapy will move into the human arena by 2010-2020, and we will begin to attempt to improve the human genome. They foresee genetically engineered human children being produced by 2020. Pearson predicts the genetically engineered creation of new life forms by 2020,[84] though Kaku is a bit more cautious, based on consideration of unraveling the polygenic dimension of genetic codes, projecting that we won't be able to design new organisms till 2050-2100.[85]

One great promise of germline therapy is the eventual eradication of **genetic diseases**.[86] Kaku estimates that 75% of all deaths in the United States have a strong genetic component. He foresees that by 2010 we will have a total listing of all genetic diseases, with a genetic cure identified for many of them. He thinks though that understanding and being able to cure polygenic diseases will take quite a while still, extending from 2020 to 2050 to complete the process.[87] Halal, on the other hand, is a bit more optimistic, predicting that gene therapy will cure most inherited diseases by 2025.[88]

Another significant promise of genetic engineering is the creation and growth of bodily organs and biological tissue. According to Weiner, in the near future there will be organ regeneration through the identification of the appropriate genes that create our stomach, kidneys, liver, and eyes.[89] As Zey points out, fetal or stem cells theoretically can be grown into any tissue or organ in the body.[90] Halal predicts genetically produced organ replacements by around 2020.[91] We will be able to replace diseased or defective organs within us by growing replacements off of our own tissue or within organ farms or banks.

As noted above, genetic engineering has been applied to agriculture and the creation of improved food products. Robert Shapiro, in fact, argues that the genetic engineering of food will save the world.[92] According to Shapiro, given the ever-increasing human population on the earth, our present agricultural methods, aside from being non-sustainable in the long run, will not be able to feed humanity. We need crops that produce a greater nutritional yield, without destroying more land in the service of agriculture. Germline engineering could produce such crops. Further, Shapiro states that biotechnological methods to protect and preserve growing crops are much more efficient and safer than chemical pesticides and fertilizers. Kaku points out that genes, which produce various hormones and enzymes in one life form, e.g., bacteria, can be moved and implanted into other life forms, specifically plant crops, and thus produce more nutritious foods.[93] Anderson, Naisbitt, and many other futurists also support the value of genetic engineering in agriculture.[94]

Yet, as Halal notes, there is significant resistance in the general public to genetically modified food.[95] Naisbitt also reviews this contemporary controversy, noting that resistance is strong in Europe as well as the United States. He foresees a split developing in the customer populations between those who purchase and use organic foods versus those who purchase genetically altered foods.[96] Halal though believes that in spite of the opposition to genetically engineered food products, the trend toward more genetically altered foods will grow in the future.

Cloning is another area of controversy within genetic engineering. As Naisbitt notes, no other issue in biotechnology generates so much emotion.[97] Ian Wilmut's cloning of the sheep Dolly generated a world wide negative reaction.[98] As a consequence, cloning has been banned in many countries as "ethically unacceptable". Yet there are a variety of good reasons to pursue cloning research and the arguments against it seem exaggerated. As mentioned above, Dyson points out that germline therapy is actually the more significant and dramatic form of genetic engineering. Basically, cloning is the copying, rather than modification of genes, leading to the replication of cells, organs, tissues, and entire duplicate organisms. Cloned cells or organisms have the same DNA as the mother cells or organisms.[99]

What are some of the concerns and criticisms regarding cloning? One worry is that unscrupulous and powerful people might clone huge numbers of undesirable or dangerous individuals, perhaps even multiple individual self-copies, forming "armies" of like-minded soulless automata. Alternatively, one person could unfairly continue his or her life indefinitely through a series of clones off of clones. Such a person though would not possess memories of his or her previous lives unless the memories were input into the newly cloned brain from some external storage device like a computer.[100] Another argument against cloning is that it could lead to certain types of individuals becoming excessively represented in the total human gene pool, robbing the gene pool of sufficient diversity. Cloning as a means of reproduction would do away with sex.[101] Cloning is "playing God".[102] Additionally, cloning could be seen as antithetical to our sense of individuality. Shouldn't there be only one of each of us? Copies of ourselves seem to rob us of our unique individuality.[103]

Further, cloning has been connected with the classic nightmarish fears of our biotechnological creations turning on us. The visual effects and provocative ideas within the movie *Jurassic Park* and its two sequels entertained many of us. Through cloning and advanced biotechnological techniques dinosaurs were recreated in the 20th Century. There is a contemporary ongoing debate whether such a feat is technically feasible, yet the possibility cannot be discounted. Efforts in fact are underway to clone the extinct wooly mammoth from frozen and relatively preserved.[104] The message though in *Jurassic Park* was that bringing dinosaurs back from the dead was vainglorious and dangerous. The movie, in fact, is an excellent example of the negative possibilities of a biotechnological creation gone “out of control”, where the creations turn out to have a mind and purpose of their own. The moral: Don’t clone velociraptors.

Yet there are many arguments in favor of the value of cloning. Christian Crews argues that cloning would not significantly reduce the gene pool. How many people would want genetic copies of themselves? Also, worries to the contrary, most people would not give up sex, even if cloning were available as a way to reproduce.[105] For both the rich and the poor, there is a high demand and desire to have children, and if cloning were to be available, many people would take advantage of it.[106] Again, the concern with producing multiple copies of the same person misses the basic point that a clone would only be genetically identical to the parent. A person’s unique personality is significantly a consequence of his or her memories and experiences in life, which a clone does not share with the parent. Identical twins, though having the same genetic make-up and sharing many personality qualities, are still two different people.

I have already mentioned above that new organs could be biotechnologically produced in the future. The mechanism involved in this process would be cloning. Dyson discusses a variety of medical benefits associated with cloning, including organ replacements, but also the creation of tissues, cells, and proteins to replace diseased or deficient components of a person’s body.[107] Naisbitt also includes the production of prize livestock and the preservation of rare or endangered species as benefits of cloning.[108] From a scientific point of view, Wilmut’s work demonstrated that differentiated cells, which he used as the starting point for growing Dolly, could be reverted back to an undifferentiated state, similar to the state of a newly fertilized egg cell, and from there grown into a whole, complete living organism.[109] This discovery and biotechnological achievement is significant.

As Zey speculates, in spite of the social and political pressures against cloning, a human might already have been cloned somewhere in the world.[110] The unwarranted exaggerated stigma surrounding cloning is, in fact, pushing the activity into an undercover, black market operation. It is much better, for a number of reasons, to pursue this line of research openly where it can be scientifically assessed and monitored for quality. As with genetically altered food, the benefits associated with cloning will hopefully win over people’s minds in the longer run.

Cloning produces duplicates of already existing species; germline genetic engineering promises to produce new species in the future.[111] What might be some possible consequences of introducing new life forms on the earth? Two general possibilities have already been identified. New life forms could threaten the survival of existing species, including humans, or new life forms could have great benefits, associated with industry, environmental management, food production, and medicine.

Another possibility is that newly created life forms might simply replace presently existing ones. Natural history seems to reveal that approximately every 26 million years life on earth goes through a **mass extinction**. During these extinctions a significantly large percentage of the living species die out (in some cases over fifty percent).[112] The last mass extinction occurred thirteen million years ago. The mass extinction involving the dinosaurs occurred 65 million years ago. Yet presently, according to Gregory Stock and many naturalists, we are in the midst of another mass extinction.[113] Living species are disappearing on the earth at a rate equal to the rates of other mass extinctions. But why should a new mass extinction be occurring thirteen million years ahead of schedule? According to many naturalists, the powerful presence of humanity worldwide is causing the high rate of extinction. Yet even though the bio-diversity on the earth is presently dropping at a fast pace, Stock suggests that we will soon begin to replace the variety of vanished species with new genetically created living forms. In the coming centuries, according to Stock, we are going to repopulate the earth with an even vaster array of new species than existed before the beginning of the present mass extinction.[114]

Extrapolating on Stock's idea, such new species will probably come in all sizes, varieties, and capacities, exceeding our present imagination regarding the types of conceivable life on earth. They will probably go beyond the present main phyla and kingdoms of life. There will be populations of microscopic life that, together with nanotechnological and robotic devices, will support the basic ecological and environmental conditions on the earth, e.g., controlling the chemistry and atmospheric conditions of the earth. But there will also be many new macro-level forms interacting with humans in a variety of ways. We could create various intelligent, sociable, or aesthetically beautiful animals and plants. What could we design or evolve as new companions, pets, or equals? When we imagine the future, we usually think of our physical technology as being altered and advanced. Can we imagine a drastically altered population and ecosystem of living forms?

Following from Kelly's ideas on organization and control in biological systems, it is doubtful whether we could completely control, toward our own ends, a multitude of new living forms. The introduction of new species will produce various interactive effects between new forms, old forms, and humans, as well as many unintended consequences and surprises, good and bad. Also new life forms will show levels of autonomy and inventiveness. A new ecosystem of living forms would need to be evolved through a series of gradual genetic steps along many lines of development. The new evolutionary thrust must be approached with a respect for the new forms of life and ecological intelligence regarding all the potential interaction effects.

Following from a partnership model of life, should we treat these new species as simply instruments for our own ends, or rather, should we treat them as co-equals in the ongoing evolution of life on earth? Of course, we probably would not accord partnership status to many of the more microscopic or primitive species. Yet, for many of the more advanced species that are created, how do we treat them? How will they want to be treated? The concept of working in a partnership with new species contradicts the idea of ownership and the patenting of new forms of life. Do we own a newly created living form even if we created it? Will the life form want be owned? Doesn't the new species have rights? The well-known movie series *Planet of the Apes* explored the theme of creating a new life form to serve us, and how the servants eventually turned on their human masters, wanting their own rights and self-determination, and eventually achieving the beginnings of a partnership relationship with humanity.

This idea of new living forms, working together with us toward cooperative, as well as inventive and creative ends, sounds so strange and alien to the modern mind that it is hard to imagine what it would be like or how it would work. What would become of humans in such a new ecology? Would we maintain our supposed elevated position in the ecology of life?

Although our ecology will change in the future, so will we. It is almost certain that genetic engineering will also be applied to humans. Various predictions were identified earlier regarding the introduction of genetic engineering into humans, including germline therapy that would permanently alter the genetic lines in human generations. The idea of trying to improve the biological make-up of humans is referred to as "eugenics", and generally is first associated with the efforts and writings of Sir Francis Galton on creating a "perfect human".[115] Futurists such as Walter Anderson, John Naisbitt, and Michael Zey all believe that eugenics, accomplished through genetic engineering, is inevitable and desirable. Zey argues that we need to create an enhanced version of humans and through this effort we are gaining control of our destiny. Naisbitt and Anderson both note the controversies through history associated with the eugenics movement, but as both Naisbitt and Zey argue, a significant portion of the general public is actually supportive of genetic efforts to improve humankind.[116] Naisbitt also points out that eugenics and genetic engineering will be motivated by the pervasive Platonic-Christian notion of striving toward ideals of beauty and human improvement. Further, according to Naisbitt, basic human competition will propel the acceptance and use of genetic engineering. There will be competition among parents who don't want to handicap their children.

As noted earlier, different genes are being identified that correlate with various disabilities, diseases, and health problems.[117] With the promise that in the next generation human genetic codes can be altered to correct such problems, presumably we would support such efforts. Would we not approve genetic efforts to eradicate hereditary diseases? A central issue though in debates on genetic engineering is at what point do we cross the line between eliminating a problem and introducing a design improvement? Further, at what point does an enhancement cross the line into simple cosmetics? Many people support the use of genetic engineering to correct diseases and disabilities, but oppose the use of genetic engineering for simple cosmetic reasons. Yet as Naisbitt argues, and I would agree, there is no clear dividing line between cures and enhancements and cosmetics.[118] Naisbitt discusses as one example the issue of obesity. Being overweight is strongly connected with various health problems, but there are also cultural values, at least in many countries, associated with being slim and trim. If we could identify a gene complex connected with the predisposition to being obese, would we approve genetic engineering to change these genes in our children? Is this cosmetic or health related, or both? Bringing in other human qualities, would we want our children to be highly intelligent, strong and physically healthy, beautiful, and good-tempered? Would we want our children to live longer? Would we choose to enhance these qualities in our children through genetic engineering? Are we correcting problems, making design improvements, or simply trying to make the package more appealing by selecting for each of these traits?

Enhancement versus problem correction is also relative because what may not be seen as a problem today could easily become a problem or disability tomorrow. As Naisbitt states, our definition of handicaps will change. If people begin to use genetic engineering in reproduction, than various qualities such as intelligence, sociability, creativity, or beauty may be significantly enhanced within the overall general population, and what we would now call "normal" or "acceptable" would in the future be seen as below average or unacceptable. Recall Kurzweil's argument that within a hundred years humans who are not technologically augmented will be incapable of functioning in human society. The same could be true for genetic enhancements. The introduction of both technological and genetic improvements into the human population will stimulate individuals to make additional improvements to keep pace. Since what is normal will change, what is a disability will change as well.

Additionally, although many people verbally oppose genetic engineering for simply cosmetic reasons, I would agree with Naisbitt that once genetic engineering is available and affordable, there would be a big business for cosmetic applications. The cosmetics industry is big business now, and biotechnology is already making significant inroads in this area, e.g., breast implants, various facial and body rejuvenations, etc. People will attempt to "improve" their appearance and abilities when the opportunity presents itself, and frankly, why shouldn't they? Individual values and choices will vary, I would presume significantly, but the general fact remains that genetic engineering of humans will be available in the next few decades, and for many different reasons, including aesthetic ones, people will take advantage of it.

Ethical and emotional issues come to the forefront in considering the biotechnological manipulation of humans. As one basic concern, it is frequently argued that we should not attempt to tamper with nature. Nature should be respected. It is simply "unnatural' to try to change or improve our biological make-up. Yet don't we already do this? As Anderson states we have always practiced eugenics, in one form or another.[119] We continuously attempt to influence the characteristics of the offspring we produce through the selection of mates, lifestyle choices while pregnant, and how we raise and educate our children. Genetic biotechnology is, though, a much more powerful form of biological influence and manipulation.

The argument that genetic engineering goes against nature is connected with the simple fear or apprehension that tampering with nature will produce a variety of unintended and disruptive consequences. Nature can be seen as a harmonious whole, balanced and perfected in its workings, and consequently our efforts to change it will unsettle this harmony. This model of nature though is invalid, since nature is not some type of idealized Newtonian machine. Nature is to a degree unsettled and filled with chaos and the unintended consequences of numerous species having multiple effects upon it. Although following Kelly, efforts to influence life will produce effects that will not be either anticipated or totally within our control, we are not disrupting a perfectly coordinated system when we engage in biotechnology. As Kaku points out, critics of biotechnology that bring up the issue of unintended consequences, miss all the potential positive benefits that the technology could have.[120]

Aside from arguing that genetic engineering goes against nature, another criticism is that we are playing God or going against the design of God by entering into genetic engineering.[121] Central to many negative images of the effects of biotechnology is the connection drawn between human hubris, vanity, and megalomania and the disasters that ensue as a consequence of trying to create or control life. The message is that we should not aspire to Godlike status, and if we do, we may be punished (by God?) for our inflated self-image and excessive need for power and control. Yet, Naisbitt in surveying a number of theologians found that many think we were expressing the "image of God" through our capacity for creation in genetic engineering. Modifying the human biological form is not attempting to destroy the human embodied image of God, but is an expression of the image of God as creator. Naisbitt contends that the worry over "playing God" in genetic engineering is more a media obsession than a concern of either the general public or theologians.

Still, Naisbitt does believe that science and religion should come together on issues of biotechnology, religion providing some guidance and sense of values in genetic engineering. As noted earlier on several occasions, there is an ongoing concern that technology should be guided more by ethics and higher humanistic values, rather than simply commercial or egocentric needs. Naisbitt also raises the issue that genetic engineering may be too focused on physical health and improvement instead of psychological health and improvement. Further, citing the views of various religious leaders, he asks whether it is necessarily a good thing to eliminate suffering, mortality, and aging, all of which are promised benefits from genetic engineering. Perhaps dealing with our infirmities, limitations, and problems is an important part of life, instilling in us higher character traits such as courage, patience, and faith.[122] Even granting some truth to this claim, this argument could be interpreted as a rationalization for pain, and one promise, among many others associated with biotechnology, is the elimination or significant reduction of pain, physical and psychological. David Pearce of the *Hedonistic Imperative Web* argues that suffering and pain can be eliminated through technology and the consequences will be positive, rather than negative.[123]

Another criticism of genetic engineering is that it promises much more than it can deliver. In particular, genetic engineering assumes an extreme form of biological and genetic determinism and reductionism, which simply is not true. Although we may find various gene complexes connected with different traits or dispositions, for almost all human traits there are environmental and volitional determinants as well. Genes do not determine; they only predispose people in different directions. The environment, learning, experiences, and human choices in life (the element of free will) all affect how we develop in life, both physically and psychologically. Consequently, looking for ways to solve the problems and challenges in life through genetic engineering is a way to avoid our own responsibility in creating our reality – we are not simply victims of our genes. [124]

Weiner also raises a variety of social and ethical issues concerning human genetic technology.[125] Future human society may put increasing pressure on people to conform through genetic engineering to ideas of what is healthy and normal. Systems of crime and justice could adopt a genetic engineering approach based on the idea that criminal tendencies may be genetically based. We may divide into "the haves and the have nots", since people will need money to benefit from biotechnology and genetic engineering.

