Eaarth

MAKING A LIFE ON A TOUGH NEW PLANET

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A NEW WORLD

Imagine we live on a planet. Not our cozy, taken-for-granted earth, but a planet, a real one, with melting poles and dying forests and a heaving, corrosive sea, raked by winds, strafed by storms, scorched by heat. An inhospitable place.

It's hard. For the ten thousand years that constitute human civilization, we've existed in the sweetest of sweet spots. The temperature has barely budged; globally averaged, it's swung in the narrowest of ranges, between fifty-eight and sixty degrees Fahrenheit. That's warm enough that the ice sheets retreated from the centers of our continents so we could grow grain, but cold enough that mountain glaciers provided drinking and irrigation water to those plains and valleys year-round; it was the "correct" temperature for the marvelously diverse planet that seems right to us. And every aspect of our civilization reflects that particular world. We built our great cities next to seas that have remained tame and level, or at altitudes high enough that disease-bearing mosquitoes could not overwinter. We refined the farming that has swelled our numbers to take full advantage of that predictable heat and rainfall; our rice and corn and wheat can't imagine another earth either. Occasionally, in one place or another, there's an abrupt departure from the norm—a hurricane, a drought, a freeze. But our very language reflects their rarity: freak storms, disturbances.

In December 1968 we got the first real view of that stable, secure place. *Apollo 8* was orbiting the moon, the astronauts busy photographing possible landing zones for the missions that would follow. On the fourth orbit, Commander Frank Borman decided to roll the craft away from the moon and tilt its windows toward the horizon—he needed a navigational fix. What he got, instead, was a sudden view of the earth, rising. "Oh my God," he said. "Here's the earth coming up." Crew member Bill Anders grabbed a camera and took the photograph that became the iconic image perhaps of all time. "Earthrise," as it was eventually known, that picture of a blue-and-white marble floating amid the vast backdrop of space, set against the barren edge of the lifeless moon.[1] Borman said later that it was "the most beautiful, heart-catching sight of my life, one that sent a torrent of nostalgia, of sheer homesickness, surging through me. It was the only thing in space that had any color to it. Everything else was simply black or white. But not the earth."[2] The third member of the crew, Jim Lovell, put it more simply: the earth, he said, suddenly appeared as "a grand oasis."

But we no longer live on that planet. In the four decades since, that earth has changed in profound ways, ways that have already taken us out of the sweet spot where humans so long thrived. We're every day less the oasis and more the desert. The world hasn't ended, but the world as we know it has—even if we don't quite know it yet. We imagine we still live back on that old planet, that the disturbances we see around us are the old random and freakish kind. But they're not. It's a different place. A different planet. It needs a new name. Eaarth. Or Monnde, or Tierrre, Errde, оккучивать. It still looks familiar enough—we're still the third rock out from the sun, still three-quarters water. Gravity still pertains; we're still earth*like*. But it's odd enough to constantly remind us how profoundly we've altered the only place we've ever known. I am aware, of course, that the earth changes constantly, and that occasionally it changes wildly, as when an asteroid strikes or an ice age relaxes its grip. This is one of those rare moments, the start of a change far larger and more thoroughgoing than anything we can read in the records of man, on a par with the biggest dangers we can read in the records of rock and ice.

Consider the veins of cloud that streak and mottle the earth in that glorious snapshot from space. So far humans, by burning fossil fuel, have raised the temperature of the planet nearly a degree Celsius (more than a degree and a half Fahrenheit). A NASA study in December 2008 found that warming on that scale was enough to trigger a 45 percent increase in thunderheads above the ocean, breeding the spectacular anvil-headed clouds that can rise five miles above the sea, generating "supercells" with torrents of rain and hail.[3] In fact, total global rainfall is now increasing 1.5 percent a decade.[4] Larger storms over land now create more lightning; every degree Celsius brings about 6 percent more lightning, according to the climate scientist Amanda Staudt. In just one day in June 2008, lightning sparked 1,700 different fires across California, burning a million acres and setting a new state record. These blazes burned on the new earth, not the old one. "We are in the mega-fire era," said Ken Frederick, a spokesman for the federal government.[5] And that smoke and flame, of course, were visible from space—indeed anyone with an Internet connection could watch the video feed from the space shuttle *Endeavour* as it circled above the towering plumes in the Santa Barbara hills.

