Science and the Technological Vision of the Future

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The Future of Science and Technology

"Science is what the universe says to itself
when the universe gets old enough to speak."

Robert Artigiani

I will begin the chapter by considering the **dreams** and **fears** associated with science and technology. Will advances in technology benefit humanity or will technological developments harm or even destroy humanity? In this chapter I will also continue the history of science begun in Chapter one, tracing the **development of science** up to contemporary times, and speculating on where science may be headed in the future. I will consider the various effects, past, present, and potentially into the future, of the scientific perspective on the human mind and human society. Finally, I will examine the general theme of the **technological restructuring** and **infusing** of nature and human society, highlighting as starting points, energy, resources, transportation, nanotechnology, and mega-technological projects.

This chapter explores theoretical science and physical technology, beginning with a general discussion of the possible benefits and dangers of both science and technology. The second section examines basic theoretical science, including cosmology and the quest to understand the fundamental nature and origin of the universe. The next sections look at the ongoing and pervasive technological revolution, including energy, materials, nanotechnology, transportation, and global super-projects.[1] The chapter concludes with a discussion of the possibility of understanding and mastering the very fabric of space and time and the dynamics of the universe in the far distant future.

The central theses of this chapter include the following hypotheses:

- There is an essential and reciprocal connection between humanity and science and technology. For better or worse, our values, nature, and ways of life are inextricably tied to science and technology. Humanity and technology will co-evolve in the future.

- The new ideas of 20th Century science go beyond and, in many ways, challenge the original views of the Scientific Revolution. These new ideas constitute a **Second Scientific Revolution**. At the most basic level, the Newtonian model of the universe, a dualist and static vision of nature, is being progressively replaced by an evolutionary and reciprocal theory of the cosmos. Whole and parts, order and chaos, and matter and energy are now seen as intimately and reciprocally connected in a dynamic transforming universe. Also a reciprocal theory of knowledge has replaced the dualist theory of knowledge in earlier science.
- Over the last couple of centuries Newtonian science and industrial technology strongly influenced social and psychological ideas and values in the modern world. The new ideas of science will change the conceptual framework of the human mind, culture, and the organization of human society in the centuries ahead.
- Future science will integrate heart, value, and meaning with the cognitive, quantitative, abstract, and factual features of traditional science. The scientific and spiritual quests for cosmic understanding and wisdom will integrate.
- Although our scientific understanding of nature has become cosmic in scope and depth, the future growth of human knowledge seems potentially infinite. Despite predictions that science will soon achieve a complete understanding of the universe, science will be an endless and infinite project into the future.
- The technological revolution in contemporary times is multi-dimensional, global, and integrative, with different technologies mutually accelerating each other. The accelerative growth of technology promises to continue into the future. Technological projects and devices will become both bigger and smaller simultaneously - nature will be technologically infused at all levels of reality. This process will transform transportation, habitation, resources and energy, and production, as well as the entirety of life, earth ecology, and beyond.
- Technology will become increasingly intelligent, self-maintaining, self-evolving, and in partnership and synthesis with the biological, psychological, and social dimensions of human reality. But it is also possible that at some point our technological creations will transcend us.[2]
- It is possible, if not probable, that human and/or technological intelligence will gain an understanding and significant degree of control over cosmic dimensions of reality and sweep out across the universe and beyond.[3]

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Included in the notes for this chapter is a list of websites on physical science, cosmology, and general areas of technology.[4] Later chapter notes include websites on information technology and biotechnology.

The Dreams and Fears of Science and Technology

*"New technologies alter the structure of our interests: the things we think about.
They alter the character of our symbols: the things we think with.
And they alter the nature of community: the arena in which thoughts develop."*

Neil Postman

*"A machine is as distinctly and brilliantly and expressively human
as a violin sonata or a theorem by Euclid."*

Gregory Vlastos

"The world has changed far more in the last hundred years than in any previous century. The reason has not been new political or economic doctrines but the vast developments in technology made possible by advances in basic science.

Stephen Hawking

Does technology enfeeble or empower us? It does both. By becoming dependent on technology to perform different functions, we lose the capacity to perform those functions ourselves. The machines we create though perform the functions better than if we were to use nothing but our natural bodily abilities and hence we use them. We can move about (locomote) much faster in an automobile than by walking, but if we never walk to get anywhere we would lose this ability. We become stronger with the machine and weaker without it.

We should look at humans and technology parts of a **reciprocal** or **symbiotic system**. Humans and technology are interdependent. The human-technology system can perform many functions that humans could not perform alone and can perform most human functions better than humans alone.

Since the beginnings of the **Scientific Revolution** in the 17th Century, science and technology are often seen as epitomizing the promise of the future. Through science we will discover the ultimate secrets of the universe. Through technology we will harness the forces of nature and create a world of "miracle and wonder".[5] Clearly, this promise of science and technology in creating a new future has in many ways been fulfilled. As Stephen Hawking notes in the opening quote above, science and technology have done more to transform our world in the last century than any other single factor.[6] Yet the world transformed by modern science and technology is, in many people's minds, a mixed blessing, and the future of science and technology is frightening to many individuals.

Science can be defined as a set of methods for understanding nature and the cosmos. Out of this methodology, which includes experimentation, observation, and mathematical analysis, a set of scientific theories have developed (and continue to grow and transform) that provide a relatively integrative and detailed description and explanation of nature and the universe. The scientific method emerged in the 17th and

18th Centuries in the works of Copernicus, Galileo, Descartes, Bacon, Kepler, and Newton. The goal of these earliest scientists was to achieve a rational and theoretical comprehension of nature and the universe. The methods and theories of science that they developed have had a powerful impact on the modern era and the modern mind. Due to science, the Western view of the universe, nature, and humanity has been transformed in the last three centuries, replacing in great measure the earlier medieval conception of reality.[7] If anything, with the continued growth of science, the future may be even more dominated by its ideas and principles.[8]

Technology involves the application of scientific ideas and principles to practical and instrumental ends. Why a machine or technological apparatus works and how it works derives from science, for example, the principles of optics, mechanics, electricity, or thermodynamics. Technology though can, in turn, affect science, for as more complex and powerful instruments are developed for observing and manipulating nature (e.g. the Hubble telescope, the electron microscope, and cyclotrons) our scientific knowledge grows through new observations and experimental results.[9] Further, new technologies often redefine our values and ends – thus technology is not simply a means to a predefined end but an end in itself.[10]

During the **Industrial Era**, Newton's physics was the central theory in science. Newton described the physical universe as discrete, solid objects of matter moving through empty space. Material objects influenced each other through material forces. The motions of objects and the effects of physical forces were governed by stable laws of nature. The universe, as a whole, behaved deterministically and the motions of all physical objects, earthly and heavenly, could be calculated out indefinitely into the future.

Newton's ideas provided the Industrial Era with a basic model for machines. In fact, to draw a connection between Newtonian science and Newtonian technology, Newton's science described the universe as a perfectly running machine. The clock and the engine were the prototypical machines of the Industrial Era. Newtonian machines consisted of constructions of solid matter, shaped, arranged, and welded together, that moved their parts through the application of physical forces. Newtonian technology was seen as mirroring or modeling the workings of nature.[11]

Yet as science in the late 19th Century began to understand the forces of electricity, light, magnetism and the atom in more depth, and technology advanced into the realms of electrical and nuclear devices, scientific theory and technology moved beyond Newtonian and industrial ideas. As noted above, science and technology strongly influence each other in their development. In the last hundred years both our scientific image of nature and our prototypical machines have dramatically changed. A totally new set of scientific theories has developed, replacing or subsuming the scientific theories that dominated the Industrial Era. We have been witnessing a Second Scientific Revolution. Following the rate of scientific change in the 20th Century and the transformation of fundamental theoretical ideas, technological change and invention has escalated as well, and new forms of machines have emerged.[12] The television, telephone, and computer have become the prototypical machines of the modern **Information Age**, and Newton's theory of nature has been superceded by Einstein's special and general theories of relativity, Heisenberg and Bohr's quantum theory of the atom, Prigogine's ideas on open systems, chaos, and self-organization, and Hawking's explanation of the Big Bang.[13]

Scientific theories should be fundamentally seen as sets of abstract and interrelated ideas, and, as in the past, scientific ideas have a powerful influence on the minds, behaviors, and institutions of humans. As Newtonian ideas transformed human society, the new ideas of science are altering more than just technology, but the very fabric of human existence.[14] Ideas within science take a while to permeate out into human society and culture. The full impact of the contemporary revolution in science has not yet been felt within our lives. One can imagine that our future, at both the psychological and social levels, will be much different as the ideas, images, metaphors, and meanings of the new science work their way into everyday life. We will think differently about reality and ourselves.

Given its growing influence over the last few centuries, science could be seen as a threat to our humanity. Is science destroying the place of emotion, faith, and personal meaning in our lives? Is science turning human reality into logic, abstractions, equations, and experimentation? Will science replace the human heart? Interestingly, such fears and apprehensions are, at least to some degree, based on a Newtonian image of science and an industrial model of machines. The cold and heartless mechanical machine of matter and the equally cold and heartless objective mind of the scientist are Newtonian stereotypes and ideas. As we will see, science has changed, and our machines and technologies are changing as well.

If any theme is especially emphasized in popularized visions of the future, it is the potential wonders of technology. The robot, spaceship, time machine, ray gun, teleportation beam, floating city, and self-navigating car populate science fiction stories and movies. Since the earliest days of science fiction, a powerful and captivating dream has been that technology would transform the world into a Garden of Eden or a Utopia.[15] This image of future technology transforming human society and human life into a much better, more improved world derives from the philosophy of Enlightenment and the theory of secular progress.

Yet in science fiction, equally powerful are the nightmares of technology. The nightmares include such movies as *Bladerunner*, *Terminator*, *Frankenstein*, *Matrix,* and *Dr. Strangelove*. Machines can be seen as monsters that cut us off from nature, destroy our souls, rob us of our natural abilities, negate our humanistic and spiritual values, and inevitably take control of our lives. Do we think that technology will depersonalize humanity? Do we think that we will lose control of our machines? Perhaps future machines will destroy humanity, or worse yet, surpass us.[16] And if we turn from science fiction to the actual effects of modern technology, our industries and machines appear to many people to have generated as many problems as they have solved.[17] We do not live in a modern Garden of Eden; we live in a world of pollution, traffic congestion, high tech terrorism, nuclear arsenals, and stimulus overload and stress. Is our ever advancing technology helping us or hurting us? Humanity and the machine is a classic issue - a very real issue for the future. Will technology serve us and help us or will we serve technology and end up suffering for it? Is this an either/or?

Yet, what is the image of technology that supports these nightmares and apprehensions? To what degree is it a Newtonian image of the machine that fuels the fears? It is important to note that Newtonian science and technology developed in a philosophical era of **mind-matter dualism**, where humanity, spiritually and psychologically, was seen as separate and distinct from the physical world. Mind was seen as animated, intelligent, personalized, and filled with emotion and meaning. Matter was viewed as cold and dead and pushed about by the forces and laws of nature. Of course, we would feel alienated and afraid of mechanisms and machines constructed out of this type of physical world. Envisioning machines as "soulless things", we would try to control them, dominate them, and never let them get the upper hand. But is this, in fact, the nature of physical reality as revealed in contemporary science? Is a philosophy of dualism still tenable in science? And further, is the image of the machine as an arrangement of mechanical parts pushed and pulled by physical forces a viable image of modern technologies?

One particular concern regarding future technology is our apprehension over robots, computers, and other intelligent machines. The contemporary scientist and cosmologist Frank Tipler notes that people in the West are especially distrustful of robots, unlike the Japanese who see all matter as animated and are accordingly not so deprecating of them.[18] In his view, we believe, as dualists, that the robot is nothing but a soulless, complicated hunk of metal. He goes so far as to state that we are supremacists, indeed racists, for looking down on robots. As I describe later, many people regard computers in a similar light. In both cases our sense of superiority, and equally our sense of fear, is at least to some degree based on a dualistic view of humanity and physical technology. Machines are viewed as alien beings.

Yet it is precisely when we consider computers, robots, and other types of information technologies, which in fundamental ways are clearly different from Newtonian machines, that our fears and concerns become strongest and even most realistic. In popular science fiction movies such as *Terminator* and *Matrix* it is a powerful, technological intelligence that attempts to control, if not extinguish us. Should we not realistically fear a superior non-human intelligence, even if such a mind possesses consciousness, creativity, and feeling?

Such popular media images though pale in comparison to the technological intelligences in Vernor Vinge's *A Fire Upon the Deep* and Dan Simmons' *Hyperion*. In *Hyperion*, humanity has turned over the management and operations of future society and civilization, which now stretches across numerous worlds, to a collective of clandestine and mysterious artificial intelligences, that among themselves are in an ongoing debate over whether humanity should be allowed to continue to exist. In *A Fire Upon the Deep*, all hell breaks loose, when a group of humans activates an artificial intelligence – aptly called the Perversion - that proceeds to spread across the Milky Way, like a computer virus, swallowing up whole stellar systems at the speed of light. The technological capacity, through invasive nets of nanotechnological units, to invade and explore the inner workings of the human mind is a possibility considered in Greg Bear's *Queen of Angels*. For many of us, such a technological possibility would clearly send shivers up our spine.[19]

All in all, the biggest threats to human independence and human dominance will probably come from our most advanced forms of technology, including biotechnology, artificial intelligence, and nanotechnology. The contemporary scientist Freeman Dyson identifies biotechnology and artificial intelligence as possessing the most cause for concern[20], whereas Bill Joy, in his recent popular article "Why the Future Doesn't Need

Us" is particularly concerned with nanotechnology and biologically engineered life forms. Both forms of technology have the capacity to reproduce perhaps uncontrollably.[21] Yet, it is also these same technologies that promise the greatest benefit to humanity in the years ahead, and what one person may see as a threat, for example, that our machines will surpass us, another person may see in a positive light.[22]

Our attitude toward machines, though, involves more than just fear and apprehension. People have a love affair with technology as well, and we, in fact, do personalize many of our gadgets and appliances. Consider the automobile. We are mesmerized and enthralled with the wonders of technological devices. We cater to their every need, talk to them, give them names, and polish them with loving caresses. As Barlow notes, in his article "It's a Poor Workman Who Blames His Tools", technology is often viewed in a negative light due to the fact that various businesses get rich over the marketing and selling of it, seemingly without regard to the actual benefits to people.[23] Yet Barlow points out that consumers show an unending desire for newer and prettier machines, and continue to buy them. Csikszentmihalyi says that technology has evolved to a great extent due to the enjoyment of it - the new experiences and challenges that it offers.[24] In the modern world, our technologies are our toys. Naisbitt argues in his recent book, *High Tech – High Touch,* that Americans in particular live in a "Technologically Intoxicated Zone".[25] We love to play with, make love with, and show off our technological toys. There is a practical side to our machines, but technology may take more time to service, than the time saved in having the various devices.

This love affair and fascination with technology, though, can simply reinforce our fears. Our machines may not conquer us through superior intelligence or strength; they may conquer us through their beauty, design, and sensory pleasures. Csikszentmihalyi argues that artifacts can become parasites on us, thriving in the environment of humanity. The emotional power technology possesses can become very addictive.[26] We come back to the earlier question over whether technology serves us or we serve it?

The debate on the value of technology has a long history. It continues with even greater intensity today. Some recent extensive critiques include Neil Postman's *Technopoly*, John Naisbitt's *High Tech – High Touch*, and Freeman Dyson's *The Sun, the Genome, and the Internet*. On the other side of the fence, two lengthy positive reviews of the promises of technology are Michio Kaku's *Visions* and Michael Zey's *The Future Factor*.[27] Looking at the main ideas developed in these books can help us get a more balanced and complete picture of the technology debate. There are also some recent discussions that specifically focus on the potential benefits of information technology, computers, and robots, notably Ray Kurzweil's *The Age of Spiritual Machines* and Hans Moravec's *Robot*. These books are examined in depth in the next chapter on information technology.

Postman argues that Americans have come to believe that technology is their savior in both war and peace. "**Technophiles**" (supporters of technology) tend to see only what technology can do, and not see what technology undoes. For Postman, all technologies have both a positive and negative side. They give us something new, but they also take something away. Further, according to Postman, the benefits of technology tend not to be equally distributed, with the techno-elite gaining increasing power over those unable to afford or learn the new technologies. Yet the main problem with technology is that if it becomes the central guiding force in a society, which according to Postman has happened in modern America, it creates a "**technopoly**" – a society ruled by the ideology and values of its technology, undercutting all other cultural values. Within a technopoly, technology is seen as satisfying all our needs and providing both authority and direction in our way of life. For Postman, in our modern technopoly, technology has been deified.

Although technologies can be seen as simply means to ends, as being just tools that can be used for either good or negative ends, Postman believes that technologies bring with them values, ideologies, and symbolic meaning. The structure or make-up of a technology determines, or at the very least strongly influences its function. In point of fact, a technology or machine is built with a function in mind, and the tool's function strongly inclines the tool user to look at the world in a certain way. For a person with a hammer, everything is a nail. For a person with a computer, everything is data. Technologies provide a conceptual framework for understanding the world. Although a technology may be initially developed to solve a problem, according to Postman, the technology also ends up serving a symbolic function. It becomes a metaphor on the meaning of life – witness the power of the automobile, the computer, and the television to define the meaning and nature of modern life. Further, Postman believes that the modern development of the technological and industrial world brought with it a new set of values. These values included objectivity, standardization, efficiency, and the importance of technique and measurement. Although we may naively believe that tools, machines, and technologies are simply means to ends, these various instruments do in fact shape our goals and our values. For Postman they bring with them an ideology and create a mindset. Our technologies have reshaped the social order of our modern world.

Postman further points out that the effects of technologies are not localized. Technologies cannot be contained to a limited sphere – they change everything they are connected to. The automobile did not just change transportation. The computer did not just change data management. There are numerous unintended consequences to the introduction of a new technology that ripple out through a society.[28] Our technologies are part of a vast techno-ecosystem in which different technologies compete against each other. Different companies and institutions support different technologies. Technologies are marketed and advertised for their value. We are sold on the values that these technologies offer us; advertisement attempts to convince us of the worth of its products. We live in a world permeated with the effects of our technologies and their supposed associated values and benefits. Postman contends that our modern technologies have redefined art, religion, the family, culture, and even our sense of history.

Postman believes that the rise of modern technopoly began in the Scientific Revolution. Science separated itself from the moral and spiritual dimensions of human society, claiming that its goal was simply factual knowledge. Science was presumably value-free. The Scientific Revolution supported a **dualism** of **fact** and **value**. Yet, beginning with Francis Bacon and later with the Enlightenment philosophers, science and scientific technologies were seen as the instruments of progress – as the mechanism to improve, according to Bacon, the "happiness of mankind". With the emergence of the philosophy of secular progress, science and technology quickly came to challenge the authority of the church and traditional ways of life and value systems. As Elizabet Sahtouris states, technology and the invention and use of machines became the guiding force of humanity.[29] The modern world, in great part created through the pervasive spread and ascension of science and technology, steadily eroded those spiritual and traditional values that science, supposedly, was not challenging. According to Postman, because science questioned religious truth, it also discredited religious moral authority. Yet science and technology also brought with them a new set of values and goals, often at odds with religious and traditional values. These values and goals derive from the very principles by which science and technology are organized and practiced. The industrial world was a world organized and ruled by the clock and punctuality; factories emerged that relied on efficiency, measurement, and analysis, and progress became increasingly measured in terms of production and the accumulation of material wealth.

The outmoded belief that technologies are value free is a direct outgrowth of the dualist philosophy of early scientists and technocrats, but this philosophy is a mistake, since science and technology did challenge and undercut the values and ways of life of the pre-modern era. Science and technology are not value free. They are not simply means but also ends in themselves. They helped to define a new set of values, a new set of goals, and a new way of life. This is one of Postman's main points.

Postman is particularly concerned that technopoly on one hand undercuts all fundamental world-views while providing no overall new pattern of meaning and direction to take their place. He states that technopoly eliminates all "higher philosophical ideas and ideals" that do not fit into its reality. For Postman, technopoly gives no moral guidance. "**Scientism**" – the elevation of science to a supreme authority - undercuts the values of subjectivity and creativity in favor of precision and objectivity. And because both science and technology emphasize the value of technique, they undercut the value of thinking. In the final analysis modernized humans end up serving technology because in a technopoly it is technology that defines the goals and values of life.

John Naisbitt's critique of modern technology in *High Tech – High Touch* reinforces many of the ideas of Postman. As noted above, Naisbitt believes that Americans have become intoxicated with technology. We live in a "**Technologically Intoxicated Zone",** saturated with a multitudinous array of techno-promises. In agreement with Postman, Naisbitt argues that technology is not neutral – it is not simply a set of tools for achieving predefined ends. It has consequences and influences our way of life. Technology has become an integral part of culture. (Postman's argument is a bit stronger. For him, we have surrendered culture to technology.) Naisbitt believes that "technology is the currency of our lives"; the two biggest markets are consumer technologies and ways to escape from consumer technologies. Although the promise of technology was to save time and labor, it ends up consuming time and labor. I would note that this reverse effect of technology on time indicates that technology is not simply a means to an end but has become an end in itself. Time itself has changed. Where once human life was structured by nature's rhythms, now it is structured by high tech time, with a sense of urgency, precision, and obsessive order.[30] We have become increasingly concerned with productivity and efficiency – again echoing a point in Postman – and seem to have developed a mass case of Attention Deficit Disorder.[31]

Naisbitt lists six basic symptoms associated with our high tech world:

- First, we have come to favor the quick fix. We live in a Band-Aid culture. There is a gadget or a product to quickly alleviate any problem.[32] Further, we have become impulse and stimulus driven with no time for reflection.
- Second, we have come to both fear and worship technology. We swing between antagonism and inspiration. Naisbitt accuses Nicholas Negroponte (who is discussed in the next chapter) of deifying technology.[33] Postman, to recall, accuses American society in general of deifying technology. Yet we also fear that we are becoming slaves to our machines, both weak and dependent upon them.
- Third, because technology simulates and creates surrogates of reality, the distinction between the real and the fake has blurred. There are screens everywhere, and though the screen invariably presents a technologically created scene, scenario, or visualization, the world on the screen has become what is most real for many of us.[34]
- Fourth, we have accepted violence as normal. Video and computer games and the media are filled with simulated violence. Naisbitt describes "**The Military-Nintendo Complex**", in which the military and toy industries have cross-fertilized each other, sharing ideas and technologies, over the last few decades. Inspired by battle simulations developed in the military, electronic and video games are "hardwiring" young people for shooting at humans. In this case, in particular, technology is not neutral – it teaches.
- Fifth, we love technology as a toy. According to Naisbitt, new technologies begin as luxuries and become necessities, eventually evolving into toys. Witness both the automobile and the computer. Adult technological toys have become ubiquitous in our culture.
- Finally, we live our lives distant and distracted. Technologies create both physical and emotional distance between us – a point that Postman also raises – and we become even distanced from ourselves and our own concerns and values. Interestingly, although technology has been blamed for the loss of community, Naisbitt notes that our communities are beginning to be wired. He describes the high tech community being developed in Celebration, Florida by Walt Disney – one of a hundred similar communities emerging across the nation – that is infused with communication and information technologies. The question for Naisbitt is whether such high tech communities will bring us closer to each other, or alienate us further from both our neighbors and ourselves.

According to Naisbitt, our technological intoxication is squeezing the spirit out of us. We have more, but feel more impoverished. Increasingly we search for meaning in our lives. Hence, Naisbitt, like Postman, believes that the overall effect of technology is de-humanizing. In sympathy with Postman, he thinks that we have lost our sense of meaning, value, and direction to our technological gadgets. Naisbitt thinks that our sense of "High Touch" must inform and guide our technology.

