

Darwin Initiative

Sixth Darwin Initiative Lecture, 27 October 2004

How Human Health Depends on Nature

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I want to thank the Darwin Initiative and Defra for organizing this lecture and for inviting me to deliver it, and especially Sarah Moon for enduring my many emails over the past few months and helping me enormously. Thank you all.

It is wonderful to see so many old friends on this side of the pond and to be back in the world of Darwin, Huxley, and Haldane, and a Dr. Ashmead, an eminent physician from Gloucester, who in the 1720s planted one of my favorite apples in my heirloom orchard, Ashmead's Kernel, which I believe to have an even richer and more complex flavor than the famous British apple, the Ribston Pippin, and which almost rivals my very favorite, America's 1st apple, the Roxbury Russet, bred in the 1620s in Roxbury, Massachusetts.

I want to open with a story. It seems that our President, Mr. Bush, grew tired of working on one of his speeches during a visit to Alaska, so he drove to some nearby mountains, hiked a trail, and sat, with his loaded shotgun, waiting behind a tree. After some hours, a large brown bear emerged, and seeing the President, began to run at full speed towards him. Bush aimed his gun and pulled the trigger, but the gun jammed, and in a panic he began to pray "Oh Lord, he said, "I have always been your faithful servant. Please Lord, Please, Please make that bear a Christian." At that very moment, the bear came to an abrupt halt, put its huge paws together, looked up at the sky, and said "Dear Lord, I thank thee for the gift I am about to receive."

As you might have guessed, I'm rooting for the bears....especially in this case, because bears are totally unique and remarkable creatures that are highly threatened by human activity and that hold enormously important secrets for human medicine, which I shall talk about a little later.

When I was on a flight some years ago from Washington D.C. to Boston, there was all of a sudden a great commotion around me. It turns out that a large brown moth had somehow gotten onto the plane, and everyone, it seemed, including the flight attendants, being startled and afraid when it landed near or on them, wanted to kill it. Suddenly I found myself standing up, much to my own surprise and embarrassment, and saying in an unusually loud voice—"Don't kill it, its totally harmless, let's catch it and let it go later." I had absolutely no idea how I was going to do this at the time, but fortunately, it came to me that the vomit bags were good for something, so I blew one up and proceeded to race around the plane, crashing into several people, finally catching the moth on the top of the newly coiffed hair-do of an extremely annoyed older woman. I was savoring one of those moments when I thought people might be asking themselves "who is this extraordinary man?" but knowing deep down they were wondering "who is this mad man?" Not a good thing for a practicing psychiatrist.

I tell this story because it illustrates how separated we have become from the environment in which we live, how disconnected from the natural world, which increasingly exists, as we become more and more urbanized, in zoos and aquaria and botanical gardens, so disconnected that true nature, like the moth, seems to many an alien creature, as a hostile force to be conquered and overcome and even killed. To very many, if not most, people, this disconnect takes another insidious form—that the global environment is seen an infinite resource that exists for our use alone, that we can take as much as we want from, or as an infinite sink that we can dump as much as we want into—that we can alter and degrade the atmosphere, the oceans, the forests, and the soils, endangering perhaps millions of species we share this planet with, some of which have been on Earth for hundreds of millions of years longer than we have,

like sharks and dragonflies and frogs, as if these alterations had nothing whatsoever to do with us at all, as if we were totally immune from their impacts.

This lack of connection to the environment, this fundamental failure to understand that our health and lives ultimately depend on the health of the natural world, is, in my view, the most important problem we face in the years ahead.

Now what is it that prevents us from recognizing the threat that global environmental change poses for us?

- For one, it is too abstract, too hard to relate to, occurring on too large a scale and evolving too slowly over time, outside the range of our everyday experience, especially for those of us in rich nations like the U.K. and the U.S., not living at the margins of survival, as large numbers of people in developing countries do every day, at the mercy of every cyclone, every crop failure.
- Global environmental change is, in addition, too frightening—the specter of floods, drought, fires, famine, and epidemics, all these are too overwhelming to contemplate, biblical in their proportions. And, for the most part, the problems seem too large to solve, making people feel frightened, helpless, and hopeless, and wanting to avoid thinking about them at all, sometimes even to deny that they exist.
- It is also too complicated and technical, made worse by scientists who write and speak in jargon-filled language, unable to communicate with policy-makers, the media, and the public, so that people find the science of global environmental change generally too hard to understand.
- And it is too hypothetical, only a theory in the eyes of some skeptics, a result of the difficulty of coming up with proof of cause and effect, the reality that there are often large natural fluctuations and the fact that there is only one earth, and we have never been in this situation before, and

there is no control subject for the global experiments that are taking place, no other Earth where the many variables can be held constant so we can figure out what is going on. So we must rely on models and projections that sometimes are less than convincing.