Or consider the white and frozen top of the planet. Arctic ice has been melting slowly for two decades as temperatures have climbed, but in the summer of 2007 that gradual thaw suddenly accelerated. By the time the long Arctic night finally descended in October, there was 22 percent less sea ice than had ever been observed before, and more than 40 percent less than the year that the Apollo capsule took its picture. The Arctic ice cap was 1.1 million square miles smaller than ever in recorded history, reduced by an area twelve times the size of Great Britain.[6] The summers of 2008 and 2009 saw a virtual repeat of the epic melt; in 2008 both the Northwest and Northeast passages opened for the first time in human history. The first commercial ship to make the voyage through the newly opened straits, the MV *Camilla Desgagnes*, had an icebreaker on standby in case it ran into trouble, but the captain reported, "I didn't see one cube of ice."[7]

This is not some mere passing change; this is the earth shifting. In December 2008, scientists from the National Sea Ice Data Center said the increased melting of Arctic ice was accumulating heat in the oceans, and that this so-called Arctic amplification now penetrated 1,500 kilometers inland. In August 2009, scientists reported that lightning strikes in the Arctic had increased twentyfold, igniting some of the first tundra fires ever observed.[8] According to the center's Mark Serreze, the new data are "reinforcing the notion that the Arctic ice is in its death spiral."[9] That is, within a decade or two, a summertime spacecraft pointing its camera at the North Pole would see nothing but open ocean. There'd be ice left on Greenland—but much less ice. Between 2003 and 2008, more than a trillion tons of the island's ice melted, an area ten times the size of Manhattan. "We now know that the climate doesn't have to warm any more for Greenland to continue losing ice," explained Jason Box, a geography

professor at Ohio State University. "It has probably passed the point where it could maintain the mass of ice that we remember."[10] And if the spacecraft pointed its camera at the South Pole? On the last day of 2008, the *Economist* reported that temperatures on the Antarctic Peninsula were rising faster than anywhere else on earth, and that the West Antarctic was losing ice 75 percent faster than just a decade before.[11]

Don't let your eyes glaze over at this parade of statistics (and so many more to follow). These should come as body blows, as mortar barrages, as sickening thuds. The Holocene is staggered, the only world that humans have known is suddenly reeling. I am not describing what will happen if we don't take action, or warning of some future threat. This is the *current* inventory: more thunder, more lightning, less ice. Name a major feature of the earth's surface and you'll find massive change.

For instance: a U.S. government team studying the tropics recently concluded that by the standard meteorological definition, they have expanded more than two degrees of latitude north and south since 1980—"a further 8.5 million square miles of the Earth are now experiencing a tropical climate." As the tropics expand, they push the dry subtropics ahead of them, north and south, with "grave implications for many millions of people" in these newly arid regions. In Australia, for instance, "westerly winds bringing much needed rain" are "likely to be pushed further south, dumping their water over open ocean rather than on land."[12] Indeed, by early 2008 half of Australia was in drought, and forecasters were calling it the new normal. "The inflows of the past will never return," the executive director of the Water Services Association of Australia told reporters. "We are trying to avoid the term 'drought' and saying this is the new reality."[13] They are trying to avoid the term *drought* because it implies the condition may someday *end*. The government warned in 2007 that "exceptionally hot years," which used to happen once a quarter century, would now "occur every one or two years."[14] The brushfires ignited by drought on this scale claimed hundreds of Australian lives in early 2009; four-story-high walls of flame "raced across the land like speeding trains," according to news reports. The country's prime minister visited the scene of the worst blazes. "Hell and its fury have visited the good people of Victoria," he said.[15]