One reaction against the high tech world that Naisbitt discusses is the "**Voluntary Simplicity**" movement.[35] Yet it seems both unrealistic and undesirable that we should abandon technology for a simpler way of life, and as James Gleick points out in his book *Faster: The Acceleration of Just About Everything,* the voluntary simplicity movement itself has generated its own accelerative complexity with competing lists and books galore of how to simplify your life along a myriad set of life's dimensions.[36] At the very least, Naisbitt believes that we need to enter into a global dialogue on the benefits and dangers of technology, and that religious and spiritual ideas, having been undermined by the philosophy of secular progress, science, and technology, need to re-enter the discussion of our goals and values for the future. But as Reverend Donald Shriver, quoted in Naisbitt, points out "The power of scientific curiosity, technological ambition, and economic profit are together a very formidable power."

The relationship of technology and ethics is an important issue for Freeman Dyson. In his book *Imagined Worlds*, Dyson considers the positive and negative consequences of technology.[37] He argues that science and technology become evil when they provide toys for the rich, and good when it provides necessities for the poor. Science and technology can exacerbate the differences between the rich and the poor, creating an educated and techno elite. Further, if technology becomes driven by ideology and politics, it gets into trouble, creating disaster and excessiveness, a point he repeats in a later book, *The Sun, the Genome, and the Internet*.[38] In this latter book, Dyson adds that both high tech medicine and high tech communication, though promising various benefits, have had negative effects on people, generating depersonalization and often involving high financial costs. The Internet, though promising enhanced economic access and opportunities for all, still generally serves only the rich and competitive today.

Yet in *The Sun, the Genome, and the Internet*, Dyson does present a well-developed argument regarding how technology can contribute to social justice and the betterment of humanity. The crux of Dyson's argument rests on distinguishing between ethics driven by technology versus technology driven by ethics. As we saw in the discussions above on Postman and Naisbitt, it is clear that technology brings with it values and goals. Technology is not value free. In Dyson's mind, when ethics are driven by technology, negative effects on humanity often follow. Instead, he argues that our ethics must drive our technology. We must identify humanistic goals that will benefit all people, and then create technologies that will address these goals.

If the separation of technology and values is one form of dualistic mistake, the separation of technology and humanity is another dualistic mistake. Technology is not simply a tool of humankind. Not only does technology bring with it new values, it also alters our very nature. As Dyson correctly notes humanity and technology co-evolve in symbiosis.

The effects of technology upon humanity can be either negative or positive. It should be clear from the above critical reviews of Postman, Naisbitt, and Dyson, that technology can be seen as having negative effects on human nature. In turning to some recent reviews of the present benefits and future promises of technology, one theme will be how technology can improve the very nature of humanity.

Michio Kaku and Michael Zey are two writers who strongly support the value of technology and its potential benefits for the future. For both Kaku and Zey, advances in technology should benefit humanity financially and vastly enhance our collective wealth.[39] Zey sees a time of superabundance resulting from technological advancement – a hypothesis he also defended in his earlier book *Seizing the Future*.[40] Additionally, they both agree that the future of technology promises increased mastery of nature, a promise also made by the original founders of Enlightenment philosophy and secular progress. Zey, citing Kaku, argues that we are moving from a time of passive bystanders to one of active choreographers of nature. He also believes that through technological achievements and increased "**dominionization**" of nature, we enhance our self-esteem and sense of self-efficacy.

There is considerable debate as to whether increasing financial and material wealth constitutes an adequate definition of progress. But it does seem clear that technological innovation and development, which has exponentially grown in the 20th Century, are directly connected to both increasing wealth and increasing abundance of resources, luxuries, and fundamental sustenance items.[41] Moore and Simon propose that the three most important factors, all technological factors, which have generated immense material progress in the 20th Century, are electrical power, drugs and vaccines, and the microchip. The material benefits of advancing technology though are not equitably distributed throughout the world, but this inequality is directly connected to which areas have advanced technologically and which have not.[42]

Yet even if technology, wealth, and material abundance are directly connected, does it follow that the human condition in general is improved through technological advancement? As David Myers points out there is no positive correlation between human happiness and material abundance once basic sustenance needs have been satisfied.[43] Of course, the promise is to bring the benefits of advanced technology to those people around the world who as yet do not live at even a fundamental sustenance level. Sadly, as critics such as Dyson point out, the benefits of contemporary technology have tended to concentrate in the rich and in the populations of modernized countries.

Another argument that advancing technology will benefit humanity pertains to the future possibilities of biotechnology. Kaku identifies three fundamental areas of scientific advancement in the 20th Century: quantum theory and the study of the atom, computer science and artificial intelligence, and theoretical biology and biotechnology.[44] Our increasing scientific understanding of life and biological processes has already greatly benefited humanity with monumental advances in medicine, health, and agriculture.[45] But as Kaku and Zey point out, the 21st Century should see the growing application of genetics to improving the physical health and vitality of humans and eventually, even our mental health and general psychological abilities as well. Through the genetic modification of our DNA structure at conception or at some later stage of life, we should be able to progressively improve our minds and bodies and hopefully the quality of life. What biotechnology brings into the picture is that we are no longer attempting to improve only our external environment. We are also applying technology to ourselves with the intent to improve ourselves. (On a related note, although computers initially developed as a way to deal with problems we faced in our environment, the promise here as well is that we will eventually apply computer technology to our own biological and psychological make-up, again for the purpose of self-improvement.)[46]

Whether we are applying technology to our environment or to ourselves, we should consider the related questions regarding what values and goals the technology is intended to serve, and what might be the possible consequences of introducing the new technology. As Ohler suggests, we need criteria for assessing technology, identifying possible negative and positive effects on the environment, social relations, work, the self, education, and the human body.[47] Ohler's list brings home the point made by Postman that technologies affect all aspects of human life and are not localized in their impact, e.g., the automobile does not just affect transportation and the computer does not just affect record keeping and computational issues.

Although Postman and Dyson bring up the point that values and ethics can be driven and influenced by technology, we should attempt to guide our technological developments and innovations through our values and consider whether a new technology might undercut some value we think is important. Following Naisbitt and Dyson, among others, it appears that new technologies often prosper and grow to serve the profit motive of businesses and the entertainment needs of those who can afford to buy the newest gadgets. Are these the kinds of values that should be guiding our technological evolution? Joseph Pelton points out that initially industry and technology developed in the modern world to serve short-term gains of material growth and financial wealth without a necessary balance of long-term survival and concern for the environment.[48]

Not to paint a one-sided picture, many technologies are developed that promise to help the common person and really address fundamental humanitarian concerns. As Moore and Simon point out, there have been many basic benefits accrued through the incredible technological achievements of the last century, and the benefits of new technologies are spreading throughout the world.[49]

All things considered, I think that Michael Dertouzos, in his book *What Will Be: How the New World of Information will Change our Lives*, is correct in arguing that technology is not just a tool to achieve some purpose, but that technologies create new purposes.[50] The position that purposes create technologies is too linear – causality runs in both directions. Values and technologies evolve in interaction – a reciprocal evolution of ideals and machines. Since for Dertouzos, technology is unstoppable, we must continually consider how a new technology fits into present human reality and how it contributes, for better or worse, to the ongoing further creation of human reality. According to Dertouzos, a view he shares with some of the top thinkers and contemporary scientific minds, such as E.O. Wilson and Murray Gell-Mann, the real challenge in the future is to unite the humanities and its considerations of value and ethics with technology and science.[51]

Based upon the above critical reviews of the effects of technology upon humanity, one thing is clear; we cannot separate technology from ourselves. It impacts our lives, our society, our values, and who we are. Technology is not simply a tool to serve us. The tool molds the tool user. The dualism of mind and machine is mistaken. We should see our relationship with our machines as a reciprocity – each molding and influencing the other. As Dyson states, technology and humanity will co-evolve in the future.[52] In fact, this process of **reciprocal co-evolution** has been going on throughout human history.

Although machines are often seen as contributing to the dehumanization of human life, machines and various artifacts and instruments have been an absolutely essential feature of human life throughout recorded history. Many anthropologists and historians believe that it was the development of tools that drove the recent accelerated evolution of human intelligence and the human brain. We are naked without our artifacts and machines. We are unequivocally interdependent with them. Human civilization would vanish without technology. It is, in fact, almost a contradiction in terms to say that machines dehumanize.

Consequently, although there have been and continue to be counter-reactions to technology, it seems to be nonsensical to suggest that we could create a future without it. Ray Kurzweil, for one, thinks that technology is inevitable because evolution favors intelligence and the manipulation of nature.[53] Humanity throughout history has attempted to improve the conditions of life and such efforts involve both the manipulation of the environment, as well as ways to enhance human capacities and skills. These efforts invariably involve new technologies. With the accelerative development of technology, there will undoubtedly be future negative reactions to its growth. For example, Pearson foresees an anti-technological backlash to the increasing electronic intrusion into the monitoring of our lives.[54] Yet, as Robert Wright points out, throughout human history and the evolution of human cultures, it is the more technologically advanced cultures that have won the day and continued to progress.[55] Technological advantage and advancement seems to be selected for in evolution.

Further, with the burgeoning areas of biotechnology and information technology promising the potential to technologically manipulate and alter our very bodies and minds, new opportunities for technological advancement are opening up. Yet as Anderson notes many people don't want to have this increased freedom and responsibility.[56] But we do have the freedom and the responsibility, and they are, if anything, growing as science advances in its understanding of nature and humanity.

Although the intimate connection between humanity and technology has been apparent throughout human history, there has recently been a significant jump forward in the degree to which humanity and technology are intertwined and interdependent. According to Walter Truett Anderson, although we have always lived in symbiosis with our inventions and tools, as extensions of our bodies and minds,[57] we are now evolving into a new type of living form, an "**augmented animal**", where technology and biology are integrating into singular and interconnected technologically enhanced bodies.[58] Beginning slowly, with the emergence of eye spectacles, hearing aids, artificial limbs and more recently artificial organs, more and more of our body parts are being replaced and redesigned with technology.[59] Equally so, there are numerous detachable technologies that we use to enhance our motor, sensory, and communication capacities, and via these devices we are increasing "wiring together" and extending our collective reach into the environment.[60] The various augmentations are parts of our culture and are shared and refined among us, in a constant state of evolution. With the Copernican and Darwinian Revolutions, over the past centuries the philosophical dualisms of heaven and earth and mind and nature have broken down. According to Anderson, and echoing Postman and Dyson, another dualism in our thinking is breaking down; we are in the process of learning that we are not separate from our tools.[61] Making a similar point to that of Kevin Kelly's argument that the distinction between the "born" and the "made" is blurring,[62] Anderson states that the boundary between the "given" and the "made" is shifting.

Although some level of technology has existed in humanity for thousands of years, the emergence of science triggered an accelerated growth of technology during the Industrial Era. Scientific ideas and principles permeated into every aspect of technology, from agriculture, irrigation and transportation to manufacturing, construction and energy production. Within the 20th Century, theoretical science played an even bigger role in technological development. According to Daniel Bell, inventions in the past often occurred without any understanding or inspiration from theoretical science. With the systematic organization and application of ideas from science in our contemporary world, technology is increasingly driven by scientific theory.[63] As noted above, Kaku sees modern advances in three fundamental theoretical areas of science, specifically quantum physics, computer science, and biology, as informing and guiding technology into the 20th Century.[64]

The changes occurring in science are going to transform our machines in the decades ahead. We are going to see a whole new wave of machines that are highly flexible, intelligent and self-regulating; they will be the antithesis of the dumb, inert mechanism that needs to be plugged in, pushed, steered, and turned in order to move. The machines of the future will learn, self-organize, reproduce, and evolve. These new technologies, further, will be personalized to the individual interests and needs of the person.[65] Our new machines will transcend the Newtonian image – they will be more in tune with our psychological attributes and needs. Before looking more closely at these newer machines, in this chapter and other chapters ahead, the next section examines the new scientific ideas that are supporting and guiding these new technologies. [66]

The Second Scientific Revolution

"What is the universe? Is it infinite or finite?
Is it eternal, or did time begin at some first moment?
If it began, what began it?"

Lee Smolin

Francis Fukuyama points out in his book *The End of History and the Last Man* that modern science brought a dimension of universal direction into the human world through progress in technology, the rational organization of industry and work, the competition of increasingly improved products, the growth of knowledge, and the progressive conquest of nature.[67] Overall the scientific demand for rationality imposed both an order and direction on human technology and social structures. Modern science was a creation of many noteworthy individuals, including Galileo, Kepler, and Descartes, but it was Isaac Newton in his grand synthesis of physics and mechanics that became the central figure and guiding light of the Scientific Revolution and provided the theoretical groundwork for the growth of industrial technology. But as critics of Newtonian science and industrial technology such as Elizabet Sahtouris point out, the model of order embodied in the Newtonian-industrial vision of reality imposed a rigid, unnatural, mechanistic, and monolithic structure on modern Western human society.[68] Still, Fukuyama is correct in his overall assessment that an enhanced level of order, direction, productivity, and control over nature emerged in modern Western society inspired by the introduction of Newtonian science and technology. If this is the legacy of the Newtonian era and the first Scientific Revolution, what is the vision of the Second Scientific Revolution? Where are the new ideas of science going to take us?

As a starting point, although the Second Scientific Revolution began with the emergence of Einstein's special and general theories of relativity and quantum physics[69], which challenged and either replaced or subsumed many aspects of Newtonian physics, the revolution is not over. In fact, the creation of relativity and quantum theories, which instigated the revolution a hundred years ago, is precisely what is holding the completion of the revolution. As numerous physical scientists have pointed out, relativity and quantum theory are fundamentally incompatible, and as yet no one has been able to synthesize them into a unified and complete theory of physics. Newton had provided a singular and complete vision of the physical world. At present, we do not have that kind of integrative vision.[70] Beginning with Einstein's own efforts in this direction, many of the greatest scientific minds of the 20th Century have attempted to synthesize relativity and quantum physics, and there are theoretical candidates, most notably superstring theory and M-theory, that could provide an integration, but at present there is still much work to be done, and the question remains open regarding how this synthesis will be achieved. One of the central challenges for science in the future is the creation of such a grand unified theory of physics.

Yet many pieces of the puzzle have emerged, and there are a set of significant and inter-connected themes and ideas that describe the contemporary reality of physical science. One fundamental feature of contemporary science is a multi-faceted shift away from many of Newton's ideas. But more so, the revolution runs deeper into human thought and human history and overturns a mindset that goes back to **Platonic dualism**.[71]

I propose that two central ideas within this Second Scientific Revolution are reciprocity and evolution. More specifically, the shift in thinking involves a replacement of absolutist concepts with relational concepts, a change from a static universe to an evolutionary universe, and a rejection of dualism in favor of reciprocity. This revolution actually begins with the introduction of Darwinian thinking in the 19th Century, but really takes off with the overturning of Newtonian physics by relativity theory and quantum physics.

Numerous writers and scientists have described the contemporary scientific transformation in varying ways, highlighting different key elements, but there appears to be an overall consensus and connection among these various interpretations of the new ideas of science. For example, Sally Goerner describes the Second Scientific Revolution as a shift from a mechanistic to an ecological world-view.[72] Her interpretation highlights, among other things, the concept of reciprocity. Ilya Prigogine describes the change as that from a "theory of being" to a "theory of becoming", hence emphasizing the dynamic and evolutionary vision of contemporary science.[73] Similarly, Elizabet Sahtouris suggests that science has moved from describing nature in terms of nouns and static entities to describing nature in terms of verbs and a creative living "dance".[74] Stephen Hawking, in his explanation of the emergence of relativity theory, contrasts the differences from Newton's absolutist theory of space and time with Einstein's dynamical and relativist (hence relational) views and further points out that it was Einstein's general theory of relativity that first seriously raised the possibility that the universe as a whole had a dynamical and changing history. Hawkins also, as one of the central spokesmen of contemporary theoretical physics, has consistently advocated for a comprehensive scientific theory of the universe that would not need to include any reality or force outside of the physical universe to explain it.[75] This position entails a scientific rejection of metaphysical dualism.

Lee Smolin provides a comprehensive overview of many of the main features of the transition from Newtonian physics and Platonic philosophy to contemporary scientific thought.[76] First, Smolin argues that within physics we have moved from a Newtonian **absolutist view of space and time** to a relational theory of space and time. The relational theory was supported and defended by the 17th Century philosopher and co-inventor of calculus, Gottfried Wilhelm Leibniz, who was one of Newton's central scientific adversaries and critics. Hence, in Smolin's mind we have moved from a Newtonian to a Leibnizian perspective on physical reality in contemporary times. According to Smolin, the new relational view of reality extends beyond considerations of space and time. Newton also saw material objects as possessing intrinsic qualities such as mass, whereas, Smolin, in direct refutation of this idea, points out that, increasingly, all the properties of physical objects are seen as relational and arising in interaction with other physical objects and forces. Hence, although Smolin does not use the word, the properties of physical entities are reciprocities rather than intrinsic qualities.[77]

Although Einstein, according to Smolin, was inspired in his scientific quest to find a transcendent, eternal, and abstract order to nature, Smolin, in agreement with a similar idea of Hawking described above, believes that any comprehensive scientific explanation of the universe cannot include reference to any transcendent reality beyond the natural world. Smolin believes that both Platonism and the idea of a transcendent God are similar in supposing that order is imposed on the world of nature from some higher realm. He sees both these views as dualistic and unscientific. As Smolin notes, Newton's concept of the universe and natural laws involves a similar dualism as well. Smolin opposes the ancient dualist idea, which was still embodied in Newtonian physics, that order was imposed upon the primordial realm of chaotic nature from some transcendent and eternal reality. Further, Smolin thinks that dualist thinking supports the idea of absolutes, where as contemporary science is increasingly moving toward a relational and interactive view of all of nature. The scientific rejection of the dualism of order and nature began with the emergence of the theory of evolution, which proposed that there was a natural explanation of order within the physical world. Similarly, Smolin argues that evolution can provide an explanation of order in the cosmos as a whole, including the laws of nature, without resorting to some transcendent and dualist reality. In Smolin's mind, there are no absolutes, within nature or beyond. He believes that this is the direction science has been taking over the last hundred years.

Thus in the ideas of both Smolin and Hawking, as well as numerous other contemporary scientists, the presumed boundary between a scientific vision of the universe and a metaphysical vision of ultimate reality is breaking down. As Paul Davies so aptly puts it, physicists are attempting to understand "the mind of God".[78] And, as will be seen in the following sections, physicists like Smolin and Hawking are pursuing general explanations of the entire cosmos, including its origin, its evolution, its laws, and its ultimate future.[79]

Given this introduction to some of the general themes in the Second Scientific Revolution, I now turn to some of the main theories, topics, and issues in contemporary science. In order, these are:

- Open systems, chaos, and complexity theory
- Quantum, relativity, string theory and particle physics
- The philosophy of science and scientific knowledge
- Cosmology and the Big Bang theory
- The future of the universe
- Explanations of the laws of nature
- Information, intelligence, and the cosmos
- Science and religion
- Fractal geometry
- The future evolution of scientific knowledge

Though described separately, the above topics, theories, and issues in various ways interconnect in various ways. Following a description of each main theme or set of theories, some of the basic implications for the future are noted.

The theory of **opens systems** provides a new framework for describing and explaining the nature of the universe. In particular, the theory emphasizes that the entities or units of nature are interactive and mutually supportive, exchanging energy and matter in order to support their inner complexity. Causality is always multiple rather than singular - each system in the universe is simultaneously being affected by and affecting multiple other systems. The emphasis on interaction and interdependency within the systems of nature has replaced Newton's view that nature could be described as a set of discrete and independent units of matter.[80]

The concept of interdependency of the units of nature is a clear example of the idea of reciprocity in open systems theory. Reciprocity, in fact, is one of the most central concepts in open systems theory. Although open systems are distinct, they are interdependent. Sally Goerner uses the expression "ecological" to highlight this essential dimension of nature. Smolin uses the term "relational" to describe the properties and reality of physical units. In her discussion of biological and ecological systems, Elizabet Sahtouris raises the point that the principle of survival of the fittest entails that life forms must fit together – they must be mutually possible. What is fit depends upon its compatibility with other living forms – a species survives because it fits with other species in its environment.[81] Leibniz, in fact, had proposed the idea of "compossibility" to explain the existence and specific variety of entities in the universe. In all these examples the individual units of nature are described as existing in a state of mutual interdependency.

The idea of reciprocity has also been applied to the relationship of the whole and the parts. Smolin, for one, contends that the smallest units of the universe must be connected with the most expansive and general properties of the universe as a whole.[82] The whole and the parts must fit together. Clearly, the whole and the parts of any natural system are distinct realities, yet the whole and the parts are also interdependent. Connecting the reciprocity of the whole and the parts with evolution, Sahtouris states that the universe evolved as a balance of the great and the small. For Sahtouris, order in the universe did not come about by being imposed top-down or being built up out of aggregates bottom-up, but by both factors at work in interaction.[83]

Sahtouris applies her theory of wholes and parts in describing the general pattern of evolution. Following Arthur Koestler's highly influential concept of the **holarchy**, she points out that all entities in nature are both wholes containing differentiated parts and parts of even greater wholes. Everything in nature is both a whole and a part. Koestler refers to the units of nature as "**holons**", to emphasize their dual property of being both wholes and parts.[84] Sahtouris sees evolution as cyclic and rhythmic, where wholes, possessing unity, inevitably differentiate and individuate, which leads to conflict among the parts. The parts, though, eventually find a way to cooperate, creating a new unity and whole. She also describes this cyclic process as a movement back and forth between balance of the parts, the creation of imbalance, and the eventual restoration of balance.[85] This evolutionary model is very similar to Hegel's theory of the **dialectic** – the movement between unity and difference and back again – and the open systems concept of order giving rise to chaos and then leading back to a new type of order. Sahtouris' comprehensive theory of evolution, which is described in considerable detail at the level of ecological and biological systems, illustrates the centrality of reciprocity along several different dimensions. There are reciprocities of wholes and parts, unity and difference, balance and imbalance, and order and chaos emphasized within her theory.

As noted earlier, Sahtouris contends that nature is fundamentally dynamical and more like a process or a dance than a set of static entities. She sees the Newtonian model of nature as a machine as totally inappropriate and inaccurate in describing the universe. The systems of nature grow, change, adapt, and are self-maintaining and self-producing. She believes that the Newtonian concept of a machine described an unchanging concatenation of solid parts that needed to be assembled and moved about.[86] Yet open systems are intrinsically dynamical. Of special note, the theory of open systems is closely connected with an evolutionary perspective on nature. Open systems evolve. Newtonian machines do not. Within general scientific theory, the dynamic units of open systems theory have replaced Newton's inert and stable units of lifeless matter. Matter appears much more alive within the context of open systems theory. According to open systems theory, all physical systems in nature are dynamic, moving, and vibrating realities.[87]

Open systems show the property of **self-organization**. New order is created within a system, often as a consequence of chaotic upheaval and interaction with its surroundings. Further, open systems are described as self-regulating, maintaining a level of organization through the inner coordination of their parts, and self-renewal via the input of energy and matter. In fact, relative to its surroundings, an open system maintains a level of **disequilibrium** or contrast, e.g., inner body temperature versus outer environmental temperature. Open systems are not totally in harmony or equilibrium with their surroundings - this would be a move toward entropy and death. Open systems are not even in equilibrium within themselves – they possess inner structure and differentiation. This self-generated and self-maintained state of differentiation highlights how open systems are in fact distinct from each other, yet this very distinctiveness is maintained through a controlled interaction with other open systems. Hence, they exist in a state of reciprocity with each other.