- Many people also feel that it is not worth worrying about, believing that if science got us into this mess, it can surely get us out—that we will invent or synthesize or engineer our way out of all of our difficulties. While science has much to offer, we must be humble and fully aware of its limitations, especially in the face of understanding highly complex, non-linear systems. Witness what happened with chlorofluorocarbons, originally greeted as the most wonderful chemicals for refrigeration ever made, because they were so unreactive chemically that initially no one ever dreamed that they would cause any environmental damage at all, much less catalyze destruction of the stratospheric ozone layer.
- Furthermore, in contrast to the issue of nuclear weapons, which I spent many years fighting, where there were no changes we had to make in our lifestyles to reduce the threat of nuclear war, with global environmental change, we are all a part of the problem and of course, also of the solution, and many of us would just as soon not think about, and would rather not learn about, the contribution our sports utility vehicles or mega-homes or teak furniture make to damaging the environment.
- And finally, there are powerful forces, for example in the timber, mining, energy, automobile, chemical manufacturing, and land development industries, among others, and their political supporters, including some scientists, some of whom are clearly motivated by reasonable scientific questions, but others of whom represent vested interests, motivated by greed, who have attempted, much as the tobacco industry has done for decades, to suppress scientific findings that raise health and safety questions about their practices and products, and who have tried to undermine the credibility of respected scientists and public health experts. And these skeptics are often given equal time by the media, at least in my

country, as if they represented objective, widely held, carefully researched, equally valid scientific viewpoints, which they do not, so the public is often confused and doesn't know what or whom to believe.

It was in recognizing the scope and magnitude of these barriers that make it difficult for people to grasp what human activity is doing to the global environment that we founded the Center for Health and the Global Environment at Harvard Medical School, believing that as physicians and public health professionals, we could help translate the abstract, technical language of environmental science into concrete, personal terms that people could relate to and understand—those of human health—and that by helping them understand the potential risks to their health and lives, and especially to those of their children, we could motivate people to make the changes in their personal lives and to support the public policies necessary to really protect the global environment.

My talk this evening will first look at one area of this science—the loss of biological diversity, will examine some of the driving forces of this loss, spending some time on global climate change, and will then focus on the potential consequences of these changes for human health including:

1. The loss of potential new medicines
2. the loss of critically important medical research models
3. and the disruption of what are called ecosystem services

1st slide please—

- 1) **“I need someone well versed in the art of Torture—do you know powerpoint?”** I may be the last person at Harvard if not in the Northern Hemisphere who is still showing 35mm slides, but what can you expect from someone who still does not own a pocket desk assistant and drives a 1986 Saab with more than 320 thousand km on it?

When *Homo sapiens sapiens* evolved some 130 to 160,000 years ago, the number of species on Earth was the largest ever, but as you all know, we are reducing these numbers at an alarming rate, so that many biologists like Norman Myers, Stuart Pimm, E.O. Wilson, and others believe we are in the midst of the 6th Extinction Event, the last being at the end of the Cretaceous 65 million years ago, when dinosaurs were largely wiped out,

- 2) **IUCN red book**—this is true for animals
- 3) **1/8 plants endangered**—for plants, and we presume also for microbes, but we know almost nothing about their numbers, distribution, or the degree to which they are threatened
- 4) **Amazon burning**--The causes of species extinctions are many, but the main one at present is the degradation, reduction, and fragmentation of habitats, especially in species rich areas like tropical rainforests and coral reefs.