There is in fact a general concern among many people that genetic engineering will create a genetic underclass due to a disparity in access to its potential benefits.[126] Based on present predictions, within the next decade or two, we will be able to create personalized DNA profiles, and this could lead to genetic discrimination. People could be "DNA'd" and rejected by possible mates because their genetic code does not meet certain standards.[127] Individuals without certain "genetic improvements" could be denied access to employment. The science fiction movie *Gattaca* explored this possibility. Further will our genetically enhanced offspring find us inferior? What will happen to genetically unmodified humans if various types of "super-humans" begin to populate the earth? Will such super-humans spell the end of present day humanity?[128] In response to these fears, Dyson thinks that genetic engineering will be progressively cheaper, and will actually become a public service.[129] Just as basic health care should be available to everyone, various genetic treatments will become available to all, including the lower economic class. Genetic enhancements will spread through the general population.

I see two general possibilities, which could be combined to different degrees, regarding the genetic future of humans. One possibility is that some single improved version will emerge and replace us as we replaced our hominid ancestors thousands of years ago. Weiner's comment about conformist pressures in human society would tend to push the population in a single preferred direction. Some degree of pressure to uniformity along certain standards of quality will probably occur. The second possibility is that a multiplicity of new forms of humans could develop, creating a much more diversified panorama of human types.[130] Our present species may or may not continue in this future population of humans. Perhaps humanity will radiate and diversify out, appropriately modifying in form to suit the varying conditions in the worlds of outer space. And perhaps the same will be done on earth to fit different lifestyles, philosophies, and professions. How might we design humans to better integrate with information technology? For living and working in aquatic settings? For sports and athletics? It is certainly a mistake to think that there is one type of "superior" or "perfect" human. Diversification and distribution of power, talents, and traits make sense for humanity, as they make sense for the total population of living forms on earth. Although there is a worry that through the power of genetic engineering we will all become the same, I think that it is much more probable that we will become more diversified and different.

Yet Dyson, who foresees a significant diversification of humans occurring through genetic engineering, does not think that the multitude of human species will be able to get along with each other, thus forcing the migration of different human species into outer space.[131] Clearly acknowledging the incredible impact biotechnology will have on our future, Dyson projects that the most important battles of the next thousand years will be over different conceptions of what it means to be human. As Naisbitt notes, genetic engineering is bringing to the forefront the very question of what it means to be human. Further, what do we value in humans?[132] Because we will be able to modify our “human qualities”, what was taken for granted will now become a matter of choice and value.

The transhumanists specifically challenge the assumption that human nature is a constant. They contend that the bulk of futurist projections about the future do not foresee any basic changes in humanity as such, yet according to them, such a view that human nature will remain constant is very questionable. They present what they refer to as the “Technology Postulate” which states that any of a number of developing technologies, including genetic engineering or information technology, could fundamentally change human nature. As I stated previously, they argue that humans need to be “transcended”, hence the name “transhumanism”. The transhumanists clearly support the concept of purposive evolution. They believe that technologies, such as genetic engineering, guided by reason, science, and “life promoting principles and values”, should be used to transform or evolve humanity to higher levels, physically, mentally, and socially.[133]

If we were to witness a transformation in life as a whole, or particularly with humans, through genetic biotechnology, it would be a mistake to suppose that this process would come to some finished product or end. Genetic engineering represents a new level in the process of biological change, inherently different and probably much quicker than natural selection or any other present process now at work. It is a clear example of the evolution of evolution. As we move into space, as we accelerate the evolution of information technology systems, and as we explore numerous other arenas of adventure in the future, biotechnology and genetic engineering will move along with these ongoing developments, supporting new needs and goals as they arise. Following from Kurzweil’s suggested Law of Accelerating Returns, as well as other similar views, that the speed of evolution is accelerating, genetic engineering will actually contribute to an increasing rate of change within the ecology of life and the biological make-up of humans.[134] This increasing rate of change makes it even more important that some type of ethical dialogue and guidance occur throughout the process, and the purposes and goals behind the coming biological changes are thoughtful, informed, and enlightened. If we are to transcend our present nature, we must do so ethically and intellectually as well as biologically.

Cyborgs and the Technological Enhancement of Biology

***"…we are in the midst of a profound evolutionary transition…
We are becoming a different kind of animal from any that has existed before…
we are converging with our technologies."***

Walter Truett Anderson

***"By the end of the twenty-first century,
there won't be a clear difference between humans and robots."***

Ray Kurzweil

"Resistance is futile."

The Borg

Along with bio-industry and genetic engineering, another major area of biotechnology is the development of artificial body parts or **prosthetics**. We are quickly learning how to replace parts of our biological body with technological devices that serve the same functions. In fact, in many cases, following Maddox's general characterization of biotechnology, the replacements are better than the original versions in performing the same function. What may have originally been created to replace a disabled or diseased biological system may become a design improvement.

The quick contemporary advancement in the development of artificial biological tissues and organs is being fueled, according to Forester, by the biomaterials revolution.[135] New plastics, ceramics, glasses, and other materials are being used to repair or replace almost every major part of the system of the body. Of particular recent interest is the development of "artificial blood" and "synthetic skin". Physical science and technology are interfacing with biotechnology and medicine.

External instruments and devices have long been used to correct for disabilities in the sensory and motor systems of the human body, e.g., eyeglasses, hearing aids, and walking canes. Many of our machines and instruments though are like detachable-attachable sensory-motor systems that improve or enhance our bodily capabilities, e.g., the shovel, the telescope and microscope, the forklift, and the typewriter. The computer is, in a sense, an external enhancement on the capabilities of the human brain. But what about a computer chip in your brain that improves memory or creativity? Consider the possibilities of artificial limbs, eyes, or ears. One can imagine telescopic full spectrum eyes, hyper-strong, ultra-fast arms and legs, super-dexterous hands, full frequency tone-tuned ears, and hearts that don't stop beating and kidneys that filter and purify for centuries.

Many of these possibilities and more should be realized within the next fifty years. Kurzweil identifies those artificial body parts we have already developed, including artificial jaws, skulls, hips, skin, heart valves, arterial and venal vessels, arms, legs, feet, and joints.[136] Of particular note, bringing information technology into the picture, we have already developed prototype artificial robotic arms that are tactually sensitive (we can feel through them) and various motor systems that we can move using our brains and electrode neural implants.[137] Pearson predicts artificial and fully functional hearts, ears, blood, limbs, and joints by 2010. By 2030, he foresees artificial lungs, liver, kidneys, and even an artificial penis.[138] Finally, by 2050, we should have artificial eyes, peripheral nerve systems, and brain implants, though I should add that all three of these biotechnological systems are already in various stages of development. Developing an artificial retina using computer chips is one area of particularly active research. Halal in fact is more optimistic on technologically supported vision, predicting functional artificial visual systems by 2014. [139]

As one general prediction, Pearson foresees that 95% of our body material could be replaceable by synthetic material by around 2020. Pearson sees an ever-growing industry associated with artificial body parts, with factories for growing and manufacturing eyes, limbs, organs, tissues, and synthetic materials.[140] And further, once again blurring the lines between corrective, enhancement, and cosmetic technologies, Pohl predicts that "recreational prosthetics", e.g., for sports and athletics, will become a big commercial area in the near future.[141]

Yet such possibilities are just the beginning. We could create artificial lungs to breathe the air of alien worlds, or human gills to allow people to live under water.[142] As one good example, Frederick Pohl, in his science fiction novel *Man Plus*, imagines a technologically modified human with artificial skin that could live on the planet Mars.[143] Dougal Dixon vividly presents in graphics and words a genetic and technologically modified human, a "Vacuumorph" that could live in the cold vacuum of outer space.[144]

We could also develop computer plug-in devices that would allow us to directly interface with the Internet with our own nervous systems.[145] We already have created electrode based neural implants that allow us to influence or move computer graphic displays with our minds.[146] Such computer-mind interfaces allow paralyzed patients to produce various physical motions and effects in the environment.

Another possibility is the development of all-purpose or multiple external plug-ins. We could attach different types of arms or legs for different purposes at different times to the same joint. This would be a dramatic and powerful example of detachable synthetic body parts. Just as today we have closets filled with different clothes, we could in the future have closets filled with different body attachments.

Genetic engineering will probably play a significant role in the evolution of artificial body parts. Humans could be biologically redesigned to be more compatible with attachments and replacements throughout their bodies. Dougal Dixon, in his highly imaginative and visually stunning book *Man After Man*, interweaves genetic engineering and physical prosthetics into a future history of humanity.[147] Dixon envisions a variety of future humans, genetically and technologically adapted to different environments and life conditions. He also traces a possible evolutionary sequence for these different humans, imagining various symbiotic and competitive relationships emerging. Dixon takes the view, as proposed in the previous section, that the future of humanity will show a diversity of human forms rather than some ideal type.

With advances occurring in both genetics and artificial body parts, future humans will probably reflect some ongoing synthesis of both types of biotechnology. Presently, we are beginning to remake our bodies by altering our genes and substituting new body parts. Anderson foresees a growing convergence within our bodies of biomaterial created with technology and implanted mechanical material and devices.[148] It will likely be that, out of this evolving synthesis, androids like Data on *Star Trek* will emerge. It won't happen all at once like the hypothetical construction of Data; instead, there will be a series of different stages and multiple trajectories. Everyone on The Enterprise will have artificial parts and different genetic codes.

In the ongoing purposive evolution of the human body, multiple technologies will be involved, reciprocally stimulating the development of one other. As noted above, prosthetics and genetic engineering, in various ways, will work together in creating technologically modified humans. Information technology, on numerous fronts, will also be significantly involved in this evolutionary process. As Kaku, among many others, has described, there is ongoing research into growing and interconnecting computer chips and circuitry with neurons and various bodily organs.[149] Kaku also discusses replacing neural circuits with quantum circuits, and as I described earlier, one of the great promises of information technology is the introduction of computer implants into the brain to replace damaged areas or to augment already existing neuro-psychological functions.[150]

Kurzweil argues that our brains and bodies will evolve together. As information technology progressively augments the psychological capacities of the human brain, through either direct implants or connected lines into the nervous system, the body will be redesigned and evolved to interface with this technologically enhanced brain. Genetic engineering of the brain will also undoubtedly come into the picture at some point as well, though the brain, having more genes dedicated to its make-up and functioning than any other part of the body,[151] will probably be the most challenging part of the body to manipulate and enhance genetically. Still, one of the most important and actively pursued areas in the technological augmentation of humans is the brain-body or mind-body interface.[152] The body-mind system could be significantly enhanced through technology. At present, our mental capacities to monitor and control the functions of the body are marginally developed at best, though there is a long tradition of meditative techniques that allow people to influence various autonomic activities and states in the body. Yet, with an increasing understanding of both the body and the brain, it is conceivable that a technologically enhanced brain and nervous system could gain much greater awareness and control over the workings of the body. Biofeedback is one present example of learning to control autonomic or unconscious functions using technology, but this is just scratching the surface of what is possible through "**psycho-technology**".[153]

Another converging technology in the purposive evolution of humans is nanotechnology. To recall, Kurzweil believes that within a hundred years, our entire bodies, including our brains, could be reconstructed with nano-material.[154] The basic building block of life, the living cell, will be reinvented through nanotechnology. Through various nanotechnological implants and treatments the body could be periodically rejuvenated and remade. Just as genetic engineering could lead to genetic discrimination and a separation of humans into the haves and have nots, humans who are nano-technologically altered or enhanced could become a distinct and "higher" form of human within the general population. This possibility is explored in Greg Bear's *Queen of Angels.*[155]

Anyone familiar with the Borg from *Star Trek* might see the above lines of technological development leading to a society of bizarre looking techno-automata. The Borg have no personal identities, each individual Borg creature is part of a vast technologically connected social machine; they are like walking zombies. They are malevolent and hideous in appearance, having various metallic machine-like attachments covering their bodies.[156] Yet such an image of a creature, which is part biological and part machine, reflects a Newtonian-industrial view of machines and a deep fear of being "assimilated" by such machines. If machines are without minds or souls and they dehumanize our existence, then we would imagine a being that is part biological and part machine as a soulless, mechanistic zombie. But as I have repeatedly pointed out, our technological devices are becoming more human-like.[157] Our technologies are being inspired and guided by models of living systems and intelligent flexible human capacities. Also, following from the arguments of Tipler, Smolin, Kurzweil and others, the material substrate of life is not an essential defining factor in the nature of life.[158] There does not seem to be any reason why any of the basic biological functions could not be carried out by systems constructed out of materials that are different than the organic chemical materials of the body. Why can't a being of artificial body parts feel, love, and show empathy and concern? Why can't a technologically augmented human be beautiful, graceful, and aesthetically pleasing to the eye? Why does it have to have wires and tubes extending out from its innards? Why can't technologically augmented humans have morals? And to get metaphysical, why can't they have a soul?

When Kelly describes the future blurring of the "born and the made," one thing he means by this idea is that technology in general will increasingly get its inspiration from biological mechanisms. As part of the future Neo-Biological Age, all human technology will be biologically inspired. Artificial body parts, although technologically constructed, will increasingly resemble in many ways the biological systems that they are replacing. We are learning a great deal about how to construct body replacements by looking at the operations of biological organs and systems.[159] And in reference back to our discussion on the evolution of information technology systems, biological concepts and materials will increasingly be used in the construction of computers and other intelligent technologies. What happens to our definition of life if a human has more metal in him or her than a computer and a computer has more protoplasm in it than the human? Which one is more alive? As the "born and the made" are blurring, so is the distinction of life and non-life blurring.

Whatever our emotional reactions to biological-technological integration, and the reactions vary from one extreme to the other, it is quite apparent even in our present time that as we age, different parts of our bodies are being replaced with artificial mechanisms. Based on the above-cited projections of prosthetic advances, each succeeding generation will find itself with more pieces that inevitably get substituted with technological replacements. As Kelly notes, the distinction between the "born" and the "made" is blurring. Where does the biosphere end and the technosphere begin?[160] We are becoming an amalgamation of biological and technological systems and parts. We are becoming a new type of animal, an augmented animal.[161] And even if we would have a difficult time, psychologically, accepting new technological enhancements attached to or implanted within our biological bodies, what about our future descendants and offspring? Would you like a pair of wings?[162] Would your grandchildren?[163]

We are becoming **cyborgs**. The term "cyborg", derived from "cybernetic" and "organism", was coined by Manfred Clynes to refer to technologically modified humans that could live in outer space. These humans would be a designed combination of technological implants and drug modifications, with probable genetic alterations as well. The term "cyborg" though has come to generally mean a synthesis of the biological and the technological.[164] The "Borg" of Star Trek, of course, is just a shortened version of "cyborg". Chris Gray sees the emergence and further evolution of "cyborgization" as a natural development of the ongoing integration of humans and their tools, or following Kelly and Anderson, the growing synthesis of the natural and artificial and the blurring of the born and the made.[165]

According to Gray, there is a growing proliferation of cyborgs, real and imaginary, within our culture. Cyborgs are appearing in the military, in art and entertainment, in sex and recreational activities, and in medicine and life maintenance. Cyborgization is blurring the distinction between life and death. With various medical devices connected to patients suffering from the loss of essential life sustaining physiological capacities, people can be kept alive at different levels of functionality. A technologically supported patient can be "brain dead" but still breathing.[166] Cyborgs are also working their way into pop culture, as humans in various ways, augment, decorate, and modify their bodies with all manner of adornments, devices, and attachments.[167] Gray foresees fundamental and pervasive cultural, social, and political ramifications as humans increasingly become cyborgs in the future.

Life and death, natural and artificial, and human and machine are all philosophical dualities. From the above discussion, it is clear that all these absolute distinctions are blurring.[168] With the emergence of genetic engineering, prosthetics, and biomaterial manufacturing, we will see a purposive co-evolution of life and machine, an ongoing reciprocal integration of the natural and the technological. This integration will extend beyond the synthesis of individual life forms and machines, but will also involve, if we follow Stock's thinking in *Metaman*, a merging of all of nature with technology.[169] The earth is becoming a cyborg. As discussed in the previous chapter, the Internet is functionally becoming a nervous system for the earth, with cognitive, communication, sensory, and motor functions stretching out across the surface of the globe and permeating into the seas and upward into space. Everyone and everything is "**being 'borged**".

