The Challenge of Co-Evolution

Large issues and debates often grow from a small seed. In 1969, when we saw the first pictures taken from the moon of our solitary blue green planet surrounded by dark and seemingly infinite empty space, the emotional impact of that moment was profound, even overwhelming. To overcome the feeling of how alone and vulnerable we are, traveling together through dark empty space, we often turn to our sense of the common bond we share as co-inhabitants of the Earth. We are all Earthlings. Those images from outer space provided us with new perspectives on how our earthbound struggles – amazingly invisible from so far away – continue to challenge and divide us. Though we have managed to advance from hunter-gatherer cave-dwellers to men who take pictures of themselves from the moon – certainly a glorious and amazing evolution of knowledge and accomplishment – we now find ourselves at the great crossroads of yet another millennium, one in which an intense and on-going debate rages about our relationship to our home planet Earth. The burning question is: as our population grows, can we feasibly co-evolve with our planet? In its classic form, the debate over this question has been between the environmentalists who want to minimize our impact to ensure that we do not destroy it and those who believe we need to continue to harness its resources for the benefit of our growing population. This book presents a new framework for this debate, a different approach that serves to put a whole new set of options on the table.

Today, when our astronauts gaze at our planet from space, it is actually darker than it was when we first looked at it from the moon. Ice sheets are melting, uncovering darker earth, and the blue ocean is swiftly lapping up greater expanses of low-lying areas. We are told if we continue to use energy at our current rate of increase, the earth could look like a dramatically re-painted planet by the end of this century; the frozen white will recede and the earth will look noticeably darker, as light-absorbing blue and brown regions replace reflective white. The idea that our actions could be repainting the planet in a way that is noticeable from space is a frightening thought. But, in spite of the rhetoric and anxiety this idea inspires, we have not been able to really agree upon answers to the important questions that also naturally arise: is this warming ultimately good or bad for our planet and its inhabitants? Are we in the process of building an uninhabitable planet? In order to co-evolve with our obviously changing planet, should we try to reverse or avert the process of change, or to adjust to it? If we can't adjust, could we actively design our future planet's climate according to our needs -- effectively, re-painting our planet to look and behave in a way that would be beneficial to us? Do we even know enough (and are we coordinated enough) to decide upon an optimal temperature at which we'd like to set the global thermostat?

This may start to sound like science fiction to some readers, but these questions are quite reasonable to ask in response to this scarily complex issue -- an issue which does seem to be stumping us as a species. Interestingly, recent scientific advances have begun to clarify certain aspects of how our brains make decisions based on a seemingly daunting wealth of information. And in fact, we are more equipped than we may think with regard to the knowledge and tools we would need to make intelligent decisions about the future of our planet. However, the subsequent question does also arise: if we were able to design our planet to support our increasing rate of energy use, would we? What would prevent us from taking such a step? These questions and the discussions to follow are meant to broaden the range of issues discussed in context of global climate change debate and to encourage more serious cooperative efforts to use our existing collective knowledge and tools to overcome the challenge of Earth-species co-evolution. By broadening the discussion in this manner, this book aims to become a seed from which new perspectives, new debates, and new solutions can grow.

With the advent of round-the-clock television coverage we are now able to witness the devastation of natural disasters, forcing us to become acutely aware of their presence and destructive forces. A tsunami, driven by the largest earthquake in 50 years, recently killed hundreds of thousands of people. Frequent powerful hurricanes, ice caps melting from global warming, human- driven ecosystem and biodiversity loss, and the destructive droughts and floods driven by El Nino are ravaging various parts of our planet. Hurricane Katrina and the Indian Ocean tsunami highlighted our inability to avoid the destructive impacts of natural disasters... yet, despite knowing the inevitability of these natural disasters, we did not prepare for them. And there are even more devastating disasters that we know will occur in the future. A future impact from an asteroid could be even greater than the one that made the dinosaurs extinct. Climate altering volcanic eruptions are a certainty. New York City could become the next New Orleans, as sea levels continue to rise. A mega-tsunami could cause a wave over 150 ft tall to hit the whole east coast of the United States. Will we willfully be unprepared for these future events, to our peril?

More than 99.9 percent of all species that have inhabited Earth are now extinct. This was caused mainly by their inability to cope with the combination of an ever-changing planet and natural disasters like climate change and asteroid impacts. Our own days on the planet seem numbered, since many experts believe that our own misguided actions will lead to climate change (see also climate change data), species extinctions, and our own Armageddon. Jared Diamond has pointed out in his book Collapse that many cultures became extinct despite the knowledge that the behavior patterns that had initially helped them to flourish had become destructive. They were unable to adapt. A classic example is the people of Easter Island, who continued to cut down trees long after it was evident that continuing to do so would render their island uninhabitable. A concern my students have expressed, along with many well known environmentalists, is that, as a species, we may prove unable to control our own destructive behavior. As knowledge continues to make us increasingly powerful, enabling us in some considerable measure to alter the rest of life on our planet, many question whether our increased knowledge could be leading us down the path of our own self-destruction. Should we use nuclear energy? Should we pursue stem cell research? What should we do about global warming?

We are addressing these concerns and challenges with a brain in possession of two conflicting parts. One component is hundreds of millions of years old, and we share it with reptiles and mammals – and another unique part is one hundred fifty thousand years old, and that part is what made us humans. In spite of past accomplishments, it should surprise no one that this awkward merger might have some flaws in its design, especially with regard to dealing with the challenges we face in a world already transformed by our knowledge and consequent decisions. For example, our fear reaction and the other instincts we inherited from the reptiles, which served us well as hunter-gatherers fighting for survival, are likely to lead to highly destructive decisions today. When was the last time in your life that your fear reaction helped you make a better decision? For our hunter- gatherer ancestors it helped them survive on a daily basis. However, our capacity to accumulate knowledge has grown so powerful that it has become, together with the more recently developed parts of our brain, a superior basis for important decision-making than our fear reaction and instincts. As a global species we cannot address the threat of an asteroid impact intuitively but rather need complex computer calculations to help us make well-informed decisions in response to such large threats. It could even be suggested that the complex threat of global warming has been exaggerated by our fear reaction, causing us to undervalue other threats that, in fact, may be just as pressing – or even more so.

I propose here that we sidestep the current debate and the typical opposition between the environmentalist and exploitative viewpoints, by concentrating instead on developing a framework for effectively applying our brains' unique abilities and collective knowledge to the conceptualization and pursuit of a different future. The new and amazing knowledge we are acquiring about ourselves via brain imaging machines lets us literally see ourselves think, and can help us to make greatly improved decisions in the future. Our new knowledge and understanding will identify practical ways to compensate for the design flaws in our brains. While this may conjure up SciFi-like images of mind control and androids, the reality of what is being proposed here is quite the opposite. Just as machines have helped to free us from our physical limitations, new ways now exist for us to use computers and the Internet to improve our ability to make informed decisions. Combining new insights about how our brain functions with these tools will provide us with new and more effective ways to learn and disseminate knowledge. However, to complement our improved capacity for knowledge-based decision-making, earthlings will also need new global social, political, and ethical institutions to enable us to work together as one cooperative social group, turning our powerful cache of knowledge into informed and effective decisions leading to positive change. Earthlings have the potential to use knowledge to design a better future for all. A major conclusion one can reach by reviewing our evolutionary history is that genetic-based evolution is both cruel and relatively inefficient. If our primary goals are to avoid the extinction of our species and to provide for our current needs, it seems obvious that taking a proactive, knowledge-based approach to designing the future would present the best opportunity and possibility of a much less painful future for all life on our planet. We need to co-evolve with the rest of the planet. Our well-being and that of the planet are inseparable; it is our home. So we also need to think about preventing massive extinctions and providing for the well-being of life generally. As a powerful species, designing the future to achieve these goals for co-evolution will require that we manage the planet however possible.

