to alter the current trajectory on which we find ourselves. Will the needed changes come from science, religion, politics, or some other sphere of human society?

Where Will the Solution Come From?

Some of the areas society has traditionally turned to for solutions to problems have so far failed to provide solutions to global environmental impacts. Human endeavors that could contribute to solutions are science, religion, social science (particularly economics and behavioral science), environmental activism, corporate policies, and political action. These are the questions: Can science provide a "magic bullet"? Can religion change people's behavior? Can an economic solution be devised? Can social scientists devise behavioral solutions? Can historians find solutions from past societies? Can corporations curtail their expansion of developing and using resources? Can political groups agree to cooperate on maintaining the environment in which we live? Can environmental groups provide the leadership required to nudge society in appropriate directions?

Will "Hard" Science Provide a "Magic Bullet"?

Some technological optimists do suggest that science can solve all our environmental problems, as well as deal with limitations on how many humans the Earth can support. But most of us realize that science may not be able to provide easy answers to how to use our environment sustainably for several reasons, including the unwillingness of society to employ existing scientific advances that could improve our efficiency of resource use and decrease population growth and the lack of commitment to solving global problems through science. Scientists behave like other people and mostly do only what they are given support to do. Science may not provide a magic answer to our looming environmental problems, but we already have much scientific knowledge that could be used to protect our environment. So, in one sense, the question that serves as the title of this section is not inclusive enough.

Society does not put all existing scientific information to use for a variety of reasons. We know how to conserve energy, minimize pollutants, control human fertility, manage many diseases, and feed all

people on Earth. But governments often do not implement policies required to accomplish these goals. For example, cultural, religious, and political pressure often leads to a lack of support for population-control programs, even though it is scientifically possible to provide reliable contraception worldwide. Some in the energy industry use the political system to avoid initiatives to increase energy efficiency, and many industrial and agricultural lobbyists work against efforts to minimize pollutants.

Even worse, governments may support environmentally harmful policies under the guise of environmental protection. A potential example of "environmental" policies gone bad is the promotion of ethanol (gasohol) as an environmentally beneficial fuel. As early as 1980, it was realized that using all the corn grown in the United States to produce ethanol as fuel would supply only about 7 percent of the energy consumed in the United States, and this did not even account for the energy required to grow the corn.[12] By 2004, energy use rates were such that our entire corn crop would produce only enough ethanol to equal 2 percent of the annual oil used in the United States. Accounting for minimal estimates of the energy required to grow the corn reduces the rate to about two-thirds of 1 percent. Growing crops to produce ethanol requires fertilizer and machinery, and producing ethanol from crops requires transportation and energy for refining. One study estimates that 1.29 times as much energy is used to produce a gallon of ethanol than the ethanol will yield when it is used as fuel.[13] If it requires more energy to generate ethanol than it creates, more greenhouse gases and other environmental damage are produced than by just burning the same amount of oil. But this accounting is controversial, and the issue is unresolved.

Currently, the very best yields of ethanol from biofuels are about 1100 gallons per acre per year (1000 L per ha per yr). At this rate of ethanol production, it would take 10 times as much land as we currently have in cropland on Earth to provide the global energy used in fossil fuels. How do we feed people if all cropland is producing fuel? There are certainly places on Earth where biofuels are practical (in countries where petroleum supplies are mostly imported and population density is relatively low, as is per capita energy use). Biofuels are not a solution to global energy use, however.

Some studies suggest that the net energy yield of ethanol is positive (that the energy it takes to produce each gallon of ethanol from corn is less than the energy the ethanol will yield) but that producing ethanol

from crops can lead to as much greenhouse gas emission as burning fossil fuels to provide the same amount of energy. These problems are not generally taken into account when economic benefits of ethanol are considered.[14] Using leaves and stalks in addition to the corn yields more energy than the cost of fossil fuels for production.[15] However, maintaining corn stalks in the fields after harvesting stops erosion, and removing them would exacerbate sediment pollution and loss of valuable topsoil. These calculations do not consider the environmental costs of fertilizer, sediment, and pesticide runoff. Also, the tremendous amount of water needed to grow corn, as well as to refine ethanol from corn, is not accounted for by most proponents of producing fuel from corn. Given the uncertainties of net benefit, it seems strange to push the use of edible crops such as corn and soybeans for energy production in a world where over 1 billion people lack proper nourishment.