The idea of self-organization was first applied to the study of chemical, biological, and ecological systems.[88] Yet the concept has been extended to numerous other areas of science.[89] Smolin goes so far as to suggest that the universe itself is a self-organizational system. Its laws may be a result of the process of self-organization. He argues that the laws of the universe are not fixed but rather have evolved over time. At the very least it seems clear, according to Smolin, that galaxies are self-organizational systems, involving feedback processes, the re-cycling of material, and self-maintenance. They are not like Newtonian machines. Galaxies do not exist in thermal equilibrium, but rather dynamic equilibrium, a feature they share with living systems.[90]

Self-organization occurs when there is feedback within a system – when the consequences of processes within a system feed back on and inform the system. **Feedback** is a self-referencing – a registration and sensitivity of a system to its own states. Consequently, Smolin notes that self-referencing is always within time, for feedback is a circular process of output and input. Hence, if order and structure is due to self-organization, then order emerges in time and is not imposed upon temporal realities. In fact, for Smolin, all existence is in time – there is no eternal or timeless existence – a theme I will discuss further in this section.

One of the central challenges of contemporary science is to explain how the more complex evolves from the more simple.[91] Paul Davies sees physics as increasingly turning to the issue of complexity.[92] For Smolin, explaining the structure and complexity of the universe is as fundamental a question as answering what the ultimate simplest constituents of the universe are.[93] Part of the challenge is defining the concept of complexity itself. Murray Gell-Mann believes that complexity evolves in the universe through fundamental laws, the initial conditions of the universe, and chance, or what he calls "frozen accidents".[94] Open systems theory is particularly concerned with the issue of complexity, and often the area of science called "**complexity theory**" overlaps with what scientists call "open systems theory" or "chaos theory".[95] Open systems theory proposes that complexity evolves through self-organization – that new order emerges from within systems and is not imposed upon them.

Smolin notes that the universe appears to show structure and complexity on all scales, from the very small to the very large. It possesses a fractal appearance, with increasingly smaller structures embedded within bigger structures.[96] There are, though, physicists such as Steven Hawking who believe that at the largest of scales the universe is relatively uniform, but the debate on this point is still continuing and we have only begun to extensively map the distribution of galaxies in the universe.[97] At the very least, there seems to be structure up to the level of super-galactic clusters. Just as Murray Gell-Mann identifies as a critical problem for contemporary science the question of how complexity builds up from simpler units, Smolin asks how the universe could have evolved such intricate complexity if it began, as many modern cosmologists contend, in a relatively simple and homogeneous state. Smolin suggests that the recent study of "**critical systems**" may shed light on this question. Critical systems show structure at all scales and do not form in thermal equilibrium, a general feature they share with living systems. Smolin also points out the significance of gravity in explaining structure in the universe. Systems, such as the earth, the solar system, and galaxies, which are held together by gravity, do not move toward homogeneity but evolve in the direction of heterogeneity.

For Smolin, structure in nature comes about not through a single designer but through multiple factors and forces in interaction. Similarly, Sahtouris argues that the universe came into being by the participation of all those involved.[98] This idea that structure and complexity is due to the interaction of multiplicities rather than central and singular command stations is a common theme running through open systems theory and the study of biological systems in particular.[99] Hence, just as systems exist in a state of interdependency and reciprocity, the very structure and existence of these open systems evolved as a consequence of their interaction – they co-evolved. Reciprocity is consequently intimately tied to the process of evolution, in that all evolution is co-evolution. Individual systems do not evolve in isolation. Complexity emerges as an interactive phenomenon.

The **reciprocity** of **order** and **chaos** is also connected to complexity theory. As Murray Gell-Mann and Stuart Kauffman point out, complexity is a balance or synthesis of order and chaos.[100] According to Gell-Mann, neither extreme order (simple repetition) nor complete randomness (total disorder) captures the concept of natural complexity. The largest possible "**effective complexity**" of natural systems lies midway between the complete order and complete disorder. Kauffman states that complex systems, in order to maintain a balance of flexibility and stability, evolve at the boundary between order and chaos, between convergent and divergent forces. In a similar vein, Sahtouris describes nature as being orderly without being perfect, always containing a creative, chaotic dimension.[101]

In open systems theory order and chaos are reciprocals rather than being totally distinct and separate. Chaos leads to order and order leads to chaos, and the phenomena of nature seem to always involve relative mixtures of order and chaos. As we have seen, Newtonian science, reflecting a classical dualism that stretched back at least as far as Plato, treated order as something separate from time and imposed upon the primordial chaos of nature.[102] Yet as Prigogine and others have shown, when systems become increasingly chaotic, exhibiting high levels of fluctuation, they may jump to higher levels of complexity and order.[103] The philosopher of time, J.T. Fraser, describes the nature and evolution of the cosmos as an inextricable conflict of order and chaos.[104]

Because open systems theory and the study of complexity have been applied to the whole panorama of nature, and in particular to both living and non-living systems, it addresses a significant deficiency within Newtonian science. Although Newtonian science seemed to provide a valid explanation of the physical world, it did not seem to adequately address how life fits into the universe. Sahtouris argues that the mechanistic machine model of matter failed to capture the creative, self-organizational nature of life. Rather, she sees life as a continuous evolution from non-life, and in fact, emphasizes that the universe as a whole is more organic than mechanical in the Newtonian sense.[105] Smolin similarly states that within Newtonian science, life has no place and makes no sense.[106] For Smolin, any adequate theory of the universe must cover both life and the physical world, identifying similar principles that apply to all levels of nature, something that open systems and complexity theory seem to do. In particular, Smolin suggests that the principle of self-organization may apply to all levels of order in nature, from the universe as a whole to galaxies, solar systems, ecosystems, and individual life forms, providing a connecting principle between the cosmos and living systems. The

Santa Fe Institute, specifically dedicated to the study of complexity from a multi and inter-disciplinary perspective is attempting to identify common principles of complexity and self-organization across all of nature.[107] As the popular science writer Paul Davies argues, after an initial period in science of specialization and analysis, science is now turning to a synthetic view of nature, attempting to pull the pieces together across the various disciplines and find common principles of connection.[108]

Based on many of the concepts discussed above, Elizabet Sahtouris has developed a theory of the future. Since she derives many of her ideas from biological and ecological science, I examine her futurist ideas in the coming chapters on biology and ecology. Open systems theory, though, has been an inspiration for many other futurist views and perspectives. For example, open systems theory is perhaps the key concept in Fritjof Capra's image of the future.[109] Open systems theory supports the growing ecological mindset of contemporary times.[110] Further, it implies a new view of social organizations and the individual, replacing the Newtonian model of human society. Within the open systems perspective, we are seen, psychologically and socially, as interdependent and evolving realities.

Mention should be made of two social thinkers who specifically emphasize open systems concepts. The futurist Hazel Henderson contends that an open systems approach is necessary for understanding the nature of the contemporary transition in human society. According to her, we cannot understand what is happening to our world today if we stick with a Newtonian model of change and order. Our transition into the future is non-linear and creative, rather than linear, cumulative, and methodical. Further, Henderson sees a change occurring in industrialized countries toward new values, new lifestyles and behaviors, and new beliefs based on open systems principles. Henderson lists six basic principles of open systems science: [111]

- Interconnectedness
- Redistribution (Cycling)
- Heterarchy (Network organizations)
- Complementarity (Reciprocity)
- Uncertainty
- Change

The theory of open systems is the foundation of Peter Senge's theory of **Learning Organizations**.[112] Senge's model of learning organizations is evolutionary and holistic. According to him, members of a learning organization need to share a collaborative vision and a commitment to continual improvement and suspend judgment on what is possible. For Senge, the team (the whole) is smarter than the individual members. Senge also advocates for a network and pluralistic approach to managing change - the world is too complex for one person to figure it out, or one person to direct the entire organization from the top down. Hence, he believes that order in an organization should emerge through the interaction of its members, instead of being imposed from above. Further, Senge sees causality as circular. Humans need to see that they are part of the system. Humans can no longer approach reality as linear, seeing causality as running in one direction. They need to see their responsibility and recognize their influence in working conditions. Everyone interacts. Everyone contributes to the make-up of an organization. Learning organizations require a sense of community, dialogue, and mutual commitment.

Now that open systems theory has been described in considerable detail, and in particular, how it undercuts various Newtonian ideas about nature, I turn to the two main scientific theories that contributed to the overthrow of Newton in theoretical physics. First, **quantum physics** - the theory of the atom and the fundamental constituents of the universe - has revealed an underlying element of indeterminism and apparent contradiction at the smallest scale of physical reality. Subatomic particles have probabilistic locations, states, and effects, and they seem to possess contradictory properties, depending on how they are measured, e.g., they behave as both localized particles and distributed waves. This double-aspect feature of subatomic reality is referred to as the **complementarity principle**, e.g. the electron is both a wave and a particle. Quantum physics appears to contradict Newton's singular vision of reality.

Quantum physics began, early in the 20th Century, in the studies of Max Planck and Albert Einstein. Based on experimental studies and theoretical considerations, Planck came to the conclusion that the basic physical properties of the universe, including space, time, mass, and energy did not vary continuously, but existed in discrete amounts. Hence, there is a smallest unit or "**quanta**" of space, time, mass, or energy. Einstein, continuing this line of thought, proposed that light energy could be described as discrete units or particles of energy called "photons". In fact, since Einstein's work, all the fundamental forces of nature have been described as being carried by elementary particles. Forces come in quanta or localized packets of energy. Yet, light energy, previous to Einstein, had been described and understood as a wave phenomena, spreading out as a rippling through space, possessing both frequency and wavelength.[113] This dual description of light, and later of the electron, both as a wave and a particle, eventually lead Neils Bohr to formulate the complementarity principle as a way to understand the nature of quantum realities. Interestingly, Bohr used the symbol of the Yin-Yang, to represent this complementary union of apparent opposites in subatomic reality.

The **uncertainty principle**, formulated by Werner Heisenberg, is the basis of **indeterminism** in quantum physics. According to this principle, we cannot have complete knowledge of quantum reality. If we know the position of a sub-atomic particle, we cannot accurately ascertain its movement and vice versa. Based on the uncertainty principle, the location and path of sub-atomic particles is described as a probability wave or distribution. A particle has a range of possible trajectories – its path is not precisely defined or determinate. In fact, even quantum units of empty space, a vacuum, exhibit a probabilistic distribution of potential energy states.[114] Empty space, possessing this probabilistic spread of energy states, is consequently creating a perpetual flickering of virtual particles coming into existence and going out of existence. Because quantum reality is probabilistic, there is a constant fluctuation and vibration of energetic states even within empty space. Since physical reality is probabilistic at the quantum level, the future history of the universe is a set of probabilities rather than any individual deterministic pathway.

Newtonian physics is deterministic. Quantum physics challenges Newtonian **determinism** in two ways. First, Newtonian physics entails that if complete knowledge of a system is ascertained at a given point in time, a future (or past) state of the system can be predicted with complete accuracy. Quantum physics states that the future state of a system can only be predicted as a range of probabilities. But second, Newtonian physics assumed that a precise and unambiguous description of a physical system was possible, whereas in quantum physics, the states of physical systems are probabilistic and not precisely definable. Subatomic reality is to a degree "fuzzy" – it is not determinate.

There has been significant dispute regarding whether the probabilistic nature of reality and future states of reality are limitations in our capacity to know reality or inherent features of reality itself. This dispute, though, is connected to the epistemological issue of whether it makes sense to think of reality independent of observation. For example, in measuring particle or wave features of a subatomic state, the properties of reality revealed depend upon the experimental set-up of measurement and observation. If the experimental conditions are arranged one way, particle like properties are observed; if the experimental conditions are arranged a different way, wave like properties are observed. Reality seems inextricably linked to observation – to the act of knowing it – and hence to discuss reality independent of observation is perhaps meaningless.[115] I return to this question of the relationship between reality and knowledge in the discussion ahead on contemporary philosophy of science, but it should be noted that quantum physics seems to imply that we cannot meaningfully separate the nature of reality from the nature of knowledge.

Further, quantum physics describes the universe as an entangled whole.[116] According to Smolin, quantum theory is a non-local theory of subatomic reality. If one is to understand and correctly describe the local state of a particular particle, the local conditions surrounding that particle are not sufficient to determine the state of the particle. The work of John Bell and Alain Aspect, inspired by the Einstein-Podolsky-Rosen argument, seemed to indicate that sub-atomic particles that have interacted with each other, mutually constrain each other's states in the future no matter how far apart they have moved.[117] Hence, although the universe at the quantum level possesses a granular or discontinuous fabric, the states of these fundamental units are interdependent with each other.

Fritjof Capra, in his book *The Tao of Physics* and movie *Mindwalk*, popularized the holistic interpretation of quantum reality.[118] Newton had described matter as a set of discrete and separate particles or objects that possessed intrinsic properties such as mass and size. Capra contends that quantum physics instead reveals that reality is a "web of relationships". Similarly, Smolin states that the properties of subatomic particles are "relational" rather than "absolute", arguing that this insight in quantum theory again represents a shift from Newton to Leibniz in our fundamental thinking about physical reality.[119] This relational theory of the entities or objects of physical reality was introduced above in my discussion of open systems theory. Smolin believes that quantum theory is one important reason for rejecting what he calls "**radical atomism**" – the belief that the physical units of nature possess fixed and intrinsic properties.

The implications of a **holistic image** of nature and humanity are enormous. On many contemporary fronts of human society, the holistic image is rapidly replacing the idea of humans and human institutions as a set of discrete and autonomous entities. To be discussed later, the holistic theme is crucial in contemporary ecological science.[120] We can no longer see ourselves as separate from nature. We can no longer see anything as truly separate. Capra points out that the holistic view sees relationships rather than things as primary. There are no real boundaries - rather there is continual exchange. Problems and issues regarding reality or the future cannot be separately and locally addressed, since everything is connected.

As noted, quantum physics attempts to define and understand the smallest and most fundamental units and entities of physical nature. Toward the end of the 19th Century, the popular belief in science was that all physical matter was composed of atoms, possessing different atomic weights or masses. The study of the atom though as it moved into the 20th Century revealed that the atom actually consisted of smaller constituent parts, notably the nucleus of protons and neutrons and a “shell” of orbiting electrons. Protons possessed positive electrical charges, neutrons possessed neutral charges, and electrons possessed negative charges. Further, protons and neutrons had much higher masses than electrons. The different atoms, such as hydrogen, oxygen, and carbon, had different masses depending on how many protons, neutrons, and electrons were contained within them. Originally, these subatomic particles were imagined as distinct and solid bits of matter, and the atom was envisioned as a miniature solar system with tiny planetary electrons orbiting around a central more massive nucleus. Yet, based upon further study and experimentation, Bohr reinterpreted and re-described this subatomic reality in terms of quantum physics, and the electron was no longer envisioned as a discrete and determinate tiny particle circling the nucleus along a determinate path – the electron became a probability distribution.

Quantum physics, in its study of the atom, sub-atomic particles, and the fundamental forces of nature, has transformed our understanding of matter. In interaction with each other, the smallest units of matter and energy transform into each other and pop in and out of existence in continual fluctuation within the fabric of space. There is a perpetual becoming and passing away - an ongoing dance of creation, transformation, and annihilation. The solid bedrock of physical matter, a seemingly obvious fact of our common sense perceptual world, as well as 19th Century physics, has evaporated beneath our feet.[121]

As quantum physics and the study of subatomic reality evolved in the 20th Century, something very interesting developed. One central quest of physics has been to identify the fundamental building blocks of nature. Early on it appeared that the fundamental building blocks of matter consisted of the proton, neutron, and electron. Yet, new subatomic particles were discovered, including the muon and the neutrino, progressively increasing the number of fundamental particles. Further, based on the **symmetry principle** within quantum physics, the theory of anti-matter emerged implying that for each particle of normal matter there is a corresponding anti-particle possessing the same mass but the opposite charge, e.g., the anti-particle for an electron is a positron, possessing a positive charge. To complicate the matter (pun intended) further, Murray Gell-Mann in the 1960’s developed the theory of **quarks**, in which protons and neutrons are revealed to be composite structures made up out of simpler units, which he named “quarks”. Yet, according to Gell-Mann, there appear to be eighteen different types of quarks, falling into three families, as well as a corresponding set of eighteen anti-quarks. Finally, for each of the four fundamental forces in nature (strong nuclear, weak nuclear, gravity, and electromagneticism) identified in contemporary physics, it was hypothesized that there was a particle that carries the force. For example, photons carry the electromagnetic force and gluons carry the strong nuclear force. All told, by the end of the 20th Century the list of fundamental particles had grown to sixty-one according to Gell-Mann. Such a vast assortment of elementary particles does not seem to make much sense to particle physicists. Smolin believes that the "building block" approach to physical matter may have reached a dead end with the proliferation of so many presumed elementary particles and that a different perspective is needed to explain the ultimate composition of physical matter. One central goal and challenge of physics in the future is to find some system to explain this variety of particles in terms of more fundamental principles.[122]

There is the possibility, though Gell-Mann seriously doubts it, that both quarks and electrons, the basic composite units of atoms, have internal structure and can be further subdivided into even smaller units.[123] Although Smolin thinks that **superstring theory** has its own problems, the idea that elementary particles actually are manifestations of incredibly tiny vibrating strings in different states is one possible way out of the quagmire of the vast zoo of elementary particles.[124] Yet if superstring theory were to provide a complete and testable explanation of the elementary constituents of matter – something it has yet to do – it would mark the end of a long tradition of attempts to explain the composition of matter in terms of object or particle-like realities. Newton's notion of the atom as something like tiny billiard balls would have been replaced by vibratory patterns.

As the number of particles discovered increased through the 20th Century, physicists using the principles of quantum theory attempted to explain the behavior of these particles and connect particle behavior with the fundamental forces of nature. **Quantum electrodynamics** was developed to explain electron and photon behavior and the electromagnetic force. Later, in the work of Murray Gell-Mann and others, **quantum chromodynamics** was created to explain the behavior of quarks and the strong nuclear force, which holds quarks and the atomic nucleus together. Still, later it was demonstrated that the electromagnetic force and the weak nuclear force could be united as manifestations of the same underlying force – the **electro-weak force**. At this stage of theoretical integration we have come to what is commonly referred to as the **Standard Model** of particles and forces in physics.[125]

Aside from efforts through the years to explain the diversity of physical matter in terms of some fundamental set of elementary particles, physicists have also been working toward the reduction and simplification of the various forces of nature. As noted above, contemporary physics has identified four fundamental forces, but the belief and hope of physicists is that these four forces are actually manifestations of some unitary primordial force. Connecting the electromagnetic and weak nuclear forces seemed to be a significant step in this theoretical unification. Given this success, physicists began discussing a **Grand Unified Theory**, which would unite the electro-weak force with the strong nuclear force, but there are still theoretical problems and challenges in achieving this end.[126] As Murray Gell-Mann points out, the Grand Unified Theory, even if successful at uniting the electro-weak and strong nuclear force, still doesn't account for the gravitational force. As many physicists would state, we still do not have an acceptable **quantum theory of gravity** and this problem is considered one of the central challenges of contemporary physics.[127] Einstein's general relativity theory provides an explanation of gravity, but relativity theory describes the universe at a cosmic scale, rather than a quantum scale, and as noted in the introduction to this section, relativity theory is incompatible with quantum physics. A quantum theory of gravity would describe gravity at the quantum scale were the probabilistic qualities of reality come into play.

Another unresolved issue in quantum physics is the high number of unexplained values and constants in the physical world. The various quarks have specific masses, as well as each of the other subatomic particles. Why these particular numerical values? The different forces have different strengths. Why? The constants in physics such as the gravitational constant and the speed of light also have specific values. In fact, there are over a dozen arbitrary constants. Why do they have these values and not others?[128]

Brian Greene and many other physicists believe that many of the above challenges of theoretical physics can be resolved in superstring theory.[129] Aside from providing a way to explain the huge assortment of elementary particles in terms of vibratory states of strings, superstring theory also promises to explain gravity at a quantum level and unite the gravitational force with the other main forces of the universe. As discussed below, superstring theory promises to unite quantum physics with relativity theory as well. Superstring theory offers a **Theory of Everything**, explaining all the particles and forces in terms of one theoretical framework.

Yet, according to John Maddox, the testing of superstring theory is still off in the future. The testing of subatomic theory has progressively involved the construction of increasingly expensive experimental devices, up to and including massive particle accelerators and colliders. The proposed Super-conducting Super-Collider in the United States, which potentially could test the newer theories of subatomic reality, was put on hold due to budgetary constraints.[130] Further, Maddox has his doubts as to whether superstring theory will accomplish its goal of explaining all the particles and forces of nature in terms of vibratory states of hypothesized strings.

Regardless of how the future of particle physics evolves, one belief that seems to unite different theoretical perspectives is that the fundamental properties and values of subatomic reality are intimately connected with the origin and initial state of the cosmos as a whole. There are different theories of the origin of the universe, but there is a common belief that the whole is connected to the parts and the beginning of the universe somehow determined the make-up of the cosmos. Further, physicists believe that the four fundamental forces will come together as the universe is traced back to its beginning. All told, understanding the beginning of the universe is the key to understanding the basic forces and elementary particles of nature.

Zohar and Marshall, in their book *The Quantum Society*, propose that quantum ideas can form the basis for a whole new approach to human and social affairs. As Newton's ideas structured everyday human thought and action in the Industrial Era, they believe the new ideas of quantum physics can offer a different mentality for the future of all humanity. In particular, they argue that the complementarity principle contradicts the black-and-white, dualistic thinking of the past and the indeterminacy principle undercuts the idea that reality is a single determinate truth. Instead they suggest that there are always two sides to every coin and reality should be viewed as multi-faceted potentials. Zohar and Marshall see the Newtonian philosophy of determinism and a determinate reality as leading to an **either-or logic**, and the quantum philosophy of indeterminateness and uncertainty leading to a **both/and logic**.[131] These new ideas of quantum physics would significantly alter our view and approach to other individuals and our relationship to groups and social institutions. In particular, the principle of complementarity, as created and articulated by Neils Bohr, would support a logic of reciprocity in understanding human reality. Analogous to the idea that a subatomic reality is both a particle and a wave, the idea of reciprocity entails that natural units, including humans, are both distinct and yet interdependent.

What is particularly interesting, as well as unnerving about quantum physics is that it seems to undercut the principles of common sense. It is not just a challenge to Newtonian thinking; quantum physics is a challenge to a variety of basic beliefs most people, at least in the West, have about reality. For example, is there a reality independent of a person's perception of their world? Can the location of an object be indeterminate? Can objects pop into and out of existence? It seems that common sense would answer these questions one way, whereas quantum theory would answer them differently. Can the basic fabric and structure of the human mind be changed to see reality differently? Zohar and Marshall seem to think this transformation is not only possible but also desirable.

Besides quantum physics, the other fundamental challenge to Newton's vision of the universe that emerged in 20th Century physics was **Einstein's special** and **general theories of relativity**. Einstein replaced Newton's ideas of absolute space and time with operationally defined ideas of relative space and time. In Einstein, location is relative to a frame of reference and measurement, and time is equally relative to a frame of reference and measurement. For Newton, space and time presumably exist independent of objects and processes within them. In Einstein, time is always relative to a clock, which measures duration, and space is always relative to a device for measuring direction and distance. Consequently, whereas in Newton, there can be empty space or empty time, in Einstein there is no empty space or time. Further, whereas in Newton, motion and rest are absolutes, in Einstein, motion and rest become relative. An object can be moving or at rest, depending on one's observation point. Smolin points out that this change in thinking represents a significant shift away from an absolutist vision of reality to a relational view, yet again a shift away from Newton to a Leibnizian theory of reality.[132]

In Einstein's universe, all the basic properties of nature are interconnected and interdependent. Smolin argues that the belief that objects possess absolute and intrinsic properties presupposes the ideas of absolute space and time. Within the general theory of relativity, space and time become dynamical properties that are affected by the distribution of matter in the universe. Both space and time are curved, squeezed, and stretched as a consequence of matter and the force of gravity. They become relational and dependent properties rather than absolute and intrinsic properties. In Einstein's vision of the universe, the mass and measured length of objects vary as a consequence of their velocity through space. In essence, where Newton saw matter, space, and time as separate and independent realities, Einstein sees them as interdependent. Further, Einstein connects energy and matter. From Einstein's famous equation that energy is equal to mass times the speed of light squared, it follows that energy can be converted to matter and matter can be converted to energy.