Many people oppose the idea of designing our future and managing our planet. That has been the instinctive response of most of my students when I asked them about it at the beginning of the course I taught at Columbia on this subject. For many, the past use of the nuclear bomb and the unintended consequences of using DDT make them fearful about pursuing such opportunities as nuclear energy, genetically modified crops, or controlling our climate. They do not trust our own species to use knowledge wisely. The new approach presented here does not dismiss their or your concerns. There is a need for us to be very cautious. Environmentalists have developed a Precautionary Principle that asserts that we should not undertake an action that can impact the environment unless we know in advance that it will not cause damage. On the other hand, a new "Cautionary Principle" recognizes that human progress always involves risk; however, there are things we can do to avoid catastrophic change and damage. First and foremost, we can make informed decisions. Our past pursuit of a better life has clearly been successful even though the cost has been high for the pioneers. While the benefits promised by our new knowledge have increased, so have the potential dangers, due to the mistakes we might make in pursuing our goals. However, our knowledge of past mistakes enables us to pursue a better future much more effectively than in the past. Columbus had no idea what risks he might face if the world was indeed flat. In contrast, we were able to anticipate challenges like reduced gravity and no atmosphere before Armstrong ever took his first step on the moon. Even since that July day in 1969 when he took "one small step for man and one giant leap for mankind," the very same knowledge that enhanced our capabilities dramatically also exposed the many dangers we face. We have reached a tipping point. We can prudently aspire together to design a better future, or, if we do not, the past would suggest that our knowledge and power will very likely be used destructively.

Our shared values will be critical in determining whether knowledge is used for good or evil. The need to achieve greater global economic and educational equity can now be justified based upon the increased practical benefits global cooperation can bring. The same economic development logic we use for our local communities is even more powerful globally. More generally, a dispassionate analysis of our new knowledge about the Earth and ourselves can provide a rational basis for values very much in line with the highest ideals shared by both secular and religious perspectives. It has been deeply reassuring to me to realize that our advanced knowledge and all the major religions point to some common wisdom and values. Other aspects of religion that seek denominational hegemony share some of the unnecessarily destructive aspects of secular competitiveness. Earthlings can address the future with values that unite the important parts of religious and secular perspectives. The fact that our shared ideals and pragmatic interests are aligned can certainly help bridge the barriers between us, created in the past by our basic pursuit of survival.

The bottom line is this: we need to change how we think about ourselves. We need to move away from the concept of individual or group survival to recognize and believe that we are part of a powerful global species that has a critical role in and responsibility for the global web of life. As Earthlings, it is the overall well-being of our species and our planet that count most. By changing our perspective and becoming empowered Earthlings, we can address together the immense challenge of co-evolution, providing meaning for so many who are alienated by the contemporary extremes of self-indulgence, competition, and materialism, or lack of basic needs. While the prospect of a safer and more meaningful future is very appealing, it cannot be guaranteed either that we will adopt the ideas presented here or that they will succeed. However, it is almost certain that we, and the other species on our planet, will suffer a fate of continued unnecessary destruction and a violent extinction if we adopt either the business-as-usual approach or the leave-nature-alone approach. It is highly plausible that if we recognize the power that knowledge has given us and accept the responsibility that comes with it, our future will instead look very different and pessimism will turn into hope.

My students challenge my interpretations and help me see things in new light. One very bright young woman asked me near the end of my course at Columbia: "Will designing earthlings be happy?" She, like many others, was worried about losing the identity that our focus on competition provides. It is, after all, how we have been taught to view the world. I had an opinion but not enough knowledge to give her a satisfactory answer. It was one of those simple yet profound questions that only young minds can ask. A year later, after considerable effort and help from another student (who gave me the book Exuberance by Jamieson to read), I discovered a key new insight that provided the answer. Yes, designing earthlings can be happy. The reasons for my answer will unfold in the forthcoming discussion of our brain, since our brain not only helps us make informed decisions but also determines how we feel about them. But, to preface that discussion, even if we cannot speak with absolute certainty on the subject of our future happiness as a species, I will maintain that we will have a better chance of being happy if we choose to adopt a more proactive approach to designing our future. This book is not about predicting the future. It is about defining the approach that provides the best chance for lesser destruction and greater fulfillment.

The questioning of many students has enabled me to anticipate the concerns I am sure you share with them. While my students all start out somewhat skeptical about the meaning of our new knowledge about ourselves and our planet, those who participate in a dialogue end up seeing the world differently. My hope is that Designing Earthlings will impact you as it did the student who wrote to me after the class: "The discussions in the class have profoundly influenced the way I see myself and the world around me. This in turn impacted my perception of my role as an "Earthling" and how I see myself working to bring positive changes in the relationship between the environment and the economy."

The Big Picture

Some simple visualizations are helpful to illustrate how our increased knowledge has changed our relationship to nature. These visualizations are assembled by identifying the major elements involved in our relationship to nature and to ourselves, and then showing the evolving interactions between these elements. The major elements involved are shown in Figure 1 and are described further below. [Editorial Note: These are not the final figures- images are needed which help give meaning to the labels and make the figures appealing and interesting on their own]

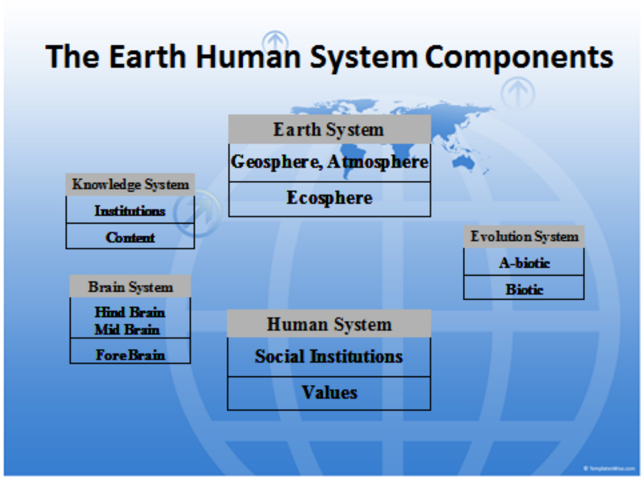

Figure 1. The Earth/Human System Components

As our planet evolved after its violent formation over 4 billion years ago the connections between the elements changed with time. How life got started on the planet is still a mystery. However, after life became well established, our planet's evolutionary history involved the strong impacts of a changing planet and the life it supported, as shown in figure 2.

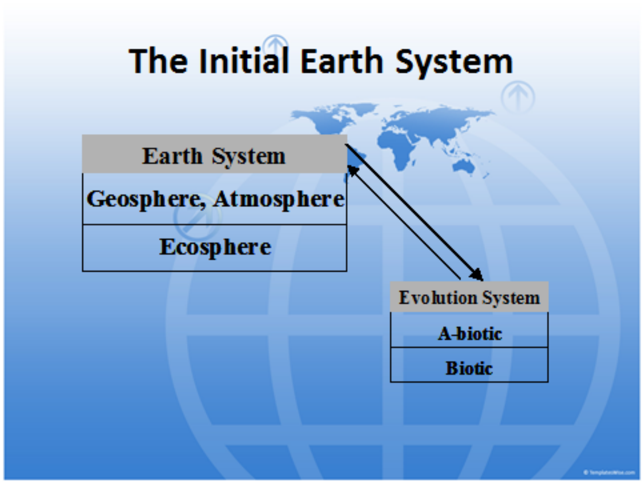

Figure 2. The Earth/Life System

The arrows in figure 2 indicate the existence and direction of impacts. When the arrows go in both directions it indicates that feedbacks can exist. For example the arrow from the Earth System to the Evolution System includes the impact of the planet's conditions on the biotic (genetic) evolution of microbes. The availability of the ingredients needed to provide energy to support the needs of growing populations of microbes became limited about two billion years ago. A new process evolved in cyanobacteria that used abundantly available water, carbon dioxide, and the sun. The arrow in the other direction includes the impact these bacteria had on the atmosphere; as their population greatly increased via the new successful process, they released increasing amounts of oxygen. The change in the atmosphere created by the release of oxygen was, in turn, poison to some other microbes that were part of the Ecosphere (web of life). Their demise is thought to have triggered the appearance of a whole new form of life, a cell with a nucleus deep inside, protected from the poisonous oxygen. Thus, an impact in one direction causes a feedback in the other; some species prosper, others become extinct, and new species emerge. All of this unfolded over billions of years.