And such hell is not confined to the antipodes. By the end of 2008 hydrologists in the United States were predicting that drought across the American Southwest had become a "permanent condition."[16] There was a 50 percent chance that Lake Mead, which backs up on the Colorado River behind Hoover Dam, could run dry by 2021.[17] (When that happens, as the head of the Southern Nevada Water Authority put it, "you cut off supply to the fifth largest economy in the world," spread across the American West.)[18] But the damage is already happening: researchers calculate that the new aridity and heat have led to reductions in wheat, corn, and barley yields of about 40 million tons a year.[19] The dryness keeps spreading. In early 2009 drought wracked northern China, the country's main wheat belt. Rain didn't fall for more than a hundred days, a modern record.[20] The news was much the same in India, in southern Brazil, and in Argentina, where wheat production in 2009 was the lowest in twenty years.[21] Across the planet, rivers are drying up. A massive 2009 study looked at streamflows on 925 of the world's largest rivers from 1948 to 2004 and found that twice as many were falling as rising. "During the life span of the study, fresh water discharge into the Pacific Ocean fell by about six percent—or roughly the annual volume of the Mississippi," it reported.[22]

From the flatlands to the highest peaks. The great glaciologist Lonnie Thompson, drilling cores on a huge Tibetan glacier in

2008, found something odd. Or rather, didn't find: one of the usual marker layers in any ice core, the radioactive particles that fell out from the atomic tests of the 1960s, were missing. The glacier had melted back through that history, wiped it away. A new Nepalese study found temperatures rising a tenth of a degree Fahrenheit annually in the Himalayas.[23] That would be a degree every *decade* in a world where the mercury barely budged for ten millennia. A long-standing claim that Himalayan glaciers might disappear by 2035 has been discredited, but across the region the great ice sheets are already shrinking fast: photos from the base of Mount Everest show that three hundred vertical feet of ice—a mass as tall as the Statue of Liberty—have melted since the Mallory expedition took the first photographs of the region in 1921.[24] But already, while there's still some glacier left, the new heat is flustering people. The rhododendrons that dominate Himalayan hillsides are in some places blooming forty-five days ahead of schedule, wrecking the annual spring flower festival and "creating confusion among folk artists."[25] The same kind of confusion is gripping mountaineers; one experienced high-altitude guide recently reported abandoning some mountains he'd climbed for years because "of the melting of the ice that acts as a glue, literally holding the mountains together."[26]

It's not just the Himalayas. In the spring of 2009, researchers arriving in Bolivia found that the eighteen-thousand-year-old Chacaltaya Glacier is "gone, completely melted away as of some sad, undetermined moment early this year." Once the highest ski run in the world, it now is nothing but rocks and mud.[27] But it's not the loss of a ski run that really matters. These glaciers are the reservoirs for entire continents, watering the billions of people who have settled downstream precisely because they guaranteed a steady supply. "When the glaciers are gone, they are gone. What does a place like Lima do?" asked Tim Barnett, a climate scientist at Scripps Oceanographic Institute. "In northwest China there are 300 million people relying on snowmelt for water supply. There's no way to replace it until the next ice age."[28]

When I read these accounts, I flash back to a tiny village, remote even by Tibetan standards, where I visited a few years ago. A gangly young man guided me a mile up a riverbank for a view of the enormous glacier whose snout towered over the valley. A black rock the size of an apartment tower stuck out from the middle of the wall of ice. My guide said it had appeared only the year before and now grew larger daily as its dark surface absorbed the sun's heat. We were a hundred miles from a school, far from TV; no one in the village was literate. So out of curiosity I asked the young man: "Why is it melting?" I don't know what I expected—some story about angry gods? He looked at me as if I was visiting from the planet Moron.

"Global warming," he said. "Too many factories." No confusion there. We hiked back to his hut and shook hands. I climbed into the Land Cruiser, which took me to the airplane. And so forth.