But we must be aware that other factors are involved as well, and that one,

- 5) **Dog and fan**—GLOBAL WARMING and the associated changes in global climate,
- 6) **Scientists predict global warming cause extinctions**--will assume greater and greater importance in coming years. Let me say a word about this critical issue.
- 7) **1998 and last 100 years**—1998 was the warmest year since 1856 when average global surface temperatures were first accurately measured by U.K. scientists. 2002 was the 2nd warmest, 2003 the 3rd, 2001 the 4th—4 of the hottest years on record have occurred in the past 6 years. And if you look at the past 125 years or so, since the industrial revolution began in earnest, average global surface temperatures have increased by slightly more than 0.6 degrees Centigrade.
- 8) **Last 1000 years**—if one looks at marine sediments and tree rings and ice cores, we can determine that the past century has been the hottest in the past 1000 years

- 9) **Last 160,000 years**—and from Greenland and Antarctic ice cores, where air bubbles are trapped, allowing us to analyze temperatures and atmospheric gas concentrations going back in time, we can see that CO₂, now at more than 375 ppmbv, has increased by more than 30% over levels which hadn't exceeded 280 ppm for 160,000 years, and in fact for more than 400,000 years. With projections based on our current emissions of CO₂, predictions for the year 2100 are that we will reach twice the amount of CO₂ concentrations that exist now, levels not present on Earth for millions and millions of years.
- 10) **Last 20,000 years**—you may be familiar with this slide showing that global temperatures on average have been remarkably stable for the past 10,000 years, allowing human civilization to develop and prosper. But I want you to notice an important part of this graph. If you look at the change predicted for 2100 in average global temperatures, which by this IPCC II estimate has an upper limit of about 3.5 degrees C. (more than five times what we have had thus far) and note that the new upper limit has been raised by the IPCC III to about 5 degrees C., this degree of warming compared to temperatures present now, which may not seem like much as we have this amount of temperature shift all the time from week to week and even sometimes from day to day. But to give you an idea of how enormous this degree of warming is, note that it is the same amount as that which has occurred since the end of the last Ice Age around 18,000 years ago, when my home in Boston was under a glacier one mile thick.

What is important here is not just the magnitude of the change, but the rate, which will be 10-100 times greater than temperature warmings of the past, posing enormous risks to other species. Why is this?

Because species have evolved to live within specific temperature ranges and either they will have to adapt to warmer temperatures, along with all the species they depend on and that depend on them, or migrate to areas where the temperatures are the same.

The fossil record shows that climate change was the dominant factor in the great extinctions of the past—both warming and cooling—directly because of the temperature shifts, and indirectly, because of changes in habitat, e.g. the formation of glaciers or changes in sea levels. With warming, species moved towards the poles and to higher altitudes, and with cooling, they moved back towards the equator and to lower altitudes.

When species could not adapt or shift their ranges, they were lost, either because the rates at which they were able to change their distributions were too slow, or because there were geographic barriers blocking their advance. In the past, these temperature changes generally occurred over thousands or tens of thousands of years. Now the change will take place over 100 years, and there are barriers everywhere—roads, cities, farms, etc., so that many, many will be lost.

Recall that in the past 100 years, global mean surface temperatures have increased about 0.6 degrees C., so are we seeing any evidence of migrations now?

The answer seems to be yes—

- 11) **Edith's checkerspot**—this lovely butterfly, called Edith's Checkerspot,
- 12) **checkerspot moves northward**--has had its range move to higher latitudes in the western U.S. over the last several decades,
- 13) **plants in alps**—and there has been an upward climb of several vascular plant species in the Alps over the past 70-90 years. Global warming poses a potentially larger threat for boreal or alpine species, as not only is there an increased rate and magnitude of warming at high latitudes and high altitudes, but when species reach the most northerly or southerly latitudes or the tops of mountains, they will have nowhere to go to escape the heat. These species shifts as the planet warms, also have enormous potential significance for the spread of some vector-borne diseases.

There are other mechanisms by which global warming may threaten species—

- 14) **coral bleaching and disease**—tropical corals begin to bleach when sea surface temperatures exceed around 33 degrees C., because they lose

their symbiotic algae that give them pigment. Prolonged bleaching by itself can result in coral death and also makes corals vulnerable to various fatal infectious diseases. More than 30% of the world's corals have been lost, and the remainder are increasingly threatened, along with the countless species that live in them.

- 15) **golden toad**--warming seas in the past decade are also thought to have been the cause of the disappearance and presumed extinction of some 20 amphibian species in Costa Rica, including the Golden Toad, as warm, dry upwelling air dramatically changed the environment of the cloud forests where they lived.
- 16) **1/3 of amphibians threatened**—the situation is dire for amphibians around the world because of global warming, along with a number of other environmental factors such as habitat loss, ozone depletion, and pollution.
- 17) **Graph of decoupling**--Finally, global warming and climate change can lead to a disruption in the timing of biological events, with some species changing their cycles significantly and others little or not at all. These decouplings, for example, with an earlier date for the hatching of the eggs of some wild bird species, as in this slide comparing 1980 with now, but without a concomitant earlier availability of winter moth caterpillars, an important food source for them, can threaten many species with extinction.