Scientists have warned repeatedly of problems resulting from an increasing consumption of resources and a larger human population. The National Academies of Science of 73 nations have warned of problems associated with resource use, population growth, and global environmental damage and the need to make a transition to a sustainable world.[16] The Union of Concerned Scientists released the "World Scientists' Warning to Humanity" in 1992, signed by 1700 scientists, including most living Nobel laureates in sciences.[17] This declaration briefly mentioned most of the issues covered in the first few chapters of this book. Warnings about greenhouse gas releases have had little influence, however. Bill McKibben published a detailed account of greenhouse warming in 1989 that was widely read and commented on, but it spurred little concrete action.[18] The Union of Concerned Scientists' warning was followed up with a "Call for Action" in 1997, set forth at the Kyoto Climate Summit and signed by 1500 scientists, including 110 Nobel laureates and 60 U.S. National Medal of Science winners, urging effective controls on human practices affecting climate.[19] Despite clear, scientifically accurate warnings for over 15 years, the rate of release of greenhouse gases has only increased.

Another reason science cannot necessarily solve our problems is that it does not have the solution to all problems. Or, at least, science is not always able to provide answers to problems when we need them. For example, huge amounts of money and effort have gone into curing the many types of cancer, but only moderate progress has been made. AIDS cannot yet be cured despite decades of significant research. Likewise, a clean source of energy that is cheap and easily available would

go a long way toward easing global environmental impacts. Although curing AIDS or providing cheap, abundant, and environmentally benign energy would lead to wealth and fame for some scientists (there was tremendous initial excitement and press over false claims that cold fusion reactions could supply unlimited energy), no such advances have been made.

Technological advances often contain their own environmental costs. When automobiles were first introduced, they were touted as a solution to the health and aesthetic problems of horse feces filling city streets. The impact of air pollution from autos (locally and globally) was unforeseen. Likewise, it has been suggested that a hydrogen economy could decrease greenhouse emissions but lead to the destruction of upper-atmosphere ozone (endangering all life with increases in UV radiation). What appears to be a clean energy source could have its downsides as well.

Another reason science cannot provide answers is that not all scientists and engineers care about the environmental implications of their research. Designing a luxury car or sport utility vehicle is not going to decrease global warming, yet many are dedicated to monetary gains derived from professions in science and engineering.

An adequate food supply may be another problem science cannot solve. One triumph of modern science has been the green revolution, or the drastic expansion of crop yields that has occurred over the past 40 years. Without technological advances in this arena, we could not support all the people on Earth today. As Earth's population continues to grow and the standard of living increases, a similar expansion of food production will be required over and above what has already been accomplished. But food production per unit area of cropland has inherent limits. For example, per capita cereal grain production has not increased over the past five years.[20] With plant breeding, optimum light, nutrients, and temperature, crops can grow only so fast, given the physical and chemical laws of our universe. In addition, as discussed in chapter 3, the green revolution has come with a substantial environmental cost. Most of the green revolution is driven by the use of fossil fuels, chemicals (fertilizers, pesticides, and irrigation), and water. A clean source of unlimited energy could be invented that would allow us to artificially light huge buildings containing rack upon rack of food plants, or that energy could be used to convert atmospheric CO_2 directly into food without the intermediary plants, but I would not bet that this will occur soon.

Can science provide technology to support an expanding human population, grow more food per unit area of cropland, and control environmental impacts associated with the greater crop production? Although technological optimists say yes, we are gambling with the well-being of humankind by assuming that science will be able to solve all problems as they arise. The stakes could not be much higher, and, as the old saying goes, you should look before you leap.

Scientists can find only those answers they are funded to find. Thus even though the United States should be less dependent on oil as an energy source for economic, political, and environmental security, an extremely limited amount of funding is earmarked for research on alternative energy sources. If grants are available, scientists will apply for funds and might eventually find some answers. Take my promotion of support for research with a grain of salt, given the principle I put forth in the preface: the more someone has to gain from a statement, the less you can believe it. Because I am an environmental researcher, I have something to gain from promoting more funding for my area of research. Also keep in mind that scientists are likely to tell the truth about their research subjects regardless of consequences, because presenting all the facts is the ethical cornerstone of our profession.

Although scientists may never find a "magic bullet," we can learn many things about preserving Earth. Our scientific understanding of the Earth that supports us is incomplete. Scientists once attempted to support humans in a sustainable sealed system called the Biosphere, but our knowledge of plants, microbes, and animals is not extensive enough to create even such a small self-supporting ecosystem.[21] Those responsible could not completely seal the Biosphere and sustain human life for more than a few weeks without inputs of oxygen. Animal diversity could not be maintained in the small Biosphere rainforest; one species of ant dominated all other insects, and all animals other than humans had to be removed. The inability to control even a relatively simple ecosystem does not mean that incompetent scientists were running the Biosphere; they just did not have sufficient knowledge to make it work. How can we hope to have a predictive understanding of the capacity of a highly complex and diverse Earth to withstand the insults we visit upon it when we cannot even assemble the components of nature into a small isolated environment well enough to support human life? The precautionary principle seems applicable in this case.