The a-biotic (physical) forces on our planet also cause impacts that have feedbacks. Originating in the interior of our planet, hot magma pushes out of cracks in the earth's mantle, causing the continents that are sitting on tectonic plates to move slowly. We were unaware of these movements as recently as 50 years ago. The continents were once all connected, making up one giant continent called Pangaea. The slow movement of continents, inches per year, has resulted over hundreds of millions of years in their current relationship. The changing relationships between the continents significantly impacted the web of life. Sometimes lava erupts violently through other cracks causing volcanoes, which some experts speculate triggered the biggest extinction of all. Geological movements also change features of our Geosphere, e.g.

creating mountains. This is usually a very slow process, but in the form of earthquakes, sometimes the movement is fast and violent. Strong feedbacks between the living and physical parts of our planet make it impossible to really separate the two. This led to the view of the Earth system as a living system. This concept of a living Earth system was given the name " Gaia" by James Lovelock in the mid 1960's.

Microbes have altered the evolution of our planet and the rest of life in very powerful ways. Their own evolution provided the basis for the metabolic and reproductive designs used by more complex life like ourselves. For example, microbes practiced sexual reproduction long before any birds, reptiles and mammals even existed. Their successes led to destruction by way of changing the atmosphere of our planet. As we will see in the next chapter, the choice that confronts us can be symbolized by whether microbes or we will determine the future of our planet.

It took microbes a long time, billions of years to have a global impact on our planet. Like them, we were not capable of impacting the Earth system on a global scale during most of our roughly 150,000 year human history. For the long period before our global role, our relationship to nature looked like Figure 3.

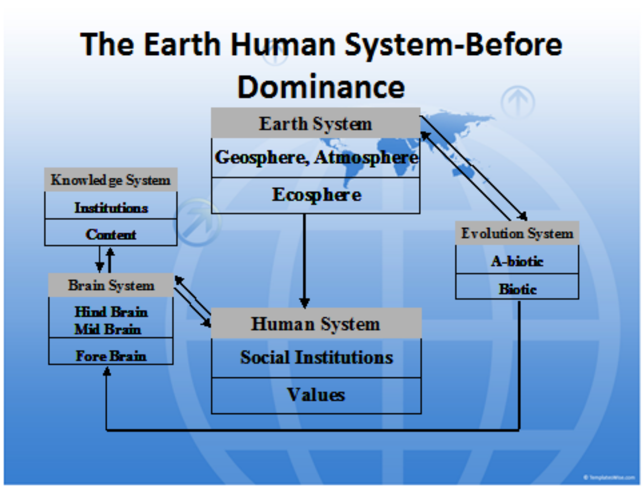

Figure 3. The Earth/Human System – Before Global Impact

The main message from Figure 3 is that we had the same type of connections to the Earth as any other animal in the Ecosphere. Our hunter-gatherer ancestors used their brains, primitive tools, and the other knowledge passed from one generation to another to try to adapt to the changes in the Earth system and the threats posed by predators both big and small. While our survival strategy was different, we were otherwise like any other animal species. Key to our success was the power of our knowledge, decision-making skills, and human organization and values. The arrows go both ways between the Brain and the Knowledge and Human components, indicating feedbacks between them. Our brain, on the one hand, determines our values and institutions. The values and institutions we adopt will in turn shape future decisions we make, including what new knowledge to seek. In the past, when we used our Human System to decide what actions to take, we had largely local impacts and did not affect the overall Earth system. Thus, as shown in Figure 3, there is no impact arrow connecting the Human system back to the Earth system. We did domesticate animals and plants which impacted other life regionally. But most importantly, we had to adapt to the various threats created by biotic and a-biotic driven evolution. They included (beyond avoiding being eaten) threats from climate changes (e.g. glaciations), asteroid impacts, volcanoes and earthquakes, microbes causing infectious diseases, and ecosystem collapses. Of course, we also created threats to each other through conflicts for resources and for power. It was a very Darwinian, survival-of-the-fittest reality, modified by our recognition of the benefit of cooperation to defeat more powerful predators and to meet our basic needs.

Today, as shown in figure 4, like the microbes in the past, we can impact globally what happens on our planet and to other life. And like them, our most worrying current impact is on the atmosphere. It is impressive and important to note that we achieved global scale impact about 10,000 times faster than microbes did. As a powerful species, what we decide to do from here on out will create a set of feedbacks that will have a big, if not determining, impact on the future of our species and our planet. This is reflected in Figure 4 where we have added the impacts that our species has on the other components. As indicated by the arrow going from the Human System to the Earth system, our species now influences the Earth System directly at the global scale. Like the microbes before us, our use of energy is altering our atmosphere globally. It is plausible and to be expected that we will change our climate as they did in the past. Also an arrow has been added going directly from the Human system to the Evolution system, since we now can influence the drivers of the Evolution system itself on the global scale. The secrets of the genetic code also were largely unknown as recently as 50 years ago. Human- designed genetic techniques can now be used to protect threatened species. By practicing what some call Geo-engineering, we can use physical techniques at a global scale to alter the planet. An important example, to be elaborated on later, is the idea of controlling the amount of carbon dioxide in the atmosphere.

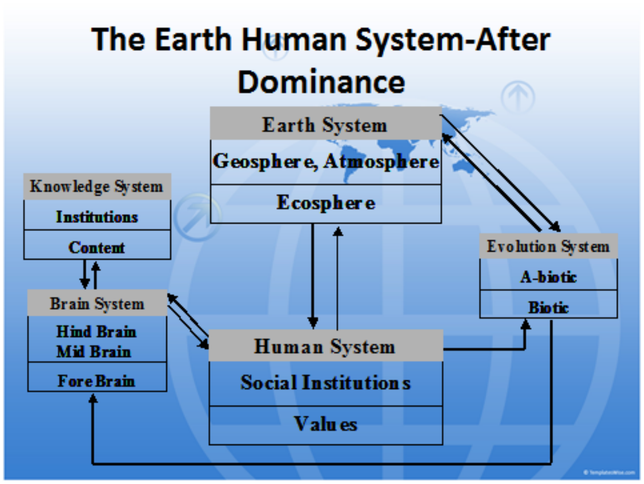

Figure 4. The Earth/Human System – After Global Impact

The recipe shown in Figure 3, which depicts how we use The Knowledge, Brain, and Human system (the KBH system, for short) to survive and prosper as a species needs to be extended and modified to fit the challenges that a powerful species poses to the rest of the planet. The recipe needs to be modified, because we are no longer simply vulnerable hunter/gatherers, and we therefore no longer have the same goals for the KBH system. It will be helpful to distinguish between internal parts of the KBH system and its interactions with the Earth and Evolution systems. This is shown in Figure 5.

This depiction of our relationship to nature is called Co-Evolution, because both the KBH system and the Evolution system will determine the future of our planet and other species. In this visualization, we have removed the direct impact of the Evolution system on us. This is not because evolution will cease to impact our species. Rather it is because its direct influence on our species is likely to be secondary to our impact on ourselves through our use of knowledge. The timescale of genetic evolution-based changes is much too slow and ineffective to compete with the quick and profound impact our knowledge will have on how we use our brains. This plausible premise will be supported by a more detailed analysis in chapter three of the comparison between genetic based changes and those based on the KBH system.

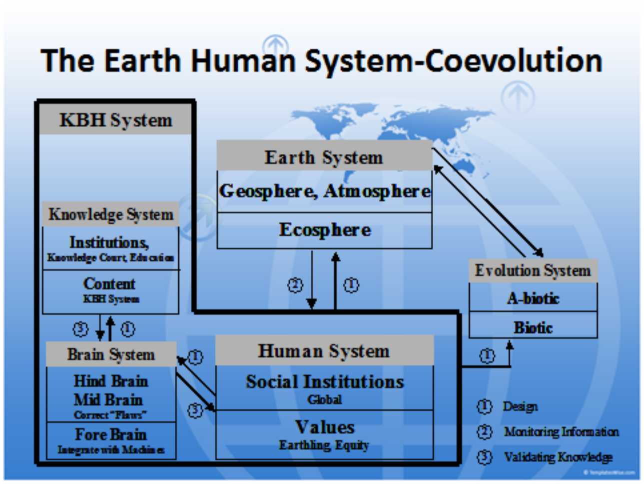

Figure 5. The Earth/Human System – Co-evolution

The relative speed at which an initial impact occurs can alter the feedbacks that are created. A gradual cooling (or warming) of the climate over the whole planet can allow species time to migrate to new areas that support their needs. A fast climate change of the same magnitude could cause their extinction. This is an important characteristic of this highly connected system that is generally very important for determining what will actually happen. There are two aspects of the speed of change that are important for our current discussion. The first just mentioned is that our rate of changing the planet through use of knowledge is much faster than changes created by other species, though certainly slow compared to an asteroid impact or huge volcanic eruption. The second is the flip side of that speed – our ability to respond to changes is much faster than any other species. While both are true, it should be clear even at this simple level of analysis that, without speed of response, we would be just as defenseless as other species against many fast developing physical threats. For a pervasive cooling, like the one that is thought to have produced the so-called Snowball Earth, it would make little difference whether the change was slow or fast. We would need to prevent it from occurring to avoid extensive destruction. More generally this becomes another point of departure with those concerned by our impact on the planet; they rightly stress the danger of the speed with which we are altering the Earth, but they do so without also championing the speed at which we can defend against threats, and the capabilities we bring to the task, if we make the decision to act.