Medicine and the Evolution of Health

As Moore and Simon report, physical health along numerous dimensions has vastly improved in modernized countries within the last century. There has been a considerable decline, if not almost complete elimination of most infectious diseases. Nutrition has significantly improved worldwide. More people died of famine in the 19th Century then in the 20th Century, though the average human population throughout the 20th Century was many times greater than the average population in the 19th Century. Famine, malnutrition, food poisoning, and hunger, all common problems throughout history, have all been measurably reduced in the last century. There has been a doubling of life expectancy since the beginnings of the Industrial Age in modernized countries, and significant increases are also beginning to show up in poorer countries. The death rate is declining in every age group. Americans, in particular, are bigger, stronger, and taller than in previous generations, all these increases being correlated with improved health. Although many factors, medical and nutritional, have contributed to the improving health of the human population, Moore and Simon note that there appears to be a significant correlation between freedom and health, democratic countries showing the most dramatic improvements in health and longevity over the last century.[170]

Even though the last hundred years has witnessed phenomenal improvements in health and medicine, the coming century may be still more dramatic. William Schwartz predicts the coming of a "**Medical Utopia**" with further significant improvements in life expectancy as well as quality of life, while reducing overall health care costs.[171] Not everyone is so optimistic, for the price of such a medical utopia may be beyond the means of the majority of the world population, but there is an incredible array of developments emerging around us that promise to transform medicine and health.

There are many areas of technology that will significantly influence medicine and health in the future. As Dertouzos states medical professionals are generally very enthusiastic about ongoing technology developments and desire the latest technologies to help them in their efforts.[172] The Internet and the Global Information Marketplace is one area of technology that will clearly impact medicine and health. Computer and communication technology is creating a worldwide databank of medical knowledge and providing for global diagnostic conferencing among specialists around the world. The emergence of a global medical information system will undoubtedly contain a **World Medical Library** for both professionals and anyone interested in the latest information on health, medical disorders, preventive measures, and treatments.[173] Dertouzos foresees a comprehensive integration and automation of all aspects of medicine, for both information storage and transmission across the globe.[174] Doctors will be able to access information on their patients, including X-Rays and other imaging data, from medical record bases from anywhere in the world.[175]

According to different predictions, somewhere between 2010 and 2020 there will be home expert systems that provide biological monitoring of vital body functions.[176] In conjunction with these home monitoring systems, we should also see the development of “electronic health coaches”. These health coaches could be robotic or agent-like, and worn on the body. They would monitor various body states, e.g., temperature, blood pressure, and heart rate, and provide appropriate recommendations for diet, exercise, and medical treatments. Dertouzos refers to such personalized health monitoring-coaching systems as “**Guardian Angels**”, and they will be able to access both general medical information and personal medical and health data from any relevant information source within the world.[177]

Computer technology will transform medicine in other ways. Aside from teleconferencing among doctors, many futurists predict the emergence of **tele-surgery** in the next ten years.[178] Doctors will be able to perform surgery on patients at distant locations through computer connected robotic devices.[179] Dertouzos foresees the emergence of robotic and mini-robotic surgery and technologically augmented reality surgery.[180] Pearson predicts the continued development of computer diagnosis within the next ten years,[181] a technological capacity that will work its way into the operations of personalized “Guardian Angels”, providing ever more detailed and sophisticated on-the-spot health and medical assessments of the individual. According to Pearson, eventually nano-surgeons by around 2020 will enter the picture as well, providing for computer guided removal, cleaning, and reconstruction of bodily tissues and structures.[182] As a general trend, if we were to follow the predictions presented by Moravec on robotic evolution and intelligence, we should see robots and nanotechnology being able to handle both the diagnosis and treatment of all medical problems within the next century.[183]

Contemporary imaging technologies, supported by the information processing power of computers, are enhancing our ability to observe the incredible complexity of the human body. The development of magnetic resonance imagery (MRI), positron emission tomography (PET), and computed X-ray tomography are allowing doctors to view the inner workings of the body three-dimensionally in action. We can send fiber optic cables into the body to microscopically view biological structures and processes. Nanotechnological devices will probably develop for providing even more refined examinations of physiology and anatomy.[184] As Kaku points out, we should expect a continuing evolution of imaging devices and computer technologies that will provide ever more detailed and dynamic visions of the body.[185]

As the Internet provides an ever-increasing web of information, professional teleconferencing and cooperation, and computer facilitated treatment, we should see both a decrease in the number of large hospitals and a more informed, independent patient population.[186] Doctors, using the resources of the Internet and computer technology, will carry out numerous types of surgery and treatment from more localized and distributed medical centers. Patients, able to stay informed of both general medical information and their own physical health, through self-monitoring systems and health-medical discussion groups on the Internet, will be able to intelligently select for appropriate professionals, confer with them, and guide to some significant degree their own health and medical regimes. Halal and the George Washington forecaster group predict computerized self-care by 2007. Anderson already sees an emerging social-information network of patients, researchers, and doctors supported by the Internet. In general, medicine and health will move from large centralized factory-like facilities treating lines of uninformed patients to a globally connected, distributed network of technologies and patients and doctors in collaborative relationships.

As I described in the previous section, genetic biotechnology and the development of artificial body parts will have dramatic effects on the future of medicine. Genetic engineering could eradicate genetic diseases within 20 years, and in approximately the same amount of time, many body organs could be replaceable through either genetically grown replacements or technologically engineered prosthetics.[187] Individualized DNA profiles will be available in the next decade or two, thus identifying hereditary dispositions for various physical problems, and facilitating preventive medicine and health care.[188] Since genes are connected with the production of different proteins and complex chemical molecules in the body, medicine will increasingly move into molecular and protein targeted drugs as different genetic deficiencies are identified and mapped within the human genetic code and appropriate drugs are synthesized to correct for these molecular deficiencies.[189]

As Kaku notes, chemical and drug treatment in medicine has evolved through the ages from herbal and natural remedies to vaccines and antibiotics and presently to the creation of molecular compounds.[190] Empowered by scientific advances in biochemistry and molecular biology, pharmacology continuously produces more powerful and effective drugs every year. As Stock notes, the national publicity program for a "Drug-Free Society" is so highly misleading and oversimplified as to be counterproductive.[191] Rather, the use of drugs is steadily climbing. Drugs are being manufactured and distributed, both legally and illegally, around the globe.[192] Since at one level of scientific analysis our body could be accurately described as a huge, complex biochemical system that manufactures, uses, and recycles a vast array of chemical molecules, manufactured drugs are not necessarily unnatural or artificial substances being introduced into our bodies. Our bodies are filled with drugs. Since we are chemical factories, we can attempt to correct for biochemical problems and deficiencies through the use of drugs, often that mimic or replace bio-chemicals normally produced in our body. There are numerous disorders of the body that can be treated with drugs, and the list of treatable disorders through drugs keeps growing. Drugs can also enhance or improve biochemical functioning. Our life expectancies are being increased through drugs, while the quality of our lives is also being enhanced. As Moore and Simon report, almost half of the increase in life expectancy this century is due to vaccines, drugs, and medical treatments.[193] Experimentation with drugs, both legal and illegal, often backfires and people can become addicted to drugs or cause significant harm to themselves through drug use, but humanity is not moving toward a drug-free society. We are moving in the opposite direction. We clearly believe and behave in accordance with the philosophy of "better living through chemistry".[194]

Increasing genetic knowledge will facilitate the production of better drugs. Kaku predicts that we will develop the technology to quickly create "**designer molecules**" targeted to the genetic structure of diseases that infect our bodies.[195] Kurzweil foresees drugs being custom engineered to the specific genetic and chemical make-up of a particular patient.[196] Schwartz in fact believes that with advances in genetics and pharmacology, as well as in other medical areas, we could see a relatively disease free future.[197]

According to many futurists, we should see in the future great medical progress in the treatment and cure of disease. Humanity throughout history has waged an ongoing battle, with both up's and down's, with innumerable killer diseases. In many respects we seem to be winning the battle. As I stated earlier, Moore and Simon report that many major diseases have already been eradicated.[198] Pearson projects an overall further worldwide decline in deaths from infectious diseases from 17 million today to 10 million by 2020.[199] Yet while some diseases, such as smallpox and typhoid fever, have dropped to close to zero incidence, other diseases such as cholera and diphtheria, Pearson reports, are showing resurgence. Tuberculosis is also increasing due to the spread of HIV around the world. Still, even with such present challenges, new cures are foreseen for heart disease, cancer, arthritis, and Alzheimer's disease in the next twenty years.[200]

Cancer has been one disease that been a real struggle to conquer. Yet, in spite of the fact that its death toll is actually rising, there is significant optimism that we are going to win the battle in the near future. Present treatments are increasingly effective in extending the lives of cancer patients,[201] and Kaku reports, based on his survey of experts in the field, that the "mystery of cancer has been solved".[202] According to Kaku, cancer has a clear genetic component, involving the mutation of certain genes in the human genome. Based on a growing molecular understanding of the disease, both early detection of the disposition toward cancer and advanced molecular targeted treatments are coming in the next couple of decades.

Over the last couple of decades, the **HIV/AIDS epidemic** has been spreading throughout the world. According to present projections, the disease will not peak until around 2006, when over 100 million people will be infected and the annual death toll will reach 1.6 million.[203] Although the epidemic is most highly concentrated in Africa and Third World countries, the disease is clearly a global concern calling for international efforts in diagnosis, treatment, and control.[204] Pearson points out that numerous diseases, which begin in relatively localized areas of the world are spreading across the continents due to the increasing movement of people and goods in our burgeoning global society.[205] HIV/AIDS probably began in Africa, but has spread to every populous continent in the world. In general, as the global society continues to emerge, the health care of the world will become everyone's business and concern. Although medicine and health care, as Moore and Simon report, have vastly improved in modernized countries such as the United States, should only a select few be privileged to the best health care? What we do or do not do in other parts of the world will affect all of us. The ever-growing world population, with all of its health and medical problems, is knocking at our doors.

The phenomenon of HIV/AIDS illustrates another significant challenge for the future of medicine. The virus mutates and various strains become resistant to previously effective pharmacological treatments. This adaptive evolutionary process is not limited to just the HIV/AIDS virus. If a drug is used that kills some type of bacteria or virus, the environmental conditions are created that push the bacteria or virus in the evolutionary direction of making itself immune to the effects of the drug.[206] This type of evolutionary counter-reaction has been observed in the agricultural use of pesticides, where agricultural pests have evolved to become immune to the poisons sprayed on them. It has also been observed in the use of antibiotics, with the emergence of “super-bugs” that are resistant to the effects of the antibiotics.[207] Instead of nature simply passively giving in to the efforts of humanity to manipulate it (an Industrial model of technology), nature pushes back and moves in a new direction. The various bugs, microbes, and bacteria find a way, even if by random trial and error, to perpetuate and survive in an environment filled with drugs. We are interacting with autonomous, flexible, and tenacious living forms when we try to subdue or eliminate them through pharmacological means. Future pharmacology will involve an ongoing tug of war with all of the different microscopic organisms that try to live off of us (or within us). Through the advancement of drugs and pesticides, we are pushing them to new heights of evolution. In turn, our methods will also become more sophisticated.

As an alternative to the use of drugs in medicine, behavioral, mental, and spiritual approaches are becoming increasingly popular. Traditionally, we separated mind and body as two distinct realms. But as mind-matter dualism has increasingly lost its hold on contemporary thinking, the possibility of mental control over biological functions has become more plausible. For example, psychological stress probably produces damaging physical effects on the body, and changes in attitude, mental states, and even increased social interaction can improve physical health.[208] Meditative and mystical techniques are being used to maintain physical health, as well as to cure diseases and infirmities. Many medical doctors no longer simply address the specific biological problem; they address the whole person, his or her attitudes, feelings, lifestyle and state of mind. Medicine is becoming holistic. Halal predicts that **holistic healthcare** will become very common by 2007.[209] We may see a time in the future where the mind is as important in medicine as drugs and technology.

Overall, health is becoming more and more a lifestyle issue that the individual is responsible for maintaining. As Pearson reports, as death tolls from infectious diseases decrease, lifestyle diseases are progressively responsible for a greater percentage of all deaths. He sees this trend continuing in the future.[210] For example, death from diabetes, due to increasing numbers of overweight people, should double by 2025. Deaths from smoking should increase from 3 million in 1990 to 10 million in 2030. Although advances in genetics and drugs are going to be important, an evolving understanding of dietary habits and environmental factors will also significantly impact the future of medicine and health.[211] Futurists foresee considerable growth in behavioral and lifestyle medicine, which are holistic approaches to health, and greater stress on preventative measures rather than cures after disorders have emerged.[212] Clement Bezold in fact states that in spite of the promises of curative medicine in the future, we should put much more emphasis on preventative lifestyle medicine. The bulk of medical costs are on cures for health problems, and preventative medicine could greatly reduce such costs.[213] Lifestyle changes though are mostly the responsibility of the individual. As noted earlier, the general public is becoming more informed about medicine and diseases. Also recall, that bio-monitoring devices, further empowering and informing the individual, will become available in the next couple of decades. Centron and Davies relate that the personal health movement continues to grow; diet, fitness, stress control, and general health clubs are booming businesses.[214]

Yet there are paradoxes within the contemporary holistic and personal health movements. There is more emphasis on diet in modern countries, but people on the average are getting fatter.[215] Although health clubs are doing well, the general population in modern countries does not exercise enough.[216] Stress, anxiety, and depression, psychological states clearly connected with basic lifestyle habits and health, are pervasive throughout the modern world. We may be talking the talk about improving our health habits and lifestyles, but many futurists argue that as a society we are becoming more addicted to the quick fix, rather than future oriented, long term changes associated with mental attitudes and behavior.[217] Postman argues that we are becoming increasingly dependent on medical technology, which would contradict health approaches that highlight personal responsibility.[218]

With all the types of changes in medicine and health described above, many futurists see fundamental changes in the health care system in the years ahead.[219] With the population in the United States on the average increasingly older, the health care industry has been in steady growth. Yet the health care system is in some ways in turmoil as well. The new technologies keep making health care more expensive, and the ever more sophisticated and educated consumer wants better services and more of a say in medical treatment decisions. Many people are being out-priced of the best medical care. Recall the concern that genetic engineering will not be available and affordable for most people. Yet doctors have been steadily pushed into having to raise their prices due to insurance costs and lawsuits. Presently, health care accounts for approximately ten per cent of the gross national product.[220] Some futurists have predicted that health care in the future will take up a greater percentage of our budget, personally and collectively. Consequently, it is one of the most promising professions to pursue and one of the most profitable industries in which to place investments.[221]

Yet other futurists predict that health care costs may dramatically decrease.[222] According to Michael Fossel, most health care costs are associated with aging. What if it were possible to slow down the aging process and eliminate the diseases, e.g., Alzheimer's disease and cancer, presently connected with getting older? What if we had a population of healthy centenarians? Fossel argues that both aging and diseases associated with aging are going to be treatable in the very near future, and consequently health care costs are going to come down. Although it might seem that aging is a phenomenon that could not be slowed or even halted in humans, one of the most dramatic promises of genetic biotechnology is that it may be possible to stop this seemingly inevitable process. The topics of aging and death are the focus of the next section.

Human Immortality

"The supreme goals, or values, of human life are, in the last analysis, set by an individual in an act of free choice. This produces the historic plurality of ethical and religious teachings. There is, however a common denominator to these teachings: the will to immortality. The animal is not aware of its imminent death: the human person is. The human will to immortality is a natural extension of the animal will to life."

Principia Cybernetica

"I don't want to achieve immortality through my work. I want to achieve it through not dying."