Or consider the ocean, that three-fourths of the planet that we usually don't consider. Different? One hundred eleven hurricanes formed in the tropical Atlantic between 1995 and 2008, a rise of 75 percent over the previous thirteen years. They're stronger, stranger. "Storms are not just making landfall and going away like they did in the past," said a researcher at the National Center for Atmospheric Research. "Somehow these storms are able to live longer today." In the summer of 2008, he added, "meteorologists watched in amazement as Tropical Storm Fay crisscrossed Florida a record-breaking four times" before it finally broke up; Hurricane Gustav carried its hurricane force winds all the way to Baton Rouge, a hundred miles inland, surprising the

evacuees who had fled there from the coast.[29] In the last half decade we've seen the earliest-forming Category 5 hurricane ever recorded (Emily, 2005) and the first January tropical cyclone (Zeta, 2006), the first known tropical cyclone in the South Atlantic (Catarina, 2004), and the first known tropical storm ever to strike Spain (Vince, 2005). The hurricane season of 2008 was the only one on record in the Atlantic that featured major hurricanes in five separate months, from Bertha (July) to Paloma (November). And elsewhere? "The increase in ocean temperatures," according to one study, "has led Bangladesh to encounter more than twelve storm warnings per year when the previous average was three." A succession of typhoons hit the country in 2006, inundating two-thirds of the nation; a year later Cyclone Sidr killed three thousand.[30] In the summer of 2009, a train of epic typhoons rolled across the Pacific. Ketsana dropped record rain on Manila and Vietnam; Morakot dumped nine and a half *feet* of rain on parts of Taiwan. All together? According to the *New York Times*, "the last thirty years have yielded four times as many weather-related disasters as the first three quarters of the 20th century combined."[31]

But lay aside hurricanes and wreckage. Just concentrate for a minute on how the sea is changing. For far longer than human civilization, those globe-girdling oceans have been chemically constant. They're so vast that we've taken their stability as a given. Even most oceanographers were shocked a few years ago when researchers began noticing that the seas were acidifying as they absorbed some of the carbon dioxide we've poured into the atmosphere. "It's been thought pH in the open oceans is well buffered, so it's surprising to see these fluctuations," said the University of Chicago biologist Timothy Wootton, who found acid levels rising ten times faster than expected.[32] Already ocean pH has slipped from 8.2 to 8.1; take one of those strips you dip in a hot tub, and you can tell the difference. The consensus estimate is that the pH will reach 7.8 by century's end.[33] The sea is already 30 percent more acid than it would have been because of our emissions, a process that Britain's Royal Society described as "essentially irreversible."[34] Already the ocean is more acid than anytime in the last eight hundred thousand years, and at current rates by 2050 it will be more corrosive than anytime in the past 20 million years. In that kind of environment, shellfish can't make thick enough shells. (Think of DDT and birds' eggs if you want an analogy.) By the summer of 2009, the Pacific oyster industry was reporting 80 percent mortality for oyster larvae, apparently because water rising from the ocean deep was "corrosive enough to kill the baby oysters."[35] At a conference in the spring of 2009, the American researcher Nancy Knowlton put it with refreshing bluntness: "Coral reefs will cease to exist as physical structures by 2100, perhaps 2050."[36] "We are overwhelming the system," says Richard Zeebe, an assistant professor of oceanography at the University of Hawaii. "It's pretty outrageous what we've done."[37] Which is as objective a scientific statement as you're likely to hear.

The idea that humans could fundamentally alter the planet is new. The Swedish chemist Svante Arrhenius broached the notion a century ago that we were "evaporating our coal mines into the air," and calculated that this would eventually raise temperatures, but nobody paid much attention. It wasn't until the 1950s that scientists even began measuring the amount of carbon dioxide in the atmosphere, from a small hut on the side of Hawaii's Mauna Loa, and they found that indeed the atmospheric concentration was steadily rising. But we didn't have the computing power to know what to make of that until the early 1980s, when a

few research teams began investigating, and almost nobody outside of a few labs had heard of the notion until a NASA scientist named James Hansen testified before Congress in June 1988 that global warming was almost certainly beginning. Even then, though, the people most worried about the problem called it a future threat: the declaration that concluded the huge Rio summit on the environment in 1992 didn't even mention climate change, but did recommend, meekly, that "in order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities." People spoke mostly about global warming in the future tense; the word was always *threat*, right up through the 2008 presidential campaign. Unveiling his global warming initiatives at the University of New Hampshire, Barack Obama sounded a familiar note: "This is our generation's moment to save future generations from global catastrophe."