Einstein's ideas lead to a variety of strange and interesting implications regarding space and time. Concerning time, if Newton's physics described a universe of absolute and intrinsic properties, it also described a static universe that fundamentally remained unchanged through time. But as Steven Hawking notes, general relativity suggested that the universe might not be static but changing.[133] Because Einstein's theories bring time as a variable into the equations of the physical universe, the prospects of time travel can now be considered and understood in light of scientific ideas. **Time travel** is no longer just a fantasy. The issues are complex and there are a variety of technological challenges, but various scientific proposals for time travel continue to emerge and refine themselves in light of Einstein's ideas.[134] Also, if Einstein is correct, traveling to distant stars becomes a possibility since time slows down for the traveler as a spaceship approaches the speed of light. In fact, if time slows down relative to a ship approaching the speed of light, then traveling into the future becomes possible. A ship which took off from the earth and accelerated to some significant fraction of the speed of light could return to the earth thousands or millions of years into the future, although subjectively and relative to clocks on the ship, only a few years may have passed.[135]

Because matter curves space, it is conceivable that a rocket sent out into space, if given sufficient time, could eventually return from the opposite direction. Space may be without a boundary and yet be finite and self-contained. Einstein's theory of the relationship between matter and space also lead to the idea of **black holes**, where the concentration of matter becomes so dense that space is curved in on itself to the point where light cannot escape from the black hole.[136] Further, there is considerable discussion that if it were possible to enter a black hole, without being totally compressed and destroyed due to the force of gravity, one might emerge at some other distant point in the universe or even in a different universe. This popular idea of "**wormholes**" in space, with both entry and exit points, is a common element in numerous science fiction novels, providing future humans with a way to tunnel across vast distances of space in minimal amounts of time. Within Einstein's special theory of relativity, the speed of light, which is approximately 186,000 thousand miles a second, is considered the absolute limit of physical velocity for any object moving through space. But going into a "wormhole" would bypass this constraint, since the traveler would not be passing through space in jumping from one location to another. The two sides of the wormhole would be spatially contiguous although varying distances in normal space would separate them. In fact, it has also been theorized that entering into a wormhole might be a way to travel through time, both forwards and backwards.[137]

According to Smolin, both quantum and relativity physics embodied only partial rejections of Newton's overall theory of the universe. Smolin believes that whatever theory eventually integrates these two main pillars of contemporary physics and brings to completion the Second Scientific Revolution must totally transcend Newton's absolutist concepts of nature. Although Einstein popularized the notion of relativity, he still believed, according to Smolin, in an absolute objective reality.[138] One reason Einstein could never accept quantum theory was its apparent implication that reality was inherently indeterminate. Einstein believed in the reality of objective laws of nature. Yet, except for the speed of light, which Einstein believed measured the same regardless of the observer's motion, the velocity, position, and temporal placement of an event is relative to an observer and measuring device. In quantum physics, the properties identified within a subatomic event are intrinsically tied to the method of observation. In fact, quantum physics could be interpreted as implying that the reality studied and observed involves the participation and contribution of the observer.[139] Both the theory of relativity and quantum physics bring into question the idea of an absolutely objective and independent physical world, but for Smolin this transformation of thought is still incomplete.

Smolin argues that Newtonian science assumes the idea of a detached observer who can stand back from the world and observe and describe it. He believes that the concept of **absolute reality** presupposes the idea of a detached observer. The idea, though, of a detached observer is a reflection of dualist thinking, of the separation of mind and nature. Yet if the observer is embedded within the world, the best the observer can hope for is a point of view, a perspective on reality, rather than some absolute truth regarding the thing itself. As he argues there is no scientifically conceivable way to stand outside the universe in order to describe it. Smolin does point out that the idea of God standing outside of the universe embodies the notion of a detached observer who could understand the absolute reality of the universe, yet he finds this idea scientifically suspect. Also, Plato had proposed a dualism of absolute reality and knowledge versus appearances and relative opinion, where the mind through pure rationality could apprehend absolute truths. But Smolin rejects any form of philosophical dualism. It does not seem possible to him that one can transcend the relativity of being situated somewhere in the world. Smolin believes that one cannot formulate a theory of reality independent of observers embedded within that reality. He thinks that both quantum physics and relativity theory have been moving toward that conclusion.[140]

Criticisms of the ideas of absolute truth and scientific objectivity have also developed within contemporary philosophy of science. Thomas Kuhn's influential *The Structure of Scientific Revolutions* brought into question and debate the idea of scientific progress.[141] Kuhn, together with numerous other contemporary philosophers, including notably Paul Feyerabend, began to question whether science was based upon a set of unbiased, objective facts, since all facts and observations are perceived, described, and measured within the context of a particular theoretical framework. For both Kuhn and Feyerabend, the concepts in a scientific theory provide the meanings given to observed facts. Theories also guide the observer in the selection of facts to be studied and described. For example, the concepts of mass, space, and time in Einstein are different from the concepts of mass, space, and time in Newton. When an object is described in terms of its temporal, spatial, and mass properties in Newtonian physics it means something different than when the object is described within an Einsteinian framework. Facts are always theoretically relative. In fact, for Kuhn, when the **paradigm** or dominant theory in a science changes, the facts change as well.[142]

All in all, contemporary science, aside from being in the midst of a theoretical revolution, has been in the throes of an identity crisis. Besides its objectivity having been questioned, its supposed rationality has also been critiqued. Again using Kuhn as a starting point, he has examined why scientists switch their allegiance from one paradigm to another. Kuhn believes that scientists do not change their beliefs because of some simple rule of logical reasoning or because of some crucial experiment or newly discovered facts. The standard textbook descriptions of the scientific method of reasoning are oversimplified at best, and incomplete or invalid at worse. There are social and psychological factors, involving group pressure, personality, emotion, and culture at work in scientific change. Scientists will hold to beliefs and theories that appear to have been falsified by experiments because they feel or intuit that the theory must be right. Science involves passion, commitment, and intuition as well as reason - scientific change is not simply based on logical conclusions.[143]

These serious doubts regarding both scientific objectivity and rationality are associated with a general critique in modern times of **objective truth**. According to many philosophers and social commentators, we have entered the **Postmodern Era** where all beliefs, scientific or otherwise, are seen as psychologically, historically, and culturally relative.[144] All beliefs are equally subjective and biased. The absolutist beliefs, convictions, and values of previous eras can no longer be rationally supported. The belief in absolute objectivity itself is a bias – a particular theory of reality and knowledge.[145] Elizabet Sahtouris, in fact, contends that science has discovered that there is no single and complete world-view – that all world-views including science are subjective.[146] One could say that the meta-paradigm of western rationality is in chaotic upheaval.

Not everyone agrees with the subjectivist and relativist philosophies that have emerged in recent times. Kuhn has been criticized for emphasizing the conceptual aspect of science to the exclusion of the technological aspect. As Freeman Dyson notes, there are two types of scientific revolutions. There are "concept driven" revolutions and "tool driven" revolutions.[147] Dyson identifies the revolutions associated with Copernicus, Newton, Darwin, and Einstein as primarily conceptual revolutions, involving new ways of thinking. On the other hand, there are revolutions associated with the introduction of new or improved instruments of measurement and observation, such as with the telescope and the computer. New instruments reveal new data and discoveries that may transform science. For example, the computer has introduced a new type of science, "cyberscience", where complex calculations and simulations beyond the individual or even collective capacity of scientists and mathematicians, can be carried out that yield new discoveries and insights into nature.[148] It was the introduction of computers into science that lead to the development of Chaos Theory and the discovery of fractals.[149] But these types of revolutions are driven by facts rather than ideas. For Dyson, such tool driven advances reflect the quality of the tools and not the "ideologies" or belief systems of individuals. In fact, with the introduction of new instruments, most discoveries are "stumbled on" rather than anticipated. According to Dyson, because Kuhn emphasized conceptual transformations in science he misled others into ignoring the significance and centrality of observational and experimental facts in science. Even if facts are theoretically described and interpreted, the vast expanse and depth of factual information, revealed by ever more sophisticated instruments and technology, has grown immensely in the history of science. There is cumulative progress in science.

There are other critics as well. The futurist Wendell Bell, for one, while acknowledging the value of Kuhn and others in pointing out that pure objectivity is not possible and all facts are theoretically relative, does believe that objectivity is a goal of science, and each theoretical advance brings us closer to this goal.[150] Kuhn makes it sound as though all beliefs are equally subjective and irrational, including scientific ones, yet there are scientific and philosophical standards of reason, experimentation, and debate that are used in evaluating ideas and theories. Murray Gell-Mann points out that the ideals of rationality and objectivity may not always be practiced or attainable, but science at its best, does work toward these ideals.[151] Even Walter Truett Anderson, who supports a relativist philosophical position, acknowledges that knowledge does grow through achieving broader and broader perspectives on reality.[152] Returning to Smolin, although he does think that all knowledge of reality is relative to observers in the world, he proposes that science can reach toward an objective understanding of the universe via multiple points of view. Truth and objectivity are progressively achieved through a multiplicity of perspectives, rather than through any single point of view.[153]

Even if we follow this line of thought that multiple points of view bring us closer to an objective understanding of reality, we are still forced into acknowledging that the observer and the knower cannot be separated from what is known. One cannot achieve a detached position from reality and simply describe reality as it is. A multiple set of perspectives or broader and broader perspectives are still perspectives. Objectivity emerges in the context of subjectivity – reality is always being defined in the context of observers, their theories, and their methods and instruments of observation.

The process of taking multiple perspectives on reality, as well as on our own thinking and beliefs, is in fact a real strength within science. Although scientists are often resistant to giving up a cherished or favored theory, the practice of science involves questioning and subjecting to criticism all beliefs. Science is fundamentally an open discourse. Different views are examined and compared. Taking different points of view, both observationally and theoretically, expands our overall perspective outward. As Anderson states, knowledge grows through a broadening of perspective, and this broadening is achieved by breaking out of the limiting constraints of our present view. It is frequently pointed out that Newtonian physics describes nature within a more limited framework than Einsteinian physics. Science moves toward increasing objectivity by expanding its point of view. It is important though to always keep in mind, following the ideas of Kuhn, Feyerabend, and Smolin, among others, that however expansive our perspective becomes, it is still a perspective rather than some absolute vision of reality.

Further, on a related note, since the time of David Hume, it is clear that all scientific or empirical beliefs are contingent. There is always an element of **epistemic uncertainty** within them. We cannot say that within science we have achieved any absolute, indubitable truths. But this is a fundamental strength of science. Scientists should always stay open to the possibility that their point of view is limited or mistaken, and there may be a deeper truth or perspective to be found in the future.

The positive side to the contemporary dethronement of science from its professed position of absolute objective truth and rationality is that the activities and discoveries of science can no longer be viewed as cold, impersonal, and lacking in passion or meaning. The world of science is infused with all the human color, life, and spirit it stereotypically was supposed to lack. If the rational, objective image of science was presumably its strength, it was also its weakness and a source of apprehension and fear among humanity. According to Smolin, the detached observer is a "God-like" notion, clearly inapplicable to science. In fact, science is a creation of individuals and social organizations embedded within the world being studied.

As Vaclav Havel notes, traditional science helped to create the modern dilemma - of living in a schizophrenic reality of objective truths and little meaning and purpose.[154] The belief in absolute truth and pure rationality reflects dualist thinking and the heritage of Plato. It creates the "schizophrenic" split Havel describes. Science, viewed in the traditional Newtonian way, would rob science of its heart and personality. But if Kuhn and Feyerabend are to some degree correct in their analysis of science, this was always a sham and hypocrisy. Science, in the future, may reconnect with the heart and all the personal elements of the human spirit.

The old stereotypes of science really break down if we look at contemporary **cosmology** - the study of the origin and nature of the cosmos. Contemporary physical science is in search of an answer to the universe. Many popular descriptions of science state that science does not ask or try to answer ultimate questions, but this is simply wrong, especially for contemporary physics and cosmology. Physics has been developing and testing the **Big Bang theory** of the origin of the universe, and quantum physics is working on the issue of why there was a Big Bang.[155] Stephen Hawking's worldwide bestseller, *A Brief History of Time*, presents an early outline of his theoretical explanation of the cosmos, totally within physical and scientific concepts.[156] The main thrust of his ideas is that his explanation does away with the need for any supernatural or metaphysical forces starting the process of creation. In his more recent book, *The Universe in a Nutshell*, Hawking further elaborates upon his quest for a scientific explanation of the universe, now including ideas from superstring theory, multiple universes, the anthropic principle, brane theory, and holography. As Hawking states it, "We must try to understand the beginning of the universe on the basis of science. It may be a task beyond our powers, but we should at least make the attempt."[157] This constitutes a deep break with Newtonian science. Newton assumed that God, standing outside of the universe, as in the Biblical account, created the universe and the laws of nature. Hawking believes that there may be a scientific explanation.

We could question whether a complete scientific explanation of the universe could ever be achieved, especially if we believe that human knowledge is an open-ended process raising new questions whenever new answers or discoveries are found. Or perhaps, we believe that a Supreme Being is necessary in order to explain the universe. Yet, it is significant that a potentially complete scientific theory could even be created. The human mind boggles at this possibility.[158] How have we come to the point where such a theoretical explanation is possible, and what will it mean for humanity in the future?

Although Einstein's general theory of relativity suggested the possibility that the universe was not a stable system but rather had a dynamic history, the real breakthrough into our contemporary understanding of the history of the universe came with Edwin Hubble and Milton Humason's discovery in 1929 that the universe appeared to be expanding. Based on observations of a variety of galaxies through the Mt. Wilson telescope, Hubble came to the conclusion that the galaxies observed (in most cases) were moving away from each other, and the farther away the galaxy was from the earth, the faster it was receding away from us.[159]

If the galaxies were receding from each other, extrapolating backwards in time, the idea emerged that in the distant past the matter of the universe was much more densely packed together. The Catholic priest and scientist, Georges Lemaître, first suggested the hypothesis of a "primeval atom" of super-dense matter as the origin or starting point of the universe. George Gamov, in the late 1940's, proposed that the beginning point of the universe was a small bubble of empty space, filled with radiation and at an extremely high temperature, which due to the pressure of radiation began to expand. Gamov's theory, involving the expansion of radiation filled space, became known as the Big Bang theory (though there was no bang or explosion in this process). As the universe expanded, it cooled, and matter was formed from the incredible amount of energy contained within the growing universe. Gamov's Big Bang theory explained the formation and concentration in the universe of the lighter elements, such as hydrogen and helium, based on the idea that in the earliest period of the universe its temperature was great enough to allow for the fusion of subatomic particles into these elements.[160]

The next significant breakthrough came in 1966 when Arno Penzias and Robert Wilson discovered that microwave radiation at 2.73 degrees Kelvin was coming toward the earth from every direction in the sky. This radiation was relatively uniform across the sky and did not vary over time, from night to day, and through the year. This background radiation was seen as clear evidence for the Big Bang theory – a cosmic relic of the early period of the life of the universe. Based on this observation, which since has been further researched in much greater detail, cosmology clearly became an experimental science, where implications based on different theories of the origin and evolution of the universe could be tested and compared with observational data.[161] For example, estimates on the age of the universe have varied between 10 and 20 billion years depending upon theoretical assumptions regarding its origin, and these different theoretical explanations yield different conclusions regarding the make-up and composition of the present universe that can be compared with observational data.

Based on various theoretical and observational considerations, Alan Guth in 1980 introduced the "**inflationary**" model of the Big Bang.[162] The inflationary model hypothesizes that the universe in its early growth went through a short and abrupt period of rapid accelerative expansion – in a tiny fraction of a second it grew 10 to the 28th power times its size. (This number is 10 followed by 28 zeros.) This rapid expansion created the immense amount of energy that generated all the matter of the universe and the rapid expansion smoothed out the universe of any significant irregularities. The inflationary model has gone through a variety of modifications, but Guth has attempted to draw various predictions from it that can be tested experimentally.

According to Smolin, the quest to understand the Big Bang is becoming the central issue in theoretical physics. Cosmologists and theoretical physicists believe that the unification and integration of quantum physics and relativity theory will come when the beginning of the universe is understood. They believe that the four fundamental forces of nature will be theoretically connected and integrated within a correct explanation of the origin and subsequent evolution of the universe. Physicists also think that the vast assortment of elementary particles will be explained and tied together once we see how it all began. Further, why are the laws of the universe the way they are? And why are the values of universal constants what they are? Perhaps the answers are to be found within the Big Bang. At least to some degree, understanding the origin of the cosmos will tell us where it might be heading in the future. All these basic questions of physics could be answered at the beginning of time.

Some of the most interesting ideas in contemporary physics have developed in thinking about the Big Bang and the origin of the universe. Quantum physics has been applied to the origin question. To recall, quantum theory states that any quantum state is indeterminate to a degree and will exhibit a probability distribution of possible future states. Based on this idea, Hugh Everett proposed that each of the possible directions of a quantum state could be thought of as actually occurring, thus producing a multiple branching of causal lines or histories at each point in space and time. Everett's idea came to be referred to as the **"Many Worlds"** hypothesis, for it seemed to imply that the universe is continuously branching into multitudinous pathways. In some universes within this branching, humans exist; in other universes humans do not exist. In some universes each of us exists or similar versions of us; in other universes we are never born. The list of possibilities and possible universes is astronomical within such a theoretical framework.[163]

Although Everett's "Many Worlds" hypothesis may seem extremely strange or improbable, there are many physicists, including Steven Hawking, Frank Tipler, and Murray Gell-Mann, who support some version of it.[164] The "Many Worlds" hypothesis is, in fact, an example of a more general idea that has become very popular in modern cosmology – the idea of the multiple universes. Alan Guth's inflationary model seems to imply that other universes might exist, forever separated from ours.[165] The **multiple-universe hypothesis** has also been connected to the inflationary model in Andre Linde's explanation of the Big Bang.[166] Linde proposes that our universe emerged as a quantum fluctuation within a primordial multiverse and quickly inflated and stabilized. Other universes are also being born within this hypothesized multiverse, some of which collapse back while others take off and evolve.

The ideas of Everett, Guth, and Linde lead us to an explanation of the Big Bang. Why did it happen? Recall that quantum physics implies that reality at the quantum level is indeterminate and that quantum fluctuations, even in empty space, generate a plethora of virtual particles coming into and going out of existence. Now one fundamental metaphysical problem that has puzzled philosophers, theologians, and scientists since the beginnings of recorded history is how the universe could come into existence without there being some force, prime mover, or deity behind the scenes creating it. How could something – the universe – arise from nothing? Yet, according to quantum physics, nothing would be an unstable state, subjected to indeterminate quantum fluctuations. Bubbles of space-time would percolate up within the void of emptiness. Further, obeying the principle of conservation of mass/energy, if these primordial bubbles possess equal amounts of positive and negative energy, positive and negative charges, or matter and anti-matter, their sum total of energy and matter would equal zero, thus "nothing" would be conserved.[167] Thus, according to quantum physics, one can get something from nothing, as long as the something preserves or conserves a zero sum of mass/energy.

One could argue that that void out of which the universe appeared is not strictly speaking nothing since it obeys the laws of quantum physics – at the very least these laws exist prior to the creation of the universe. But we should keep in mind that this hypothesized void possesses neither spatial nor temporal dimensions. Space and time are created within the Big Bang – they do not exist "prior" to it. Still the laws of quantum physics have an existence that is more fundamental than the particular manifestation of our universe, and because of these laws, the void does churn with indeterminate quantum fluctuations. Hence, we come to the idea of the multiverse – the quantum existential ground of creation – out of which our universe was born. If our universe emerged within this creative, unsettled, and primordial state, then other universes probably emerged as well. The hypothesis of a multiverse is basically this notion of a timeless and space-less quantum state of indeterminacy that sets the conditions for the creation of multiple universes.

This explanation of the origin of our universe is a clear example at the cosmological level of the principle of order evolving out of chaos. Ilya Prigogine, in his book *The End of Certainty*, argues that our universe emerged from a primordial state of creative and chaotic fluctuation. Prigogine, in his argument, attempts to synthesize principles of quantum physics and self-organizational theory to describe how our universe began within this chaotic and indeterminate reality. In particular, he emphasizes that this primordial state is creative and dynamic, filled with becoming and passing away. We exist within a self-creative cosmos.[168] Prigogine's views, aside from providing a framework in which to connect quantum physics and self-organizational theory, also scientifically support and reinforce Alfred North Whitehead's philosophy that the universe is fundamentally a creative process.[169] And to return to the puzzle of how the universe began, Prigogine and numerous modern cosmologists are arguing that physical reality is a self-creative process and does not require something behind the scenes instigating the birth of the cosmos. The hypothesis of a creative multiverse, and the emergence of the universe within this context, is a scientific proposal that attempts to explain our origin without recourse to supernatural forces.

The concept of self-creation, applied to the cosmos, may not seem acceptable to those individuals who believe that some type of Supreme Being is needed to explain the origin and existence of the universe. The puzzle of how something can arise from nothing may seem unanswerable or incomprehensible. Yet theories of God invariably invoke this very idea in understanding the nature of a Supreme Being. For example, Spinoza, in his *Ethics*, defines God as the cause of itself[170], and generally if one was to ask someone who believed that God created the universe, what or who created God, the answer would be that nothing created God. God exists eternally. But still, why, we could ask, does God exist eternally, and I think, we are back to Spinoza's idea that God must be conceived as self-caused and self-created. If we were to assume the existence of God, then we are logically forced into the position that something can be created out of nothing – that God literally pulls itself up by its own bootstraps in an act of self-creation. If so, then what modern cosmology is attempting to do is to explain and describe in detail, in a manner that can be, in principle subjected to the standards of scientific inquiry, a theory of the self-creation of existence. Further, in an ultimate rejection at the cosmological level of philosophical dualism, modern cosmology attempts to provide an explanation of the universe without recourse to some transcendental or metaphysical realm that exists beyond nature.

The act of pulling oneself up by one's own bootstraps is in fact an idea that pervades much of contemporary science. The theory of self-organization, discussed earlier, implies that open systems in nature are self-creative and self-sustaining. Sahtouris argues that the universe is created through the mutual participation of its members.[171] Instead of assuming that something outside of nature creates the universe, a dualistic and top-down model of reality, we can see nature as a collective, self-supporting reality. For example, the **bootstrap principle** has been applied to particle physics, as a way to explain the variety and relationship of elementary particles. As Murray Gell-Mann describes it, the idea is that all the elementary particles are constituents of other elementary particles, all the elementary particles are carriers of the forces of nature holding the particles together, and all the elementary particles are composed of other elementary particles.[172] Such a system of particles would give "rise to itself", without there being something more basic supporting or creating it.