The greater impact and the rapid rate of knowledge-driven evolution vs. genetic based evolution creates new threats associated with our dominance. I have called them Knowledge Gap threats. We are, of course, continually improving our capabilities to anticipate and respond to changes that might occur. But a technocratic solution alone is not enough. As shown by the impact arrows in the previous figures, our brain is at the center of the KBH system, which is influenced by both our knowledge and our human institutions and values; it, in turn, influences them. This internal KBH feedback loop presents us with some interesting dilemmas as we attempt to respond to changes and to design the future. I have collected some of the logical dilemmas created by the central role played by our brain into what I call the Human Uncertainty Principle, which I'll discuss shortly.

The Threats and Challenges We Face

Our changing planet will of course continue to challenge us in the future as it has challenged life more generally in the past. The chapter on What the Evolution of Our Planet and Life Tells Us reveals how the hard work of paleontologists has greatly increased our knowledge of our planet's past. A picture has emerged of a continually changing planet, one that challenges the survival of species with catastrophic events that have caused massive extinctions. The causes of the catastrophes include climate change (see also climate change data), asteroid impact, and huge volcanic eruptions. Other significant destructions and extinctions involved various levels of ecosystem collapse – in particular, the changes caused by microbes. Extinction is clearly an outcome all species are trying to avoid; however, very few have been able to do so. A major objective of co-evolution for our species is also resilience, the avoidance of either extinctions or the extensive loss of life. Ours is the only species (we believe) that can think, and in any way be aware of, threats from events that occurred before our species evolved. Thus, until now, the survivability of other species has been a matter of luck. Their success via Darwinian adaptation could not prepare them for changes or catastrophic events that had no precedent in the lifetime of their species. The dinosaurs had no way of knowing that an asteroid was headed for our planet, and they could have done nothing about it even if they knew. We do know and can do something about it. But will we?

When discussing the threats and challenges to co-evolution, it is helpful to separate them into two groups. The first group is called "proximate" and involves threats and challenges we are presently facing and for which there is a known solution. The second group is called "ultimate"; in these cases, we have no current solution to the threats or challenges we are contemplating. This distinction is useful for separating our current legitimate concerns from any long term concerns and, in turn, for deciding whether we should be optimistic or pessimistic about our future. Here we will identify the various threats and challenges we face and briefly indicate the class to which they belong. In the chapter on 'Confronting the Threats We Face,' we will describe the approach needed to address each threat and challenge.

The challenges to meeting our needs for energy, food, water, and shelter provide a good example of the changing nature of the challenges we face as a powerful species. It was as recently as the 1970's that Paul Ehrlich published his book, The Population Bomb, in which he speculated that the world's resources would be swamped by an out-of-control population growth. We now know that will not be the case. As people move out of poverty, their birth rates go down. The recognition of the threat of population growth led to conscious attempts to limit it, with China being the most controversial example. The situation in some developed countries has progressed to the point that some are actually decreasing in population. The estimates now are that the planet will peak at less than 10 billion people and then possibly decline. The United States uses roughly 25% of the world's resources but is only 5% of the global population. It would take about ten times the currently available resources to support a world at the current standard of the United States and at the expected peak in population. It is already clear that we can provide ten times today's resources for our use in the future. This is an insight that took many of my pro-environment students some time to accept.

In the current discussions about the challenges we face in meeting our basic needs, energy-use is at the top of the list. The concern is both about the impact of our use of energy on the environment – i.e. climate change and pollution – and more generally that the technology-based approach for meeting our needs involves an unsustainable use of energy. Our use of energy is central to our well being. We now know (thanks to Einstein) that mass m and energy E are related, as we can see from his famous equation, E=mc2. The conversion of mass into energy occurs in the fusion reaction, fusing two hydrogen atoms to form helium. It is this reaction that provides the energy produced by our sun and other stars. A very small amount of mass, the difference in mass between two hydrogen atoms and a helium atom converts into an enormous amount of energy. For example, our sun produces 100 million times as much energy per second as all humans on our planet use in a year. It is, of course, the sun's energy coming from over 93 million miles away that is used by most of life to survive. Fusion produces no significant impact on our atmosphere and no radioactive waste. It offers the potential of providing a safe, clean, and inexhaustible source of energy. Nuclear energy is of course another alternative as are renewable energy sources like solar and wind. We also still have a lot of fossil fuels available for use. One can conclude that the challenge of providing energy is clearly a proximate one.

Energy will be revealed in our analysis to be a long-term strength of the KBH system approach to co-evolution. The knowledge that unlimited sources of energy exist means that we can plan for the long term; we are able to support energy intensive solutions to the challenges of co-evolution just as we have used energy in the past to meet our basic needs. If one had to identify one cause for our success as a species, it has been the variety of ways we have used knowledge to design ways to convert energy into work. The second industrial evolution, about 150 years ago, was the turning point in our energy use, and it was, in many ways, the tipping point in our transition from a struggling species to a dominant one. With unlimited energy at our disposal there is almost literally nothing we cannot do. Energy is a good issue to look at when distinguishing between proximate and ultimate causes of concern for co-evolution. In the proximate sense, providing energy is a real concern. In the ultimate sense, providing energy for our use is the greatest strength and resource we have in addressing the challenges of co-evolution. By looking at energy, we can clearly see the difference between the designing earthling approach and the current way we are addressing our global energy needs and proximate energy concerns. A detailed plan for developing and using energy both to meet our future needs and to remove the threat of climate change will be presented in the final chapter, 'Designing Our Future as Earthlings.' It is practical and based on knowledge we already have.

There is clearly enough water in our oceans and known desalinization technology can make it useable, as Israel has already demonstrated. The proximate concern about water is not an ultimate concern. The same can be said about food production. We can meet the needed factor of ten in food production by applying our genetic modification techniques to mimic the known best performances of existing plants in terms of low water requirements, rapid growth rates, and minimal soil disturbance. The factor of ten in food production could then be achieved with less soil deterioration and using the same amount of land and water we are using today. The same can be said for the materials needed to provide us with shelter. This is not to minimize the challenges that still remain to meet our basic needs, but as will be made clear, they are all clearly proximate challenges.

While we can provide for our basic needs and more, serious ultimate threats still remain. They include those we ourselves create in meeting our needs and the catastrophes caused by our changing planet. Past extinctions have some important lessons for us concerning the catastrophes that lie ahead. Most importantly, climate change, asteroid impact, earthquakes, massive volcanic eruptions, ecosystem collapse, and infectious diseases are going to happen again in the future. They will occur even if our species disappears or if we were to reduce our impact to zero. Conservation and sustainability will not provide protection from the destruction and the extinctions they can cause. The same can be said for smaller scale natural disasters like hurricanes, tornados, floods, earthquakes and mega-tsunamis. The events that cause them will be part of our future, just as they were a part of our past. This often neglected reality will turn out to be very important for rejecting the position that we should minimize our impact on the planet. One past major extinction (which we will describe in detail in the next chapter), The Permian extinction, raises an important insight that can help identify possible ultimate threats. Namely, as we saw in the microbe case, we need to be more concerned about the feedbacks created by an initial event than the event itself. A more contemporary example of this feedback effect is HurricaneKatrina. Many believe that our reaction to the disaster made things worse. It also does not take too much imagination to realize that a major interruption today in the supply of energy could spark a very destructive global conflict for available resources. Yet, here too, we are behaving as if a major interruption in supply will not happen; and, we have few if any contingency plans to deal with it if, or when, it occurs. How to plan to defend against feedback effects from a threat caused by our own failed defenses will be an important issued addressed in the chapter on 'Confronting the Threats We Face.'