Here's his opponent, John McCain, a few months later: "We and the other nations of the world must get serious about substantially reducing greenhouse gas emissions in the coming years or we will hand off a much-diminished world to our grandchildren."[38]

In fact, if you've got a spare month some time, google *global warming* and *grandchildren*. Among the 585,000 essentially identical and anodyne responses:

Ted Kennedy, to Congress in 2008: "I cannot look into the eyes of my grandchildren and tell them: Sorry, I . . . can't do anything about it."

Barbara Boxer, at the National Press Club: "Will our grandchildren know the thrill of holding their child's hand watching with excitement a towering snow-capped mountain or awesome, calving glaciers?"

Arnold Schwarzenegger, signing new energy legislation: "I want to make California No. 1 in the fight against global warming.

This is something we owe our children and grandchildren." And Arnold at the United Nations: "We hold the future in our hands. Together we must ensure that our grandchildren will not have to ask why we failed to do the right thing, and let them suffer the consequences." And in a statement he e-mailed to the Chinese news agency Xinhua explaining the state's new mileage laws: "Last month I signed an Executive Order creating the world's first Low Carbon Fuel standard so our vehicles will emit less carbon and bring a healthier future to our children and grandchildren." Hasta la vista, grandchildren!

Joe Lieberman: "Shame on us if 100 or 200 years from now our grandchildren and great-grandchildren are living on a planet that has been irreparably damaged by global warming, and they ask, 'How could those who came before us . . . have let this happen?'"

David Attenborough: "If we do care about our grandchildren then we have to do something."

Former Illinois governor Rod Blagojevich, addressing his Climate Change Advisory Group: "By committing ourselves to action in Illinois, we can help minimize the effects of climate change and ensure our children and grandchildren inherit a healthy world full of opportunity."

The late Jerry Falwell: "I can tell you, our grandchildren will laugh at those who predicted global warming. We'll be in global cooling by then, if the Lord hasn't returned. I don't believe a moment of it. The whole thing is created to destroy America's free enterprise system and our economic stability."

Sir Richard Branson, chair of Virgin Airways: "I think businesses can influence leaders who are not worrying enough about our grandchildren."

Bill Clinton, stumping for his wife in Colorado: "We just have to slow down our economy and cut back our greenhouse gas emissions 'cause we have to save the planet for our grandchildren."

Let's let the movie critic Roger Ebert sum up the general feeling, in his review of Al Gore's *An Inconvenient Truth*: "You owe it to yourself to see this film. If you do not, and you have grandchildren, you should explain to them why you decided not to."

So how did it happen that the threat to our fairly far-off descendants, which required that we heed an alarm and adopt precautionary principles and begin to take measured action lest we have a crisis for future generations, et cetera—how did that suddenly turn into the Arctic melting away, the tropics expanding, the ocean turning acid? How did time dilate, and "100 or 200 years from now" become yesterday?

The answer, more or less, is that global warming is a huge experiment. We've never watched it happen before, so we didn't know how it would proceed. Here's what we knew twenty years ago: the historic level of carbon dioxide in the atmosphere, the level that produced those ten thousand years of stability, was roughly 275 parts per million. And also this: since the dawn of the Industrial Revolution we'd been steadily increasing that total, currently raising it more than two parts per million annually. But no one really knew where the red line was—it was impossible to really know in advance at what point you'd cross a tripwire and set off a bomb. Like, say, melting all the ice in the Arctic.

The number that people tossed around for about a decade was 550 parts per million. Not because we had any real data showing it was the danger point, but because it was double the historic concentration, which made it relatively easy to model with the relatively crude computer programs scientists were using. One paper after another predicted what would happen to sea levels or forest composition or penguin reproduction if carbon dioxide levels doubled to 550 parts per million. And so—inevitably and insidiously—that's the number we fixated on. Since it wouldn't be reached until the middle of the twenty-first century, it seemed to offer a little margin; it meshed plausibly with political time, with the kind of gradual solutions leaders like to imagine. That is, a doubling of carbon dioxide would happen well beyond the time that anyone now in power was likely to still be in office, or still running the company. It was when everyone's *grandchildren* would be in charge. As late as 2004, the journalist Paul Roberts, in his superb book *The End of Oil,* was able to write quite correctly that "most climate models indicate that once concentrations exceed 550 ppm we will start to witness 'dangerous' levels of warming and damage, especially in vulnerable areas, such as low-lying countries or those already suffering drought." But by then some doubt was beginning to creep in. Odd phenomena (large chunks of the Antarctic falling into the ocean, say) were unnerving scientists enough that, in Roberts's words, most "would much rather see concentrations stabilized at 450 ppm . . . where we might avoid most long-term effects and instead suffer a kind of 'warming light,' moderate loss of shorefront land, moderate loss of species, moderate desertification," and so on. And since even 450 was still 15 percent above our current levels, "we have a little room to breathe, which is handy."[39]