One central issue within physics is explaining the various numerical values that the laws, constants, forces, and elementary particles possess.[173] Why does an electron have the specific mass that it does? Why is the force of gravity what it is, and not smaller or greater? Why is the speed of light not higher or lower? As Murray Gell-Mann notes there are approximately twenty apparently arbitrary values in nature that cry for an explanation.[174] Further, it appears that these various numerical values, if they were to be even slightly different, would have produced a universe much different from the one we exist within, and that life and intelligence, as we understand it, would not be possible.[175]

This apparent coincidental alignment of the numerical values within our universe with the possibility of life and intelligence has led numerous physicists and cosmologists, including Frank Tipler and John Barrow, to propose what is referred to as the "**anthropic principle**".[176] The anthropic principle can take different forms, but one version, called the "**weak anthropic principle**", states that the reason why the numerical values of the universe are what they are is that if they were not what they are, we would not be here to observe them as they are – life and intelligence would be impossible. Any universe in which these values were different would not be accessible to observation since there would be no observers within it.

There is also a "**strong version**" of the anthropic principle, which states that the values were set such that life and intelligence could evolve within the universe. The strong version though is teleological and suggests the idea of a creator of the universe who determined the nature of the universe to allow for the emergence of life and intelligence. Generally, physicists and cosmologists, with Frank Tipler being one notable exception, reject the strong version as unscientific.[177] The futurist Michael Zey, also seems to support the strong version, though contrary to Tipler, he does not think that the strong version implies a creator of the universe. Zey believes that the universe, in a self-creative and teleological act, sets its own values to allow for the emergence of life and intelligence.[178]

The weak version of the anthropic principle though does have its advocates within science, including Stephen Hawking, for it seems to provide a selection principle to explain why we live in the kind of universe that we do.[179] The hypothesis of multiple universes suggests the possibility that other universes could have different numerical values for its constants, laws, and mass and force quantities. According to the weak anthropic principle, the vast majority of these universes would be inhospitable to life and intelligence and non-observable.

Superstring theory is also relevant to the hypothesis of multiple universes. As superstring theory developed it became apparent that there were different versions of the theory, but these different versions seemed to connect together, and that underneath their apparent diversity, there was a more fundamental theory, yet to be worked out in detail. This hypothesized more fundamental theory was identified as "**M-**

theory" to connote its element of mystery.[180] If M-theory turns out to be the grand theory of the cosmos, it seems to imply, interestingly, that there is a whole range of different possible universes that, in fact, may manifest more or fewer dimensions than our own universe. Our own universe, within the framework of superstring and M-theory, possesses four observable dimensions (three spatial and one temporal) but actually has eleven dimensions where the other dimensions are curled up at the super-small, sub-atomic level. The four fundamental forces of nature, within this framework, are actually curled up dimensions. Other permissible universes could exhibit more or fewer of these eleven dimensions. Hence, the weak anthropic principle, coupled with M-theory, would state that we exist in the type of universe that we do, with the numerical values that it possesses, which includes four observable dimensions, because in the permissible range of universes, this universe allows for intelligent observers to measure those particular numerical values.[181]

Not everyone believes that superstring theory and the anthropic principle can provide an explanation of the constants and numerical values of the universe. Murray Gell-Mann states that the weak anthropic principle is "trivial" and the strong version is "ridiculous".[182] Maddox states that superstring theory has been around twenty-five years and has still not fulfilled its promise of providing a way to unite quantum and relativity physics into a theory of everything. Further, Maddox describes the anthropic principle as "a monumental banality".[183] Lee Smolin finds superstring theory and the anthropic principle insufficient to explain the numerical values of the universe. Instead, Smolin proposes that a non-dualistic physics coupled with the principles of evolution and self-organization can provide a scientific explanation of our universe.[184]

Smolin begins with the idea that the simplest and most unstable of universes would be generated within the quantum fluctuations of the void or multiverse. These created universes would exhibit basically random variation in their laws and constants, only constrained by the fundamental principles of quantum fluctuation. Yet, given the probabilistic distribution of quantum states, there will be some universes that achieve relative stability. Within this population of stable universes, the capacity for self-reproduction will emerge in some of them. Smolin proposes that black holes, which form with the collapse of giant stars, provide such a reproductive mechanism. He suggests that black holes, where space and time collapse, open up on their other side into the creation of new universes. Universes, in essence, bubble or bud off of each other via black holes. The Big Bang, observed in our own universe, is the expansion of a self-contained universe generated out of the black hole of a mother universe.

Smolin assumes that each offspring universe shows slight and basically random variation in the numerical values of its laws and constants relative to its mother universe. Hence, universes generate relatively similar offspring. **Reproductive universes**, and in particular, highly reproductive universes, will come to dominate the multiverse since each of them will have similar offspring, which in turn will produce more similar offspring, whereas non-reproductive universes will not generate any offspring at all. This process is analogous to the principle of natural selection, only what are being selected for are highly reproductive universes as opposed to highly reproductive life forms. The most highly reproductive universes are those types that produce the greatest number of black holes. Smolin argues that our own universe possesses the specific numerical values that it does because our universe possesses those numerical values associated with high reproduction. In this sense, the laws and constants of our universe are a product of evolution through the natural selection of highly reproductive universes.

Basically, Smolin wants to explain the universe in evolutionary and historical terms, rather than postulate eternally fixed laws and arbitrarily defined numerical values. He sees the latter type of explanation as no explanation at all – something is just postulated as a given without any explanation of why it is the way it is. For Smolin, there can be no **unexplained explainers**. Aside from the apparent arbitrariness of the laws and constants of the universe, another puzzle for cosmologists is the particular initial condition of the universe at its beginning. There are many possible or conceivable starting points one could envision; yet our universe began in a highly unique way. Why? Again, according to Smolin, the initial condition of the universe was the result of a process of natural selection and evolution.

Smolin also believes that the explanation of the universe must do away with any form of dualism or reference to some supernatural realm, a conviction he shares with Stephen Hawking. As I noted earlier, Smolin rejects the idea of a detached observer standing outside the universe. Yet, he also rejects the idea of a detached creator. As he puts it, the idea of a detached creator assumes that there is something that exists which acts upon reality but is not in turn acted upon. In his mind, all existence is interactive and Leibniz's relational physics should be applied to all aspects of the cosmos. There are no absolute realities. Consequently, he rejects the Platonic idea that reality reflects some eternal mathematical form; an assumption he thinks is embodied in superstring theory. Also, as noted earlier, he rejects what he calls "radical atomism", which is the belief that the elementary particles of the universe have fixed and absolute properties.

Yet the real integrative leap in Smolin's cosmology involves his attempt to pull together relativity and quantum physics with self-organizational and complexity theory. In essence, he believes that a theory of being must be tied to a theory of becoming, and in turn tied to a theory of complexity. Since relativity and quantum physics and self-organizational complexity theory are the main elements or components of the contemporary scientific revolution, a successful integration of them would constitute a more complete and definitive transformation of physical science away from Newtonian physics and dualist thinking. To quote Smolin, "…I think a successful theory that merges relativity and cosmology with quantum theory must be a theory of self-organization…This means there must be some relationship between quantum theory and relativity and self-organization, so that it's logically impossible to describe a relativistic, quantum-mechanical world unless mechanisms of self-organization act in that world to produce the complexity the theory needs if it's to be logically consistent."

Both quantum physics and relativity theory, according to Smolin, define physical reality relative to an observer making measurements within that reality. There are laws in both these theories, but the laws are invariant features of reality described in the context of observations and measurements. In fact, following a relational theory of reality, all properties and facts of the universe are described as relationships between entities or events in nature, and this relational reality also applies to the observer and the observed. What is observed is defined in relationship to the observer. Now quantum and relativity theory require, Smolin argues, a level of complexity in the universe being described to make any sense. For example, time measurements involve some type of clock, whether it is natural or constructed, yet clocks are complex realities.

Consequently, time can only exist in a universe complex enough to have clocks[185], and both relativity theory and quantum physics require clocks in their measurements and descriptions of reality. Smolin, following current thinking in complexity theory, argues that complexity involves a balance or combination of order and variety, of regularity and change.[186] And further, he points out that both relativity theory and quantum physics, in general, embody in their laws a necessary combination of regularity and variation. Now, since for Smolin all complexity in nature is due to self-organization and evolution, or to put it more generally, all order emerges in time, any viable theory of physical reality – a theory of being – must include a **theory of becoming**, for being requires complexity and complexity requires becoming.

It is interesting that Smolin's conclusion dovetails with Prigogine's ideas on open systems and self-organization. Prigogine, back in the 1980's, had argued that physics required a theory of becoming to complete its explanation of nature, which in his mind, up through and including quantum physics, was still basically just a **theory of being**.[187] Further, again in agreement with Prigogine and current thinking in open systems theory, for Smolin complexity and order emerge as an interactive process among the systems of nature. There is nothing outside nature bringing order to it; there is nothing in nature that is fixed or arbitrary that is not a consequence of dynamic interaction. As noted earlier, Smolin, in agreement with both current thinking in complexity theory and physical cosmology, argues that the individual elements of nature (the parts) and the cosmos (the whole) are an interactive reality as well. Recall that contemporary cosmologists think an explanation of the elementary particles of the universe will involve an understanding of the origin of the cosmos as a whole. All told, Smolin, like Hawking, believes that a totally self-contained explanation of the universe is both possible and desirable, and for Smolin, this explanation will describe the cosmos as an interactive, self-organizing reality.

As we can see, explanations of the origin and nature of the cosmos have emerged, evolved, and proliferated in science over the last century. There is increasingly sophisticated dialogue and research focused on developing a complete and comprehensive understanding of the universe. Although Newton provided a unified picture of nature, something that contemporary physicists are still struggling to re-achieve, Newton left many factors unexplained, relying on the hand of God to account for them. In Newton's mind, God created the universe, its laws, and all its constituent parts. In contemporary physics and cosmology, none of these basic facts of existence is treated as a given – all of them are open to investigation and explanation. As Maddox points out, the very fact that we are even able to formulate possible explanations of the origin and entire nature of the cosmos is an incredible achievement and advance in our thinking.[188] From one perspective, the Second Scientific Revolution could be viewed as the overthrow of Newtonian physics in all of its main components and implications, yet since Newton, as well as the other architects of the first Scientific Revolution, saw God as occupying a central role in their complete vision of existence, the Second Scientific Revolution could be seen as an abandonment of the need to postulate the existence of God to explain any aspect or feature of the natural world. Though physicists such as Paul Davies talk about science as being an effort to read the "mind of God", an expression that goes back to Einstein as well as early scientists who believed understanding the laws of nature was in fact understanding God's master plan, the existence of God has progressively moved out of the picture as a necessary element in explaining any feature of the universe.[189] As I noted earlier in this section, science has been steadily moving into areas and topics previously thought to be exclusive concerns of religion, metaphysics, and theology.

Modern cosmology and physics, as I have argued above, constitute another clear example of the abandonment of dualistic thinking associated with earlier eras of western civilization. In this case, the dualism that is breaking down is between the religious-supernatural and the scientific-natural. Science, in the 20th century, has definitely bridged the division created in the Scientific Revolution between science, on the one hand, and religion and metaphysics on the other. Frank Tipler, for one, wants to break down the separation of science and theology.[190] Other cosmologists, such as Smolin and Hawking, want to do away with any need to postulate God or metaphysical-supernatural forces in their explanation of the universe. A significant event in the coming centuries almost certainly will be the formation of a new relationship between science and religion. The implications of the new physics and cosmology will undoubtedly permeate into culture and society just as past scientific ideas influenced social and cultural practices and beliefs. The separation of science and religion was intimately connected with the mindset of the Industrial Era and Newtonian science, and this mindset is being rejected along many fronts in the ongoing evolution of science and technology.

If there is to be a new dialogue in the future between religion and science, it could take different forms or go through different stages. One can imagine a new war emerging between scientific cosmology and religious views of the origin of the universe. A war of words and ideas - an information war - is still being fought between the evolutionists and the creationists.[191] Perhaps in the future the dialogue will be more constructive, open, and mutually enriching. Regardless, something very new is brewing in modern science and its effects are going to ripple out into theology, religion, and other aspects of human society.

The dualism of Newtonian era science and religion is also reflected in their understanding of order and natural law. Newton had assumed that the laws of nature were supernaturally set at the beginning of time, and the ordered arrangement of nature and its constituent parts was also seen as created and set by God. In general, the Newtonian model assumed that order was imposed on natural reality. Yet, in many respects, contemporary science has abandoned this view of natural order, and instead has approached order and law as a consequence of evolution and natural processes. This change in perspective is clearly obvious in Smolin, who believes that the laws of nature and all complexity are the result of evolution and self-organization. Murray Gell-Mann, Paul Davies, and Stuart Kauffman see the explanation of complexity as a central concern in science. Theoretical physicists are working toward an understanding of all the basic physical forces that would describe and explain the sequential evolution of the basic laws of the cosmos. As the universe cooled the various fundamental forces and the specific laws that describe them presumably differentiated, producing the complex array of regularities we see in the present universe.

Following from the idea that order and laws evolve, contemporary social thinkers and futurists argue that the laws of any organization should not be viewed as something imposed, but rather as something that develop within an organization. Order comes from within - not from above. As Toffler, Wheatley, and others note, business, economic, and social institutions of the Industrial Era were modeled on Newton - order should be imposed from the top.[192] Industrial age organizations were hierarchies with authorities creating the rules for everyone to follow. Many human organizations are presently moving toward a new model of order - rules of order arise through the participation of everyone involved. It is clear that this new scientific perspective is transforming our world.[193]

There are, of course, some big questions that have yet to be answered within contemporary science, and there are undoubtedly other big questions that have yet to be asked.[194] The most significant present theoretical puzzle is probably how to integrate relativity theory and quantum physics, though as we have seen, superstring and M-theory offer possible solutions to this problem. The puzzle is often described as finding a quantum theory of gravity or finding a way to unite the large-scale principles of relativity with the subatomic scale of quantum physics.[195] Both Kaku and Maddox believe that the solution lies in a deeper understanding of space and time. Whereas Newton believed that space and time were absolutes and homogeneous continuums, relativity and quantum theory have revealed that space and time are more complex and dynamic. Superstring theory, in fact, describes space and time as possessing a deep microscopic structure or fabric – an intertwined vibratory labyrinth.[196] If the origin and primordial composition of the universe lie within an ultra-small bubble of space-time, then we may find that the laws of the universe are somehow embedded within what we refer to as “empty space and time”.[197] According to Kaku, if we can understand and eventually master the very fabric of space and time, we can answer whether wormholes for jumping about the universe or between universes, as well as time machines, are possible, and perhaps even construct them.[198]

As our understanding of the origin and evolution of the universe has grown, our ability to predict the future evolution of the universe has also grown. In fact, understanding the history and laws of the universe is helping us to understand and predict the future of the universe. Again, just as possible answers to the origin of the universe are open to debate and subject to further discoveries, answers about the future of the universe are also contingent and evolving. Yet, there are a variety of important insights that have emerged, as well as numerous issues and controversies.

Two of the earliest theories of the future of the universe are the downhill and cyclical theories of time. Following from the **second law of thermodynamics** and the principle of **entropy**, scientists in the 19th Century proposed that the universe must be progressively winding down and eventually will reach a “heat death” where all complexity will dissipate and the universe will come to a state of thermal equilibrium. This is basically a **downhill theory of time**. The **cyclical theory of time** has a much earlier origin, deriving probably from early observations on the various cycles of nature. If applied to the universe as a whole, it predicts that the universe will circle back on itself, one or more times, perhaps for all eternity. Both of these theories, in essence incompatible with each other, need to be evaluated in the context of contemporary physics and cosmology.

As Murray Gell-Mann notes, quantum physics implies that the future development of the universe is at best probabilistic. The principle of indeterminacy entails that predictions of the evolution and fate of the universe can only identify a range of possible trajectories as opposed to some definite path and outcome.[199] This element of uncertainty could be interpreted as allowing for the possible intervention and guidance of intelligence in the future evolution of the universe. Various scientists, such as Frank Tipler and Ray Kurzweil, believe that intelligence will play a role in the fate of the universe.[200] But the quantum indeterminacy principle could be interpreted as implying that whatever scientific or technological capacities emerge in the universe, the future will always contain an irreducible element of uncertainty and adventure.

Yet, even granting the element of indeterminacy, there are certain general directions that the universe could follow that derive from considerations of its overall make-up and the laws of nature. Three basic scenarios have been defined, contingent upon the rate of expansion and the total amount of matter within the universe. Assuming the universe is expanding, scientists predict that this rate of expansion is being progressively slowed down due to the force of gravity pulling matter together. To recall, space is curved due to the gravitational force of matter. If there is sufficient matter in the universe to eventually stop the expansion of space and reverse the expansion, the universe will eventually begin to shrink in size, overall temperature increasing and matter compressing, and collapse backwards into a sub-microscopic point. This scenario is popularly referred to as the **Big Crunch** and represents what cosmologists call a "**closed universe**". If on the other hand, there is not sufficient matter to slow down and stop the expansion, the expansion may continue forever, galaxies and physical matter becoming increasingly spread out and dissipated, and the overall temperature of the universe progressively going down. This scenario is referred to as the **Big Chill,** an "**open universe**", and is a variation on the Heat Death theory. The third scenario assumes that the universe possesses a "critical density" of matter, just enough to progressively slow down the expansion, but not quite enough to stop the process. This slowing down will continue indefinitely and represents a "**flat universe**".[201]

One problem in predicting which of these three scenarios applies to our universe concerns ascertaining the present rate of expansion. This has been a point of concern and issue since Hubbell first discovered that the galaxies were moving away from each other. The greater the present rate of expansion, given its age, which is still open to dispute, the more matter is required to slow down and reverse the process.[202] Also, there is still discussion regarding whether the rate of expansion is slowing down or perhaps, for reasons uncertain, speeding up.[203] The central issue, though, concerns the amount of matter in the universe. Various measurements and estimates have been made, and the observational data, at one level, seems to indicate that there is not enough matter to slow down and stop the expansion. Hence, we live in an "open universe". Yet, predictions about the amount of matter generated within the Big Bang, and in particular, those predictions associated with the "inflationary model", seem to imply that the universe possesses a "critical density" of matter, and hence, we live in a "flat universe". Where though is the missing matter? There are various proposals, including the idea that there is sufficient "**dark matter**" surrounding the galaxies (suggested by observations of the rotational pattern and coherence of galaxies) to account for the missing matter needed to make the universe flat.[204]

Whether the universe is flat or open, our present understanding of the physics of stars and matter leads to a variety of general predictions regarding the evolution of the universe at least trillions of years into the future. Fred Adams and Greg Laughlin, in their book *The Five Ages of the Universe*, have, in fact, outlined a future history that extends outward to mind-boggling numbers, way beyond mere trillions of years, based simply on contemporary astronomy and physics.[205] According to them, the laws and constants of the universe constrain the physical possibilities of the future. Adams and Laughlin begin by assuming, based on present measurements of the amount of observable matter, that the universe is probably open. They divide the life of the universe into five cosmological decades, each of which represents a fundamental type of astronomical ecology and composition to the universe as a whole.

The first decade or era is the **Primordial Age**, when the universe was radiation dominated, and this age runs from the Big Bang to approximately 10,000 years. The second era, our present period, is referred to the **Stelliferous Age**. During this age, atoms and galaxies formed and the universe is "filled with stars". Our sun, a normal yellow star, has a predicted life span of approximately 10 billion years and is around half way through its normal period. Its present state and level of luminosity will end when it burns up all its available hydrogen fuel, and after a short period of swelling into a red giant, it will shrike into a dwarf star. Stars' life spans can be predicted, based upon their mass and rate of fuel consumption. Generally, the more massive the star, the quicker it burns its hydrogen fuel, and the shorter its lifespan. Red dwarfs, much smaller than our sun, burn their fuel more slowly, and have expected life spans running up to trillions of years. During the Stelliferous Age, although the galaxies will continue to move apart, galaxies that are relatively close together may be gravitationally drawn together into meta-galaxies. Our neighbor, the Andromeda galaxy, appears to be moving toward the Milky Way, and the two galaxies will probably collide six billion years into the future. The Stelliferous Age will come to an end when the available gas for new star formation is gone and red dwarfs have mostly all burned out. Adams and Laughlin estimate the end of the Stelliferous Age at approximately 100 trillion years into the future.

The third age, the **Degenerate Age**, will run from approximately 100 trillion years to ten to the 39^{th} power years into the future. (This number is one followed by 39 zeros.) During this age brown and white dwarfs will dominate space and the universe will become much darker with little light. Although brown and white dwarfs burn their fuel much slower than our sun, they will eventually come to an end off in the distant future. During this period, the last planets will also disappear, at approximately 10 to the 20^{th} power years into the future. Further by the end of the Degenerate Era, galaxies will have significantly disintegrated, and the only stellar bodies remaining will be black holes of various sizes. The fourth era, the **Black Hole Age**, will run from approximately ten to the 40^{th} power years to ten to the 100^{th} power years (a googol years) into the future. During this time, black holes will slowly release their energy, predicted by Hawking's quantum theory of black hole radiation, and eventually evaporate.

Through these different ages, the universe will continue to expand, perhaps increasingly more slowly, but by the time we get to the final age, the **Dark Era**, the universe could be trillions upon trillions of times its present size. The matter of the universe will be entirely composed of subatomic particles, the present composition of compressed atoms also eventually dissipating, and these subatomic particles may form into colossal sized, yet incredibly dispersed systems where elementary particles circle each other in orbits bigger than the present size of the observable universe. The Dark Era runs from ten to the 100^{th} power years outward.

Although the amount of available energy decreases as we move outward through these succeeding eras, the time scales of events progressively increases, and according to Adams and Laughlin, the universe never reaches a state of total quiescence. New processes emerge to dominate the cosmic story and history never comes to an end. It is quite conceivable that systems of life and intelligence could evolve in future eras. These systems would be vast in size and longevity way beyond our present understanding of life and intelligence. Adams and Laughlin describe the possibility of intelligent beings and modes of communication developing that utilize black holes as a source of energy. Ephemeral beings could even emerge in the Dark Era, where their bodies stretched across trillions of light years, and communication among them required time periods that exceeded the present age of the universe. Such systems, from our point of view, would seem to exist and operate exceedingly slowly, analogous to how our rate of operation would appear to the subatomic realm where events are measured in trillionths of a second. Yet, the amount of available time within the Degenerate, Black Hole, and Dark Eras vastly exceeds, by powers of trillions upon trillions, our limited time period within the fast paced Stelliferous Age.

Even when we come to the Dark Era, various further possibilities suggest themselves. Adams and Laughlin discuss the multiverse concept and in particular cite and support Andrei Linde's idea of eternal and continued creation of new bubble universes. They also consider the idea that the universe, given sufficient time, might go through a phase transition and enter into a whole new period of evolution, with perhaps different laws and a different composition. All in all, they do not see time and history as coming to an end or repeating itself, but rather continuing indeterminately with potentially endless novelty and transformation.[206]

The ideas of Adams and Laughlin, which I have only sketched in outline within this summary, illustrate how our contemporary scientific understanding of the universe can lead to sophisticated and detailed extrapolations far into the distant future. There are numerous other scientists, including Michio Kaku, Freeman Dyson, and Frank Tipler, who have also considered in detail the distant future and the ultimate fate of the universe. Kaku discusses both the Big Chill and Big Crunch scenarios as likely candidates for explaining where the universe is heading; he also though considers as a real possibility the eventual ability for intelligence in the universe to tunnel into another universe and escape extinction. He believes that if humans can achieve a deep and fundamental understanding of space and time and manipulate the fabric of space and time, we, or our descendents, might accomplish this feat.[207] The capacity to create a hole in space and leave the universe is a scenario described in Stephen Baxter's *Vacuum Diagrams*, though in this novel, it is the mysterious and alien Xeelee that create this escape route out of the universe and not humans (though a few humans do follow the Xeelee through the wormhole before it collapses).[208] In fact, the eventual fate of the universe is often linked to the presence and potential advanced powers of intelligence within it.[209] Dyson and Michael Zey both consider how intelligence might find ways to adapt to and control a universe that is flat and at critical density, and continue to exist and thrive indefinitely.[210] Tipler, whom I discuss in detail later in Chapter Five, considers how intelligence could control a Big Crunch, and generate an infinite amount of power and subjective time, and in essence, live forever.[211] All told, there are at least four or five different technological proposals regarding how intelligence in the future could avoid extinction and oblivion within either a Big Crunch or Big Chill scenario.