We have achieved an impact on the planet and on other species that makes us a future evolutionary force on a scale that no other species aside from microbes has ever achieved. Our global impact goes well beyond the reduction of the ozone layer and changing the amounts of greenhouse gases in the atmosphere. It also includes using eight percent of the freshwater and eleven percent of the surface area of the planet. Our use of the land has led to the erosion of about thirty percent of the topsoil. Our mining moves more minerals than the earth does by erosion. Agriculture harnesses fifty percent of the suns energy used by all the earths green plants. We are causing a loss of about 1% of our forests and 50 species per year, both of which are much greater than rates without human impact. The new giant dam on the Yangtze River in China will even mildly impact the rotation of the planet. Since our impact is knowledge-driven, unlike that of other species, we will continue to create new impacts at a rate much faster than genetic based evolution can adjust to. Altogether, these developments are changing our climate and causing the extinction of species. Infectious diseases, ecosystem collapse, and climate change are natural threats capable of global destruction that the success of our species has made worse. The scale and speed of our success as a species has led to the concern that our use of knowledge to improve our fitness is the greatest threat to our planet and ourselves of all. This Knowledge Gap threat is the fourth and most serious threat that we are implicated in.

Microbes and the diseases and destruction they can cause have been present from the onset of life. Many microbes produce new generations at an amazing rate, some in tens of minutes. This is about one million times faster than us. It allows them to genetically evolve to adjust to changes more quickly than other species. A relevant example of their ability to adapt is the speed with which microbes develop a resistance to a new drug. This adaptive speed forces our medical scientists to continue to produce new drugs to deal with ever- new varieties of drug resistant microbes. A global presence and increased connectivity is also a consequence of our success as a species. This increases the threat of infectious diseases in three ways: greater exposure of humans to places they were not present previously; greater dissemination of diseases because of our global travel patterns; and greater ability of diseases to spread as a result of our increasing populations, concentrated in crowded cities. The threat microbes pose has a long history. They have caused global pandemics like the so-called black plague, a most notorious example from our past, which caused one third of the 75 million person global population in 1350 to die. Today we have concerns that an avian flu virus will cause a global pandemic. What is clear is that, while destructive, a pandemic is unlikely to cause our extinction partly because some of us (as was the case with the black plague) would probably be naturally resistant to it. This resistance by a minority of humans is one good reason to maintain human diversity in the presence of uncertain future threats. This is part of the knowledge we have acquired in our long history of fighting diseases. Our past experience will be very useful in designing our approach to other microbe threats as described in the chapter on 'Confronting the Threats We Face.' Microbes represent an ultimate threat against which we will need to remain vigilant.

Biodiversity loss is the second threat we are making worse by our actions. Estimates of our impact on the extinction of other species vary. They span from a hundred to ten thousand times the rate expected if we had no impact. One lesson from the next chapter is that all natural species cause the extinction of other species as a result of their dominance. Redwoods completely dominate and dramatically reduce the biodiversity of their environment. The cyanobacteria did the same thing on the global scale. Our ancestors who lived directly off the land had a complicated relationship with other species. They killed some to survive and worshipped others out of both fear and respect. Using conventional breeding techniques, our ancestors formed more alliances with other plant and animal species (like wheat and cows) than any other species in the history of our planet. But, in the future, Earthlings should aspire to do better and to strive to be deeply concerned about the rest of life on our planet. In the case of our relationship to other life on our planet, our ideals and pragmatism can lead us all to the same answer – that is, if we are watchful of the extent to which we let emotions play a role in our debates and decision-making.

As a threat, our current impact on biodiversity is a proximate threat. Biodiversity is not an ultimate threat and, like energy, can be a long-term strength. Our knowledge has provided us with a lot of options and, like energy, could serve to make our planet a Noah's Ark luxury liner for an unlimited number of different passengers. Genetic tools can be used to address health threats to other species and to preserve the genetic code of threatened species. Clearly, albeit controversially, they could also be used to design and create increased biodiversity in the future. I am sure many of you share the concern with many of my students about us designing new forms of life. These are very serious concerns that need to be addressed. But, for the moment, the important point is that biodiversity provides a clear example of the new choices we have. If we can become confident, or have the trust and optimism, that we will be able to use our capabilities wisely, rather than destructively, then we will be able to rejoice in the fact that we have the capability to make nature a much richer and more harmonious place than it has ever been.

A third threat, which our actions seem to be making worse, is global warming. Our impact on the atmosphere is a basis for major concern, given its key role in determining our climate and in supporting all life. The specific issue of global warming will be analyzed in detail later. However, it is interesting to note that in the past, global cooling caused the most destruction. Periods much warmer than today have existed in the past and have been associated with periods of high biodiversity and with life prospering. I have provoked many of the students in my class when I've asked them, "What's so wrong with having palm trees on the poles of our planet in the future as was the case in the past?" There is no systematic assessment yet of whether the benefits of a warmer planet are worth the costs of the disruption that would accompany it. Global warming and asteroid impact threats will be compared in the chapter on 'Confronting the Threats We Face'. The comparison will come after 'Our Brain's Glories and Limits for Designing the Future,' in which I will describe how we are currently evaluating their comparative threats incorrectly.

One of the final and most serious threats we pose is our use of knowledge. Given the key role our decisions and their consequences can have on the earth, this is to be expected. Any mistakes in using knowledge can have serious consequences. As Hurricane Katrina and the Indian Ocean tsunami demonstrated, our failure to use known knowledge to address an inevitable threat can have disastrous results. Similar situations exist with regard to threats from earthquakes and volcanic eruptions in many places on our planet. Poor use of knowledge and poor decisions are responsible for many of the destructive things we do to each other. On a micro level, these failures prevent many of us from solving our myriad personal problems; on a larger scale, however, the misuse of knowledge can result in significant threats to our well-being and survival.

Knowledge as a Threat

The gap between the rate at which humans can cause global changes and the rate at which our planet changes is called the Knowledge Gap (KG). The KG presents a threat to our species in two ways. In the past, as shown figure 3, we were continually threatened by our limited ability to adapt to our changing planet. In this case the KG was negative. This is simply the reality that all life struggles with. Thus, in the past, the threat to our well- being was due to a lack of knowledge. As our knowledge grew, our ability to survive increased and our species prospered. It is difficult to pick the exact moment at which our impact arrow on the planet began to be comparable to the planet's impact on us. However, it is plausible to associate it with the second industrial revolution around 150 years ago when we developed new ways of providing energy like electricity, and knowledge became more widely disseminated through improved printing and paper production.

In this sense our evolution can be viewed as changing the KG from negative to positive. From that viewpoint, it should not be surprising that our relationship to the rest of nature underwent a transition as we moved from a negative to a positive KG. And, to be even more precise, the KG is not the same for all threats. The knowledge gap threats are those created by our use of knowledge that can cause global destruction because the rest of the planet cannot adjust. The proximate aspect of this threat is created by our current lack of knowledge about the consequences of certain decisions. And, as long as we continue to alter the planet, there is an ultimate aspect to the KG threat. Knowledge is clearly a double-edged sword that creates both threats as well as solutions. We already know enough to design solutions so as to eliminate many non-KG threats and to protect ourselves from the damage of those that remain. Until very recently, any statement such as this was not true, even if some past technological optimist uttered it. Today, however, it is not only true, but we now know what we have to do make it happen.