There are other driving forces for species loss as well, all of which are driven by growing human populations and unsustainable consumption, that are causing species loss at rates that are 100 to 1000 above normal background levels, and I will just mention them—including increased ultra-violet B radiation, which damages DNA and proteins in all animals, plants, and mirco-organisms.

- 18) **deformed frogs**—pollution, which can result in endocrine disruption, a loss of fertility, immune suppression with resulting infections and tumors, or in deformities, as in the case of these frogs, making them more vulnerable to predators.

- 19) **Purple loosestrife**--Invasives—such as this very beautiful plant, the purple loosestrife, which is choking out native species in marshes in New England
- 20) **Atlantic fishing**—over-exploitation, such as what we are doing to the oceans, depleting fish stocks, in some cases, in the past century, by over 90%
- 21) **gorilla paws**—or simply wanton slaughter, such as with these gorilla, which are killed, along with other higher primates and countless other forest animals, as bushmeat to feed poor burgeoning native populations as well as foreign miners and loggers, or to have their body parts sold as medicines or as trophies.

There is an added concern about bushmeat, as the world pandemic of HIV/AIDS almost certainly originated from an SIV, a simian immunodeficiency virus, in a chimpanzee from Cameroon, and there are at least 13 other SIVs, not to mention ebola, found in other primates in Africa that could trigger other human epidemics in the future.

Now, what does all this have to do with human health?

- 47) for one, with a loss of species, we are losing the possibility of discovering new medicines. Over the course of millions of years, species have developed chemicals that have protected them against infections, tumors, and other diseases, and have allowed them to capture prey and avoid being eaten, chemicals that have become some of today's most important pharmaceuticals.
- 22) **cinchona**--Tropical rainforest organisms, for example such as this cinchona tree from South America, have given us quinine (the 1st major treatment for malaria) and quinidine (a medicine for cardiac arrhythmias), and erythromycin and neomycin from soil bacteria.

Temperate species have also yielded some of our most useful drugs—the drug wonder aspirin, originally derived from salicin extracted from the willow tree, is still one of the best medicines around for pain and inflammation, and everyone

over the age of 50 in my view, unless there is a contra-indication, should be taking one every other day, as it significantly reduces the risk in most people of bloods clots that cause myocardial infarctions and strokes. There is also evidence that regular ASA use lowers the risk of developing some cancers, for example those of the large bowel. The more we know about aspirin, the more we learn about its remarkable healing potential.

23) **fox glove**—And the synthetic drugs digoxin and digitoxin derived from digitalis which came from the foxglove plant, this one from my garden, are still widely used to treat heart failure, and atrial fibrillation.

More than half of the most frequently prescribed drugs in the U.S. are derived from, or are patterned after compounds derived from, natural sources. And of course, 80% of people in developing countries still rely on traditional medicines, which largely come from plants.

Two examples of recently developed medicines are important models that deserve mention:

47 The story of taxol and the Pacific Yew tree illustrates how we may be losing new medicines from common species that become extinct without ever having analyzed them for their chemical content, and of course, from species that go extinct before they have even been discovered. Most of you know that we have identified only about 10% of species on Earth, and maybe even less than that.

24) Pacific Yew--The commercially useless Pacific Yew was routinely discarded as a trash tree during logging of old growth forests in the Pacific northwest, until it was found to contain the compound taxol during the U.S. National Cancer Institute's massive screening program of plant species for anti-cancer activity.

25) Cells dividing—perhaps you recall this image from secondary school biology class showing sea urchin cells dividing. The chromosomes, after division, move along micro-tubules in a structure called the mitotic spindle. Taxol kills cancer cells by a mechanism unlike that of other known chemotherapeutic agents —by stabilizing the protein tubulin which makes

up these micro-tubules, thereby inhibiting the disassembly of the mitotic spindle, and preventing cell division. Other agents work by preventing the spindle's assembly. Early clinical trials reported that taxol was able to induce a remission in advanced ovarian cancer cases that had been unresponsive to other treatments

26) New taxoids-- and recent experience has shown that taxol and the newer synthetic taxoids offer great promise for other malignant cancers as well, including malignant melanomas and those of the breast and lung. Taxol, the most profitable cancer chemotherapeutic agent in the U.S., is also now widely used to coat arterial stents so they are not blocked by cell regrowth. How many other species like the Pacific Yew are being lost without our ever knowing whether they contain drugs as useful as Taxol?