The significance of intelligence within the universe has already been discussed in the context of the anthropic principle. I have also examined the apparent necessity of including observers within any meaningful description of reality. Intelligence though can also be connected to the physical universe in the context of information and computer theory. The universe can be described as a great information processing or **computational system**.[212] Information scientists would argue that the universe is fundamentally a highly complex and interactive pattern of information and information processing. Time (or change) is simply the universe computing or processing the information content of the universe. In essence, the universe of matter and energy is a vast computer (hardware) and the laws, patterns, and relationships of the universe are its software and information content.[213] Yet in this case, the universal computer is somehow writing its own software, and this software, with the progressive emergence of intelligence, is manipulating the hardware. It has even been suggested both in science fiction and non-fiction scientific speculation, that the universe might be a virtual reality simulation being run in a computer in some higher dimension or level of reality.[214]

Ray Kurzweil has described the process of evolution in terms of information theory. Evolution involves the emergence of higher levels of complexity, of more complex systems. More complex systems embody more information content. They process both more information and more complex patterns of information. Further, increasingly complex systems, such as living cells, nervous systems, and brains possess higher informational density (more information is stored per unit of space) and process information at increasingly higher rates.[215] For Kurzweil, intelligence involves the capacity to marshal and use information to influence the physical environment, and throughout evolution, life forms have developed increasing intelligence.

Murray Gell-Mann presents a model of the evolution of **complex adaptive systems**, which illustrates a similar idea. For Gell-Mann, all complex adaptive systems, which include living forms, social organizations, and computers, acquire and organize information about themselves and their environment, use this information in interacting with their environment, and further modify and develop their information content based on interactions with their environment. In essence, complex adaptive systems learn and what they learn is new information. Further, as Gell-Mann notes, biological evolution is itself a complex adaptive system. For Gell-Mann, complex adaptive systems seem to generate more complex adaptive systems, as life generated nervous systems and thinking humans, which in turn generated social and cultural systems, which in turn created technology and computers.[216]

Consequently, in alignment with Kurzweil's thinking, Murray Gell-Mann sees evolution as involving the progressive growth of more complex systems, which embody and process more complex forms of information. The process being described here is, in fact, the process of self-organization understood in terms of information theory. For Kurzweil this evolutionary process equates with higher levels of intelligence. Within an information theory model of the universe and its evolution, intelligence can be seen as a natural development of increasingly complex modes of information storage and processing.

The information-computational perspective is interesting because it is a good example of how technology can influence scientific theory. A technological device and the theory associated with it provide a model of nature. Second, as noted earlier, computer technology opens up a whole new arena of scientific experimentation and research – what Kaku has referred to as **cyberscience**.[217] Models of natural systems (e.g., galaxies, solar systems, and ecosystems) are being simulated and investigated on computers.[218] Instead of trying to run an experiment in the real world, the essential variables of some natural system are programmed into a computer and the experiment is run on the computer. Chaos theory evolved from computer simulations of weather forecasting, and physicists have explored and tested various computer models of the Big Bang. Artificial worlds and artificial life can be created and evolved on computers.[219] Experiments that would be impossible to do in the real world can be simulated on a computer.

Historically, humans have used their inventions, machines, and technologies as metaphors or models of life, society, and often, themselves.[220] For Newton, the universe was a clock and Descartes saw the human body as a vast network of pumps and levers. Seeing reality as a vast computer or information processing system is simply the latest example of "technologizing" nature. Further, humans create and mold their realities in accordance with their technological models and metaphors; we infuse our technologies into nature and society. We are, in fact, altering our world again, both physically and psychologically, in accordance with the image and reality of computers. The future could be a world that, in its material organization and functioning, looks and behaves like a vast network of computers. (Some would say that this computerization of reality is already well underway.) The belief that nature and human reality is like a computer (or is a computer) could turn into a self-fulfilling prophecy.[221]

The theory that the universe is a vast computer brings us to the idea that nature possesses some type of intelligence and this intelligence is evolving. Instead of viewing the world of matter as inanimate and disconnected from humanity, the world of matter is seen as a complex pattern of information that is computing its own behavior and activities. This "**intelligence model**" of nature affects how we see technology. If matter and nature possess intelligence, how can we view machines as dumb, soulless mechanisms? This new perspective also changes our perception of natural processes from mindless forces and reactions to a reality that is similar to the processes of intelligence in the human being. As Elizabet Sahtouris points out, the mechanistic view of matter and nature actually replaced an earlier organic vision of nature that saw the universe as alive and possessing intelligence.[222] We have already noted that galaxies appear to be self-organizational systems involving feedback and sustained states of disequilibrium. How clearly in nature can we draw the lines between the inorganic, the living, and the intelligent?[223] Within an information-processing model, nature is evolving intelligence within itself, and further, we are part of this evolving intelligence. Within this context, information technology can be seen as part of this natural evolution - enhancing and accelerating the ascension of mind within the cosmos.[224]

Some writers, such as Michael Zey, even argue that the universe, through the evolutionary process, is seeking intelligence as a survival strategy to avoid a Big Crunch or Big Chill and its consequent demise into oblivion.[225] Zey believes that in the long run intelligence will undermine entropy. As Zey argues, our vision of cosmology influences our thoughts, actions, and goals. The Big Bang theory and associated Big Crunch and Big Chill scenarios lead to a general philosophical nihilism about reality, and the rise of Postmodern thought has undercut Western notions of progress. We are a culture in need of a new positive vision for the future that gives direction and that is supported by modern science and cosmology. Zey thinks that a cosmology that sees a central guiding role of intelligence within it would provide such a realistic and positive vision. I would add, though, that any positive and realistic cosmic vision will require dramatic and narrative embodiment as well, supplied through various science fiction epics about the future of intelligence within the cosmos.

One additional contemporary scientific idea, relevant to this present discussion of intelligence in the universe, is **fractal geometry.**[226] Fractals were first discovered and studied extensively by Benoit Mandelbrot, and one of the most famous fractal patterns, the **Mandelbrot Set**, presumably the most complex object uncovered in the universe, is named after him.[227] Fractals are geometrical patterns created with computers by simply recalculating the same equation over and over again, innumerable times, using the result or product of a calculation as the input for the next calculation. The results of these calculations are graphically plotted on a computer. Out of this circular process of output becoming input emerge the most intricate and beautiful forms. These forms are strikingly similar to numerous patterns in nature, including hurricanes, trees, circulatory systems, coastlines, and galaxies. Fractals look like ever-branching whirlwinds and vortices and no matter how minutely they are examined, the same patterns keep repeating themselves, in endless variations, over and over again, e.g., like a tree that would keep branching into smaller and smaller branches of similar pattern.

Fractals clearly resemble the turbulent forms of chaotic systems in nature. Many contemporary scientists, including Mandelbrot, believe that fractals embody the general form of all systems in nature, synthesizing the elements of order and chaos, of regularity and variation. Smolin, for one, thinks that the patterns of nature are much more like fractals than they are like the structures of Euclidean geometry.[228] Beginning from ultimately simple mathematical concepts and evolving through the process of feedback, fractals show a level of complexity and detail highly suggestive of nature's richness and depth. Fractals are like critical systems, or perhaps, more correctly, critical systems are fractals, for critical systems show the pattern of structure at every level of size or scale, analogous to the endless embedded intricacy within fractals. Interestingly, fractals are becoming one of the most popular art forms to emerge out of computers and chaos theory - they are the art of the future. Smolin even proposes that a scientific based concept of beauty can be founded upon fractal geometry.

It is important to note that fractals show the property of **self-reflectivity** or symmetry, mirroring their same general form down to infinitely small size and detail. They evolve through a self-reflective operation of output becoming input. As I noted earlier, Smolin contends that all self-organization in nature requires self-reflection. If fractals do model or represent the basic patterns of nature, then it is interesting that they are the result of computation, feedback, and self-reflectivity. Nature computes and creates its forms through a type of functional self-awareness.

Further, the idea of reflectivity within nature brings us back to an idea expounded in both Leibniz and, even earlier, in Leonardo da Vinci. Leibniz proposed in his theory of "**monads**" that each entity in nature is a mirror on the universe – a unique reflective perspective on the whole.[229] Leonardo da Vinci suggested a similar idea of how nature was organized and individuated. In my previous discussion of the reciprocity of the whole and the parts, I stated that many scientists contend that the units of the universe reflect the make-up of the whole and vice versa. The idea of fractals bring us back to this idea that reflectivity is built into the very fabric of the universe and is responsible for the creation of the multi-leveled and intricate structure of natural systems. The distinctive features of a fractal structure build up through a reflective process among its myriad elements.

Finally, it should be emphasized that fractals are evolutionary forms. They are dynamically created, and their patterns emerge through a process of computation and self-reflection. As Goerner notes, treating the geometry of nature as dynamic involves a significant shift away from the Platonic notion of eternal and static geometrical and mathematical forms.[230] Smolin, to recall, argues that all structure and order in nature evolves within time, and that self-reflectivity, the foundation of self-organization, is a dynamic process within time. Fractal geometry, consequently, further reinforces the scientific hypothesis that the forms of nature are not given in creation, but rather evolve.

Given this review of contemporary scientific theory, it should be clear that the ideas of evolution, reciprocity, and a multi-faceted rejection of dualism define the present direction of our growing understanding of nature and the universe.[231] In spite of all the debates and discussions over whether Darwin was right and what kind of revised theory of evolution should replace his views, the general principle of evolution has only grown in significance within the last century of science.[232] The evolutionary theme runs from open systems theory to cosmology and information theory, creating a much more dynamic and developmental picture of the universe than Newton's physical theory. In general, the physical universe is no longer seen as a stable clock-mechanism; rather, nature is now seen as composed of a set of interactive systems in continual fluctuation, mutual creation, and further development. The mechanical and rigid machine as a model of nature is being replaced by a fluid, dynamic, and creative system in evolution. This ubiquitous contemporary scientific principle suggests many metaphors, analogies, and implications in viewing human society and planning for the future. Order should be evolved within human organizations rather than being imposed from above; there is no perfect system because evolution is open-ended and ongoing; organizations should be seen as fluid rather than fixed.[233] Within the last hundred years, the scientific idea of evolution has rippled outward, influencing the modern mind, human life, and human society. It is one of the most common and central ideas in various theories of the future. It is a basic premise in the futurist visions of Toffler, Stock, Sahtouris, Kelly, and Zey, to name just a few of the futurist theorists discussed in this book.[234]

If the mechanical clock had been the Newtonian model of the universe in the Industrial Era, the atom, with its central nucleus and orbiting electrons, became a basic icon of science early in the 20th Century. The early model of the atom, though, is like a mechanical clock, with the periodic and determinate revolutions of electrons. Further, this model represented the atom as a centralized and **hierarchal** mechanism with its relatively heavy nucleus holding the system together. But later in the 20th Century, with advances in quantum physics, this simple model of the atom has broken down. Throughout science, the **network** of interactive parts has replaced the order-imposed, centralized hierarchy as the icon and model of natural organizations. The evolving, interactive network has replaced the rigid hierarchy, as both the model of nature and the model for contemporary and future human society.[235]

The concept of networks brings us back to the idea of reciprocity – of mutual interaction and mutual dependency. The universe is a reciprocity of whole and parts, of systems in mutual creation, of order and chaos, of knower and known. Efforts to comprehend the cosmos without reference to transcendent unexplained explainers reflect the movement away from dualism toward a reciprocal self-contained vision of the universe. Smolin's interactive model of the cosmos, aside from being a thorough evolutionary view, also embodies the idea of reciprocity in his rejection of absolutes, where all of nature is interdependent and nothing stands alone.

Further, as will be examined in more detail in the next chapter, the relationship between physical matter and intelligence no longer seems to be an absolute dualism as envisioned, for example, in Descartes' dichotomy of body and mind. Descartes' dualism reflected the metaphysical separation of science and religion and matter and spirit supported within the first Scientific Revolution. And as one final blow, perhaps the quintessential blow to dualist philosophy, science has crossed over into questions and areas that presumably were reserved for religion, theology, and metaphysics.

The ideas of evolution and reciprocity, coupled with contemporary cosmology, suggest that traditional dualist conceptions of God need to be revised.[236] Within the Newtonian mindset, a transcendent and perfect being created the perfectly running machine of the universe. Yet nature is not a perfectly running machine.[237] Further, the evolutionary and information theories of nature imply that intelligence, complexity, and organization are being worked out within time. Following Tipler, perhaps the ultimate realization of these developments lies in the future.[238] Perhaps God lies at the asymptote of evolutionary time.[239] At the very least, if we assume the existence of God, then God should be thought of as something within nature, perhaps synonymous with the self-creative process of nature, as many pre-modern cultures believed. This process is more an adventure, an odyssey, than a perfect eternal reality.

We come then to a very basic question regarding science, evolution, and God. John Horgan has argued that scientific advancement is reaching an end. In his book *The End of Science*, Horgan contends that most of the basic laws and principles of the universe have been discovered and except for filling in the details, we pretty much have a complete picture of the truth.[240] Hawking, in his *A Brief History of Time*, proposes a similar idea, and Michio Kaku, in agreement with Horgan, states that the basic laws of matter, life, and mind are now known.[241] Kaku argues that the "**Age of Discovery**" is coming to an end. All these writers appear to think that a complete understanding of the cosmos and nature is possible and a singular truth about reality makes sense. Yet if reality is fundamentally evolutionary, then is there a complete picture of reality? If the universe is literally a self-creative system and we are part of this system, how can we put a boundary on what is going to evolve within the total scheme of things? Perhaps the universe will intelligently evolve new basic laws.

It has been a common belief through the ages that we were close to achieving a complete understanding of the universe. Yet, history has repeatedly shown that our confidence is ill founded. New discoveries, new insights, and general revolutions in thought keep overturning our belief systems. It seems as if there is something perpetually and inherently incomplete about human knowledge. Additionally, it seems to be a truism of discoveries that for every answer found, new questions emerge as a consequence. In Hawking's more recent book, *The Universe in a Nutshell*, he still argues that a complete scientific theory of the universe is something we should strive to achieve, but the guarantee that it is just around the corner seems to have disappeared.[242] In fact, it is interesting that in the period between the two books, Hawking notes a variety of theoretical advances in our understanding of the cosmos, and includes a host of new ideas such as M-theory, branes, and possible dimensions to the cosmos beyond the observable four dimensions. Though the picture has become more fascinating, mind-boggling, and rich in detail, it does not appear that we have come to one definitive explanation of the cosmos. As described in this chapter, there are a variety of issues and theoretical points of view concerning the origin and fundamental nature of the universe.

John Maddox, in his book *What Remains to be Discovered*, comes to a very different conclusion from Hawking and Horgan regarding the present state of scientific knowledge.[243] Maddox points out that scientists still have not been able to theoretically unite relativity and quantum physics, in spite of all the hype that superstring theory promised to do just that. In fact, Maddox doubts whether superstring theory will turn out to be the final theory of everything. He states that promises that a theory of everything is close at hand are misleading. Present formulations of the Big Bang theory also have problems, since recent measurements of some stars seem to indicate that they are older than the estimated age of the universe according to the Big Bang theory. The origin of galaxies is still an open question, as is the mystery of quasars. In fact, the origin of life on earth is still a puzzle, and though we have discovered the basic genetic code of life, we have only begun to understand the interactive patterns and effects of genes. We are not sure whether the universe is at critical density and the search for the hypothesized dark matter goes on. Our mapping of the heavens seems to indicate more intricate and cosmic structure than our theories of the evolution of the universe would imply. We, in fact, have only begun to map the overall structure of galaxies in the universe, as well as even in our local region of the universe. For Maddox, we need better maps of the cosmos. Furthermore, I should cite Adams and Laughlin's point that more and more of the cosmos becomes visible and observable with time, due to the restriction of the speed of light on signals from distant sources reaching us.[244] How far out does the cosmos extend? What may lie beyond the present horizon of observation? As Maddox states, "It will be time enough to talk about a theory of everything when we know what everything is."

All fields of science, according to Maddox, possess significant areas of ignorance or inherent contradictions. There are many questions and new ones will undoubtedly arise in the future. As Maddox notes, the history of science is filled with conceptual revolutions, which alter our very understanding of "what remains to be discovered". He states that the "excitement in the years ahead will spring from the answers to the questions we do not know enough *yet* to ask." (My italics) Although certain questions, such as the origin of life and the universe, have been asked since the beginnings of recorded history, our understanding of these questions will deepen and grow richer in the future. Each century of science brings with it new achievements and these advances are built on what came before but the story of science goes on. Maddox predicts that in the future the theory of a "once and for all universe" will be found to be false. The emerging ideas of a multiverse and higher dimensional spaces could lead us into a cosmos of indeterminate or boundless nature.

Knowledge is fundamentally an evolutionary phenomenon. Just as nature, in general, evolves, knowledge systems as part of nature evolve as well. If we think there is some limit to knowledge, as we might think there is a limit to reality and the cosmos, then I think this would imply an absolute or final state regarding the scope or powers of the mind, and I doubt that is the case. The quest for absolute, complete, and even omniscient knowledge reflects the idea that such a state is possible – Smolin's detached observer who can see the universe as a whole – the quest to understand the "mind of God".

Further, science itself will evolve in the future. It is not simply that we will discover new laws and facts, but the kinds of discoveries and the methods we use to reach these discoveries will change. At the beginning of this chapter, I provided a definition of science, yet over the subsequent pages I noted that our thinking on science has changed. The Newtonian model of building abstract theories through detached logic and observation has been challenged on many fronts. We are beginning to experiment with cyberscience. Where will this new approach lead us? What will science be like in the future? I think that this is clearly an open-ended question, and if it is, how can we put a limit on the kind of knowledge we may be able to obtain? As Dyson states, if we try to imagine science in a thousand years, the possibility exists that what we mean by science may have disappeared.[245]

The Technological Revolution

"Technology, like any evolutionary process, builds on itself. This aspect will continue to accelerate when the technology itself takes full control of its own progression."

Ray Kurzweil

Michio Kaku believes that scientific advances drive the growth of technology, though it is equally true, as Freeman Dyson notes, that technological innovations open up new areas of scientific investigation and discovery.[246] There is, in fact, a reciprocal relationship between science and technology, and the growth of each in a **positive feedback loop** amplifies the development of the other. Coupled with the Second Scientific Revolution there has been, in contemporary times, an unparalleled **technological revolution**. The rate of technological invention and innovation has steadily climbed throughout the last century.[247] Given the growing influence and pervasiveness of technology in our times, many futurists have identified technology as the central driving force in our evolution into the future. As I noted earlier in this chapter, not everyone sees the growing power of technology in our society as a positive trend. Writers such as Neil Postman and Elizabet Sahtouris believe that we place too much emphasis on technology in defining our history, our culture, and our personal reality, what Postman calls "**techno-determinism**".[248] Yet there is no denying that we are in the midst of a multi-faceted technological revolution, where the numerous technologies are mutually reinforcing each other, and that this revolution is spreading into all areas of human life.[249]

Moore and Simon point out that the number of inventions and innovations keeps accelerating. The number of new U.S. Patents each year grew from 25,000 in 1900 to 150,000 in 1997. Further, the time for a new invention to move from initial creation to commercial and practical application keeps shrinking. In 1900 it took 50 years on the average; in the past 25 years the time necessary has gone down to 20 years. The diffusion rate of a new technology has also been decreasing. It took the automobile 55 years to go from its first commercial production to being owned by one quarter of the population in the United States. The personal computer, to achieve the same diffusion, took only 16 years. Research and development spending keeps increasing and the number of scientific journals and abstracts has now grown to over 300,000.[250]

There are numerous theories of the contemporary technological revolution. Kaku believes it is being informed and inspired by advances in quantum physics, genetics, and computer theory. Kaku describes how developments in each of these three sciences and their corresponding technologies have repeatedly facilitated developments in the other sciences and technologies, producing an interactive amplification of innovations across a diverse array of technologies.[251] Michael Zey believes the fundamental human force of **vitalization** is driving technological development. Zey defines vitalization as the drive to spread humanness and life into the environment and to master the environment and improve and change it.[252] As noted earlier, technology can be seen as an essential feature of humanity, and futurists, such as Gregory Stock, view the global spread of technologically enhanced humanity as the budding emergence of a new higher life form on the earth.[253] Both Ray Kurzweil and Hans Moravec see the accelerative growth of technology as the leading edge of the **accelerative rate of evolution** on the earth.[254] Kurzweil and Moravec connect technological growth with the ongoing evolution of increasingly complex systems in nature that store and process increasing amounts of information. Consequently, in their mind, the technological revolution is the expression of a natural evolutionary phenomenon. Other technology writers, such as William Halal and Ian Pearson, also strongly connect the overall contemporary technological revolution with the accelerative growth of computers and information technology.[255]

Although the technological revolution is an interconnected array of mutually reinforcing technologies, various futurists have attempted to identify key individual technological developments in the coming years. The following lists of predictions of specific emerging technologies, though, cover such a wide range of innovations that it is clear from these lists that the revolution is occurring across all spheres of technology.[256]

Douglas Olesen, in 1995, identified the "Top Ten Technologies" for the coming decade.[257]

1. Genetic Mapping
2. Super Materials
3. High Density Energy Sources

4. Digital High Definition TV
5. Miniaturization
6. Smart Manufacturing
7. Anti-Aging products and services
8. Medical Treatments for detecting and treating diseases
9. Hybrid Fuel Vehicles
10. Edutainment

Although, as noted, computer technology is often identified as the central driving technology in the contemporary technological revolution, the list above includes innovations and developments in genetics and health, materials and energy, and transportation. All of these areas though, directly or indirectly, are being influenced and supported in research and implementation with the use of computers and information technology.

More recently, based on the George Washington University technology forecasting study[258], an ongoing and growing systematic enterprise, where 65 experts around the world are repeatedly questioned and polled on future technology, William Halal reports[259] that the top ten emerging technologies for the next decade are predicted to be:

1. Portable Personal Computers
2. Fuel Cell Automobiles
3. Precision Farming
4. Mass Customization
5. Teleliving
6. Virtual Assistants
7. Genetically Altered Organisms
8. Computerized Health Care
9. Alternate Energy Sources
10. Smart Mobile Robots

Note that in this more recent list, anticipated developments in health care, energy, genetics, and transportation vehicles occur again. Mass customization is similar in meaning to "**smart manufacturing**" in the first list, where technologies are produced to suit the individual customer that will require computer monitoring and control of each individual product that comes off the assembly line. The George Washington University list especially emphasizes information and computer technology, identifying three new developments, portable computers, virtual assistants, and smart robots, which will emerge on the scene in the next ten years. In the decade after, the George Washington forecasters predict further advances in transportation systems and biogenetics, as well as new developments in computing with light and space colonization.

A third list, provided by Stephen Millet and William Kopp, takes a somewhat different approach and predicts the top ten innovative products for the next decade.[260]

1. Genetaceuticals
2. Personalized Computers

3. Multi-fuel Automobiles
4. Next Generation TV
5. Electronic Cash
6. Home Health Monitors
7. Smart Maps and Tracking Devices
8. Smart Materials and Smart Fabrics
9. Weight Control and Anti-Aging Products
10. Never Owned Products

Again, there are anticipated developments in genetics, new automobiles, better materials, and health care. The main theme though that Millet and Kopp emphasize is the **personalization** of technologies. They believe that individualized or customized products in all areas of technology will increasingly replace mass production. This general direction clearly indicates an effort to integrate machines and humanity.