We are only just beginning to understand the rules of thumb to be used in ecology with regard to species invasions and extinctions.[22]

Likewise, global biology and climate are characterized in only a rudimentary fashion.[23] Without considerably more funding for research on Earth's ecosystems, such an understanding seems unlikely in the near future. As need grows, so does scientific expertise. So why has environmental science not kept pace with global environmental problems?

Science may not provide a solution to environmental problems because scientists (like other people) are most concerned about problems that will immediately influence them and their chances for success. Most scientists do not study environmental problems. The developed world puts tremendous amounts of resources into the science of how to cure cancer and heart disease, and a large number of the world's top scientists are concerned with these and related problems. These diseases are experienced by both the people who study them and their relatives. Funding agencies and scientists will truly start to work on Earth's environmental systems and human behavior toward them only when there is funding to do so. Funding will come only when there is a general consensus that Earth's capacity to sustain our standard of living, including the health of individuals in developed countries, is in immediate peril. Until that time, issues thought to be more important in the short term will take priority.

Scientists want to be recognized for their work. The most prestigious awards in science are Nobel Prizes. Many of these awards go to scientists who make advances that improve the health of people in developed countries or create technological advances that raise the standard of living of people who already have more gadgets than they need to survive. No Nobel Prize for environmental research exists, although there are several prestigious, but less well known awards such as the Crafoord Prize, the Swedish "Nobel" for ecologists.

Another way to gauge what the scientific community views as important is by the types of science published in premier scientific journals. The two most prestigious, broad-topic, international scientific journals are generally agreed to be *Nature* and *Science*. I perused the first 100 research articles published in each of these journals in 2006. Molecular, cellular, and health biology were the most common subjects of the articles in these journals (47 percent) and are most often the subjects of press releases and awards. Small-scale physics and chemistry, particularly materials science, were well represented (20 percent), as were space science (15 percent), particularly planetary exploration. All the rest of the sciences—including geology, evolution, sociology, and paleontology—are covered in the remaining 18 percent. Ecology and

global environmental change research reports make up about one-half of that 18 percent. Environmental contributions are not prominent in the most prestigious journals. Emphasis on areas other than environmental research must affect specialties chosen by new investigators; most promising young scientists notice which fields receive most attention and which fields are most prestigious.

Scientists as a group might be expected to be more aware of the scientific basis of our environmental problems than the general population. They have the training to understand scientific principles behind the greenhouse effect, ozone depletion, and other forms of pollution. Even scientists who are well versed in the environmental impacts of humans behave in ways that are destructive to our environment. I will use myself as an example. Obviously, I think that Earth is under pressure from human activities. Still, I have a high standard of living and use more than my share of resources simply by living as a middle-class U.S. citizen. I recycle some trash, ride my bicycle to work (about 37 times more energy efficient than a midsize car and better for my waistline), and turn the heat down in the winter. But I use more resources than necessary. I switch on an air conditioner in the summer; eat fresh vegetables throughout the year; use a car for most trips longer than a couple miles; fly on airplanes for pleasure trips; ride ski lifts; take long, hot showers; and undertake many other activities that use more energy and resources than are essential. Like most scientists, I know that my work does not directly address the most important issues in our world's future but only nibbles at the edges.

Can Religion Rise to the Challenge of a Global Environmental Crisis?

Religion has no built-in way to protect the environment. No major world religion has a *central* tenet that the environment should be protected. Religion is primarily concerned with human behavior toward other humans (morality) and God (or at least ultimate meaning), although some secondary support for environmental responsibility can be found in the world's mainstream religions.

In the United States, religion, particularly biblical literalism, is significantly negatively correlated with support for the environment.[24] People who believe in God are less likely to support spending money to protect the environment: a more rigid view of religion is correlated with lower support for environmental protection. Andrew Greeley, the

author of the study that found these correlations, hypothesizes that biblical religion per se was not responsible for these survey results; rather, biblical literalists have a rigid, general political view that includes an antienvironmental sentiment.

The primary reasons for Muslims, Jews, and Christians to preserve our environment come from the concept that Earth was created to sustain and be cared for by humans.[25] Buddhism is concerned with the idea of interdependence of all things, and this can be interpreted as an environmentalist position.[26] Hindu writings describe the destruction of the world through overpopulation and environmental devastation by humans.[27] The concept of ahimsa, respected by both Buddhists and Hindus, requires that a person not kill any animal life. Chinese and African religions can also be interpreted to include aspects compatible with environmental protection.[28] However, most of these religions, and even the indigenous traditions in many parts of the world that are commended for their reverence of nature, do not directly address overpopulation and excessive consumption of resources, because all the major religions arose before these were serious ecological problems.[29]

In the worst case, some use religion to justify population growth and environmental damage. Some claim that God put us on Earth to multiply and made the world for humans to use however they please. Others believe that the end of this Earth is near—that environmental destruction is a sign of the Apocalypse—so how we treat it is of little consequence.