Woody Allen

According to many medical experts and bio-technical researchers, we should expect in the near future a dramatic upswing in the **average human life**

expectancy. In 1900 in the United States, the average life expectancy was 47.3 years; it is now around 77 years.[223] This increase has been primarily due to finding cures for most fatal childhood diseases, but the average human life expectancy has increased for all age groups. Further, although life expectancies in poorer countries are still behind modernized countries, in this century there have also been noticeable increases in these poorer countries as well. Yet within the 21st Century, as I described in the last section, various medical advances should have a dramatic effect on the infirmities and diseases that kill adults, and human life expectancies will increase even further in both modernized and developing countries.[224] Four main reasons should contribute to significantly extending the average human life expectancy, if not the upper limits on the human life span, in the century ahead:

1. The new imaging technologies
2. Genetic technologies
3. Improved medical practices and skills
4. Environmental, socio-cultural, and psychological changes involving lifestyle and living conditions

Based on these developments, it is not inconceivable or implausible to believe that people will live into the 125-150 year range within the next century.[225] Although some estimates are more conservative,[226] Halal predicts an average life expectancy of 100 years by 2030 and Pearson predicts an average life expectancy within the range of 100 to 130 years by 2020.[227]

The scientific challenges in this century will be to understand the biological processes of aging and dying. Why do we get old? Why do we die? How are the processes connected with our genetic structure? Can they be modified or even stopped? From a social, if not ethical perspective, will we want to do this, if we figure out how to accomplish it? How will a population of 200, 300 or even 1000 year-old youthful adults affect the fabric of human society? These questions are not far-fetched since, as I mentioned above, scientists are making real progress in understanding the causes of aging and death.[228]

As Centron and Davies report, there have been various remedies throughout history for slowing the process of aging. Scientific evidence, until recently, seemed to demonstrate that the only clearly effective counter-measure against aging was a restrictive diet with a low caloric intake. More recently, the hormone melatonin, produced by the pineal gland, has also been strongly connected with retarding the aging process.[229] But the most dramatic and promising scientific discovery on aging is concerned with the **telomere** structures that exist at the end of chromosomes. Whenever cells divide, the number of telomeres on the chromosomes is reduced. Cells can no longer divide if their chromosomes have lost all the telomeres. The lost of the capacity for cells to divide and reproduce is clearly connected with the eventual aging and death of living forms. It has been found that the enzyme telomerase, the "**immortalizing enzyme**" as some have called it, stops the loss of telomeres and halts the aging process. Though telomerase has the side effect of instigating cancer growth in some animal subjects, the hope is to find a way to prevent this negative side effect.[230]

Aging and death have also been connected with the genetic structure of DNA. As Kaku points out, some life forms seem to have indefinite life spans, being able to continually reproduce healthy and functional new cells in their bodies. Many scientists believe that there are genes that instigate the aging process, and consequently it is not inevitable that a living form must age and die, if these specific genes are not present or can be removed.[231] Many scientists also believe, according to Kaku, that aging and death are connected to entropy. As an example of entropy, errors in information transference build up in DNA over the repeated divisions and reproductions of the genetic code throughout the life of an organism. As the errors build up, order breaks down.

Assuming that aging and death are connected with specific structures or changes in the DNA code, the telomere ends on chromosomes, or other molecular components of the body, it is quite possible that various technological means can be developed to correct these changes. Scientists have proposed the use of nanotechnological devices that would proof read DNA and fix any transference errors. More generally, nanotechnology could be used to clean and rebuild all deteriorating structures and tissues in aging bodies. Additionally, molecular engineering could address the decay of significant biochemical components that are associated with aging.[232] According to Schwartz, aging will be a treatable condition by 2050.[233]

As Fossel notes, in spite of all the medical advances over the last century and consequent increases in average human life expectancy, up to this point in time, science and technology have not been able to extend the **maximum human life span** of 120 years.[234] The expression "life span" refers to the maximum age that a living form can reach. The expression "life expectancy" refers to the statistically expected age that a living form will reach.[235] Although the average life expectancy has been going up over the last century, people on the average staying alive longer, the life span for humans has not. The maximum age that any human seems to be able to reach is around 120 years, both now as well as a century ago. According to Fossel and others, if telomerase treatment or something functionally similar can stop the loss of telomeres in the chromosomes, the human life span will be extended. Bodies will not have to age, and in fact, the introduction of effective telomerase treatment might reverse the aging process and make older bodies young again.[236]

Even if telomerase treatment is not the complete answer to preventing aging, Centron and Davies hypothesize that life extension treatments will build on themselves. If a person's life expectancy could be extended 20 to 40 years right now, by the time they would have reached that extra 20 to 40 years in life, additional treatment advances will have been achieved that will further extend their life.[237] As Fossel states, the human life span may become indefinite and uncertain. We may become functionally immortal. Further, according to Fossel and others, future medicine will keep humans healthy, vigorous, and youthful even into "old age" (whatever that will mean).[238]

Significantly extending the human span will generate a population explosion, first in modernized countries, but then spreading to developing countries as aging treatments become more available. Retirement will be pushed further into the future, perhaps indefinitely, since not only will people live longer, but also they will be much healthier and highly productive in spite of their vastly increased older age. In general, the conquest of aging will have monumental effects on all aspects of human society.[239]

Assuming that through genetics, nanotechnology, and telomerase treatment we can lengthen the human life span indefinitely, we come to the next watershed point in our assault on mortality. From the previous section on artificial body parts, it seems apparent that we will be able to replace more and more parts of our biological body with improved bio-technical structures. The biggest challenge will be the brain and all its neurologically coded personal experiences and memories. As Kurzweil suggests, within a hundred years, it should be possible to download into an advanced computer-like mechanism the total psychological make-up of a person that is embodied in their biological brain. When this happens we will have created an artificial brain. Although according to Kurzweil, our conscious mind will exist in a virtual reality environment created by an advanced global intelligence network, we could also materialize as a nanotechnological body. To recall, we could take different forms in our nanotechnological manifestations, and we would experience the physical world around us through these nano-bodies, but our minds would maintain their grounding or connection within the computer network. In essence, we would have transcended the constraints of our present biological bodies and created a whole new physical foundation for our lives, minds, and personal identities. Through such technologically constructed bodies and brains that would not age like our former biological bodies and brains, we would live for as long as the global network, or some analogous structure that would serve as a host, continued to exist.[240]

Moravec proposes an even more advanced technological substructure that would support the continued existence of conscious minds and selves, arguing that eventually the ultimate fabric of space-time can be redesigned as a computer-like network that would support a virtual reality universe in which conscious minds could exist.[241] Again, whatever type of conscious self and form of life were to exist in such a reality, it would be able to maintain its continued existence for as long as the underlying network continued to exist. Yet, following from the ideas of Kurzweil and Moravec, it seems clear that such conscious beings would transcend the present psychological architecture of human minds and personal identities.

One can imagine that the sciences and technologies of artificial intelligence, virtual reality, nanotechnology, and biotechnology will all converge in the future in the human quest for **immortality**.[242] Can human life and consciousness, or some evolved version, achieve immortality? Frank Tipler believes this possibility will be realized in the distant future.[243] For Tipler, the type of physical form that could live forever would be significantly different than our present biological form. These conscious life forms would exist within a virtual reality universe embodied in a hyper-energetic physical medium. As we can see, in many ways, his ideas dovetail with those of Kurzweil and Moravec.

Hence, present speculation seems to lead to the conclusion that immortality can be achieved, but it will require a totally different type of physical medium to support it and the resulting conscious experience will be something like a virtual reality universe. Would we accept immortality within cyberspace? What would it be like? Given the present evolution of virtual reality and its technological possibilities, Tipler, as well as Kurzweil and Moravec, all believe that it will be much richer and more varied than our present solid-state reality. Whether Tipler's particular vision, or those visions of Kurzweil and Moravec, are realized in the future, in the coming centuries, as our sciences and technologies evolve, we will probably see a steady and multidisciplinary assault on mortality.

Immortality is a theme usually associated with religious prophecies and mystical revelations. Christianity promises that God will raise true followers from the dead to live eternally in heaven. Hinduism and Buddhism contain the idea of reincarnation and gradual ascension to a higher eternal plane. It may therefore seem sacrilegious to bring up the idea that immortality could be achieved through scientific and technological means. Yet this attitude reflects our dualistic thinking on the scientific and the religious.

Tipler's theory of immortality attempts to synthesize the scientific and the religious. He sees religious and mystical views on immortality as essentially correct, but he believes that the road to immortality is a natural evolutionary process accomplished through advanced science and technology. According to him, most major world religions believe that God will raise humans from the dead and provide them with some type of eternal existence. Tipler believes that God is the culmination of evolution, a cosmic mind that will emerge as the universe is integrated through technological intelligence, and that this Supreme Being will raise all intelligent minds from the dead near the end of physical time. As can be seen, Tipler's view of God is an example of the idea of an evolving cosmic intelligence introduced in the previous chapter. Tipler thinks that such an evolutionary God will be a being of infinite power, as well as infinite benevolence, one that will decide to give eternal life to all intelligent beings.[244]

To me it seems that there is an evolutionary connection between Tipler's image of the resurrection of the dead and present scientific and technological efforts to extend human life. As we progress along multiple pathways in science, medicine, biotechnology, and information technology, we will extend human life toward ever-expanding limits. Further, Kurzweil and Moravec's ideas regarding mind and consciousness moving into highly evolved technological systems and networks sound like precursors to Tipler's notion of a cosmic technological intelligence that envelops and supports all conscious minds within it.[245] We are evolving toward a state of immortality.

In order for conscious beings to achieve immortality, they must exist in a universe that does not end. As I described in Chapter One, there are different cosmological theories of our universe and it is not clear at this point in time whether our universe is in fact eternal. It may not be. If we are bound to our present universe, how can we become immortal if our universe isn't? Yet the future of the universe is a question yet to be answered, or perhaps, to quote Kurzweil, it is yet to be "decided". Tipler in fact believes that the ultimate fate of the universe will be determined by conscious and intelligent design. Kurzweil believes the same. If we were to follow this line of thinking, then perhaps eternal existence is something to be achieved or created in the distant future. In order to create immortality for ourselves, we will need to ensure immortality for the universe. In some sense, in achieving this feat, we will have to transcend the limits of time.

Artificial Life

Genetic engineering is an experiment in evolution. There is another type of experiment in evolution presently emerging that is perhaps even stranger in its nature and implications. This new area of research is **artificial life**, which exists in cyberspace, that is, in the electronic and informational reality created in computers. In the last section, my discussion of immortality led to the futuristic notion that life and consciousness could possibly exist eternally in some type of virtual reality universe. As it turns out, research is already occurring that attempts to create virtual living forms within cyberspace.[246] This research could be seen as the beginnings of efforts to simulate a virtual universe in which life could exist. In looking at this new area of investigation, our fundamental concepts of life are being brought into question and possible revision.

Artificial life is created within a parallel processing computer system. A computer is inputted with a host of relatively simple programs that operate in parallel with each other. Each of the programs is given some basic operational features or rules, such as how they can interact with other programs, how they can learn, what their programming goals are, and how they can reproduce. When all of these program units are turned on simultaneously, they begin to interact with each other.[247]

What will emerge over time in such a situation are ecological and evolutionary features in the population. Cooperation, competition, and symbiotic relationships show up. Different types of programs may come to dominate the cyberspace ecosystem. There will be oscillations over time in the populations of different programs. Ecosystems will stabilize, undergo mass extinctions, and evolve. In general, scientists can observe and investigate the dynamics of life and evolution in this virtual or simulated reality. As noted earlier, scientists are able to study the behavior and evolutionary dynamics of many different kinds of natural systems that can be simulated on a computer. Within artificial life research, the basic operating principles of the systems have been selected to simulate at least some of the presumed activities and features of living forms.[248]

Christopher Langton describes artificial life in terms of self-organizational concepts and theory. Artificial ecosystems are created through the interaction of the individual programs or parts. The whole becomes more than the sum of the parts. Further, ecosystems emerge without any direct guidance. It is a bottom-up process without a central controller. As noted above, there will be ongoing changes within these ecosystems, with new ones replacing old ones. The overall result, according to Langton, will be the production of novelty within the simulated reality. The evolving organization will be more robust, adaptive, and creative than if the simulated system had been completely programmed. For Langton, the emergent realities are complex enough to be considered alive.[249]

The question has obviously arisen whether these informational units are in fact alive. They show many of the features of material living forms. They simply exist in cyberspace rather than physical space. Hence, aren't they functionally alive? Further, they can be programmed to interact with us as well as with each other, and based on neural net programming they can learn. Not only are such simulated beings functionally alive, living within an ecological space and evolutionary time, they possess levels of intelligence and can communicate with us through cyberspace. The newest interactive computer games and the characters that populate their simulated virtual worlds are a simple and popular example of these various properties and capabilities.[250] Analogously, consider how intelligent and interactive "agents" evolve and learn. Would we consider them alive?

Obviously, the question of whether artificial life is really alive depends upon one's definition of life. Interestingly, this issue is very similar to whether computers could possess a mind. Recall that computers are frequently denied mentality and consciousness because their physical substrate is silicon-based and metallic, rather than protoplasmic. Does something alive have to be based upon a certain type of physical foundation? In fact, does something alive have to have a body of solid matter at all or can it exist in a medium of energy and information processing? Tipler defines life as an entity that codes information and passes the information on through natural selection.[251] Although Tipler describes this definition of life as a physical description of the essentials of life, he does not refer to any specific physical substance in his definition. In fact, he intentionally avoids including any reference to the type of physical make-up that life must possess; his definition is purely formal and functionally similar to his formal definition of mind. According to Tipler's definition, computers are alive, and artificial life forms existing within computers are alive as well.

According to many scientists and computer technologists, artificial life and artificial intelligence are related phenomena.[252] In both cases, the systems are processing information, and in both cases, the systems evolve and learn by interacting with information. Also, artificial life forms clearly possess degrees of artificial intelligence, having the capacity for memory, learning, and goal directed action within their virtual environments. As Langston states, AI and AL (artificial life) deal with the same process of trying to simulate and synthesize information processing activities as they occur in nature. One could also draw an analogy between computers and robots, and AI and AL. Robots need to not only process information, as computers do, but to function within a physical space as well. AL needs to possess some level of artificial intelligence, but it also needs to function and survive within a virtual space, often involving competing artificial life forms. Of special interest, Langton discusses von Neumann's efforts to define the logical requirements for life and self-reproduction, independent of any particular physical form. According to Langton, researchers in AL using simulated realities need to show how the reproductive capacity in life could evolve in a “noisy environment”.[253]

Artificial life can be programmed with different capabilities and features. One interesting approach has been to program one population with "**Darwinian-like**" features and a second population with "**Lamarckian-like**" features and compare how the two populations evolve. Darwin believed that offspring are random and those that survive to reproduce hit upon competitive advantages through a process of random trial and error. Prior to Darwin's theory, the biologist LaMarck had proposed that evolution occurs by offspring inheriting acquired or learned traits from their parents. Modern genetics, however, strongly opposes LaMarck's idea. According to modern genetics, the DNA in parents is not modified as a result of what the parents learned in their development. Learning is not passed on genetically. Yet, artificial life forms can be programmed to pass on in reproduction what they have learned. It turns out that a population that evolves according to Lamarckian principles evolves much quicker than a Darwinian population of random trial and error. The gist of this type of research is that various strategies and principles of evolution can be tried out and compared. We are learning how to evolve living systems. This knowledge will contribute to the purposive evolution of life in the future.[254]

One implication of artificial life in the future is that we may live within a world that is not only populated by new physical living forms, but also populated with a whole new breed of electronic or informational forms. "Max Headroom" and "The Lawnmower Man" are hypothetical examples of this possibility. Recall Moravec’s similar idea that the future will contain a vast ecosystem of different types of AI’s. Computer software is already available to the general public for evolving such artificial life systems on personal computers. In the future, we may be interacting with a plethora of virtual living forms and artificial intelligences, many of our own creation. Imagine a world like the holo-deck on *Star Trek*, filled with virtual beings. And lest we forget to put two and two together, the development of virtual reality should allow us to enter the cyberspace of these informational creatures and live and interact with them. We could, of course, become them, as Kurzweil has suggested.[255]

Considering the implications of genetic engineering, prosthetics, and artificial life, we stand at a highly significant point in our evolutionary history. Our experimentation and study in the process of evolution is opening up the possibility of influencing how evolution occurs. As I have noted on several occasions, one popular contemporary view is that the process of evolution undergoes changes across time. Evolution is evolving. Following from the ideas of Kurzweil and Stock, among others, nature seems to progressively find more efficient ways to accelerate its own development.[256] Human biological science, as an outgrowth of evolution itself, seems to be ready to contribute to this process by providing the theoretical and practical know-how to consciously guide evolution. Evolution is about to become self-conscious and purposive, and whether we like it or not, we sit at the helm of this evolutionary ship.[257]

The Future of Evolution and Life

"In the last half of this century, the view has emerged that life and consciousness are natural and inexorable outgrowths of the emergent and self-organizing properties of the physical world."

J. Doyne Farmer

"We're the amoebas, and we can't figure out what the hell this thing is that we're creating. We're right at that point of transition, and there's something coming along after us."

W. Daniel Hillis

What is the meaning of life? Does life somehow fit into the cosmic pattern of the universe? Christian de Duve, in his article "Life and Meaning in the Universe", raises these types of questions.[258] Is life inevitable and ubiquitous throughout the universe? Is life a significant and somehow necessary prelude to intelligence, mentality, and self-consciousness emerging in the universe? Is life a consequence of some cosmic design? In his discussion of the significance of life in the universe, Christian de Duve cites John Barrow and Frank Tipler's famous Anthropic Principle.[259] As I described in Chapter One, Barrow and Tipler, among others, have pointed out that the laws and constants of the universe are amazingly compatible with the necessary conditions of life.[260] If these laws and constants were slightly different than they are, life, as we understand it could not have evolved. It almost looks as if the universe was constructed to allow life to exist. Do we live in a universe that supports the emergence of life throughout the cosmos? Is this by design or because of the natural laws of the universe? Perhaps we are not special; perhaps we exist within a thriving, living universe. If life is part of the cosmic scheme of things, what is the cosmic scheme of things? And what is the cosmic meaning of life?