27) Cone snails--These beautiful shells are from cone snails, a large genus of more than 500 species that live in tropical coral reefs, mostly in the South Pacific.

28) Harpoon--They feed by firing a poison-coated barbed harpoon at their prey—

29) cone snail and fish--worms, fish, and other molluscs, paralyzing them. The toxins are polypeptides like the toxins of snakes, scorpions, spiders, and sea anemones, and each species is thought to make 100 distinct toxins, so that there are thought to be as many as 50,000 cone snail toxins in all. Only about 100 of these have been studied, and already, a large number of compounds have been isolated that have enormous potential for medicine. The reason they are so useful to medicine is that they bind with great potency and enormous specificity to an extraordinary number of receptors on the surfaces of all animal cells, that regulate the cell's functions.

30) Spinal cord--One calcium channel blocking toxin from cone snails binds with great specificity to neurons in the dorsal horn of the spinal cord shown here in cross section, where pain impulses are transmitted up to

the brain, without blocking pathways that mediate fine touch or temperature.

31) Zinconotide study--Its synthetic form called zinconotide, which may be on the market shortly, has been shown to be 1000 times more potent than opiates like morphine. And in a study with AIDS and cancer patients who had severe chronic pain that was unresponsive to opiates, more than 50% of those receiving zinconotide had moderate or complete pain relief, without their developing addiction, or tolerance, i.e. the need to give more and more drug to achieve the same effect. Tolerance has limited the long term usefulness of morphine and other opiates, so this new potent pain-killer would be an enormous breakthrough.

Several cone snail species are likely to be endangered, as they inhabit narrow ranges in coral reefs, mostly in the South Pacific. As I mentioned, coral reefs worldwide are increasingly endangered, and so are species like cone snails that live in them. This is work being done by my colleague Callum Roberts from York University.

32) cone snails in Lavendou--Cone snails are also threatened by over-collection for the shell trade, this slide taken in an open air market in Provence last year showing boxes of cone snail shells for sale, and perhaps also by burgeoning levels of biomedical research.

Other cone snail toxins are being tested for epilepsy, spasticity following spinal cord injury, and a host of other disorders. Cone snails may contain the largest number of medicines for human disorders of any known species group. To lose them would be a self-destructive act of unparalleled folly.

48) Species also may lead to the loss of invaluable medical research models that help us understand normal human physiology and disease. Take bears for example.

Bear populations are threatened in many parts of the world because of the destruction of their habitats, and because of over-hunting secondary to the high prices their organs, reputed to have medicinal value, bring in Asian black markets,

33) Thai black market-- Bear gallbladders are worth the equivalent of 18 times their weight in gold. There is a flourishing illegal trade in bear parts, e.g. in South Korea or here in Thailand.

The tragedy is that living bears are worth far more than the sum of all their body parts.

34) black bears--Consider black bears. In winter months, they enter a 3-7 month period of hibernation, more accurately called “denning” in which they neither eat, drink, urinate, nor defecate, yet they maintain a normal body temperature, are alert and reactive, can deliver as many as five cubs and nurse them, and grow new tissues. They accomplish these seemingly impossible physiological feats by recycling essentially all their body wastes.

For example, despite inactivity and a lack of weight bearing, bears do not lose bone mass, that is they do not develop osteoporosis. All other mammals, including humans, do so with a lack of weight bearing. A bedridden patient, for example, will lose one fourth to one third of his or her bone mass during a 5 month period. Osteoporosis is an enormous public health problem—afflicting 28 million people in the U.S. alone (mostly post-menopausal women), causing 1.5 million bone fractures and 70,000 deaths each year, and costing the U.S. economy more than U.S. \$14 billion annually. Bears have substances in their blood that stimulate bone forming cells and inhibit bone dissolving cells. If we understood how these substances worked, we could perhaps develop new preventative measures and treatments for osteoporosis.

Bears also do not urinate for up to seven months. If we stopped urinating for only a few days, we would die. There is no cure for those people with end stage renal disease—they have to have either kidney dialysis or a kidney transplant to survive. If we understood how bears recycled essentially all of their urinary wastes, and converted these into amino acids and new proteins, we could

possible treat renal failure, a condition which costs the U.S. economy an additional \$16 billion a year. We might also improve the health and survival of large populations of starving people in developing countries by reducing protein loss.