In spite of this potential for success, the KG threat is the one kind of threat that correctly concerns many people, and that can cause bad outcomes in four general ways. As already mentioned, the first way is through its role in enabling us to alter nature globally, thus creating the possibility of shifting the whole Earth/Human system into a new state that is catastrophic for our species survival. Specific examples of this include human-induced climate change or ecosystem collapse. One can also include resource depletion in this class of threat. The second is that our new innovations themselves can have unintended and catastrophically negative consequences. The best example of the fears associated with this kind of threat is the response of many to genetically modified foods. Here the unintended consequence could be that a human engineered species will unleash a chain reaction of feedbacks that will destroy the ecosystem or ourselves. DDT was the original example that alerted us to this danger and one can also include human-caused pollution generally in this class of threat. The third way the KG can threaten co-evolution is through the use of our innovations destructively against one another. Weapons of Mass Destruction (WMD) are a modern version of this fear that originated with the concern that the use of nuclear weapons could cause a catastrophic nuclear winter. Our increased knowledge of how to kill one another has grown faster than our social institutions and values can cope, raising the question of whether we can be trusted in the future not to kill each other with our powerful new capabilities. Once again, my students are skeptical about this issue, given their justifiable mistrust based on how we have made decisions in the past. This is related to the final and currently greatest KG threat, which is the misuse of knowledge. As discussed in the preceding 'Big Picture' section, both our brain and our institutions impact how we use knowledge. The latter will require new institutions to ensure the proper use of knowledge. I call these institutions the Knowledge Court. In simple terms it will perform the function for knowledge-based decisions that our Civil Court does now for our commercial transactions. It will not determine what is the right or wrong decision or opinion, but rather whether the knowledge-using process meets agreed upon standards. The concept of the Knowledge Court will be described in more detail in the chapter on 'Organizing Ourselves to Use Our Brain.'

The most debated global example of a KG threat today results from our use of energy. The concern is focused on emissions from burning fossil fuels, which could alter our atmosphere and trigger global warming. The KG threat also impacts us at an individual level in ways that are instructive for understanding global threats. For example, when we were hunter-gatherers, struggling for survival, the ability to store energy in the form of fat increased our fitness. Food was available only erratically and one pound of fat stores an astounding 3,500 calories for delayed use at any time in the future. For many people today, food is reliably available, and as we live to an older age, the propensity to keep fat has turned into a liability for our long-term health. Our success in agricultural technology and in increasing our lifespan has led to a new threat to our individual well-being. The global food distribution system is also exposing people in many regions to new types of food, which is causing severe health problems for local populations. Their digestive systems are not able to deal with many of the things they are now eating. On the other hand, our knowledge of the dangers of fat, and the ways in which we can best deal with it, is being used by many of us to prevent its destructive impact. Others continue to ignore the danger signals, risking their health and even premature death. This is, of course, an example of poor personal decision-making.

As the above example shows, we should be concerned by the manner in which we use knowledge, while the rest of nature continues on unconcerned with the destructive outcomes of using the genetic code. Genetic driven evolution allows its creations to persist for as long as they can and destroy what they will while they exist. Genetic evolution is not concerned about using the code poorly or developing more advanced species. This approach is not one we should mimic for the practical purposes of wanting to improve the future and to avoid the destruction a failed experiment might create. Thus we do need a new "Cautionary Principle" to help us use knowledge to avoid destructive errors in our pursuit of improved fitness. This new approach will use the two positive capabilities that created the KG. The first is the high speed of human innovation and its deployment. The second is our ability to plan in advance for potential threats created by the application of knowledge. Planning using knowledge of what might happen, and using knowledge to provide timely and effective defenses in case of unexpected consequences, can form the basis for a new "Cautionary Principle." This same recipe, of course, works for the previously described threats posed by a changing planet, and is an important aspect of making informed decisions across the board.

Sadly, when we will review our past, many of our efforts to help regional ecosystems survive through our use of knowledge actually made things worse. For example, the abundant populations of fish which once called the Continental Shelf home, have not yet recovered from our over-fishing of the area or our follow-up attempts to try to fix the damage our over-fishing did. Those failures to make informed decisions were, in part, due to a fundamental misunderstanding about knowledge itself.

To rely on knowledge as the basis for making informed decisions as opposed to our emotions or intuition we need to understand the limits of knowledge and its use. Our emotions can lead to the destructive misuse of knowledge. The misuse of knowledge that results from drawing unwarranted conclusions especially with regard to claiming certitude when none exists, will also be very destructive in a knowledge-driven future. Defining limits to knowledge and its use has a long and growing history in science. Three distinct types of limits have been defined that are relevant to making informed decisions. Our knowledge is useful because of the inferences it lets us make. Knowledge is built on a foundation of logical relationships. For example, if one knew A is greater than B and B is greater than C than one could conclude that A is greater than C. Mathematics is the language of logic. The first and the most fundamental limit to our knowledge stems from our inability to devise a logical mathematical system that is both complete (able to address any question), and consistent. In our example it would not be consistent if A were not greater than C. In 1931, Godel asserted that it was not possible for the same system to be both complete and consistent. He reasoned that any complete mathematical system would have to be able to prove the truth of statements such as "I am lying", which cannot be proven. If I am lying then the statement must be incorrect, and if the statement is incorrect, then I must be telling the truth. On a practical level this means there are self referential questions we cannot ask like: What is our purpose in life? A related, but more operational, limit to what we can know was developed by the father of the modern computer, Alan Turing. He developed the concept of the Universal Turing Machine specifically to address the question of whether something was computable or not. His machine and its later generations continue to define practical limits to what we can hope to use machines to help us evaluate.

A second conceptual component limiting knowledge relates to the inherent indeterminacy of outcomes in complex systems. The Earth Human system shown in fiqure 5 is a complex system as are many of its components like the atmosphere and our brain. In complex systems, feedbacks can cause new forms of organization to emerge spontaneously and self assemble in an inherently unpredictable way. This is the origin of the so called 'butterfly effect," through which a set of feedbacks can allow a single butterfly to (conceptually, at least) alter the whole planet. This was one of the major reasons for our past failures to manage some regional ecosystems like the continental shelf fisheries. The fish stocks can rise and fall, based simply on unavoidable fluctuations in how successfully the fish are reproducing. The feedback from a successful breeding cycle could deplete their food supply, causing a dramatic drop in their ultimate survival.

It is important to understand how being 'complex' is different from being 'complicated'. Exxon's oil refinery is complicated, as is the space shuttle, but their performance is predictable. Reductionism, supported by experiments, has given us many of the cause-and-effect rules that we can use to make predictions and exert control. For example our understanding of gravity enables us to predict how an apple will fall from a tree, but it can also help us design airplanes and rockets. We can use experiments to demonstrate the predictability of outcomes. This is the basis for the design of the Exxon refinery. The scientific process, using reductionism and the experimental approach that supports it, has been how we have determined our knowledge and applied it. It has been the main recipe for our success as a species. In comparison, a regional ecosystem is complex and its evolution in time is fundamentally unpredictable. In some complex systems there are regular patterns that emerge which have predictable behavior. However, what is unpredictable is when they will switch from one regular regime to another. For example, one great concern with regard to global warming is that the rapid change of our atmosphere may trigger by feedbacks a change to a completely different climate pattern that will cause great destruction.

In brief, the solution for dealing with unpredictable events could be to impose a human-designed controllable solution on the complex phenomena at their root, which will either prevent them from occurring or defend against potential destruction if they do occur. A concrete example of prevention might be the design of a system that will prevent a future asteroid from hitting our planet. In that case, even though we cannot know when an asteroid will next hit, we can certainly prevent its destructive impact. Using our telescopes we have the ability to discover early enough when one is coming. We currently have several untested approaches, to be reviewed later, that provide us with the capability of preventing an asteroid from hitting our planet. Another example of a defense system is the use of dams to prevent flooding from very infrequent and unpredictable rains that can produce more water than the rivers can handle. In that case, we cannot prevent the rain from hitting the earth, but we can design a way to prevent its destruction in advance. The key insight here is that unpredictability does not mean that destruction is unavoidable. The choice between when to go on the offensive and alter what happens, and when to go on the defensive and prevent or minimize the destruction, is a critical decision addressed in detail in the chapter on 'Confronting the Threats We Face'.