As Smolin states, within a mechanistic and dualistic universe, life seems out of place and inexplicable.[261] This apparent lack of connection between life and the physical universe seems on the surface rather paradoxical, since God presumably created this physical universe for humans. But since this universe was dualistic, separating matter from spirit and mind, humanity as a mental being found itself lost and alienated in a world of soulless, cold, inanimate matter. Although early scientists such as Descartes and Harvey attempted to describe the functioning of a living body in Newtonian and mechanistic terms, thus assimilating life to the soulless world of matter, many scientists, past and present, have found this approach to life lacking in something essential about the very nature of life.[262] Yet over the last century, the mechanistic model of the physical world associated with Newton has been replaced. In Chapter One, I reviewed the various problems and critiques of Newton's theory of the universe. I also described the newer self-organizational, quantum, and relativistic scientific theories that have taken the place of Newton's physics and cosmology. Based on the newer theories of physical science, scientists, such as Lee Smolin, Stuart Kauffman, and Ilya Prigogine, are attempting to demonstrate that life naturally follows from the basic laws of the cosmos. Life is not a cosmic oddity, but perhaps a cosmic necessity that fits within the re-conceptualized physical world.[263]

The main thrust of the contemporary scientific efforts to connect the physical cosmos with the presence of life is to unite the physical and the biological through self-organizational, complexity, and evolutionary principles. As I explained in Chapter One, modern physics and cosmology views the universe in evolutionary terms. The laws and entities of the universe are explained as consequences of a grand evolutionary process that extends from the smallest and simplest to the most complex and holistic. As Smolin argues, both the physical and the biological follow the same lawful principles. In particular, he believes that the earth and living systems on the earth inherited the products, conditions, and processes of self-organization that emerged in galaxy formation. For him, our individual galaxy, as well as the universe as a whole, is a hierarchy of self-organizing systems embedded within each other.[264] Life is a natural progression within an evolving self-organizing universe. Similarly, Kauffman sees the emergence of life on earth, at least to some significant degree, as a result of the principles of self-organization that have created order and complexity throughout all of nature. In addition, Kauffman proposes that the process of self-organization follows a similar pattern throughout all of nature, occurring at the boundary between order and chaos, an idea that is expressed by many other scientists.[265] As two other illustrative examples, Kurzweil hypothesizes an exponential accelerative growth of order building upon itself throughout the history of the cosmos leading to the emergence of life and intelligence; Murray Gell-Mann proposes a progressive cumulative evolution of increasing complex systems from chemistry to life to culture.[266] In general, according to these different scientists, not only does life evolve, but also, life itself emerged in the cosmos because of evolution.

If life is a natural consequence of the basic laws of the universe, then it seems quite reasonable to believe that life exists in many places throughout the universe. I discuss in detail in Chapter Five the topic of alien life and intelligence, but I should note that there are many ongoing efforts to locate life on other worlds either in our solar system or beyond. In this search for extraterrestrial life we should keep our mind open regarding what life might be like on other alien worlds. As different scientists argue, we need some general principles regarding the fundamentals of life so as not to get blinded by what may be the peculiarities of life on earth. Life may be a natural consequence of the laws of the universe, but we need to describe these basic laws in a sufficiently abstract manner, and consider all the different possibilities consistent with these general principles. If life is a cosmic process, then a **cosmic theory of life** must be sufficiently broad to encompass a myriad of possibilities. If life fits within the cosmos, it might fit in many different ways.

There are different ways to approach the cosmic possibilities of life. Science fiction writers over the decades have imaginatively considered in great detail what these different possibilities of life throughout the universe might be. Stanislaw Lem wrote a famous science fiction novel titled *Solaris*, where humans landed on an ocean covered planet, and because of humanity's earth-centric notions of life could not grasp the fact that the entire ocean of this planet was actually a single living organism.[267] As Michael Zey reports, NASA has developed an Astrobiology program to study and consider the question of life in the universe and what it might be like.[268] Researchers in artificial life are studying and attempting to understand the general parameters and dynamics of life that would follow from basic information processing and evolutionary principles. Perhaps most importantly, life in the cosmos needs to be examined in a futurist context. What forms of life could emerge in the future? Various non-fiction writers, such as Kurzweil, Moravec, Adams and Laughlin, and Tipler, as well as numerous science fiction authors, have explored the future possibilities of life, including robotic, cyberspace, and holistic forms, as well as beings that could exist in totally different configurations or levels of matter and energy from what presently exist on the earth.

Within this chapter I have looked at the promises of biotechnology and the ideas of biological science as they apply to human society. At the center of contemporary biological and biotechnological thinking is the theory of evolution. Evolution, in fact, brings together the study of life in the cosmos, the future of life, and the significance of biotechnology. Evolutionary thinking, as I have described it, came to the forefront of science and in particular biology in the writings of Darwin. Since then it has gone through different changes, bringing genetics into the picture, being modified by Gould and Eldredge in their theory of punctuated equilibrium, and more recently, being connected with self-organizational and open systems theory and consequently expanded to explain the overall development of the cosmos.[269] As noted above, the theory of evolution explains the origin and development of life in the cosmos and connects life with the physical universe. Evolution also provides a conceptual framework for understanding the thrust of biotechnology. Biotechnology can be described as the purposive and informed technological effort to guide the biological evolutionary process. (Parenthetically, technology as a whole could be described as the informed and purposive effort to guide the evolution of the cosmos.)

Purposive evolution is an evolution within the process of evolution. It is evolution becoming self-conscious. The concept of purposive evolution, as an extension of evolution, provides a mental framework for understanding the future of life and humanity within the cosmic scheme of things. If evolution and various principles of self-organization explain the nature of change in the cosmos, then purposive evolution, which would include biotechnology, is a stage or step in this cosmic process. Evolution becomes empowered with scientific knowledge, technological know-how, and hopefully ethical and humanistic guidance.[270]

Yet evolution, and consequently purposive evolution, conflicts with various religious views of the origin and meaning of the universe and the cosmic significance of life. In particular, evolution conflicts with top-down theories of creation, which see the universe as being constructed and set in a determinate form by a controlling transcendent God. Evolution is an adventure, filled with novelty and unpredictability; a designed and stable universe is not an adventure, and there is no true novelty or unpredictability in creationist theory. Following from self-organizational principles, evolution is a self-creative process. Top-down creationism views the universe, including life, as “other created”. Within evolutionary thinking, life is an interactive and transforming network of distributed power. Although life does possess an overall dimension of integration and wholeness, this wholeness is not determined by some singular controlling force or entity standing outside the universe.[271] Within a monotheistic top-down theory, life is a stable hierarchy controlled by a transcendent “One”. Purposive evolution, which would involve efforts to transform nature by the members of nature, would consequently conflict with a top-down controlled static universe. In essence, evolution and purposive evolution conflict with **static creationism** and a singular controlling God.

The heated contemporary evolution - creationism debate clearly illustrates the nature of this fundamental conflict.[272] Creationists have accused evolutionists of arguing that all of life is due to chance, which from their point of view seems impossible and spiritually depressing; evolutionists accuse creationists of practicing “pseudo-science” and attempting to impose religious dogma upon rationality and open thinking.[273] Creationists see life as a divine construction, the assortment of living forms set by God as described in *Genesis*; evolutionists see life as fluid. For a creationist, it would be a transgression on the divinely ordered nature of things to attempt to alter or change life.

Hence how we approach biotechnology depends upon our view of the universe and our cosmic view of life. Do we think that nature is a form written in stone that should not be tampered with, or do we think that nature is growing and changing? Do we think that the patterns of nature are set from above, or do we think that the living forms within nature, which would include humans, direct the course of development? The challenge of biotechnology in the future will be an ideological struggle as much as a technological one. Our world is still not evolutionary in its ideology; in many ways it is decidedly anti-evolutionary. Many people believe that there is a natural or divinely set order to things. In particular, the majority of humans still do not believe that human life evolved through a series of stages from more primitive life forms, and many believe that humanity is somehow the crown of creation, not to be tampered with or transcended. Such static notions of life and humanity run counter to the basic ideas and implications of evolutionary thinking. Consequently, it seems highly likely that the most significant battle to be fought in future biotechnology will be over the acceptance of evolutionary thinking and its implications. We will embrace and understand biotechnology if we embrace and understand evolution.

Perhaps what is needed is a new spiritual and religious view that places evolution in the center of its vision, since the bulk of opposition to evolution comes from traditional religions. Both Tipler and Hubbard attempt to provide such a synthesis of evolution and religion, and so did Teilhard de Chardin.[274] Interestingly, all of these writers have, in some form, supported the idea of purposive evolution. Religious thinking has accused science of leaving out of its account of the cosmos any sense of meaning and purpose for humanity. Yet, as we have seen, this view of science is Newtonian and dualistic. Humanity is not separate from the physical world, and the physical world is not a system of inert matter. As Smolin and others have argued, life and perhaps even intelligence fits within the physical cosmos. Moreover, purposive evolution provides a place of future significance for life and intelligence in the cosmos; humanity will help to determine the future evolution of the cosmos.[275]

Science and evolution, however seem to leave God out of the picture. The contradiction though between evolution and God is based on a dualistic theory of reality; God from above creates order and life below. Smolin describes such a view as an “unexplained explainer”. The idea of purposive evolution as applied to both biotechnology and artificial intelligence leads in a different direction, where higher forms of life and intelligence emerge within the evolution of the universe, and perhaps eventually lead to immortal life and a cosmic mind. If evolution is the journey or pathway to cosmic intelligence and immortality, then the apparent ideological conflict of God and evolution disappears, though we will need to revise our notion of God.[276] Perhaps the crowning achievement of Neo-biological civilization will be a theology based on the principles of life and evolution.[277] We will find a new cosmic meaning within such a theology.

I conclude the last section of this chapter with a discussion of contemporary thinking on evolutionary theory and the nature of life. As can be seen from the above comments, a dualistic mindset on reality leads to contradictions between religion and God and evolution and biotechnology. But as I have stated above and explain in more detail below, evolution and life are intimately connected. One cannot understand the nature of life without evolution. Moreover, biotechnology and purposive evolution are both inevitable and desirable, and as a general principle for understanding the future, evolution correctly describes the overall direction of change for life and humanity as well as the cosmos.

Different scientific and futurist writers, such as Michael Zey and Elizabet Sahtouris, have argued that there must be a “third way” to think about the origin and development of life that avoids the opposite flaws of a controlling designing deity and a mechanistic mindless process of chance, competition, and natural selection often associated with Darwin’s theory of evolution.[278] I think that evolutionary theory, though still in a state of controversy and debate, clearly goes beyond a “**chance and competition**” model of biological change. And as I stated above, God or some type of cosmic intelligence, can be conceptualized in a fashion that avoids the notion of a transcendent controlling deity that has already determined the future course of events in the cosmos. The key idea necessary for understanding contemporary evolutionary thinking and finding a “third way” to view the nature of life is reciprocity.

Let’s begin with the nature of life. Fossil records seem to indicate that life began on the earth approximately 3.8 billion years ago. To put this beginning in perspective, the earth is estimated to be around 4.5 billion years old. Hence, life started up rather quickly after the earth formed.[279] Even if we can roughly determine when life began, there is significant debate surrounding how it began and why. Dyson, as well as numerous other scientists, identifies the "**origin of life**" as one of the biggest mysteries of science.[280]

Still there are significant pieces of the puzzle that we seem to understand. First, life is continuous with non-life. The basic building blocks of life, carbon, oxygen, nitrogen, and other chemical elements were forged in the nuclear fusion within early stars, and set free when these stars exploded, propelling their interior core elements into space. These elements concentrated in the planets of our solar system during its formation. The elements of life, as well as the earth, are composed of stardust. Further, complex organic compounds, the constituent parts of proteins, also seem to form throughout space. In general, a significant amount of chemical evolution, necessary for the creation of life, took place in stars and empty space leading up to the emergence of life.[281] Further, life has absorbed into itself and utilizes numerous non-living minerals and metals, as essential ingredients in its metabolic processes; in general, life is interdependent with various chemical, geologic, and atmospheric dimensions of the earth. Life and its effects penetrate into the structures and dynamic processes of the earth, and in turn, innumerable inorganic chemicals and processes penetrate into the ongoing metabolic processes of life.[282] The chemical cycles and substances of the earth are interwoved with the chemical cycles and substances of life. Life is an open system, in a reciprocal relationship with the chemistry and inorganic dynamics of the earth.[283] Life emerged out of the **chemical evolution** and dynamics of the universe, and has stayed interwoven with the cosmos.

A second important feature of life, which also connects life with the inorganic and the cosmos as a whole, is the central role of **chemical cycles** in life. Innumerable relatively stable chemical cycles have evolved within the history of the universe, where sequences of chemical reactions form into circles with each reaction in the cycle leading to another reaction that eventually leads back to that reaction. A causes B, which in turn causes C, which in turn causes A to occur. Chemical cycles are examples of circular causality. The metabolic processes of life are relatively stable chemical cycles, much more complex than the more primordial chemical cycles in the inorganic world, but still extensions of these simpler circular reactions. As noted above, the chemical cycles of life are in fact, still intertwined with the various chemical cycles of the earth.

Also, similar to the general chemical cycles of the physical world, the metabolic cycles of life involve two reciprocal processes, corresponding to the roles of order and chaos in the overall dynamics of the universe. These two reciprocal processes are referred to as **anabolic** and **catabolic**, the building up of more complex chemicals from simpler constituents and the disintegration or breaking down of more complex chemicals into simpler ones.[284] Metabolism is the cycling of order into chaos and chaos back into order, which would also describe the two basic reciprocal processes at work throughout the universe. At the most holistic level, the anabolic – catabolic cycle involves the intake and subsequent elimination of materials and energy sources, the chemical construction of more complex chemical compounds occurring in the anabolic phase, and the consequent creation and elimination of waste products in the catabolic phase.

Hence at a general level, the emergence of life involved the evolution of complex chemical and physical reciprocities, as extensions of simpler reciprocities within nature and still ultimately remaining tied into these more fundamental reciprocities. Yet, what appears to have happened with life is that the various chemical cycles became self-maintaining and self-protective, forming semi-permeable boundaries around themselves to selectively control for both inflow and outflow. This controlled flow allows for the chemical complexities of life, bringing in the appropriate material resources and protecting the living form against external disruptive or destructive forces.

Life is a highly complex chemical self-organizational process. As previously discussed, nature in general exhibits a self-organizational dimension. Physical systems form, such as stars, galaxies, and planets, out of simpler constituents, where order builds upon itself. As Prigogine and others have noted, innumerable chemical cycles are self-organizational as well. Given the right chemical ingredients and a flow of energy, complex circular chains of chemical reactions will emerge in an environment.[285] Living forms are relatively stable integrated sets of chemical cycles. The boundary around the collective set of chemical cycles literally keeps the various necessary chemical ingredients of life bound together in close proximity and creates a state of disequilibrium with the surround.

A key feature within self-organizational systems is the dimension of **disequilibrium**. There are two important ways in which disequilibrium is critical to self-organizational systems. First, there is a significant difference between the inside of a self-organizational system and its surround. The sun, which is a self-organized system, has a much higher internal temperature than its surround. Life is clearly in a state of amplified disequilibrium relative to its surround. This state of enhanced disequilibrium is maintained by controlling the input and output of matter and energy through its boundaries. Also self-organizational systems will emerge at points where there is thermal disequilibrium creating a flow of energy. Life on earth evolved within an environment that is not in thermal equilibrium, the flow of energy from the sun toward the earth occurring because the sun is so much hotter that the space around it which includes the earth. There is a gradient of temperature, a source of higher energy levels and a sink for energy to flow into.[286] Hence, life emerged, as all self-organizational systems do, within an environment that was not in equilibrium, and created pockets of even more complex forms of disequilibrium.

Maturana and Valero refer to the defining self-organizational properties of self-creation and self-maintenance within life as **autopoiesis**.[287] Life creates and maintains a boundary that controls the types of exchanges with its environment, selectively taking in and releasing those necessary resources to create its component parts and maintain its boundary. Autopoiesis is a bootstrap phenomenon, a loop of interdependencies, holding each other up. As Valero states, a network of chemical reactions produces a boundary that constrains the network.[288] Yet to reinforce the continuity of life and the physical world, the origins of autopoiesis are to be found in fundamental processes in nature. Chemical cycles develop in the physical world, which are relatively stable and self-maintaining. Self-organizational systems emerge in physical environments that are in disequilibrium, creating even more disequilibrium or structured differences between themselves and their surround.