35) polar bear mother and cubs-- Let me say a brief word about polar bears, which have the same remarkable denning physiology as do black bears. They are being severely threatened, not only by habitat destruction (from development for oil exploration and drilling) and by over-hunting, (wealthy U.S. hunters are paying up to \$22,000 to bag a polar bear) but in addition, they are endangered by what is happening to the Arctic where they live. For one, bears are at the top of the marine food chain and are affected by the high levels of pollutants like PCBs and other organic compounds concentrated in the fat of the seals they eat.

36) polar bears and open ice--In addition, with a dramatic loss of ice cover in the Arctic, with as much as 40% thinning in the past 30 years, some polar bears are starving because the loss of ice cover makes it difficult for them to hunt, as their practice is to wait for seals to surface for air at the rare breaks in the ice, but if the openings are everywhere, the seals are able to elude the bears.

Species do not only teach us about human physiology and disease—the secrets they hold can also help us to live better.

37) Harare office building--This is an office building in Harare, Zimbabwe, modeled after the venting and air circulation dynamics found in termite nests. Some termites are farmers, growing fungi in their nests at temperatures that must remain at a constant 30 degrees centigrade +/- 1/4 degree despite wide temperature fluctuations outside—from 1.5 degrees C. at night to 40 degrees during the day. This Harare building uses 1/10 the energy that buildings of its size would use.

49) Want finally to talk about the issue of ecosystem services—that is the ways that species interact with each other and with the inorganic parts of their environment to provide vital life support for all living things. We cannot live without these services, which purify air and fresh water from pollutants,

maintain soil fertility, pollinate plants, store carbon to slow the growth of atmospheric carbon dioxide, break down wastes and detoxify sediments and soils, among many, many others.

While we know a great deal about these services, there is much we don't know. For example, we generally don't know what species are necessary and in what numbers for the services to work.

38) **soil cross section**--Consider soil fertility. This cross section of soil shows some of the organisms present—insects, earthworms, mites, round worms, and a burrowing mole. In Gretchen Daily's wonderful book **Nature's Services**, she describes life under a square yard of pasture in Denmark—"there were roughly 50,000 small earthworms and their relatives, 50,000 insects and mites, and nearly 12 million roundworms. In a pinch of the soil, about a gram, there were an estimated 30,000 protozoa, 50,000 algae, 400,000 fungi, and billions of individual bacteria." Which species make the soil fertile? How many are needed? Are there some that are so-called "keystone species" that is, species the ecosystem could not do without, whose absence would cause the collapse of its functioning? No one really knows the answers to these questions.

One important ecosystem service is the holding of plant and animal diseases and pests in check by an array of predator-prey, and host-parasite relationships. I would like to focus, from my anthropocentric viewpoint, on a human disease that illustrates well how biodiversity contributes to our health.

39) **Lyme disease map**—this is a map of recent Lyme disease cases in the U.S. with each dot being a case. Lyme is the most common human vector borne disease in the United States, with over 19,000 reported cases a year, and many, many that are not reported. You can see the greatest concentrations in the Northeast and Middle Atlantic states.

40) **White tailed deer**--The disease is a complex one involving white-tailed deer,

41) **white footed mouse**—the main host, the white footed mouse

42) **black-legged tick**—the vector, the black-legged tick

43) **Borrelia**—and the infectious agent, the spirochete bacteria called *Borrelia burgdorferi*

Humans are an accidental host. It had long been observed that although ticks were infected in the West, few people came down with Lyme Disease. This may be because one of the favorite hosts for the tick in the West is the Western Fence Lizard, whose blood contains a substance that kills the infectious bacteria. Many species of reptiles are, as you know, threatened, so the question must be asked, what would the incidence of Lyme Disease be in the West if the Western Fence Lizard were to be wiped out.

By contrast, the white-footed mouse's blood provides an ideal medium for the bacteria's proliferation. In the East, it was observed that in areas with low species diversity, such as on the island of Martha's Vineyard, rates of infection were higher, and recently, it has been shown by elegant field experiments that species diversity protects humans from infection by Lyme, by what is called a "dilution effect." If there are large numbers and types of vertebrates in Lyme areas, some of which are dead-end hosts for Lyme, that is they do pass on the bacteria and continue the Lyme life cycle, because the ticks attach themselves to almost every animal they encounter, these animals serve to dilute the bacterial population, and make it less likely for people to become infected. In addition, high vertebrate diversity also means more predators and competitors for white-footed mice, keeping their populations low, and thereby reducing the risk of human exposure. Forest fragmentation reduces the diversity of vertebrates, so as people move more and more to forest edges and break up forested areas with development, we may see larger numbers of Lyme disease cases.