Environmental damage is common in societies dominated by all religions, even those in which the government is a theocracy. A strong component of environmental protection in all the world's major religions would probably not solve our environmental problems; a substantial proportion of people ignore religious ideals. For example, most major religions preach against material desires and accumulation of wealth, but few people heed these ideals.[30] As already discussed, it takes only a portion of the world's population using resources at greater than sustainable rates to seriously deplete resources for all.

The idea that Native American and non-Western religions have an innate respect for the environment has been suggested as a possible avenue for ethical protection of the environment.[31] Unfortunately, societies with naturalistic religions are not immune to destruction of the environment around them. I have discussed how the Anasazi and Mayan civilizations may have collapsed in part because of nonsustainable

use of their environments. Reverence for nature does not ensure that it will not be overexploited.

Religion is an example of human behavior that gives hope of modifying actions in spite of basic human nature. Major religions promote many unselfish behaviors. They are able to survive and attract followers even though many concepts they promote are contrary to selfish behaviors innate to humans (although they may play to self-interest, such as an ultimate entrance into heaven). Thus a religion-based movement to preserve the global environment could help transcend basic human desires to use more resources.

Any solution involving human behavior as it influences the global environment must include religion, because most people adhere to a religion. The Gallup-International Millennium assessment conducted in 60 countries showed that two-thirds of the people in the world feel that God is an important part of their life. Religion guides many people's views of right and wrong. A big step would be instilling a moral obligation in people now to protect the environment for future generations.[32]

Some religions are moving toward promotion of environmental stewardship.[33] The International Parliament of World Religions, attended by 8000 people in 1993, issued the statement "Global Ethics of Cooperation of Religions on Human and Environmental Issues."[34] International meetings on the environment and religion were held in 1988 (Oxford), 1990 (Moscow), 1992 (Rio de Janeiro), and 1993 (Kyoto). In England, the Alliance of Religions and Conservation publishes books on religion and environment, and in the United States, the National Religious Partnership for the Environment (NRP) joins Jews and Christians concerned about conservation of the environment. These are small steps in the right direction.

Some religious leaders are realizing the ethical importance of preserving our environment. In 2002, Pope John Paul II and Bartholomew I, patriarch of the Eastern Orthodox Church, issued their "Common Declaration on Environmental Ethics," stating that environmental degradation was "betraying the mandate God has given us: to be stewards called to collaborate with God in watching over creation in holiness and wisdom."[35] Reverend Richard Cizik, vice president for governmental affairs of the National Association of Evangelicals, has said that "polluters will have to answer to God, not just government."[36]

Religions do not have to be moribund. For their own survival, and that of all people, religious leaders must respond to the challenge of

helping to solve modern environmental problems. Will the world's religions emerge as leaders in the morality of environmental protection? For the sake of humanity, I hope so.

Economics

The ability to manage our socioeconomic circumstances, and regulate the relationship between environment and global economic activity, will be central for global environmental management. Economists have not yet provided strategies, or the strategies have not been adopted by policy makers, to stabilize and equalize economic activity around the world. In many ways, economists are similar to ecologists (although they do have their own Nobel Prize). Just as ecologists could not maintain the Biosphere, economists do not understand everything about economics. If they did, many of them would be fabulously rich.

The global economy is volatile and can change rapidly. Economics has not provided the ability to buffer the economy from perturbations. For example, when terrorists attacked the World Trade Center and the Pentagon on September 11, 2001, the economy of the United States and the rest of the world suffered to a much greater degree than the direct economic damage caused by the attacks. Long-term stability would require a less-fragile economic situation than we currently have, and economists will need to point the way to attaining stability.

Historically, little recognition of the economic importance of environmental factors has taken place. Many economists treat environmental considerations as "externalities"; they are difficult to quantify, so they simply are not considered in economic equations. Many conservative economists do not believe that excessive human use of our planet's resources will constrain human economies and well-being. These economists think that people will substitute other resources when they run out, and that human ingenuity will solve any environmental problems that arise. The ability of Earth to support humans indefinitely, regardless of what they do to it, has been taken for granted by many economists. But some economists do not take the environment for granted.

Researchers in environmental and resource economics recently began attempting to quantify the monetary importance of the services that ecosystems provide to humans. These approaches value the materials that ecosystems produce (such as fish from the ocean and trees from the forest) and the services they provide (such as removal of