One final list, provided by Freeman Dyson, is much shorter than the above top ten lists. Dyson identifies three key technologies in the coming decades: the Internet, genetics, and solar energy.[261] Dyson's list, though, contains a strong prescriptive or value driven dimension. He believes that these technologies possess the potential to greatly benefit the general population of humanity. To recall, there is considerable concern among many writers, futurists, and social thinkers that technology is influencing human life too much or is serving the desires of the rich rather than the needs of everyone. Also, as Dyson argues, ethical and humanistic considerations should be guiding technological development rather than technology and economics determining the direction of human society. We should note, though, that all the above lists identify customization and personalization as a key theme in technological innovation. There seems to be a general direction toward technology serving humanity and not the other way around, though customization could translate into catering to the whims and wishes of the affluent.

From a related angle, Zey believes that technological development is motivated by a basic human drive to control the environment and, even more so, to spread our humanity into the environment. Zey cites and supports Kaku's position that humanity is moving from being a passive bystander to an active choreographer of nature.[262] The permeation of human qualities into the world could include ethical and humanistic values, but as critics of the Industrial Age point out, the drive to control and manipulate the environment can also be an egocentric power trip. If we are to alter our world through our technology, which seems to be an inevitable process, then we need to consider what goals and values are being served in this technological reconstruction of the world.

Aside from identifying top technological developments in the coming decades, various futurists and other writers have also created estimated timelines for technological breakthroughs that extend through the coming century and beyond. Kaku, Pearson, Halal, Moravec, and Zey all provide such timelines, and though there is a general degree of consensus among the lists, there are some disagreements. Zey, for one, thinks that the George Washington forecasting system does not take into account sudden innovative spurts often due to creative individuals.[263] In essence, the George Washington approach is too linear. Still, I refer to various predictions contained in these timelines in the chapters ahead as I examine in more detail the different main areas of technology in the future.

In general, the technological areas that, according to the experts, promise the most significant developments in the coming decades are genetics, computer technology, transportation, materials, and energy sources. Numerous consumer products in these areas will follow. How these products and technologies will impact our environment, human life, and even the future existence of humanity is open to debate. In the remaining sections of this chapter, I focus on energy, materials, and transportation. In the next chapter, I discuss information technology, robots, and computers. Later chapters look at biotechnology, health, and ecology and resources. One area of technology that promises to dramatically transform the human condition is space exploration and colonization, but most forecasters believe that it will be a few more decades before space technology and the exploration of space really blossom and take off. I review this area in the final chapter on the future of science and technology.

I think that it is safe to say that the present multi-faceted technological revolution will dramatically alter not only human life and the environment but also the very nature of humanity. Technology is not simply a tool to achieve human goals. It is an extension of humanity, evolving and growing, and it will transform us, biologically, psychologically, socially, and ethically in the decades ahead. Popularized images of the future usually envision contemporary human types set in the context of advanced technologies. This scenario is almost certainly wrong. We are going to co-evolve with our machines, whether we like it or not.

A number of years ago the computer scientist and science fiction writer Vernor Vinge published a highly influential and controversial article titled "The Coming Technological Singularity: How to Survive in the Post-Human Era".[264] Vinge considered the present accelerative growth rate of technology, and in particular, information processing technologies, and concluded that sometime in the next few decades artificial intelligence would pass human intelligence and quickly speed ahead, literally leaving humanity in the dust. Vinge referred to this event as the "**technological singularity**". After intelligent technology passes us by, with its continued accelerative growth of change, the world will transform around us dramatically to the point where, from our present vantage point, it will become incomprehensible to us. Vinge considered the various pros and con's regarding whether this event would come to pass and if so when, and he also considered what would become of humanity in the years past the singularity. For Vinge, the technological singularity seems inevitable, assuming that our present technology and society are not wiped out in some natural or artificial cataclysm. Further, he foresees a potential period of **human-technological symbiosis**, but humanity, as we now understand ourselves, will probably sooner or later become a memory in this hyper-intelligent technological reality. It is interesting to note that at around the same time Vinge was writing this article, he also published his Hugo award winning science fiction novel *A Fire Upon the Deep*[265]. In this novel a powerful artificial intelligence begins to assimilate the entire Milky Way, only to be stopped by humans and dog-like aliens, alas with the apparent assistance of another artificial intelligence. Vinge, though, states in "Approaching the Singularity" that intelligent technologies will probably surpass us before we even get to explore our own solar system.[266]

More recently, Richard Eckersley, expanding the scope of discussion to include genetics and nanotechnology, as well as computers, reaches a similar conclusion that sometime within the next fifty years technological growth in these three areas will reach a "spike" forcing humanity to make some fundamental choices regarding our continued existence. Eckersley sees three fundamental responses: surrender to the technologies (we become obsolescent), technological backlash (we try to pull the plug), or humanity transforms (perhaps we synthesize with our technologies). Regardless of how we react, it is important to note that this "spike" is coming and humanity will have to face it.[267]

Although Vinge considers various trends in the development of computers and artificial intelligence over the last century in making his case for the coming singularity, the argument that our technology will both dramatically transform us, as well as pass us can be presented using basic evolutionary ideas as well. Ray Kurzweil notes that the pace of evolution is accelerating. Evolution involves increasing complexity and if we trace the successive emergence of more complex systems on the earth, the time periods between salient events or levels of organization are diminishing. Kurzweil argues that within evolution, order builds on previous order, and this process of increasing order grows exponentially. As Kurzweil states in his **Law of Accelerating Returns**, "As order exponentially increases, time exponentially speeds up (that is, the time interval between salient events grows shorter as time passes)."[268]

For Kurzweil, technology is a natural outgrowth of the movement toward increasing order. Technology is defined as the crafting and shaping of resources to purposeful ends. Humans apply their increasing knowledge to the development of better and better technologies. Technology is inevitable because intelligence and the ability to manipulate the environment are favored within the evolutionary process. As Kurzweil points out, history has repeatedly demonstrated that the more technologically advanced cultures have triumphed over the less technologically advanced cultures. The rate of increasing order and complexity in technology, as measured in terms of information storage and processing power, is a continuation of the general accelerative rate of evolution. For Kurzweil, technology has picked up the rate of evolution.

Reinforcing this evolutionary picture of technology, Hans Moravec argues that we are presently witnessing the self-accelerated evolution of machines.[269] Older machines are used to build new machines. Although machines breaking down were a common occurrence in the Industrial Age, machines increasingly are participating in the design and repair of themselves. At some point in the future, this self-organizational dimension of machines will hit an "escape velocity" and technology will surge ahead of humanity in complexity and intelligence.

For both Kurzweil and Moravec, humans, in the relatively near future (probably the next hundred years), will need to be technologically enhanced if we are to keep pace with our machines. In particular, without our mental abilities being augmented we will not understand our technological world and we will not be able to function within it. Vinge refers to this process as **Intelligence Amplification** (IA).[270] Increasingly, we will need to integrate with our technology if we are to maintain control and guidance of our world. The futurist **transhumanists** argue that humanity needs to be transcended – that something better is emerging as we enhance and transform our nature through various technologies.[271] Other futurists such as Michael Zey believe that technologies will always serve human ends and that our technologies are tools that will never transcend us. We may augment and enhance our abilities through biotechnology and information technology, but we will remain in the drivers' seat.[272] Yet, in this process of integration and Intelligence Amplification, what we mean by human will undoubtedly be transformed. At what point does the level of augmentation become so significant and pervasive that the bulk and core of what we are is our technological substance and capacities?

As noted earlier, there is a long-standing fear that our technologies may, in fact, usurp control of our lives and even extinguish us. Bill Joy in his recent article "Why the Future Doesn't Need Us" restates this fear, pointing out possible dangers and threats to our continued existence within nanotechnology, biotechnology, and information technology.[273] Postman thinks the danger is more insidious, with technology undercutting and transforming our culture, values, and mindset. In contrast, individuals like Hans Moravec and Arthur C. Clarke see intelligent machines as our evolutionary children, and the transhumanists believe that we are ethically responsible for creating a more advanced intelligence. All these different interpretations come down to the same thing. In some sense or another, something new and different is coming.

We cannot pull the plug, for it is we who are plugged in. Technology is integral to the very nature of humanity, and we live in a state of increasing interdependency with it. The best approach we can take is to thoughtfully and continually consider how we might improve our lives through technologies. Pearson predicts that the increasing electronic monitoring and intrusion into our lives will cause an anti-technology backlash in the future.[274] There have been anti-technology reactions in the past, and the present conservationist-deep ecology movement today is clearly a more recent example of anti-technology.[275] However, such anti-technological movements do not grasp the reciprocal connection between humanity and machines, mind and matter. Nor do they see that technology is fundamentally an expression of the human desire to improve human life. Further, I think that Kurzweil is correct in arguing that technology is a natural development and expression of the evolution toward order and intelligence. Even if we could stop the technological revolution upon us, would we want to? Humans strive to improve their reality, and technology, if it is ethically, thoughtfully, and informatively guided, achieves this end. What we must face is that technological evolution will inextricably transform all aspects of our lives, probably to the point where our future descendents will transcend us as surely as we transcended Australopithecus.

The Stuff that Life is Made Of: Energy, Materials, and Resources

Tom Forester, in his article "The Materials Revolution", points out that each significant advance in civilization has been preceded by a breakthrough in the use of some material. In ancient times, we passed successively through the Stone Age, the Bronze Age and the Iron Age, each era involving an advance built upon the mastery of a specific material. In more modern times, the creation of cement, gunpowder, and steel preceded the Roman Empire, the Renaissance and the Industrial Era, respectively. In Forester's mind, civilization grows upon the evolutionary mastery of matter.[276]

In the future we are going to see another significant advance in civilization supported by the great strides being made in high tech plastics and ceramics. Halal, Kull, and Leffmann predict that material composites will increasingly replace metals in the coming decades, with ceramic engines becoming commonplace in our machines.[277] The new materials being designed through chemical engineering and chemical science are stronger and lighter than most metals and will form the core of future technological devices. The discovery of "**buckyballs**" and "**buckytubes**", which are carbon molecules arranged in super-strong configurations, has excited many futurists and technologists. With 100 times the strength of steel, they are only a fraction of its weight.[278] Of special note is that these new materials are being created from the ground up, beginning with scientific concepts, principles of atomic-molecular structure and behavior, and advanced technologies. The mind is inventing new forms of matter. Recall Bell's point that in the Post-Industrial Era theoretical science is directing technology.[279]

Thus, although material advance may be driving technology and civilization, it is the mind that is driving material advance. A particular form of matter begins as a scientific idea. The material is created, investigated, and manipulated using advanced technologies, which are themselves a product of previous scientific and technological accomplishments. This interactive process is a good example of the reciprocal evolution of the material and mental aspects of civilization. The new technologies developed with these designer materials will undoubtedly support even further developments in our understanding of the physical world and move the human mind, technologically enhanced, further along in the control and creation of matter. The philosophy of mind-matter dualism breaks down in trying to understand the future. The interactive and evolutionary process of mind, technology, and matter is also a good example of Kurzweil's thesis that order builds upon itself, creating more order.

As modern technology is informed and guided by science, it is fueled by natural resources and energy. During the Industrial Era, there was little thought given to the possible limits on available energy and resources - but the industrial mind saw humanity as having dominion over nature and not being particularly accountable to it. This disregard and detachment from nature was a reflection of the mind-matter dualism of the time. The Industrial Era depended primarily on **non-renewable sources of energy**, such as coal and oil, and sooner or later these energy sources will be exhausted, at least here on the earth. Consequently, many people over the last few decades have become concerned about an impending energy crisis.

While some futurists, such as Naisbitt, believe that the energy crisis is exaggerated, Naisbitt, as well as Toffler, sees a fundamental shift presently occurring from a high-energy waste-usage technology toward a more energy efficient technology that creates less waste and pollution, and uses more **renewable energy sources**.[280] Theobald, on the other hand, does not believe that the energy crisis is exaggerated, and he is skeptical of those people who think that technology will rescue us as we use up our non-renewable energy sources.[281] Theobald also notes that modernized countries use a disproportionate amount of the total energy produced in the world and, in general, humanity has not been very efficient in its use of energy. He thinks that it is critically important to slow down our use of energy and switch to renewable sources.[282]

According to many estimates, our reserves of oil and coal could run out in the next one hundred to two hundred years. At the same time our use of electrical energy is steadily climbing, as our technology becomes increasingly compact and computerized. Zey projects that by 2020 the world's electrical energy consumption will double.[283] How are the increasing electrical energy needs going to be met? What is going to replace coal and oil as the main sources of energy? Evidently, one of the critical dimensions of technology is its energy production system, and, as we will see below, modern technology is quickly advancing in diversifying and making more efficient its energy and resource production processes.

First let us look more closely at some of the present trends and statistics on energy use and production. Coal and oil still account for between 50% and 80% of the energy used by most countries across the world, with developing Asian countries such as India and China relying almost exclusively on these non-renewable resources.[284] And, as Centron and Davies note, oil consumption worldwide continues to rise in spite of the call to develop alternative energy sources.[285] Yet, by all accounts, we will not run out of oil in the foreseeable future. Centron and Davies report a one trillion barrel oil reserve at present, and new significant areas of oil production occurring in China and Russia. As Moore and Simon note, there have been repeated predictions over the last few decades that we will exhaust our oil resources but this has failed to happen. We keep finding new and innovative ways to locate and extract oil around the world.[286] Similarly, Francis Stabler in his article "The Pump Will Never Run Dry!" argues that there will not be a fuel crisis in the coming years because energy critics and alarmists repeatedly have underestimated the human capacity and modern technology to find and utilize energy resources.[287] On top of identified oil sources, our natural gas reserves exceed oil resources in energy value. Next to oil and coal, natural gas is the most significant source of energy use worldwide.[288] Looking further ahead, though, Zey predicts that oil production will peak somewhere between 2010 and 2020, when demand will began to exceed production, and this demand will be felt most in developing countries, in particular, China.[289]

Pearson estimates that energy use worldwide will increase 25 to 30% in the coming decade alone. In particular, energy use will double in developing countries in South and Southeast Asia during this time period.[290] Further, developing countries at present are much less efficient in their energy use, using twice the energy to produce the same amount of wealth as in technologically advanced countries.[291] Yet, overall, energy and especially electricity is becoming cheaper due to advanced technology spreading through the world.[292] The George Washington forecaster group predicts a 50% increase in energy efficiency by around 2020.[293]

Aside from increased energy efficiency, various other changes in energy production are needed in the future. As noted above, renewable energy sources need to become a more significant factor in worldwide energy use. There are early indicators that this is already happening. Pearson reports a 46% increase in renewable energy use in the last decade and the George Washington group predicts that in the next 5 to 10 years, alternative energy sources will match carbon fuel technology in cost and efficiency.[294] Overall, the trend seems to be toward increasing efficiency and use of alternate energy sources, including various biotechnologically engineered organic sources, in the decades ahead.[295]

Besides increasing the use of renewable resources, such as solar and wind energy, the other significant factor in supplying the growing need for energy is further advances in technology, which undoubtedly will lead to new or more refined energy production systems. Clearly the past has demonstrated that advancing technology produces cleaner energy, more efficient energy, and new resources. As Joseph Pelton notes, the key to the future is smart, cheap energy.[296] One example of this is fuel cells, a creation of advanced chemical engineering and design, which are both energy efficient and relatively non-polluting. Fuel cells have become a hot topic in recent discussions of energy sources for the future, particularly as regards automobiles.[297] The George Washington forecasters predict that fuel cells will become a common source of energy by 2009.

At this point we should stop and consider the relationship between resources and technology. As we saw above, the mind, enabled with advancing technologies, creates new materials. The idea that there are limited energy resources assumes that the physical environment which supports human society is an unalterable and determinate given. Yet, the environment that we live in is open to evolution and further development. At best, the world around us is a world of possibilities and opportunities rather than cold hard facts. Many of these possibilities have yet to be recognized or, in fact, created. In the past, we have clearly manipulated our environment in numerous ways to improve its capacity to yield resources for our evolving ways of life. The vehicle, by means of which we expand the potential of the environment, is technology. All indications point to the conclusion that advancing technology increases energy efficiency, reduces pollution, and yields new forms of useable energy. Even renewable resource energy production is a creation of technological improvements. Looking at the earth as a finite and limited reality misses the significance of the human mind and human technology, and it also misses the basic point that the earth is just as much a set of possibilities, yet to be defined, as it is a measurable quantity of physical material. Finally, as I will discuss in considerable detail in later chapters,[298] the earth is imbedded within a vast expanse of energy and resources in the solar system and beyond. The greatest single source of energy to be found on the earth actually comes from outer space. It is our sun and we have only begun to scratch the surface of how to utilize this colossal source of power.

Solar energy has been discussed quite a bit in the contemporary media. Every year, solar devices produce more electricity. As yet though, the total energy production from solar technology is minuscule in comparison to the world’s energy needs. Nonetheless, solar energy should become an increasing source of energy in the decades ahead. Dyson, for one, believes that we should increase our efforts to make solar energy a significant factor in worldwide energy consumption. For one thing, it is an available resource all over the world, since the sun radiates down upon all of us without prejudice, whether we are technologically advanced or not. Solar energy could benefit rural people who are presently being left behind in the ongoing technological revolution. Dyson suggests the development of energy production technologies that combine portable photovoltaic cells with genetically engineered plants. These could be situated throughout local rural areas to provide energy efficient power sources without having to rely upon big power generators generally distributed around modernized urban areas.[299] Again, in this example, Dyson is looking for ways to have technology serve basic human needs and address fundamental humanistic values.

Nuclear energy, on the other hand, is already a significant world source of electrical energy, accounting for up to 15% of energy production and use in European countries.[300] However, there is considerable concern and debate over the development of nuclear plants, given the perceived ecological hazards associated with such systems and the potential dangers of such systems, as evidenced in the Three Mile Island and Chernobyl disasters. Yet the construction of new nuclear plants continues, especially outside of the United States. These new plants are being engineered to meet extremely high safety standards.

One significant possibility that would address the safety needs, as well as provide for a vast increase in energy production, is the development of cold **fusion** nuclear energy systems. Presently, nuclear energy is produced through **fission**, which involves the splitting of atoms (the same process used in an atomic bomb), but nuclear energy could be produced through the fusion of atoms into heavier atoms (the same process used by the sun). This process is presumably much safer and much more energy efficient than fission and the scientific and technological race is on, worldwide, to create fusion devices.[301] Pearson predicts nuclear fusion reactors by 2040. The George Washington forecasters predict this achievement by 2030. And Kaku, based on his survey of technologists and scientists, identifies a more approximate time range of 2025 to 2050.[302]

Energy is everywhere. Basic principles of thermodynamics though constrain or limit useable or available energy-to-energy gradients (for example, high-low temperature differences) to allow for the flow of energy from one location to another. A system in a state of thermal equilibrium does not contain any available energy. Nuclear fusion in the sun creates an energy flow that reaches the earth because of the temperature difference between the sun's inner reactive core and the surrounding lower temperature of space. As Smolin has noted, living systems, which require energy to maintain their state of disequilibrium relative to their surround, emerge in spaces where there are energy gradients and consequent energy flows.[303]

The physical matter around us is a source of potential energy. Nuclear reactions release some of the energy in matter though either fission or fusion, unleashing some of the atomic energy bound up in the atoms that are split or fused in the reaction. Yet, from Einstein's famous equation regarding the equivalency of matter and energy, the amount of potential energy contained in a quantity of matter is enormous. According to theoretical physics, as well as experimental research supporting this claim, if matter comes in contact with anti-matter, the resulting collision totally transforms the quantity of matter and anti-matter into energy. Consequently, as many futurists and scientists have noted, technologies that utilized **matter/anti-matter reactions** would generate a release of energy that would dwarf any other present energy production technology, including nuclear reactors. Unfortunately, the amount of available anti-matter is scarce and the cost of producing it at this time is significant. Yet with advances in technology, there are predictions that anti-matter will become a viable source of power in the future.[304] Pearson, in fact, sees anti-matter being produced in quantity by 2025, and Marshall Savage proposes that future stellar spaceships should utilize matter/anti-matter reactors.[305]

There is another type of approach to energy production that would involve a significant change in our industrial and manufacturing systems worldwide. The answer is garbage and waste. In the earth's bio-ecological system, the waste of one living form is the resource of another living form. The earth recycles its waste. Humans have only just begun to recycle waste and garbage within our industrial system, and in general we dump our garbage back into the ecological system for the earth to recycle it. What if humans developed a full-blown **industrial ecology**, where each industry or waste production system was tied into another system's resource acquisition process? The amount of potential energy and other resources in our garbage and waste is enormous; we simply don't feed it back into our production system. Garbage and waste, in essence, is the entropy produced in the maintenance and evolution of human civilization. Yet, entropy in nature is the fuel of evolution. An industrial ecology system would be a vastly different kind of technological base than our present system. Individual industries, technologies, and energy consumption units would no longer operate independently of each other. The whole system would be networked into a web of reciprocities of input and output.[306] Everything would consume; everything would produce. We would develop a global system of ecological industries embedded within the natural ecology.

This industrial - technological change, already under way, is based upon a philosophical and scientific change in our attitude toward nature and ourselves. No longer can we see ourselves as the rulers and masters of the earth. We need to see ourselves in a partnership with nature as well as each other. We are, in fact, participatory within the intricate ecological systems of feedback.[307] Presently, we take resources from the earth and dump back into the earth our waste products, without adequately considering the consequences. We have seen the world within a linear model of reality. Moving to an industrial ecology involves seeing the world in terms of **loops of exchange**. Open systems and ecological thinking have spurred this change in mindset.

Industrial ecology is another illustration of conceptualizing our relationship with our world in terms of reciprocities. Technology impacts us as much as we impact technology. Through technology, as an extension of ourselves, we impact the world, but our effects upon the world through technology, come back upon us. The world around us is not a determinate reality independent of humanity, for we can alter it and realize new possibilities through our technologies. Yet we cannot ignore the world in which our civilization is evolving. Understanding the nature of the world, which comes through science empowered with advanced technology, is necessary if we are to further evolve our civilization. It is this scientific understanding of nature that informs both our new technologies as well as our increasing ecological sensitivity. Advancing science and technology are not enemies of nature. They are the very tools necessary to improve our relationship with nature. Our energy production systems become cheaper and cleaner the more advanced the science and technology behind them. Even if the human mind is orchestrating this evolving reality, it is a partnership or reciprocity of humans, technology, and nature that is being advanced.

The information explosion in contemporary times is also relevant to the issue of resource acquisition and usage, for information and knowledge are resources that are not only self-renewing but also self-evolving. Recall Kurzweil's view that order builds upon itself. Although we may have less and less oil as we use it up, we have more and more information and knowledge in our world. Just as coal is a source of power, so is information. Information affords greater efficiency, organization, and diversification of technological efforts. As both Naisbitt and Toffler note, information is the resource base of our contemporary technology, not raw, physical elements or physical capital.[308] If anything, our growing understanding of ecological principles, coupled with our vast data collecting of industrial resource needs and production of waste, is leading to a more efficient manufacturing and technological system. In fact, coming back to the theme of limits on resources, increasing information is one essential element in our capacity to extend what are the supposed limits of nature. Technology, which literally empowers matter, is empowered by the human mind, which in turn is empowered by knowledge and information.