Or would have been. But as it turns out, we had been like commentators trying to call an election on the basis of the first precinct to report. Right about 2005 the real returns began to flood in, *flood* being the correct verb. And what they showed was that those old benchmarks—550, 450—had been wishful thinking. No breathing room, not when hurricane seasons like 2005 were setting new records for insurance payouts, not when polar ice was melting "fifty years ahead of schedule," not when the tropics "appear to have already expanded during only the last few decades of the 20th century by at least the same margins as

models predict for this century."[40] Indeed, "ahead of schedule" became a kind of tic for headline writers: "Arctic Melt-off Ahead of Schedule" (the *Christian Science Monitor,* which quoted one scientist as saying "we're a hundred years ahead of schedule" in thawing Greenland), "Dry Future Well Ahead of Schedule" (the *Australian*), "Acidifed Seawater Showing Up Along Coast Ahead of Schedule" (the *Seattle Times*). The implication was that global warming hadn't read the invitation correctly and was showing up at four for the reception instead of six. In fact, of course, the "schedule" was wrong. And of course it was wrong—this was, as I've said, a huge experiment. Twenty-five years ago almost nobody even knew the planet was going to warm at all, never mind how fast.

It was that summer melt of Arctic ice in 2007 that seemed to break the spell, to start raising the stakes. The record minimums for ice were reached in the last week of September; in mid-December James Hansen, still the planet's leading climatologist, gave a short talk with six or seven slides at the American Geophysical Union meeting in San Francisco. What he said went unreported at the time, but it may turn out to be among the most crucial lectures in scientific history. He summarized both the real-world data that had emerged in recent years, including the ice-melt, and also the large body of research on paleoclimate—basically, the attempt to understand what had happened in the distant past when carbon dioxide levels climbed and fell. Taken together, he said, these two lines of inquiry made it clear that the safe number was, at most, 350 parts per million.

The day Jim Hansen announced that number was the day I knew we'd never again inhabit the planet I'd been born on, or anything close to it. Because we're already past 350—way past it. The planet has nearly 390 parts per million carbon dioxide in the atmosphere. We're too high. Forget the grandkids; it turns out this was a problem for our *parents*.

We can, if we're very lucky and very committed, eventually get the number back down below 350. This book will explore some of the reasons this task will be extremely hard, and some of the ways we can try. The planet can, slowly, soak up excess carbon dioxide if we stop pouring more in. That fight is what I spend my life on now, because it's still possible we can avert the very worst catastrophes. But even so, great damage will have been done along the way, on land and in the sea. In September 2009 the lead article in the journal *Nature* said that above 350 we "threaten the ecological life-support systems that have developed in the late Quaternary environment, and severely challenge the viability of contemporary human societies."[41] A month later, the journal *Science* offered new evidence of what the earth was like 20 million years ago, the last time we had carbon levels this high: sea levels rose one hundred feet or more, and temperatures rose as much as ten degrees.[42] The Zoological Society of London reported in July 2009 that "360 is now known to be the level at which coral reefs cease to be viable in the long run."[43]

We're not, in other words, going to get back the planet we used to have, the one on which our civilization developed. We're like the guy who ate steak for dinner every night and let his cholesterol top 300 and had the heart attack. Now he dines on Lipitor and walks on the treadmill, but half his heart is dead tissue. We're like the guy who smoked for forty years and then he had a stroke. He doesn't smoke anymore, but the left side of his body doesn't work either.