An apparent paradox about life is that it is actively differentiated from its environment, but it maintains this state of disequilibrium by interacting with its environment. Life is an open system and manifests the basic property of reciprocity, being distinct yet interdependent with the environment. Although Valero supports the idea that life is best described as a loop of interdependencies and he is critical of the input-output model of life[289], life is actually a set of internal cycles or reciprocities that, as I described above, are embedded within an ecological loop of reciprocities. The internal reciprocities, the various metabolic cycles of the body, create and support their integrity and distinctiveness relative to their surround by maintaining a set of controlled external reciprocities or cycles of exchange with the environment. It is loops within loops. Life may be self-organizational but it is self-organizational within the necessary context and support of the surrounding physical world.

The concept of a reciprocal open system also applies to the inner coordination of activity within each individual living cell. Although it is often stated that the genetic code within DNA controls the processes occurring within a cell, as Maddox points out, there is no central command station within a cell.[290] The activation of genes and the chemical production directions that follow are triggered into operation by changes in the surrounding protoplasm within a cell. DNA may instigate the creation of proteins within the cell, but it does not act like a simple top-down system issuing orders in some pre-determined, insulated fashion. Sahtouris, in a similar vein, states that the nucleus of a cell, which contains the DNA, doesn't control the cell but rather serves as a resource center.[291] Maddox describes the cell as a "self-regulatory democracy", a depiction that appropriately also fits a living form as a whole and sounds more like a network than an absolutist hierarchy. In effect, there are loops of interdependency within a cell.

If one finds interdependency and reciprocal loops within each cell, and between living forms and their environment, one also finds innumerable interdependencies among life forms within the entire biosphere. As Smolin notes, life traditionally has been defined as a system which exhibits metabolism, growth, and reproduction, yet this definition makes it sound as if one could have a single living system, if it would satisfy these three conditions.[292] Yet life on earth is an interconnected web, again a network of interdependent living forms that require each other for their mutual existence. I discuss in more detail the ecological nature of life in the next chapter, but it seems probable that life on earth emerged and spread as a web of mutually supportive forms. Again we see the bootstrap phenomenon at work, a reciprocal network or self-organizational process that created itself. On a related note, Sahtouris argues that when life appeared on the earth, the whole planet came alive, as a quickly enveloping web of ecological interdependencies.[293]

The ubiquity of chemical and other physiological cycles within living forms have led many scientists to highlight the rhythmic quality of life. According to Brian Goodwin, organisms are essentially rhythmic systems.[294] The different cycles of the body operate at different frequencies per unit of time, accounting for the innumerable biological clocks embedded within the physiology of living organisms. These different biological clocks though are entrained together, in so far as the various cycles of the body are integrated and coordinated into a coherent whole.[295] The basic phenomenon of reciprocities within reciprocities, of loops within loops, generates a highly complex and coordinated vibratory rhythm within the organism. Rhythmic oscillations show up throughout nature, from the subatomic to the stellar,[296] and have inspired various scientists and philosophers to describe both the universe as a whole and life in particular as a dance.[297] The metaphor of music applied to nature goes back to Pythagoras and Plato[298], and to whatever degree the metaphor is accurate points out another significant invariance of life with the rest of the cosmos. The dances, the rhythms, the music, and the clocks have become more complex as we move from atoms to galaxies to living forms, but the principle is still the same. Nature oscillates and cycles and builds rhythms onto rhythms, choreographing these motions into integrated wholes.

One central issue concerning the origin of life pertains to the respective roles of "**metabolizers**" and "**replicators**". Thus far, I have been discussing the significance of metabolic chemical cycles in the organization and emergence of life, but another often proposed defining characteristic of life is that it replicates or reproduces itself. DNA is the chemical system within life that fundamentally accomplishes this feat of reproducing itself by dividing into halves along its helical string and then locking into each half the appropriate nucleic acid matches. DNA carries the genetic memory of the life form, passing it on to succeeding generations. A debate within evolutionary theory has been whether the metabolic cyclic systems of life came first, or whether the replicating system came first.[299] DNA carries the genetic directions for the construction of proteins, the necessary ingredients that go into the various metabolic cycles, yet DNA can not accomplish its replicating function without the instigation and facilitation of various proteins. So we seem to have a "chicken and egg" situation or another bootstrap-like phenomenon. Various writers have proposed that the origin of life came about through some type of cooperative symbiosis that developed between progenitors of DNA and proteins, that is the replicators and the metabolizers.[300] The idea of symbiosis, which I discuss below in more depth, has become an influential concept in evolutionary theory, basically implying that reciprocities or interdependencies are created within the evolution of life. As I explained above, one of the most essential forms of reciprocity within life is the interdependent functioning of DNA and proteins within the cell. The self-organization of the first living cells resulted in the creation of a reciprocal relationship between replicators and metabolizers.

Smolin defines life as a self-organized and bounded set of chemical cycles, governed by a symbolically stored program, which is able to reproduce itself, including its program.[301] The stored program, in the case of life on earth, is the genetic code within DNA. Smolin wonders, as do other scientists, whether reproduction should be included as a necessary condition for life.[302] Still, Smolin's definition does highlight the significance of memory and stored information in understanding the nature of life, and connects life into the type of evolutionary picture proposed by futurists such as Kurzweil, where genetic memory systems, neural memory systems, and computer memory systems are all stages in the ongoing evolution of increasing information storage capacities within nature. The genetic code is stored information, the memory of life through the ages.[303] Looking at the entire biosphere of life on earth, what we see is complex order or pattern that is relatively persistent and stable across millions and billions of years, and yet this pattern thrives and maintains itself within a universe that in some ways fluctuates and could be very unsettling to the presence of life.

Life is not all persistence and stability. Life is not frozen. At the level of genetic replication, Maddox points out that a delicate balance between fidelity and variation is necessary for the survival of life.[304] Darwin, to recall, had noted that offspring show variation among themselves, and as a general principle in contemporary evolutionary theory it is assumed that random mutations in genes provide the ongoing variability needed for natural selection to work on creating new species. Pure genetic fidelity would not generate any biological evolution. At a general level, as scientists such as Smolin, Kauffman, and Prigogine have argued, life evolves at the boundary of order and chaos. Kauffman, in particular, believes that at the genetic level, there needs to be a balance of order and chaos. Too much order in the genetic code and life would freeze; too much chaos and life would fall apart.[305] Sahtouris points out that the "dance of life" is far from a perfectly coordinated phenomenon. There is harmony, but there is also discord and chaos throughout life, and this degree of imperfection is both necessary and, as I explain below, quite significant in understanding how life came about.

One comprehensive view of life, which highlights the central significance of both memory and loops of activity, is Murray Gell-Mann's theory of complex adaptive systems. The expression "complex adaptive system" is a popular and pivotal designation used at the Santa Fe Institute to describe the nature of living forms, and Gell-Mann's theory derives from thinking and research at the Institute.[306] In outline form, Gell-Mann describes a complex adaptive system as a system that stores **memory schema**, which are summaries of regularities about past environment data. These systems generate behavior based on stored schema as well as presently existing data. A complex adaptive system registers through feedback the consequences of its actions and modifies its schema based on these results. According to Gell-Mann, this modification of memory schema, based on actions and their effects, is in effect learning or adaptation. Hence, there is an interdependent loop between memory and behavioral effects, each influencing the other. Through this process of output and feedback, the system's memory changes or evolves.

Although the genetic code of a single living organism does not change as a consequence of the effects it produces on the environment and feedback from these effects (there are no acquired genetic traits) over successive generations of variable genetic codes, those variations that lead to the perpetuation of the species are preserved and those variations that do not lead to survival are eliminated. This process of evolution or change occurs through trial and error. Hence, the genome of a species does functionally learn and it retains as genetic memories those structures that afford survivability. Higher levels of complex adaptive systems, such as a nervous system, a cultural system, or a AI system, show greater flexibility and can record the results of their actions and change their presently existing schema or memories. These systems show acquired characteristics and are usually described as having the capacity to learn. But even for the more fundamental genetic system of life, Gell-Mann sees learning (changes in the genome) occurring across generations due to feedback effects on the survival rates of variations of the genotype. In the most general terms, biological evolution through the natural selection of certain genetic variations is a form of learning based upon interaction with the environment.

Gell-Mann sees learning, and consequently evolution, as a form of adaptation with the environment. During learning information is acquired about the environment and hence the living form's information base and memory comes more into alignment with the environment. Further, Gell-Mann views adaptation as a form of equilibrium with the environment. To adapt means to change in accord with factors in the environment. In so far as living forms remain relatively stable and interconnected with their environment and have "learned" how to cope with the various exigencies of the physical world, living forms exist in a state of equilibrium or balance with their environment.

Although there is probably a significant degree of truth in this view of life, there are certain qualifications that need to be made. As stated above, living forms, possessing protective boundaries, are to a degree differentiated and separated from their surround, existing in a state of disequilibrium with their environments. Life does not simply conform to its surroundings; if it did it would be no different than the world around it.

There are those scientists, such as Valero, Sahtouris, and Goodwin, who argue that adaptation and equilibrium are not appropriate concepts for describing life. It would be more accurate to say that living forms actively find a way to exist, to "make a living", often by modifying the environment rather than adapting to it. Consider the ecological concept of a niche. A **niche** is a set of conditions in the environment that would support the existence of a life form. There are as many different niches as there are life forms. A niche, in the general sense, provides an opportunity for living. Species are said to "fill niches". Yet, even Gell-Mann admits that organisms create niches as much as fill them. Life to some degree alters the environment to support its own existence.[307] Life creates reciprocities, self-organizing networks of interdependencies, which envelop and transform the environment. Although there is clearly some dimension of life "fitting" into the various niches and environmental conditions of the earth - life conforms - there is also a dimension of active orchestration of the physical world by life. The simple idea of adaptation needs to be replaced with the idea of reciprocity, which includes adaptation but also manipulation.

Still, Gell-Mann's general model of life does contain some noteworthy points. Life involves both a linear and cumulative function and a circular reciprocal function. The linear function is the perpetuation and continued development of schema. The circular or reciprocal function is the ongoing interaction between schema and environmental feedback. The reciprocal function, in fact, is what guides or influences the further development of the schema, but of course, the schema, according to Gell-Mann, are what guide the actions of an organism. Schema can be genetic, influenced in their development by the natural selection of preferable variations across a sequence of generations. Schema can be acquired memories in an individual organism influenced in their development by sensory-motor interactions with the environment. Interestingly, to recall, the coupling of cumulative and circular processes also occurs in the symbiotic relationship between "replicators" and "metabolizers". In fact, one could say, to make the connection even stronger, that interaction with the environment is a form of metabolism, of identifying, acquiring, and utilizing resources integral to the maintenance of life. In general, this two-fold model of cumulative growth and reciprocal interaction can be applied to a broad range of natural systems from the biological to the psychological, cultural, and technological.

Making a strong connection between evolution and learning is another important feature of Gell-Mann's theory of life. His theory unites different levels of organization in nature by highlighting the pervasive presence of information storage and acquisition in evolution. Gell-Mann's theory provides a way to explain the idea that evolution evolves. If evolution is learning based on interaction with the environment, then evolution evolving means the development of better ways of learning. Genes "learn" through random trial and error across generations; minds can learn through thoughtful experiment and creative insight.

Various scientists and futurists support the connection between genetic evolution and memory and learning. To recall, Kurzweil has argued that evolution involves increasing information storage and processing power being concentrated into the structure of matter and energy.[308] He sees life as accelerating the pace of evolution in nature through its capacity to record its achievements in genes. The capacity for computation, to remember solutions to problems and to solve new problems, increases with life. This view of genes is very similar to Gell-Mann's theory that genes are a form of memory and information storage across generations. In the earlier chapter on science and technology, I described the general "information processing" model of the universe. Kurzweil and Gell-Mann's emphasis on describing life, if not nature as a whole, as a system for storing information and acquiring new information, falls into this general model.[309] The strong comparison drawn between artificial life and artificial intelligence further reinforces the memory and learning model of genetic evolution. Life evolves by acquiring intelligence, in the form of memories and computational abilities, stored in its genes.[310] Walter Anderson goes so far as to define evolution as a learning process, involving the acquisition, use, and communication of information.[311]

Genetic information storage and learning can be identified as a distinguishing feature of life. As can be seen from the above discussion on the nature and origin of life, there are numerous continuities and connections between life, the physical world, and higher types of adaptive systems. Maddox has stated that there is no clear defining criterion for life.[312] Yet, from Gell-Mann's theory of complex adaptive systems, we could argue that life is distinguishable from non-living systems in that life demonstrates genetic learning across generations. This form of learning though is basically what biologists call evolution through natural selection. Hence, what distinguishes life is that it evolves through natural selection, which is a form of learning through trial and error, where the trials are specific variations of genotypes. This point though must be placed in perspective, since the universe, before the emergence of life on earth, showed considerable evolutionary growth. The general process of evolution is not peculiar to life, and as noted above, in many ways life brings with it the materials and dynamics of the inorganic world. Also, the process of self-organization, which many theorists see as a critical element in biological evolution and natural selection, has occurred throughout the history of the universe.[313] What may distinguish life is that it seems to have enriched and enhanced the evolutionary process through reproduction and genetic learning. It replicates itself with a certain amount of variability and evolves through the natural selection of the most successful variations. Just as systems that are able to learn within an individual lifetime represent an advance over genetic systems that could only learn across generations, perhaps life was an advance over the self-organizational evolutionary dynamics of the inorganic physical world. Prior to life, there were no physical systems that evolved through cumulative learning across generations. As such, life is a stage in the evolution of evolution.

Thus, it appears that evolution is an essential quality of life. Given our present understanding of the nature and origin of life, it would make no sense to talk about life in a non-evolutionary context. There are forms of life that do not appear to have evolved much, if at all, over extended periods of time, but clearly the whole web of life on the earth has been evolving since it began almost 4 billion years ago. Life is not static. Even if we were to adopt some different theory of biological evolution than natural selection, it does not seem that a theory of static creationism captures the essence of life. Further, though there are physical systems that have not changed or evolved for billions of years, for example, the proton or the hydrogen atom, the overall thrust of the cosmos, of all of nature, has been evolution and change. Although, as I will explain below, there is some dispute on this point, all of nature from the physical to the cultural and technological shows evolution and change.[314] To see the species of life as static, created as they are in their present forms, and set within a cosmos that is not static, seems bizarre. Additionally, complexity within the universe seems to be connected with the quality of fluidity, and life is clearly a complex reality. As described above, as we move from physical to biological to psychological and cultural, the capacity for evolution and change seems to increase. Life, as one level of complexity within the hierarchy of nature, shows a degree of flexibility above more primitive physical systems. The capacity for evolution within life, as explained above, has evolved beyond the capacity for change in lower levels of physical complexity. Life fits in the general pattern of increasing evolvability across increasing levels of complexity.

Since the process of evolution seems integral to life, I want to focus directly on biological theories of evolution and complete my survey of contemporary thinking on this process. In the above discussion, reciprocity was a central principle in understanding the dynamics and organization of life. In turning to evolutionary theory, reciprocity again will be a critical theme. In fact, based on a variety of additional points to be made regarding how reciprocity figures into contemporary biological and evolutionary science, it will become even more apparent why life cannot be adequately understood in static creationist terms. Reciprocity is a key principle in understanding biological evolution. And as I stated earlier, reciprocity provides a "third way" to conceptualize life and evolution that avoids the extremes of top-down creationism and chance and competition.[315]

First, the role of **chance** and **randomness** in evolution should be put in perspective. It is probably a mistake to think that anyone argues that evolution is a result of pure chance. All evolutionary scientists, including even Darwin, invoked some type of ordering principle in explaining evolution. Still, chance and randomness do play a critical role in understanding evolution and it is important to identify the possible ways these factors may be involved in evolution.