The third limit on our knowledge is not related to predicting the behavior of complex systems with many components, but rather involves predicting the behavior of small particles like electrons – that which everything is composed of. The Heisenberg Uncertainty Principle, developed by the physicist Werner Heisenberg, refers to the proposition that one cannot simultaneously know the position and motion of a small particle with arbitrary precision. While the technical reason for this is rather complicated, the lesson it holds for us is quite simple. Another great physicist from the early twentieth century, Niels Bohr, provided a related insight. He proposed the 'Principle of Complementarity', which "implies the impossibility of any sharp separation between the behaviour of atomic objects and the interaction with the measuring instruments which serve to define the conditions under which the phenomena appear." Our brain is the measuring instrument for the reality around us through its evaluation of the information provided by our senses. More generally our brain is the measuring instrument for evaluating knowledge. There is a version of this type uncertainty that makes it impossible to completely separate to our brain from the knowledge

The Human Uncertainty Principle

The impact of these three limits on knowledge and our ability to design the future help define what I call the Human Uncertainty Principle. One version of it is as follows: "The very act of our brain formulating a decision and then acting on it can change the basis for the decision." First, like the recursive logic that makes it impossible for a mathematical system to be both complete and consistent, there is no complete and consistent logic on which we can base our decisions. We cannot ask the question, "What would have happened in the future if we had not acted?" Secondly, the feedbacks from our actions can cause the complex Earth/Human system to change its regular patterns, suddenly causing the exact opposite result of what was intended. My favorite example for this is – What if we take strong steps to stop global warming, but find out later they were unnecessary? And, what if our focus on global warming caused us to ignore another threat which was real? This uncomfortable scenario means that considering the possible feedbacks that might result, and preparing for them, must be a part of our future. Finally, we cannot escape the fact that our brains' version of reality is shaped and limited by what available knowledge we have to evaluate. Like in the movie, "The Matrix," we cannot be completely sure that our brain is not "blind" to another reality. Science is a way for us to minimize this danger. Nonetheless, the view we have of reality will continue to impact how we process new information and will therefore change the meaning we give it. Understanding these uncertainties and limits to knowledge can help us clarify what can and cannot be predicted about the future, and what steps to take to make the best decisions possible.

Conflicts of interest are a natural part of today's KBH system, and they contribute to the Human Uncertainty Principle. For example, the experts on global warming who claim that it poses a danger to co-evolution are also asked to judge the validity of the claim, because it is too difficult for laypeople to evaluate. The scientific method, in principle, helps us deal with this issue. In practice, when dealing with issues with the above described uncertainties and that cannot be directly tested, it is more and more complicated today to determine the difference between opinion and fact. As we will discuss later, our current knowledge system is more susceptible to "groupthink" than we might like to admit, especially if we are hoping to depend on it for critical decisions.

A related conflict of interest pops up with regard to pursuing our needs today vs. devising and implementing solutions to ensure our resilience for future generations. I will show that our hunter-gatherer brain has given us a short-term bias to our decision-making tendencies a short-term bias, since hunter-gatherers were only concerned about day to day survival and had short life spans. More generally, as described in the chapter on 'Our 'Brain's Glories and Limits for Designing the Future,' distortions arise in our decisions due to our use of emotional and intuitive judgments in place of sound reasoning. These typical human responses associated with the parts of our brain designed (by evolution) for our past reality as a struggling species become ineffective, even dangerous, in circumstances in which our use of knowledge can alter our fate and that of our planet. Thus, as our dominance increases through the use of knowledge, the less useful and more dangerous it will be to use our hunter-gatherer-based intuition. This is, of course, where the Knowledge Gap threat and the Human Uncertainty Principle come together to create the greatest human based threat to co-evolution, not to mention to our daily lives. The reaction towards many contemporary issues such as stem cell research, genetically modified foods, and even the reasoning that led to the war in Iraq, can be related to the changing balance between knowledge- and emotion-/intuition-based decisions.

The Human Uncertainty Principle impacts co-evolution along the whole path from knowledge-generation to action. How our brains think about co-evolution will determine what knowledge we generate. Knowledge generators validate the knowledge generated, and the conclusions they reach can change the basis for validation. In a deterministic situation, these outcomes are desirable because they can be easily refuted by applying the scientific method. However, in a situation full of unavoidable uncertainty, problems need to be recognized and compensating measures taken. Decision making based on validated or testable knowledge differs markedly from decision-making based on uncertain, unpredictable, and unverifiable knowledge. This will be demonstrated later by describing how the current KBH system has made its decisions about global warming. The fear of changing the climate has caused many to react strongly to the perceived threat even though no one has demonstrated that the net impact of global warming would be bad overall for the planet, just that it will cause some destruction. Remember those palm trees on the poles. We will have much more to say about this provocative example and of the general difficulties we will face later in the chapter on 'Confronting the Challenges We Face.'

Just as it is important to know where the boundaries are between what is knowable and unknowable, it is also important to know what our designs for the future will not address. We know our sun will eventually run out of fuel and become a very large red dwarf in 4.5 billion years, either engulfing the earth or pushing it out into space. In either case, life on earth will come to a violent end. The destruction of our planet will begin much earlier; in about one billion years the temperature will increase to the point that the climate will become unstable. Although, the earth system, with its abundant life, is in fact in its later years, one billion years is still roughly 10,000 times longer than our species Homo sapiens has existed. Or, said another way, there is still time for about 10 million generations of Homo sapiens to solve the problem of co-evolution and another 40 million generations to enjoy the results. Of course, I hope we can do better than that. But suffice it to say, our discussion and designs for the future will not deal with the threat posed by the sun.

Neither will the proposed approach to co-evolution deal with the result of discovering intelligent life from outer space. If such an event were to occur, it clearly could change our approach to the future in so many ways that speculation on this issue would not be very useful. What knowledge or threat would visitors from outer space bring? There is one way that visitors from outer space could become part of a general issue that we would need to address. Even though we are currently very powerful as a species, and there is no immediate threat to our hegemony, we will need to constrain our approach to the future by considering the possibility that we will need a way to defend ourselves. Thus the proposed Earthling approach, which stresses cooperation within our species, will still need to include a global defensive capability.

Another caveat for the proposed approach to co-evolution is that travel through time does not become possible. This, of course, would change the whole meaning of evolution. While this certainly sounds far-fetched, physicists and cosmologists are presently speculating about the impact of the strange properties of time, as of course did Einstein. While visitors from either outer space or “outer time” seem unlikely to appear within the next couple hundred years, they cannot be categorically ruled out in the next billion years.

Designing the Path to the Future

Many suggest that sustainability should be the goal of our actions and that a primary co-evolution tactic should be the minimization of our impact on the rest of the planet. Sustaining the present Earth-Human relationship is both unrealistic and dangerous. It is unrealistic because our planet will continue to change and some of those changes are truly dangerous to life on the planet. This is a major flaw in the ‘leave-things-as-they-are’ recipe for our relationship to our planet. It means accepting the inevitable devastation that nature has in store for us. We surely can and will do better than that. The modified goal for sustainability offered by some is meant to preserve options for future generations. This tactic avoids creating any permanent changes on our planet that would restrict what future generations can do. This approach badly underestimates our capabilities and in so doing also increases our risks of future destruction. It would recommend, for example, preserving our options for using fossil fuel energy sources. Fusion, however, has the potential to change our whole relationship to energy, making the use of fossil fuels in the future as irrelevant as wood is today in the developed world. Science is providing new knowledge at an increasing pace. We can be sure that future generations will in general have more options than we do today. The designing earthling approach would begin with the importance of energy for our future, both to make our lives better and to help us defend against various threats. It would seek the knowledge needed to design and implement an approach (fusion for example) that would provide unlimited energy to all. Fusion, is in fact, being currently developed with an unprecedented level of global cooperation. This provides one of many examples described later, which show that in spite of the rhetoric, we are already pursuing the designing earthling approach.

Despite the objections to pursuing sustainability as presently defined by its advocates, the idea of being deeply concerned about our impact on other species is useful when thinking about designing our future. Our planet has been very supportive of our species and therefore, sustaining its basic state, including the ecosphere, makes sense. I certainly harbor a certain biophilia, or bond to nature, myself. The fact that our species has prospered in the environment created by the other existing life forms also offers a pragmatic reason for preserving and enhancing our current ecosphere. This idea has been captured in the efforts to determine the value of potential ecosystem services like clean air and water, which nature presently provides us for free. A similar reasoning applies to our concern about one another. In our past (characterized by a negative knowledge gap), competition was arguably the best path to increasing fitness. With a positive knowledge gap, planning and cooperation can outperform competition. Cooperation requires trust that can only be achieved by treating each other compassionately. As already mentioned there are areas of great uncertainty today in which competition remains desirable; however there are an increasing amount of areas in which planning and cooperation would allow us to achieve our goals better. Choosing which approach to use in each given situation will be an important part of the last chapter. In order to develop trust we do need to moderate our competitive behavior so that 'losers' in areas of uncertainty are treated with the respect they deserve. They are helping us all learn to avoid making the same mistakes in the future. This is clearly where the designing earthling approach differs from the business-as-usual recipe, which continues to stress the virtues of competition above all else, and in its most virulent forms even rationalizes the destruction of the losers as making us more fit.