44) **New Yorker cartoon** Now, what does all this mean? And what can be done about it?

1. **photo of people with** For one, we must look at these problems directly, without

heads buried in the sand avoidance and denial, no matter how difficult or frightening

they are, in order to begin to solve them. We cannot afford

to bury our heads in the sand, saying it is up to others

45) **cartoon of man looking** We must help those in the business world and in politics

at a tree, see that it is not a choice between a healthy environment

or healthy profits—one can have both. Indeed, without

a

healthy environment, the costs to society from the impacts on agriculture, private property, and human health will be so great as to affect every aspect of the marketplace.

As we did with the Montreal Protocol that protected the ozone layer, the U.S. and the U.K., must take the lead in world efforts to reduce greenhouse gases and to protect biological diversity.

46) 178 nations sign on –And I must say it is an embarrassment and a matter of national disgrace that my country has not yet ratified the Convention on Biological Diversity, as most of the world's countries have, and therefore does not have a seat at the negotiating table, and that with 4% of the world's population producing more than 25% of the world's human released greenhouse gases, we have sat on the sidelines and dismissed the Kyoto Protocol, which with Russia just ratifying, now becomes law. I greatly admire Prime Minister Blair's well informed, wise, courageous leadership on this issue.

I need to emphasize that what I am about to say are my views alone, and do not represent in any way those of the Center I run at Harvard, Harvard University, the Darwin Initiative, or DEFRA.

It may be said about the present U.S. Administration, which has ignored the findings of the Intergovernmental Panel on Climate Change and its own National Academy of Sciences, and about some in the U.S. Congress, and

47) **Exxon Mobil**--companies like Exxon Mobil which have spent millions of dollars trying to discredit climate change science in ads like this one that regularly run in the New York Times, and right wing so called think tanks like the Competitive Enterprise Institute, and vitriolic radio talk show hosts like Rush Limbaugh that have sprung up like metastases all over the U.S., and the editorial board of the Wall Street Journal, and others, all of whom have an appallingly meager understanding of what is happening to the global environment and of its potentially devastating consequences for human health.

It may be said of them, as Teddy Roosevelt once said of his political opponents, "that every time they open their mouths on these issues, they subtract from the sum total of human knowledge."

48) **slide of man at top of ramp** And sometimes it is not at all clear, listening to these people, many of whom I'm embarrassed to say reside in my country, whether we are at the pinnacle of evolution in terms of our ability to reason

49). **slide of man going into the sea** or at the nadir

So much for my rant.

We can and we must invest scientific effort and money on a scale similar to that which we are spending on national security, for that is what we are dealing with here, our collective security—witness the heat wave during the summer of 2003

that killed by official counts, more than 18,000 people in France alone (that is, six world Trade Centers), We must spend whatever it takes to develop inexpensive, reliable, renewable, non-polluting sources of energy—solar, wind, geothermal, bio-diesel, hydrogen-run fuel cells, and to substantially increase our efforts in energy efficiency and conservation. I am delighted to say that many companies like BP, which is on our Center's corporate council, are investing heavily in these technologies, but we must increase the scale of such investment exponentially.

We must control the discharge of pollutants, particularly those that are long lasting and which accumulate in biological systems like some toxic heavy metals like mercury, and persistent organic compounds like PCBs.

We must continue to set aside national parks and other protected areas on land and in the oceans as it is clear that these provide habitat for Nature to recover, but we cannot do this without also addressing global environmental threats that do not respect fences.

We must slow down population by supporting efforts to provide access to family planning to every woman who wants it and by increasing educational and career opportunities for women around the world.

50) fish—we are all a part of the problem-- And we must ourselves be models for responsible, healthy sustainable environmental practices by reducing, re-using, and recycling resources.

51)photo of small car by lowering our consumption of energy through driving smaller cars like this one.

52) photo of huge van rather than ones like this (that is the same person, my wife Jake who is about 5'11" in both photos—she would kill me if she knew I was showing these)

53) SUV cartoon--Let me say a word about SUVs. Uh Oh, I feel another rant coming on. They consume 2-3 times as much gasoline as a compact sedan, give off up to 5 times more air pollutants, are 3 times more likely to kill the other driver in an accident, and 2-4 times more likely to roll over when hit. The difference in greenhouse gas emissions between driving an SUV for a year as opposed to a compact sedan is equivalent to leaving your refrigerator door open for 6 months.