Murray Gell-Mann states that evolution is a result of the basic laws of nature coupled with the accidental occurrences of history. The laws of nature provide general parameters and constraints and the accidental enters the picture where chance events select for certain variations in life over others. These chance selections become "**frozen accidents**". They set the future direction of all life forms that follow from the fortunate variations. The right-handed twisting of the DNA helix in almost all life, as opposed to left-handed DNA, is perhaps a frozen accident, as well as the particular four nucleic acids included in all DNA molecules. Why is all DNA the same? It may be a frozen accident. Gell-Mann's emphasis on the significance of frozen accidents in life derives in great part from his interpretation of the implications of quantum theory, which implies a probabilistic distribution of possible outcomes in any line of causality. What determines which possibility is realized is to some degree random. Hence, at a fundamental physical level, because of the probabilistic nature of quantum reality, there is an irreducible element of chance in everything, which would include life.[316]

If one gets hit on the head by a falling meteorite while walking down the street and is killed, it is reasonable to say, unless one is superstitious, that such an event was an accident. Yet such a chance occurrence obviously has a big impact on one's life. Yet what if a large comet were to strike the earth and wipe out innumerable species of life, many of which were highly successful in "making a living" on the earth? Such an event would drastically affect the future evolution of life on earth. It is hypothesized that such an event occurred approximately 65 million years ago, ending the reign of the dinosaurs. The dinosaurs seem to have been the victims of bad luck, rather than some inherent flaw within them (though there is controversy on this point).[317] Stephen Jay Gould, in particular, has emphasized the significance of chance events in the evolution of life, arguing that often those species which persist are not necessarily the best adapted or most highly evolved, but those species that were in the right place at the right time. As one example, in examining the great variety of life indicated in the fossil records of the Burgess Shale, he can find no apparent evolutionary reason why most of the specimens found turned out to be dead ends in evolution.[318] One can easily imagine personal, ecological, and even cosmic accidents occurring that would clearly alter the future evolution of natural systems at almost any level of reality.

Gould also thinks that there are beneficial accidents, where some particular biological structure or capacity was naturally selected because it served some adaptive value, and then once developed, the structure or capacity would end up fortuitously being able to serve other functions never selected for. A case in point is the large brain of humans. There are many things we can do with our large brains, such as reading and writing that our accidental benefits of having a large brain. The capacities for reading and writing were not selected for because of some adaptive value in the environments of our early ancestors.[319] The capacity for planning and foresight within our brains may be a by-product of the natural selection of neural circuitry for aiming and throwing objects.[320] Gould argues that there are numerous "**spandrels**" in nature, accidental by-products of evolution that may not have served any adaptive value.

Darwin argued that random variations in offspring provided the necessary variety and element of competition to set the evolutionary process in motion. Without variety in offspring there would be no change. Recall Maddox's point that a certain amount of variability in the copying of DNA sequences is essential; without it a species would remain frozen. Gell-Mann similarly underscores the importance of "noise" in evolution. If the genotype does not undergo a certain amount of ongoing variation it can get stuck in a less than optimal adaptive fit with its environment.[321] Living forms, including humans, are creatures of habit, and a mode of behavior that may provide some level of sustenance may not be changed. Assuming that the genetic codes of species are "habits" of genetic memory, then continually juggling the code will keep the species open to new possibilities of making a living. Variation keeps the species open to the possibilities of further evolution.

Some would argue that the variations that occur in genetic reproduction are not simply a matter of chance.[322] Perhaps the molecular structure of DNA has evolved some internal mechanism for shuffling its cards in a way that maximizes the possibilities of beneficial changes. It has learned how to learn. Even Richard Dawkins, who believes that the natural selection of random variations in genes is the fundamental mechanism of evolution, acknowledges that there may have been an "**evolution of evolvability**" throughout the history of life.[323] But in the case of Dawkins, chance and randomness would still be at work, since those genetic structures that maximized beneficial variability would be a product of the natural selection of variations in genetic codes that randomly rearranged their genes. Michael Zey, on the other hand, believes that the variability in genetic reproduction is being moved by some order and intelligence creating principle, though he does not identify such a principle with a transcendent deity. Lynn Margulis argues that random variations or mutations are not the main cause of evolutionary change and do not answer how variability arises in life.[324] Sahtouris argues that although there is randomness in genetic reproduction, accidents tend to get repaired by the genetic mechanisms of life. Instead of viewing evolution as a mechanical process of random trial and error, she sees evolution as possessing a natural intelligence, sounding similar in her arguments to Zey.

Still there are many scientists, such as Dawkins and others, who are advocates for the **Neo-Darwinian** theory of evolution, emphasizing that the genetic variations in offspring are a consequence of chance or randomness and not due to some being or force from above guiding the production of new genotypes.[325] Dawkins, in fact, sees a Darwinian evolutionary theory as the only scientifically plausible alternative to some type of divine intervention or top-down control model of evolution and life. It is this view of genetic random variation, along with a random assembly theory of DNA molecules in the pre-biotic environment, which is characterized by creationist critics of Darwinian theory as explaining evolution and life through chance.[326]

Yet for Darwin and his contemporary advocates, chance only provides the raw materials of evolution. Within this theory of evolution, natural selection of adaptability and fit with the environment provides the ordering principle. The environment possesses a great deal of order and regularity. Life is molded by this environmental order. Using Gell-Mann's model of complex adaptive systems to help to illustrate this point, genetic structures have learned and assimilated the order of the environment, forming schema through trial and error. Life adapts and conforms to the order of the environment.

Whether or not this view of evolution is true or the whole story, some element of chance, if not chaos, would appear to make sense and serve a function in the evolutionary process. From a purely logical point of view, only randomness provides an unconstrained arena for genetic variations. As Kauffman argues an element of chaos in the generational replication of genetic codes prevents a species from becoming frozen. To recall, for Kauffman life exists at the border of order and chaos. Kurzweil makes a similar but broader statement in arguing that it is chaos that supplies the necessary variations for the universal evolution of order.[327] From earlier discussions of order and chaos in the physical world, it seems clear that the evolution of order depends upon chaos, as both its source of energy and its stimulus for reconfiguring into higher levels of complexity.[328] Prigogine, in fact, in his theory of self-organization specifically highlights the theme of "**order out of chaos**".[329] Gell-Mann, reinforcing Kauffman's point that life is a balance of order and chaos, demonstrates that the high effective complexity of life requires a mixture of order and chaos. Extreme order (or uniformity) and extreme chaos (or variability) produce minimal effective complexity.[330] In general, chaos and randomness show up at the quantum, thermodynamic, genetic, and ecological levels. Whether there are other ordering principles at work in evolution besides natural selection, evolution seems to be a mixture, in fact, a reciprocity, of the forces of order and chaos.

The related concepts of **natural selection**, **competition**, and **adaptation** have been central themes in evolutionary theory for the last century, and are often associated with Darwinian and Neo-Darwinian views of evolution. All three concepts, for a variety of reasons, have been debated and questioned.[331] Is natural selection the only ordering mechanism at work in evolution, as supporters of Darwin's theory such as Dennett and Dawkins contend? Can adaptation completely explain the present population of living species and all the various structures and functions that they possess? Is evolution simply based on competition among different variations in genotypes and different species over resources and available niches?

Beginning with the concept of adaptation, Gould argues that Dennett, Dawkins, and other traditional evolutionists are mistaken in thinking that all present species and biological processes can be explained through adaptation. To recall, Gould believes that ecological chance and accidental evolutionary by-products ("spandrel") play a significant role in what we observe in biology today. But also, following the thinking of Sahtouris and others, life does not simply conform or adapt to the environment, but actively modifies the environment to support its existence.[332]

Natural selection is connected with the concept of adaptation in that natural selection is supposed to select for those genotype variations or species that are most adapted to the environment. In this case, adaptation to the environment would mean being able to survive and produce offspring. But following from the previous paragraph, a species might persist because it has modified its environment, rather than adapting to it, or a species might survive because it was in the right place at the right time, and not because it was better adapted than other species that were victims of bad luck. Why did mammals make it through the mass Cretaceous extinction and dinosaurs did not? Were they naturally selected for because they were better adapted to their environment than the dinosaurs? An observer at the time of the Cretaceous period might have said that the dinosaurs clearly appeared to be the more successful and better adapted group of animals, given their domination of the ecology of the earth.

The effective range of natural selection also gets debated. Dawkins is well known for his "**Selfish Gene**" hypothesis, which states that natural selection works at the level of genes and that living forms are "robot survival machines" for the genetic programs that they carry.[333] In essence, the **phenotype** (the body of the life form) serves the **genotype** (the DNA molecule of genes); life forms have bodies because bodies benefit the survival and reproduction of the genes. Whether one takes such an extreme view regarding the relationship between DNA molecules and biological bodies, many biologists support the view that natural selection works exclusively at the level of genes.[334] Other biologists, such as Gould and Niles Eldredge, believe that natural selection works at all levels of the biosphere, from genes to phenotypes and species population.[335] We have already noted that the general process of evolution seems to operate at all levels of nature, from the subatomic to the cosmic, and Gell-Mann has applied his model of complex adaptive systems, which includes the process of natural selection, to multiple levels of reality. Dawkins even applies the concept of natural selection to memes, which are units of cultural information, and Stock sees a similar process at work within the product and model lines of human manufacturing and industry.[336] Natural selection has even been applied to the evolution of universes.[337]

The most significant question surrounding natural selection though is whether it is the fundamental ordering principle at work in evolution. Natural selection is connected with the theme of competition, and this connection has supported the application of evolutionary theory to social thinking, in the form of **Social Darwinism.** Within any population of natural systems there will exist variety (for example, among the offspring produced by parents of a particular species) and within the environment for this population there will exist resources as well as dangers. The different members of the population, if we follow Darwin's biological thinking on this matter, will need to find sufficient resources and avoid dangers if the members are to persist and reproduce. Yet, what if the resources are limited and not all the members can make a living? Then individual members of the population will end up depriving some other members of resources if such individuals attempt to procure sufficient resources to persist. Those members that obtain sufficient resources and avoid dangers will persist, while less fortunate members will fail to persist and reproduce. This is a zero-sum game, where one member's gain is another member's loss.[338] Thus it appears that competition among the members, where there are not enough resources to go around, is a necessary component of natural selection. Members compete for resources and compete to exist; natural selection is simply the result of this competition. If competition did not exist there would be no natural selection, since all variations would survive. Hence, inspired by the concept of natural selection and the slogan "**survival of the fittest**" which followed, competition became a central theme in Social Darwinism and various political and economic models of progress. Competition fueled progress in nature, and for social and economic thinkers inspired by this idea, competition was also necessary and beneficial in social evolution. The question, though, that has been repeatedly raised, across numerous areas of scientific and social thinking, is whether competitive forces are the only forces at work in evolution. Some biologists would even argue that the competitive model doesn't explain life at all.[339]

The counter-argument to competition and natural selection basically revolves around the theme of integration. The counter-argument contends that evolution also occurs due to integrative forces. Beginning at the physical, chemical, and cosmological levels, self-organizational processes have been identified that support the creation of numerous complex systems.[340] Self-organization in nature is fundamentally an integrative process. Basically, through self-organization, collectives of simpler systems throughout nature aggregate and coordinate into integrative more complex wholes.[341] The universe in its evolutionary history has built up a hierarchy of integrative wholes. As Koestler described this hierarchy, nature is composed of holons, where natural systems are both parts of greater wholes and wholes consisting of parts.[342] Further, when integrative systems emerge in nature the whole will exhibit properties not contained in the parts.[343] Also, integrative systems are creative and self-organizing, showing novelty and self-determination, in so far as they transcend the qualities of the parts and are a mutual construction of the parts. The term "self" in self-organization is meant to highlight the fact that the system organizes itself rather than being organized by something from the outside. Self-organization is discussed in more depth in earlier chapters, but the main point to make in the present discussion is that within the physical world, before we get to the emergence of life, there is an integrative process at work that generates evolution and order.

As I introduced earlier, Kauffman and numerous others argue that biological forms evolve not only through natural selection but through self-organization as well.[344] Self-organizational processes extend from the physical world into the biological world. Kauffman for example notes that convergent flows of activity, which generate self-organization, occur across all levels of nature. Gravity, as a force that produces convergence, generates integrative evolution, resulting in the self-organization of planets, stars, and galaxies.[345] He points out that within life there are also convergent flows of activity.[346] Kauffman sees convergent and integrative forces at work in the activity of genes, through the interaction effects of genes.

There are other examples within life of convergence and integration as well. As I explained earlier, metabolic cycles are integrative, self-organizing chemical systems. Valero describes the overall integrity of life as integrative and self-organizing, where the mutually supportive network of parts generates a boundary defining and containing itself.[347] Farmer sees the symbiosis of replicators and metabolizers as a prime example of self-organization in the evolution of life. Life literally pulls itself together.

One of the most well-known and influential critics of the competitive, natural selection model of evolution is the biologist Lynn Margulis. Margulis has convincingly demonstrated to many scientists the importance of **cooperation** in evolution.[348] In many ways, cooperation has the opposite meaning to competition, and cooperation is clearly an integrative, rather than divisive force. Margulis presented in her work a compelling case that the origin of nucleated (**eukaryotic**) cells in evolution involved the cooperative symbiosis of non-nucleated (**prokaryotic**) cells. Within the eukaryotic cells of a human body are not only human DNA molecules within the nucleus but also mitochondria within the cell body that have different DNA molecules. The human cell appears to be a merging of two different species. In fact, mitochondria can be found in both animal and plant eukaryotic cells. Mitochondria serve an essential metabolic respiratory function within eukaryotic cells and are provided with a hospitable intercellular environment in which to live.[349] There is a **symbiosis**, each life form benefiting from the presence of the other.

But the list of types of symbiosis and inter-species cooperation does not end with simply the merging of prokaryotes into eukaryotes. Multi-cellular organisms are cooperative colonies of individual cells that became specialized and interdependent some time prior to the Cambrian Period (590 – 505 million years ago). Multi-cellular organisms play host to numerous bacteria that exist in symbiosis with them. Also at the inter-species level, various combinations of multi-cellular life forms, including flowering plants and insects, exist in cooperative and mutually supportive relationships. Lichen are a symbiotic combination of algae and fungi, two life forms from different biological kingdoms.[350] Finally, at the ecological level, whole populations of numerous species exist in interdependency, where the destruction of particular members of the ecosystem will threaten, if not terminate the existence of interdependent members in the ecosystem. As explained earlier in this section, life is a web of interdependencies. This web extends from integrations of different species within cells to collectives of cells forming multi-cellular creatures to creatures forming parasitical and symbiotic relationships and whole ecosystems. As Sahtouris has described the pattern of life, it has a fractal quality, with parts within parts within parts, and the parts at each level forming integrative, mutually supportive wholes.[351] Life does not appear to be just a set of distinct life forms and species competing against each other. Rather it looks like an intricate and vast integration and cooperation of innumerable forms of life.

The argument from Margulis and others, such as Sahtouris, Gell-Mann, and Smolin, is that life evolved through the creation of cooperative and convergent relationships as much as through the natural selection of competing variations in species and different life forms. This integrative network presumably evolved through the creation of cooperative relationships within the multi-level fabric of life. Margulis argues that the most of the significant advances in evolution came from mergers into cooperative relationships. The creation of cooperative and integrated wholes in life can be seen as a basic extension of the self-organizational process throughout all of nature. The web of life is a self-organized reality, integrated and symbiotic. Yet it should be noted that cooperative mergers in life have a transforming effect on the members or parts of the newly created wholes. The parts of the whole become interdependent. For example, the individual cells within multi-cellular organisms could not continue to exist if separated from the whole. Even if some type of primitive replicating system evolved in the early stages of life, the DNA system that presently exists in eukaryotic cells could not exist on its own, without the support of various additional molecules and processes contained in the cell. The parts of an open system possess qualities reflective of being members in the whole. Sahtouris states that when biological systems integrate into cooperative wholes, they are changed and become more specialized, giving up some level of autonomy in order to benefit from the cooperative merger.[352]

Because life involves such a vast array of interdependencies and symbiotic relationships, the idea that evolution works on individual genetic lines seems at best a half-truth. Throughout the book I have described the phenomenon of reciprocal co-evolution, where interdependent realities evolve together as opposed to separately.[353] Even if we look at the idea of natural selection, which seems to imply that evolution is a form of competition among individuals, what is presumably being selected for is adaptability to an environment. Yet, what is this environment that genotypes are adapting to? Quite significantly it consists of other living forms with their own evolving genotypes. All living forms are embedded within a biosphere of other living forms, each attempting to make a living. Even if we assume nothing but passive or reactive adaptation in life forms to changes in the environment, we should see that evolutionary changes in one species will instigate reciprocal changes in other species that interact with them. But evolutionary change is also proactive in a sense, in that a change can occur that allows a species to affect or modify its environment in a way that allows for greater chances of survivability. For example, a predator species develops the capability to fool or entice prey to come close to it so they can be captured and eaten, or a prey species develops a protective chemical that repels the advances of predators. Obviously, such evolutionary changes could instigate counter adaptive measures in the implicated species. Even for something as apparently conflicting as the predator – prey relationship, evolutionary history has shown an ongoing tit-for-tat reciprocal evolution of measures and counter-measures driving the mutual evolution of both sides of the equation.

At a more general level, it is important to see that not only do individual species evolve but **ecosystems** evolve as well. All the members of an ecosystem exist in a state of interdependency, and throughout the history of life, as well as in artificial life demonstrations, holistic transformations of entire ecosystems periodically occur.[354] Evolution shows collective holistic pulses. The various periods of life on earth are identified and distinguished in terms of fundamental ecological transformations and the emergence of new integrated collectives of living forms. The mass extinctions within the earth's history are just the other side of mass ecological creations. Not all individual species change or become extinct in these holistic transformations, but the biosphere of the earth and its assortment of different ecosystems and species is significantly altered as a whole.[355] New webs emerge, carrying with them some of the past but introducing many new species.