Discussions and debates on energy use and resources invariably involve a fundamental clash between **pro-growth, pro-technology** philosophies and viewpoints that emphasize **stasis** or even a **regressive** return to a less technological human existence.[309] The conflict is particularly intense within biotechnology and ecology,[310] though it permeates through most areas of future studies. Yet, though the battle may be raging at present over whether we should slow down energy consumption for fear of running out of energy in the near future, from a pro-growth philosophy, we have only begun to scratch the surface of what is possible in energy production and consumption in the future.

The **Kardashev-Dyson model** identifies and describes three levels of civilization: the planetary, the stellar, and the galactic.[311] These three levels of civilization are defined relative to their energy use. Each level is separated from the next level by an energy factor of ten billion. A **planetary civilization** is a civilization that has developed the capacity to harness and effectively utilize the energy resources of the planet. Given estimates of energy resources on the earth, our present world is still one or two centuries away from becoming a true planetary civilization, assuming a growth rate in energy production of approximately three per cent a year. A **solar civilization** is capable of harnessing the energy of its sun, which would be around ten billion times the energy production of a planetary civilization. Finally, a **galactic civilization** would utilize the energy of a galaxy, ten billion times that of a stellar civilization. Again, at a growth rate of 3% a year, our civilization would reach a stellar level in around 800 years and a galactic level in approximately 10,000 years. Now it is clear that given our present technologies we are totally incapable of efficiently harnessing the immense energy of the sun, but as we will see in Chapter Five, there are numerous plans in development that show how this could be achieved.

These mind-boggling numbers and incredible possibilities are presented to put in perspective the contemporary "**energy crisis**" and debates on whether we are approaching the limits of energy production. Even assuming that there are finite limits of available energy on the earth which is highly doubtful from several perspectives, we are nowhere near the limits of available energy, especially if we take into account the technological possibilities of harnessing and utilizing solar energy. The immensity and scope of technological proposals for using the resources, materials, and available energy in the solar system, and the sun in particular dwarf in comparison our relatively feeble efforts thus far. Technological systems and constructions could be developed that would span millions of miles, and generate trillions of times the energy presently produced here on earth.[312]

Within future technology, there may be projects and constructions of vast size and scope, e.g., cables to the moon, solar rings, underwater or underground cities, and magnetic-electrical powered highway systems that span the globe. Moving in the opposite direction, we encounter the possible construction in the future of extremely small motors, machines, and devices too tiny to see with the naked eye. A nanometer is one billionth of a meter and the basic idea of **nanotechnology** is to construct molecular machines out of individual atoms. Given our present technology, atoms and molecules can be moved about and arranged, and motors, gears, and electrical circuits have already been produced that can be seen only under a microscope.[313]

The idea of nanotechnology was inspired by a presentation and paper of the contemporary theoretical physicist Richard Feynman, but Eric Drexler coined the term. It was Drexler who described in depth the possibilities of this new technology and popularized the idea, founding the Foresight Institute to study and develop nanotechnology.[314] Since Drexler's earliest work, main research centers for nanotechnology have developed in the United States, Great Britain, and Japan.[315] Nanotechnology is one of the great new technological promises for the future, but it is also one of the greatest sources of fear and apprehension.[316]

What is the significance of nanotechnology for the future? First, we should note that since nanotechnological devices ("**nanites**" for short) would need to be produced in very large numbers to accomplish their desired effects, they need to be self assembling or reproducing. This is the key technological challenge: producing nanites that can manufacture copies of themselves.[317] Kurzweil argues that DNA is an existence proof of this possibility since DNA duplicates itself.[318] Assuming this challenge can be resolved, imagine armies of microscopic machines, injected into a human body that would repair damaged organs or tissues at the molecular level. Imagine nanotechnological materials, "nano-assemblers", being used to construct new organs and tissues for the body. Imagine nano-computers, more powerful than any that exist today that are the size of a wristwatch or a hearing aid. Imagine billions and billions of nanites that would eat the dust in your home or eat the pollutants in the atmosphere. Such devices, given their size, would consume very little energy and would be able to manipulate, monitor, and maintain the complexities of the human environment at a microscopic level. It has even been suggested that instruments, artifacts, and machines, constructed out of intelligent nano-material, "**smart material**", could change their form and structure to meet the varying needs of humans, e.g., a chair that changed shape and size to fit the person sitting in it or a dress that would change its color and texture to suit one's mood.

Kaku suggests that the first practical step in the evolution of nanotechnology will be micro-machines the size of dust particles that will operate as sensors and motors.[319] Pearson believes that the first commercial applications of nanotechnology will occur in computing and engineering.[320] Yet eventually, nanotechnology could work its way into all aspects of human life. Kurzweil discusses two related future applications of nanotechnology. Within the future we could have all-purpose nanotech swarms, "utility fogs", which could create or form into simulations of whatever scenes, events, or objects the user desired. These nano-simulations would be virtual realities but they would exist as physical realities within our world. Our world would increasingly become (since this mixing is already occurring) a collage of the real and the simulated. Also, intelligences, artificial or human, represented within computer systems could materialize themselves, using nano-material, anywhere within the physical world where nanites were available, in whatever form the intelligence desired, and sense and act through the body of the nano-organism.[321]

There are, though, various potential dangers associated with nanotechnology. For one thing, nanites can serve military functions as well. Armies of nanites could infiltrate into buildings or installations and cause significant destruction on both technologies and human beings. Nanites with sensors could serve as spies. The malevolent liquid steel terminator in *Terminator II* is a nanotechnological type of mechanism. In Greg Bear's *Queen of Angels*, nanites are used as probe networks that permeate into people's brains and connected to the appropriate computer systems and futurist psychologists, read the thoughts, feelings, and memories within a person's mind.[322] Yet, perhaps the most worrisome possibility is that nanites would uncontrollably reproduce themselves and spread throughout the world and unsettle our environment and human civilization. This is one of the main concerns voiced by Bill Joy.[323] If nanites possess capacities for reproduction and self-organization, then without significant fail-safe mechanisms built into them, they could exhibit fundamental survival qualities such as selective or directive evolution, in much the same way that bacteria have reacted to our efforts to control them.

The possibilities of nanotechnology entail a total transformation in the material basis of human civilization. We would be able to construct our physical devices out of intelligent, flexible material and we would be able to alter or manufacture any of our constructions at the molecular level. Material in the past needed to be molded. It did not mold itself. Material in the past did not sense or monitor its own state. Nano-constructions could assess and repair for damage and wear and tear. In the past, the molecules of our construction material had rather limited properties and capacities. Nano-molecules are literally tiny machines, which can possess a host of different functions. In the past, we could not communicate with our materials. Hopefully, in the future, we will be able to communicate with our nano-materials and they will listen to us. Nanotechnology, though, is only one of the developments leading to a more dynamic and intelligent future environment for humans. The environment around us, both technological and natural, is about to become alive and sentient, and at the center of this transformation is information technology. In all probability, as writers like Kurzweil and Bear suggest, nanotechnology and information technology could very well merge, producing nano-computers and nano-robots as well as highly intelligent and flexible materials at all levels of size, networked and orchestrated together. This is of course, the great promise. It is also Joy's worry and Eckersley's concern. This is in all likelihood a significant piece of the impending "singularity".

Once again, though, if we are to stretch our imagination and consider the scientific and technological possibilities of the more distant future, we are perhaps within the coming century as Wells put it, only at the "beginning of the beginning… the dream before the awakening". Arranging atoms into molecular machines and intelligent materials is not the smallest level of size at which the substance of physical reality could be manipulated. Atoms of course divide into elementary particles, such as electrons and quarks. Such levels of reality are ordered by the principles of quantum physics, and there is no reason to suppose that future engineering projects, such as quantum computers, might not begin to orchestrate matter and energy at these even tinier levels.

Yet as scientists such as Hans Moravec and Michio Kaku suggest, with further developments in understanding the nature of space and time and how matter and energy fit into the picture, we may be able to literally construct reality from the ground up, manipulating space and time at the finest levels of size and structure.[324] (There is an identifiable upper limit to the information storage capacity of space, defined as the "**Bekenstein bound**". This upper limit allows for complexity astronomically greater than the organization and detail presently inherent within normal space and material objects.) "Objects" as informationally complex as the entire earth ecosystem or human civilization could be held in one's hand, even if they would be too small to see by normal standards of human vision. In the future we might be able to construct our material realities out of the fabric of space and time, rather than atoms. Such mechanisms and materials would possess levels of complexity so far beyond what we can presently achieve that even nano-technology will seem like nothing more than "bricks and mortar" to our descendents.

Global and Transportation Technology

Just as technology promises to penetrate into the most fundamental levels of physical reality and transform these sub-microscopic structures, technology is also reaching outward and upward, creating ever-larger constructions that will stretch across the globe and eventually beyond the confines of the earth. One of the single greatest areas of technological development in the near future will be in the area of global **Super Projects**. McKinley Conway, in his article "Super Projects: Rebuilding and Improving Our Planet",[325] notes that there are approximately 1500 super projects in the planning, construction, or fund raising stages across the world. Super Projects are technological developments usually involving multiple countries and addressing global needs. Included in Conway's survey are projects in the following areas:

1. Transportation - Tunnels connecting the continents to forge the Great Global Highway that will run across the Bering Strait and down the Pan-American Highway through the Americas. Eventually we will be able to drive around the world. Also the development of airport cities in Seoul and island airport cities in Osaka Bay (built) and Hong Kong (planned).

2. Urban Development - Rejuvenation of many cities around the world and the building of new cities.

3. Energy and Water - Plans to bring the deserts alive and various desalinization projects.[326]

4. The Environment - Great super projects all concerned with environmental impact and many projects concerned with restoring and enhancing our ecology.

5. Telecommunications - Constitutes the number one infrastructure program around the world. As Cornish notes, the electronic computer and communication system is the biggest machine ever built. The global information highway is a trillion dollar project of new cables and satellites. The goal is to generate universal communication to all parts of the world. AT&T is already running a fiber optic cable around Africa.

For Conway, the building of a global system of technology and services will stimulate both cooperation and interaction among all the countries and people of the world. Its goals will include raising the overall standard of living for people everywhere around the world. Building a global technological system will constitute the biggest development program in human history.

In a later article, "The Super Century Arrives", Conway reinforces many of the same themes.[327] He predicts that we will see significant advances in the transportation infrastructure early in the 21st Century. **Global highways** will emerge, as well as a global power grid and a world wide satellite based cellular system of communication. There will be massive environmental clean-up projects. He also foresees the construction of underground cities and super-metro urban areas emerging that will span over one hundred miles.

Michael Zey connects the development of global technological systems to the drive toward **species coalescence**, the motive in humanity to achieve unity. Zey provides a general theoretical analysis of the main components of the emerging global technological system. He sees it consisting of a global production and consumption network, a global power grid supplying energy needs around the world, and global communication and transportation systems. The global production system will eventually create an age of superabundance of foods, goods, and services for people around the world. In agreement with Conway's thinking, the various global systems will not simply stretch around the world, but will involve the contributions of countries from around the world. They will be global systems created through global efforts.[328]

The trend toward global technological projects is well documented in Zey's books as well as in Adrian Berry's *The Next 500 Years: Life in the Coming Millennium*.[329] To stretch the windows of imagination, let us consider some far-reaching super-projects that could come to pass in the years ahead. These include:

- A global farming system within the oceans and the seas with underwater installations, if not underwater cities[330]
- Energy generating systems (solar, thermal, hydro, and wind) that will stretch for hundreds of miles
- Single structure cities that house hundreds of thousands, if not millions of people and skyscrapers that tower over a mile into the sky[331]
- Elevator tethers to the moon, artificial rings of immense size that encircle planets, if not stars, and provide home to millions of people

- Automated mining and transportation systems for the asteroid belt that will bring resources (e.g., chunks of asteroids and frozen water) back to the moon and the earth
- Space stations of all sizes and functions that will stretch outward through the solar system and the galaxies
- Self-enclosed cities that would travel through space[332]

In general, we can imagine technological systems that will span continents, planets, solar systems, and galaxies as we progress through the decades, centuries, and millennia ahead of us. Referring back to the last section, as our civilization advances toward planetary, solar, and even galactic proportions, our technological systems will stretch outward to encompass these increasing stretches of space and size. I discuss these possibilities in more depth in the later chapters on ecology and space exploration and colonization.[333]

We can see then that one general promise of technological evolution is the infusion of technology into nature and human society, at every conceivable scale of size. The consequent re-orchestration of nature and society, involving the monitoring, manipulation, and interconnecting of the parts and the whole, is already developing quickly at local and global levels. Energy, materials, resources, production, transportation, communication, and living systems are all being woven together and redesigned via the pipes, wires, conduits, and engines of our machines. Such a multi-faceted, multi-level network of technologies clearly requires vast and intricate intelligence for its operation, as well as scientific understanding and monitoring of nature with humanistic-ethical considerations guiding its evolution. In looking more closely at potential developments in transportation, we can see how intelligence, ecology, and ethics will all increasingly come into play in the future in this area of technology.

The automobile is one of the crowning achievements of the Industrial Era, involving mass-produced, factory based, metal constructed vehicles propelled by powerful engines. Yet the car also clearly contradicts the view that we see our machines as depersonalizing and as simply complicated hunks of metal. Psychologically, our cars are extensions of our egos and symbols of our lifestyles. We see them as icons of beauty and style, and as possessing personality. The sports car, the mini-van, the import, the SUV, and the luxury car all have distinct personalities. As Sheehan notes, cars offer the image of power, freedom, and modernity.[334] Often, we treat them as if they were alive, with feelings, motives, and a temperament. We adorn them and fit them with the latest gadgets and options. To use Naisbitt's term, we are "intoxicated" with their technology.[335] Automobiles, though, epitomize many of the failings and limitations of the Industrial Era. We have polluted our environment and significantly reduced our non-renewable natural energy resources through them. In our great modernized cities, they are the source of congestion, urban noise, rush hour stress, and isolation. They are often seen as representing the obsessive emphasis on materialism within the modern world.

The auto industry is the world's largest single industry. Worldwide, a million new cars and trucks are manufactured every week. According to Philip Morrison, automobile production has grown in proportion to economic output.[336] By the year 2050 there should be a billion cars on the road.[337] Automotive traffic reached 23 trillion passenger kilometers by 1990 and Pearson predicts that by 2050 traffic worldwide will reach 103 trillion passenger kilometers per year.[338] As more highways are built around the world to support this massive proliferation and use of automobiles and other motor vehicles, croplands and natural habitats are steadily being diminished. All things considered the automobile and associated road systems are probably the single most powerful and pervasive technological presence in the modern world.[339]

Because cars, trucks, and automotive transportation systems are such a powerful and growing technological presence, the various ecological, social, and resource problems associated with them clearly need to be addressed in the near future. Glen Hiemstra suggests that we are going to see a **Second Automotive Era**, which will address many of the problems associated with automobiles and our road systems.[340] Robert Riley in “Specialty Cars for the 21st Century”[341] predicts that automobiles will drastically change in the next few decades. They will become smaller and much more energy efficient. As oil reserves inevitably diminish, new sources of power will become commercially available, if not necessary. **Hybrid automobiles** will soon populate the roads, using two or more different energy sources. According to Riley, cars have to become more environmentally friendly. The George Washington forecasting group predicts that hybrid and electric cars will make up 30% of commercial vehicles by 2006/2007 and fuel cell cars will become common by 2016.[342] Pearson predicts the eventual emergence of zero emission cars and automotive vehicles in the future.[343] As a general trend, Morrison states that the cars of the future will be lighter, cheaper, and more energy efficient.[344]

The biggest advances, however, according to Riley and others, will come in the intelligence systems in automobiles as well as in highways. Cars will be able to monitor their direction and location - inevitably being able to navigate and drive on their own. Monitoring and navigating systems will be tied into the Internet and the satellite **Global Positioning System**.[345] Automobiles will develop computerized interiors, providing office support systems and communication and entertainment centers.[346] Hiemstra, in fact, notes that intelligence functions in future automobiles will involve a combination of internal and external sensors,[347] which I should add mirrors the dual sensory system of animals and humans. Many of these high-tech features are already evolving in our contemporary vehicles. It is quite apparent that Information Age technology is being integrated into our cars now and becoming the brains of the machine, monitoring and controlling the Newtonian engine that is under the hood.[348]

Highway systems that control traffic will develop to support these intelligent vehicles.[349] The George Washington forecasters predict automated and intelligent highway systems becoming common by 2015-2020.[350] Further, Hiemstra imagines a time when individually guided vehicles will “morph” and merge into auto-trains within urban highway systems and de-couple from such linked auto-trains when leaving the city.[351]

Riley’s concern is whether streamlined, energy efficient self-navigating vehicles will appeal to the consumer. Bigger is not always better, especially when you consider that most of the energy used in driving cars goes toward moving the vehicle and not the passenger(s), and congestion can be significantly reduced just by making cars smaller. Further, although there is a sense of power and control (typical Newtonian concepts) associated with driving your own vehicle, both congestion and traffic accidents would be greatly diminished if we turned over the driving to information technology. According to

Riley, we need to become enamored with the qualities and values of information technology and move away from the industrial ideals of power, thrust, and acceleration.[352]

Molly Sheehan expresses related concerns regarding the future of transportation vehicles. She states that we can chose new directions that are less damaging to the environment and create a diversity of transportation options, including non-motorized and mass transportation systems. Right now, though, the trend is not toward diversification and energy conservation. Rail and bike transportation are declining, and cars and motorcycles are increasing. Building more roads and highways, in her mind, isn't going to help, for it will just support more cars, more congestion, more urban sprawl, and cut into even more so into farming lands.[353]

It has long been suggested that **mass transportation** is the solution to increasing congestion, pollution, and energy use associated with private motor vehicles. Conway foresees new high-speed rail systems connecting major metropolitan areas in the near future.[354] Yet the United States, which supports the largest number of automobiles, does not support various mass transportation efforts anywhere near as much as countries like Japan. Japan is developing Maglev (magnetic levitated trains) that would move at speeds of 300 to 400 miles per hour.[355] Presumably our individualist culture works against such intensive mass transportation efforts. Still, Pearson, for one, predicts that by 2050 high-speed trains will quadruple in their share of all private transportation worldwide.[356]

Interestingly, the science fiction writer and futurist Frederick Pohl predicts that traffic jams and congestion will disappear in the future.[357] It is a popular view that the Internet, coupled with increasing concerns over pollution and congestion, will lead to much more telecommuting and teleliving. Pohl though contends that eventually high-speed surface transportation systems such as Maglev will become popular alternatives to cars. He also suggests that vertical take-off air vehicles will come increasingly into use. Various other writers such as Hiemstra and Zey, inspired by the development of the Moller skycar, believe that we will soon create "**highways in the sky"** filled with personal aerial vehicles.[358] Such multi-tiered aerial roadways have been dramatically portrayed in the science fiction movies *The Fifth Element*, *Stars Wars I: The Phantom Menace*, and *Star Wars II: Attack of the Clones*. Pohl also suggests that large airports, for a variety of reasons including the emergence of vertical take-off vehicles, will disappear, thus relieving urban congestion further. Yet there is also clearly a trend in transportation toward the big and the fast. As noted earlier, Conway reports that major new airport installations are presently being built around the world, a fact that seems to refute the feasibility of Pohl's prediction for the immediate future. And Zey reports that hypersonic planes, capable of flying 1500-2000 miles per hour, are being developed for commercial use.

All things considered, the future of transportation will be multi-faceted and diverse, involving both personalized systems and mass transportation, both on the ground and in the air. The evolution of automobiles, aerial vehicles, and transportation systems will be guided by high technology, ecological and energy concerns, and personal styles. High technology and increased artificial intelligence will in fact provide the means to realize our energy, ecological, and personal goals in transportation. Because of advancing technology, the cars of the future will interact and talk to us and, in all probability they will acquire even more of a personality. Advanced technology will create cleaner cars and monitor and coordinate traffic. The car and the roadways will be necessarily integrated into the electronic communication and monitoring systems that will span the globe. We will be able to communicate directions from our vehicles to our home, our business, and other locations, and the world around us will communicate information back to our vehicles. They will, in essence, incorporate mapping devices, fax capabilities, and other forms of technological communication. People will however continue to want a sense of independence and individuality in their vehicles and as the total transportation system evolves, it will increasingly customize and individualize, through high technology, so as to offer a variety of options and choices on entertainment, navigation, internal accommodations, and personal expression.

Looking further into the future, perhaps one day we will be able to "**teleport**" without the need for vehicles at all. Perhaps, as in Dan Simmons' *Hyperion*, we will be able to simply walk through "farcasters" (wormholes in space), and walk out on the other side, miles or even light years away.[359] Whatever possibilities are realized, the advancing technology of transportation will have a powerful and pervasive impact on both our lifestyles and our world.

Conclusion:
The Evolution of Science, Technology, and Humanity

"As a general rule, to which there are many exceptions, science works for evil when its effect is to provide toys for the rich, and works for good when its effect is to provide necessities for the poor."

Freemon Dyson

Within this chapter, one basic fact we have seen is that technological and scientific evolution is not separate from social and psychological evolution. Scientific ideas and advancing technology both transforms and reflects the human mind, society, culture, and values. A fundamental theme throughout this chapter has been the collapse of dualist philosophy in science and technology. In reviewing and thinking about this chapter, consider all of the different ways in which humanity, science, and technology interact in their reciprocal evolution. The future interactive evolution of humanity, science, and technology, in all likelihood, will lead to the transformation and transcendence of our species.

At the same time the complex interplay of humanity with science and technology brings with it great uncertainties regarding the future. At the most fundamental of levels, quantum physics points out that the physical world does not follow a predictable, deterministic path. Open systems and complexity theory emphasize the creative dimension within all of nature. Along with the uncertainties, there is fear and concern about where advancing technology is taking us in the future. Postman and Naisbitt warn against the technological dominance and corruption of human culture. Vinge foresees a technological “singularity” usurping human dominion on the planet, if not extinguishing us. Many worry about how high technology is exhausting our energy resources. Joy, among others, speculates on nanotechnological reproduction gone wild.

Yet there are numerous indicators and trends that promise an array of positive rather than negative developments in these areas occurring in the future. In all areas of technology there is ongoing growth and positive interaction effects, and there are both short-term and long-term optimistic hopeful possibilities that bedazzle the imagination. Science and technology are essential expressions and extensions of our basic nature. We cannot return to the cave. Scientists such as Freeman Dyson argue that instead of abandoning our efforts, technological developments should be guided more strongly by ethical and humanistic concerns. In the future of science and technology, the human factor and the significance of intelligence will repeatedly come into play, perhaps even concerning the ultimate fate of the universe itself.

The evolution of science, technology, and humanity reflects the broader panorama of cosmic and natural evolution. For Kurzweil, intelligence itself is a natural expression of cosmic evolution. Within this chapter I have looked at a variety of scientific theories that support the evolutionary perspective on nature, e.g., open systems and complexity theory, cosmology, fractals, and the information-processing model of the universe. The evolutionary perspective has replaced the Newtonian and Platonic models of eternal laws and a static universe. I have also examined connections between science, metaphysics, and religious themes and proposed that science has crossed over into the area of fundamental questions and explanations once reserved for theology and religion. I have considered how the concept of God fits into the new physics and cosmology. Further, I have proposed, following Maddox and others that the scientific quest for knowledge is far from complete or finished. Following the insights of Feyerabend, Kuhn, and Smolin, among others, I suggest that all scientific knowledge embodies both a subjective and objective dimension. The Platonic quest for absolute certain knowledge is a chimera that misleads us. We have just begun the journey of enlightenment, a journey that will never end, as we reach outward and inward, exploring the vast reaches of the universe and the incredible depths of matter, space, energy, and time.

[1] As noted above, later chapters examine other parts of technology, including computers, biotechnology, and space travel.
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