54) smart car we should drive one of your wonderful Smart Cars

55) Honda Insight or better yet, we should start driving new gasoline-electric hybrid cars like the Honda Insight or the Toyota Prius, which can get 24km per litre.

Or still better yet, we should take public transportation or bike or walk.

There are other ways we can reduce our consumption of energy—lowering the thermostat at night, wearing a sweater, better insulating our homes, using more energy-efficient lighting, turning off lights in empty rooms, buying local seasonal produce, rather than, as we do in the U.S., buying food that has had to travel thousands of miles to get to us, using enormous amounts of energy in the process.

If every household in California had replaced just four 75 watt light bulbs with available compact fluorescent bulbs, the state would not have had to build three new average-sized power plants. This is not rocket science—these technologies are available now.

We need to engage in a whole array of other individual and collective actions that preserve biodiversity and the environment and serve as models for others.

- we can eat low on the food chain and avoid marine species that are endangered. Many of us in the U.S. carry around pocket cards that tell us what seafood in our regions is sustainably harvested. I suspect there are similar ones in the U.K., and if not, there should be. Encourage the aquaculture of herbivorous fish like catfish and tilapia that do not deplete wild seafood stocks like carnivorous ones like salmon and shrimp, and eat low on the marine food web, like wild caught herring and sardines and anchovies and mackerel, which also have high levels of heart healthy mega 3 fatty acids and low levels of pollutants.
- Eat less red meat, sorry to say this in the U.K., which has been so hard hit with mad cow and foot and mouth disease. And if you buy meat, buy organic meat to avoid growth hormones, antibiotics, and pesticides. Buy organic food whenever possible, and food from local farmers at farmer's markets—this will encourage organic food practices and keep those farmers trying to preserve the environment in business. Organic farming helps preserve biodiversity.
- Do not buy tropical hard-woods like teak and mahogany unless they are certified as coming from sustainable forests.

56.) **old photo of train crashing** It is not too late to apply the breaks.

through station in Paris And, like Winston Churchill and my own beloved Boston Red Sox have said and have proved, one must never, never, never give up.

I am pleased to say that our Center, the Center for Health and the Global Environment has focussed all of its energies on trying to help policy-makers and the public understand the consequences of what we are doing to the environment.

1. we teach a major course at Harvard--“Human Health and Global Environmental Change” which has been disseminated to 58 medical schools, colleges, and universities around the world and is completely archived on our website, so that anyone in this room can watch all the lectures, take the entire course free of charge online, (I will tell you our website in the discussion)
2. we teach an annual intensive course for staff of the U.S. Senate and House of Representatives and have held 14 congressional briefings
3. we work very closely with the United Nations—on a project called Climate Change Futures, looking at future health, ecologic, and economic scenarios

57) **IES** and on one called “Biodiversity and Human Health”—with the WHO, UNEP, and the UNDP. This is the interim executive summary, also on our website. The project will culminate in a book to be published by Oxford University Press in late 2005 or early 2006, and will be the most comprehensive report yet available on how biodiversity contributes to human health.

58) **bird in the hand**

I want to close with a final personal comment.

I believe we are incredibly lucky to be alive at this moment in history, for the changes to the environment I have spoken about are caused by our own decisions, by our own behavior, and we have the ability, our generation, especially those of us in the most powerful and advantaged countries on the planet, especially those of us in this room who are among the most privileged and influential members of our societies, we have the ability to slow them down and turn them around.

We are in deep, deep trouble with what we are doing to the Earth, and the level of understanding about these issues is at such a primitive level, even, I'm sorry to say, at the very highest levels of government, I believe you and I have the responsibility to learn as much as we can about these issues so that we can educate others, so that we can help people understand that their health is ultimately totally dependent on the health of the global environment. That in destroying other species and damaging the ecosystems in which they and all of us live, we are doing something that is not just morally and spiritually and aesthetically and economically wrong, it is deeply and shamefully ignorant, for we are tampering with the life support systems of the Earth in ways that we barely understand, in ways that are bound to have profound consequences for our health and lives and for the health and lives of our children.

For God's Sake, for Darwin's sake, for the sake of our children and all children to come, we can and we must do everything in our power to protect this incredibly

wondrous gift we have all been given, and so I urge all of you to join me and my colleagues at the Center, at the Darwin Initiative, and countless others around the World in this effort.

Thank you.