The concept of reciprocity provides a general principle for organizing and understanding the various aspects of the evolutionary process. First, from the above discussion, the integrative and cooperative aspects of evolution involve the development of reciprocal interdependencies and these interdependencies continue to evolve via reciprocal co-evolution. Self-organization weaves and evolves reciprocities. Basically, the plethora of "bootstrap" phenomena, throughout the biosphere, is integrated reciprocities; the parts have become inextricably tied into each other's realities. Order in nature often arises through the integrative convergence of simpler systems, and this same phenomenon can be observed in life, where collectives of simpler systems form into more complex biological forms. To recall Kurzweil's theory of evolution, order builds on itself; in Gell-Mann's theory, complexity builds on itself. This aggregative dimension of evolution generates new reciprocities within the parts of the newly created integrated systems. Earlier, I described the reciprocity of order and chaos in the fabric of life, which is an evolutionary extension of the reciprocity of order and chaos embodied in all self-organizational systems in nature. The balance and weaving together of order and chaos in life allows for both fidelity and continuance across generations of life and sufficient variability to fuel additional developments in evolution.

The relationship of order and chaos in evolution leads us to another fundamental reciprocity that provides a way to connect natural selection and self-organization, as well as the phenomena of disequilibrium and interconnectedness in nature. Scientists such as Sahtouris and Gell-Mann, among others, argue that both competition and cooperation are significant in evolution. For Sahtouris, in particular, competition and cooperation are the two sides of the evolutionary process.[356] Sahtouris describes an ongoing oscillation of competitive and cooperative motions throughout the history of life. She contends that each new cooperative merger in the history of life was instigated by a preceding period of escalating competition. The competitive side of evolution inevitably pits different species against each other over issues of survival, thus driving their mutual evolution; the cooperative motion in life brings species together for their mutual benefit and survival. Evolution moves through both "**win-lose**" and "**win-win**" scenarios. Sahtouris states that cooperation brings with it a relative loss of autonomy as life forms increasingly specialize within a newly created collective whole in order to serve the whole, but cooperation equally brings greater security and probability of survival.

It is historically and theoretically interesting to note that this view of competition and cooperation in life follows the Hegelian-Empedoclian philosophy of **opposition** and **synthesis**, or hate and love, in describing the overall dynamics of nature and reality. Competition produces opposition and cooperation produces synthesis. In competition the parts assert their individuality at the expense of other parts; in cooperation the whole asserts its value to benefit all the parts. In the philosophies of Empedocles, Hegel, and Taoism, the flow of reality has been represented as a reciprocal oscillation of unification and differentiation. Sahtouris describes the ongoing evolution of life in similar terms. Differentiation within the whole leads to competition, which instigates a counter-movement toward cooperation and synthesis and the cycle begins again, yielding further evolution and change. The whole and the parts continue to evolve together.[357] This is another example of reciprocal co-evolution, except now it is between the whole and the parts, instead of among the various parts within the whole. To recall, from my discussion of self-organizational and complexity theory in Chapter One, both the whole and the parts as well as the parts among themselves show the property of reciprocity.

Competition and cooperation connect with the phenomenon of **divergence** and **convergence** in life. Random variations in offspring and natural selection generate divergence and radiation of genetic lines, whereas symbiotic cooperatives bring species together into mutual compatibility. Margulis identifies convergence and divergence as the two fundamental ways in which new species arise, though she believes that genetic divergence has been disproportionately emphasized in explaining evolution. The dual phenomenon of convergence and divergence, as I discussed above, are fundamental dimensions of motion within the physical world, relating to the processes of order and chaos. Physical systems organize through integration and convergence, whereas divergence leads to disintegration and the loss of order. Divergent and convergent forces are interwoven into the fundamental dynamics of individual living forms as well. Anabolic processes are convergent flows, whereas catabolic are divergent. Within life there is a building up through integration and a tearing down through disintegration. This convergent-divergent process in metabolism is in fact integral to life and another significant reciprocity embodied in the dynamics of biological systems. The catabolic process releases energy used to create and maintain, through anabolic processes, the various structures of the living organism. In so far as living forms ingest other living forms to survive, the general process of digestion, which provides the raw materials for anabolic constructive processes in the organism, works by breaking apart the ingested living forms. At the most basic level all of life depends upon a divergent flow since plants survive by taking in light energy from the radiating sun.

To recall, one of the most interesting paradoxes about life is that living forms exist in self-maintained states of enhanced disequilibrium relative to their surrounding environment, but are only able to achieve this degree of separation and individuality by interacting with their environment. All of life is connected with the environment, which includes, in particular, the living component of the environment. So the balancing act in this ecological relationship is between individuality and connectedness. Life is a collection of highly complex individuals because life is a web of highly complex interconnections. Thus there is a reciprocity of individuality and togetherness, of disequilibrium and equilibrium, of autonomy and interdependency within the fabric of life. This dynamic reciprocity of individuality and togetherness is, in fact, just a different way of describing the fundamental reciprocity of the whole and the parts within the web of life.

One other reciprocity embodied within evolution pertains to the double-aspect effects of both natural selection and self-organization. Each process produces both unifying and diversifying effects on the evolution of life. Although natural selection is connected with both competition and the divergence of multiple species off of a single common ancestor, natural selection also moves species into closer compatibility with their environments. Recall that adaptation can be viewed as a form of conformity and equilibrium with an environment, and that in so far as genetic evolution can be viewed as a form of learning, whereby the regularities of the environment are encoded into genetic schema, then natural selection moves species into closer alignment with the environment, which of course, would include other species. On the reverse side, symbiosis and cooperation, in so far as they are types of self-organization, generate increasing specialization and differentiation within the collective of integrated cells or organisms. Consider, for example, the cells of a multi-cellular organism. Although multi-cellular organisms evolved from colonies of increasingly interdependent single cell creatures and all the cells within a multi-cellular creature share the same DNA code, the cells within the organism have differentiated into an incredible variety of different forms and specialized functions. Natural selection therefore generates both integration and differentiation, and self-organization produces the same dual effect.

Given this overview of the various connections between biological evolution and reciprocity, consider again the creationist – evolutionist debate on the origin and makeup of life. The creationist argument assumes that the whole present array of living forms was created by some higher or transcendent power. Life is static and “other-created” from this perspective. It is a dualist theory of life. Yet as I have described in detail, life is an interdependent web, filled with innumerable reciprocities. Each part and dimension of the web is interactive with other parts and dimensions. Events within the web instigate other events within the web, and there is an ongoing reverberation of effects perpetually rippling through the entire biosphere. Such a system is totally at odds with the hypotheses that species of life were created by something separate from life and that the system is fundamentally static. The components of the biosphere are not absolutely separate and because of their interdependency, life forms keep influencing one another to change. The species within the system are continually adjusting to the presence of other species. As Gell-Mann points out, every adaptation within one life form, in reaction to some change in the environment, instigates other adaptations within other life forms. It would be difficult to see how such a system could ever reach a state of equilibrium.[358]

The biosphere is a self-stimulating system, which in fact leads to **self-creation**. If the system was created and controlled from a top-down mechanism, one could understand how it could remain static. To recall, Kelly noted that absolute hierarchies are inherently rigid. Life though, to some significant degree, is a network of active systems and interdependent processes. In essence, a dualist perspective on life produces stasis; a reciprocal reality generates change, and the biosphere is clearly a reality of reciprocities. There is no way around the basic fact that life grows.

The idea of reciprocity can be traced back to ancient theories of balance and the cycles of nature. Such early theories viewed nature as ultimately stable, for each motion or effect led to a counter-motion or effect, returning nature to its starting point. Reciprocities, such as those in metabolic chemical cycles, create such stabilities. These stabilities are dynamic equilibria, rather than static realities. But such stabilities both draw upon the environment for energy to maintain their rhythmic oscillations and produce effects back out into the surroundings. Further, in the evolutionary history of life, as well as the universe, such dynamic equilibria are emergent realities. They are not set in stone, but they evolve through self-organization and must have some effect on the surrounding environment to maintain their order. They are open systems. Stabilities are achievements rather than givens and they are interdependent with their surrounding environment.

More generally, Yin and Yang are not separate realities. Each reciprocity in nature is an interdependent reality, where each pole reflects the co-existent state of the other. If one dimension or pole is altered, the other is altered as well, which instigates a further change in the first pole. Recall Gell-Mann’s point that every adaptation of one member within an ecosystem to other members in an ecosystem instigates new adaptations in the other members. It seems to me that because the parts are dynamically interdependent, they cannot hold still. They keep pushing each other along to change in new and different ways.

Therefore, based on the above considerations, I would propose that the "third way" to explain the evolving order and complexity in life is to argue that it is self-created and self-amplifying. It is neither a result of pure chance nor a result of order imposed from above. Life orders and complicates itself. It is an order creating system within an **order-creating universe**. It derives fundamental reciprocities and ordering principles from the cosmos, and evolves new principles, complexities, and reciprocities on top of the old ones.

One final issue pertaining to evolution is whether biological evolution generates **progress**. Biologists such as Gould, Dawkins, and Goodwin reject the idea that biological evolution produces progress, though their reasons for rejecting progress as well as their definitions of the term vary.[359] Gould, for one, states that throughout the history of life there has been no overall direction toward increasing complexity or toward increasing adaptability. Goodwin also questions whether the evolution of life involves competition and the survival of the fittest, which would presumably lead to higher levels of fitness. Goodwin sees evolution more like a creative dance. New forms are not necessarily better; they are just different expressions of the overall creativity of nature and the universe. Dawkins questions the overall cumulative direction of life; in agreement with Gould, Dawkins sees accidents and bad luck figuring into the history of life.

There are though various reasons to question these anti-progressive views of evolution. First, even if we were to grant that there isn't any increasing complexity across the history of life, there is unquestionably increasing complexity across the history of the universe, and life is a definite stage in this process. Numerous scientists such as Tipler, Kurzweil, and Gell-Mann articulate a strong case for increasing order and complexity running from the sub-atomic to the cultural and technological. Second, the numerous aggregative integrations throughout evolution point toward increasing complexity as simpler life forms merge into more complex forms. Life is a growing hierarchy. Bringing in the concept of reciprocity, life progresses through the ongoing development of "win-win" reciprocities.[360] Further, the nervous system, as the most complex biological sub-system to emerge in life, has evolved throughout the history of animal life on earth. Referring back to the ideas of Kurzweil and Moravec, the informational complexity of the nervous system, both in terms of information storage and processing capacity, increases as we move forward on the evolutionary scale of life.[361] If we look at the amount of genetic information stored in the DNA molecules of different species, there is a rough correspondence between the number of genes and the period in time when the life form first emerged. The earliest life forms have the fewest number of genes. On a related note, if genes learn through natural selection, then evolution is progressive, involving cumulative learning, although there are probably many cases of unlearning that take place as well.

Increasing complexity is probably not sufficient as a defining criterion for progress in evolution, in part because the term "progress" is a complex idea. Progress involves value judgments and the idea of progress has been evolving throughout the history of humanity.[362] Progress can involve the inclusion of new values, above and beyond the creation of order and complexity. Ethical and humanitarian values are additional candidates for inclusion in our notion of progress. Further, progress does not necessarily mean the same thing as increasing complexity. Some times things progress by becoming simpler.[363] Insights and inventions, both scientific and personal, which simplify and help to manage the complexities and challenges of life, are examples of progress.

Other definitions of progress in the evolution of life include the increasing capacity to learn. Evolution is learning and there is progress in evolution because evolution itself evolves. The progress is learning how to learn better. This definition of progress places biological evolution in the context of cosmic evolution, for the capacity to learn increases as we move from physical systems to genetic systems to neural, cultural, and technological systems. Sahtouris sees evolution as an intelligent rather than mechanical process, and given information processing and learning models of evolution, progress in evolution could be described as increasing levels of intelligence.[364] Although Gould contends that evolution does not necessarily move toward greater intelligence, the entire panorama of evolution from physical to cultural systems seems to indicate otherwise. It may not be that human-like intelligence was a pre-determined direction in the evolutionary process, but increasing intelligence has emerged as a general direction in the evolution of natural systems.

Anderson suggests that progress in evolution involves increasing freedom and possibilities of action.[365] The whole line of thinking in the creation of artificial intelligence though seems to indicate that information storage and processing capacity and consequently intelligence is connected with flexibility of action. If indeed intelligence is connected with flexibility and possibilities of action, then intelligence clearly has an adaptive value, allowing an organism to cope with a greater range of environmental conditions and effects. It would make sense, contrary to Gould, that in so far as natural selection impacts the evolutionary process, increasing intelligence would emerge as a basic direction in the evolution of life.

On a related note, biologists like Goodwin and Sahtouris have argued that evolution is fundamentally a creative act.[366] Inspired by the philosophy of Alfred North Whitehead[367], Goodwin rejects the idea that evolution is progressive, competitive, and adaptive, instead stating that organisms are expressions of the fundamental creativity of the cosmos. Life is an experiment in creativity. Goodwin connects creativity with self-organization, apparently taking the view that self-organizational processes cannot be explained in terms of natural selection. The cosmos does not create order because order is somehow adaptive. The concept though of creativity connects with flexibility and freedom of action and it would make perfect sense to argue that creativity itself would evolve through the history of the cosmos. Even if creativity were a primordial force within the cosmos, as Whitehead contends, increasing intelligence and learning would seem to facilitate higher levels of creativity. Creativity is relative, so if the universe were creative at its core, which I would agree with, then the universe, expressing this fundamental quality, would create new ways to be creative. Creativity necessarily evolves. As

I argued above, contrary to the notion that some external or transcendent force created life, which leads to a static view of life, it makes more sense to see life and the universe as a whole as self-creative. Creativity is indeed an intrinsic property of the universe.

All told, I would agree with Anderson that evolution probably has multiple dimensions of change and development associated with it.[368] Clearly there are the reciprocal dimensions of competition and cooperation, along with adaptation, complexity, intelligence, learning, and creativity. Further, if evolution itself evolves, then new dimensions could emerge in the future. Considering the introduction of purpose, technology, and ethical values into the evolutionary process and the ongoing articulation of the concept of progress itself, evolution seems to me to be an open ended reality, built upon the self-creative nature of the cosmos, but clearly far from a completely defined or pre-determined principle or law. The *Logos* or logic of change, itself changes.

Regarding the cosmic meaning and significance of life, it appears that life fits within the general pattern of evolution evolving as we move upward toward higher and higher levels of complexity, creativity, and intelligence. Life is a stage in cosmic evolution; life is an evolution in the ongoing act of creation.[369] Life is integrally woven into the fabric of the universe, drawing chemical elements and physical structures into its ecological and metabolic processes, and mirroring in many respects the dynamics and self-organizational processes of the cosmos. It sinks its roots into the fabric of matter and energy and sends its branches upward and outward into space and time.

Returning the issue of biotechnology, it seems mistaken to believe that life is something that is stable or perfect and shouldn't be changed. The essence of life is change, evolution, and creation. What about humans attempting to accelerate or guide the direction of life? To draw an analogy, as life has directed the dynamics and organization of chemical and physical systems surrounding it, culture and technology directs the dynamics and organization of life. The idea of purposive evolution highlights the roles of mental, cultural, and technological processes, as higher forms of complexity and intelligence, guiding the future development of life. If evolution is learning, within biotechnology and genetic engineering we can apply higher forms of learning to the ongoing development of genes. Finally, and perhaps most importantly, we are part of nature, along with our culture and our technology, and the history of the cosmos as well as the history of life indicates that we live in a self-creative reality. We are part of this self-creative process. To say that we shouldn't tamper with "Mother Nature" misses the points that we are part of nature and nature continually tampers with itself.

Advances in biotechnology and medicine should have powerful effects on future human society. These advances should also strongly influence our views regarding the very essence of human nature, both psychologically and biologically. We may transcend ourselves. Many people today are apprehensive of, if not afraid of or opposed to, the possibilities within these areas.[370] The Frankenstein myth seems to be upon us, and we have the images of *Jurassic Park* to contend with. The line "Life will find a way" from *Jurassic Park* perhaps aptly sums up Kelly's hypothesis that life is an active, adaptive, and creative reality that cannot be contained according to our wishes and expectations. Creativity is an adventure. Yet we cannot run from this new area of promise and further evolution. Lives by the millions can be saved, if not enhanced immeasurably. For every nightmare associated with these areas, there is a bright and hopeful dream. We often imagine the future as filled with wondrous gadgets and physical devices, yet biotechnology may provide something even more fantastic; life itself may be transformed in innumerable ways. We may not only walk with the dinosaurs; on wings we may fly circles around them.

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