Ignorance of what and why things happened was routine for our hunter-gatherer ancestors and even in the recent past. Now that the KG is positive in many areas, it has become accepted that we will use our enhanced capabilities to learn about future threats for the benefits of our health and overall well-being. Of course, the possibility exists that we are still ignorant of some major threats from the past, or that our actions are causing threats we currently do not yet appreciate. It is unlikely that there is a new kind of threat from the past that is still to be discovered, though certainly there can be new combinations of ways in which such threats could appear. Given our understanding of the limits to our knowledge, the possibility exists that our species could cause threats we are currently unaware of and for which there is no precedent. This is an ultimate threat we will always need to deal with. We do need to remember that we have survived as a species for only 150,000 years, while species of cyanobacteria have survived many billions of years. That is over 10,000 times longer than our survival, yet we have become globally powerful 10,000 times faster than they did.

So, to summarize our thoughts thus far: Co-evolution, most vitally, is about our future and that of our planet. Our recently achieved powerful role requires that we change our recipe for how we will continue to interact with our home planet. The challenge for our species, using the KBH system, will involve how to choose the best strategies to pursue and how to implement them. This challenge will require new approaches to knowledge, as well as new ways of thinking about the role of our brain and the tools we use to augment its capabilities. Future social institutions and renewed value frameworks will enable innovations created by new knowledge to be used successfully to address the threats and challenges we face. The threats to co-evolution include those that have caused major extinctions in the past: climate changes, asteroid impacts, volcanism, and microbes. They will all be a part of our future. But, threats to co-evolution also include the new knowledge gap threats created by human dominance itself and the speed of human innovation. Humankind will be clearly shown to have many roles: we are 1) the cause of many threats; 2) the analysts of the problems that arise; 3) the creators of potential solutions; 4) the decision-makers; and 5) the implementers of the solutions we come up with – and all these roles are supported by a brain saddled with serious limitations. The Human Uncertainty Principle captures some of the difficulties we presently have making consistently informed, wise decisions. It also includes some existential components that can be summarized by replacing Descartes's statement "I think therefore I am" with "What I think determines what I do." The importance of adopting the designing earthling approach stems from the operational version of our existential reality: "What WE think will determine our future."

In the chapters which follow it is important to keep clear given the above what aspects of the analysis follow from the logic of using knowledge and what is in Godel's terms the self referential aspect that cannot be proven logically. There are only two related self referential aspects that will be assumed to be true for the rest of this book in analogy with use of axioms in mathematics. They are: 1) our role as a species is to use our capabilities to survive, co-evolve, as long as we can; and 2) that we should use knowledge logically in the pursuit of our role. Analysis in the next two chapters of our existing knowledge about our planet and ourselves forms the basis for Designing Earthlings's clear and inescapable conclusions about the best approach for us to take for co-evolution. The following chapter provides an understanding of how biological genetic evolution works – not in the detailed sense, but so that the reader can appreciate the nature of the processes in question, and their real effectiveness. Those of you well-versed in this subject may want to go directly to the following chapter on our human knowledge-driven evolution. The focus will be on the evolution and functioning of the human brain. What are its strengths and what limitations does it have for the challenges we face? With the challenge of co-evolution in mind, human knowledge-driven evolution and biotic genetic evolution are compared in terms of which would be best equipped to meet the challenges and threats we face. We will conclude that the human-driven approach is a much better approach to determining our future. Think about it... Can't we do a better job using the KBH system with regard to determining the future than genetically driven microbes? However, just because the KBH system is better does not mean it is good enough for the challenges we face. We will need to determine what tools we can use to compensate for the deficiencies in our brains' design. One suggestion that my students love is the idea of requiring leaders contemplating whether or not to take their nations to war to make their decision while having a brain scan. If only their reptilian brain lights up, then their decision will be considered invalid. How many leaders do you believe would pass that test? Or, to make it more personal, what part of your brain do you think is in charge when you do things that turn out to be unnecessarily destructive to your own objectives?

We will need new approaches to education and the creation and distribution of knowledge to support improved decision-making. New approaches are needed to ensure that knowledge is used correctly, as well as new intellectual property laws to ensure that we can all can benefit from the increased knowledge. These issues are addressed in the chapter on 'Organizing Ourselves to Use Our Brain.' We will need new global institutions to help us coordinate our efforts in critical areas, like providing energy to defend against the global threats we face. Our experience in trying to manage aspects of our planet like regional ecosystems provides valuable and humbling lessons for what works and does not work. These are addressed in the chapter on 'Confronting the Threats We Face.' All of the knowledge provided in the next four chapters is then translated into specific approaches in the final chapter on 'Designing Our Future as Earthlings'. In particular, a designing earthling approach to our use of energy and the threat of global warming will be described in detail. A comparison with the currently proposed approaches of those focused on alleviating the threat of global warming or those arguing for business-as-usual, will drive home how powerful the new framework and approach can be right now.

While the challenge of co-evolution is great, I have been struck by the manner in which relatively simple and widely accepted ideas can lead one to clear, but admittedly provocative, answers. What I find remarkable and awe-inspiring is that an evolutionary leap produced, for the potential benefit of all life, our human brain. For, as our review of brain research reveals, our brain actually has the capacity to fix the one fatal flaw in genetic evolution that existed before we emerged: the inability to anticipate a future threat before it occurs and the consequent inability to design a solution fast enough to avoid it. Our knowledge of the past makes it clear that, up to this point, the success of life depended upon the fertility of our planet to generally nourish life, and the destruction of life for the purpose of renewal. We now know enough to make a distinction between our natural amazement at what was created by past evolution and the reality of how brutal and inefficient evolution can be. Even though we have succeeded on the stage of that brutal reality, the desire to make our world less brutal appears to be deeply instilled into our being. The basis for this desire, and the rationale for why it makes us feel good to contemplate using our new approach, can now be understood in terms of how our brain works.

It is important to restate that the new approach I am putting forth here is not driven by some ideological belief; rather, it is the simply a logical response to the new knowledge we have collected about the planet and ourselves. Although this may seem to be a very strong assertion, it is one I believe is supported by the facts. For many, this approach turns the classic environmental view on its head. But, it is vital for human beings to start making an important mental shift... Humans need not be the villains who will destroy the planet; rather, we can be the key to a better future for all life on the planet. The answers to the challenge of co-evolution that emerge from the analysis of our new knowledge will actually include many of the outcomes that earth-loving people value, and at the same time, they will provide the framework we need for practical success.

If we have the courage to become Designing Earthlings and to use our powerful capabilities to proactively design our future, we will have a very good chance for successful co-evolution with our planet. If we let our fear-driven, hunter-gatherer brains determine our future, we will share the same uncertain fate – a one in a thousand chance of survival – as the rest of life on this planet. This issue, as you might imagine, gets hotly debated in my classes at Columbia. The dialogue between two students I described in the Prologue can now be seen more clearly as a debate between the two parts of our brains. A graduate student in Ecology started the interchange. “Professor Eisenberger, why is it that you physicists, who know nothing about life on our planet, are optimistic about what humans can do while we ecology experts are very concerned that humans are destroying life on our planet?” An undergraduate Anthropology major responded “I have been listening to you and the other ecologists in the class, and I have concluded that you are all depressed from spending your life studying species in threat of extinction.” He went on to say that he viewed the human adventure as swimming across a large body of water to a distant shore, and that he felt many were frightened because they could not see the other shore and wanted to go back. But he said that he was excited about discovering what new landscape was to be found on the other shore.

It is very important to have a vision of that other shore, so we can move towards it successfully and safely. The best way to reach the other shore is as a cooperative group – as Earthlings making informed decisions together about the future of all life on our planet. I also believe that in the process of working together to successfully co-evolve and design our future, we Earthlings will be happier and will discover a kind of spiritual fulfillment that our current Darwinian-based existence lacks. Therefore, all you fellow Earthlings, let’s innovate together and strike out for the other shore, because as you will see, we really have no choice; the shore we already left behind no longer exist.

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