Consider: On January 26, 2009, less than a week after taking office, Barack Obama announced a series of stunning steps designed to dramatically raise fuel efficiency for cars. He also named a new envoy to aggressively negotiate an international

accord on global warming. "This should prompt cheers from California to Maine," the head of one environmental group exulted. "The days of Washington dragging its heels are over," insisted the president.[44] It was the most auspicious day of environmental news in the twenty years of the global warming era. And then that afternoon, the National Oceanic and Atmospheric Administration released a new study showing that a new understanding of ocean physics proved that "changes in surface temperature, rainfall, and sea level are largely irreversible for more than a thousand years after carbon dioxide emissions are completely stopped." Its author, Susan Solomon, was interviewed on National Public Radio that night. "People have imagined that if we stopped emitting carbon dioxide that the climate would be back to normal in one hundred years or two hundred years," she said. "What we're showing here is that that's not right."[45] No one is going to refreeze the Arctic for us, or restore the pH of the oceans, and given the momentum of global warming we're likely to cross many more thresholds even if we all convert to solar power and bicycles this afternoon.

Which, it must be said, we're not doing. The scientists didn't merely underestimate how fast the Arctic would melt; they overestimated how fast our hearts would melt. The Intergovernmental Panel on Climate Change, or IPCC, carefully calculated a variety of different "emissions pathways" for the future, ranging from a world where we did everything possible to make ourselves lean and efficient to a "business-as-usual" model where we did next to nothing. In the last decade, as the United States has done very little to change its energy habits, and as the large Asian economies have come online, carbon emissions have risen "far above even the bleak scenarios" considered in the reports. In the summer of 2008, at an academic conference at Britain's Exeter University, a scientist named Kevin Anderson took the podium for a major address. He showed slide after slide, graph after graph, "representing the fumes that belch from chimneys, exhausts and jet engines, that should have bent in a rapid curve towards the ground, were heading for the ceiling instead." His conclusion: it was "improbable" that we'd be able to stop short of 650 parts per million, even if rich countries adopted "draconian emissions reductions within a decade." That number, should it come to pass, would mean that global average temperatures would increase something like seven degrees Fahrenheit, compared to the degree and a half they've gone up already.

"As an academic I wanted to be told it was a very good piece of work and that the conclusions were sound," Anderson said. "But as a human being, I desperately wanted someone to point out a mistake, and to tell me we had got it completely wrong." According to David Adam's account in the *Guardian*, nobody did. "The cream of the UK climate science community sat in stunned silence." In fact, Adam conducted a small poll himself among researchers, politicians, and activists. "Ask for projections around the dinner table after a few bottles of wine, and more vote for 650 ppm than 450 ppm as the more likely outcome," he reported.[46] Though the economic downturn that took hold in 2009 has as least temporarily slowed the rise—in fact American carbon dioxide emissions were expected to fall nearly 5 percent in 2009.[47] Which is good news. Just not good enough. To give you an idea of how aggressively the world's governments are willing to move, in July 2009 the thirteen largest emitters met in Washington to agree on an "aspirational" goal of 50 percent cuts in carbon by 2050, which falls pretty close to the category of "don't bother."[48]

The Copenhagen conference, in December 2009, was supposed to be the place where the world took an "historic step forward." Instead, it turned into a fiasco of the first order. Sure, there were giant rock concerts and a spirited protest march and twenty thousand environmentalists from around the world who showed

up to lobby the talks. And there was actually powerful resistance to a meaningless deal from most of the nations of the world—the poor countries and the low-lying island nations stuck hard to their assessment that without deep cuts in emissions from the rich countries their very survival was at stake. Well more than half the nations of the world endorsed a strong target of 350 parts per million; the great cathedral in the center of the city, and then thousands of the world's other churches, rang their bells 350 times on the Sunday in the middle of the negotiations.

But the very next day the UN started locking the nongovernmental organizations out of the conference. An internal paper, leaked to the world's press, showed that even the UN knew the whole process was half-sham, because the proposed deals would increase temperatures much faster than the official rhetoric described. (My name was scrawled across the front, but I didn't leak it.) At week's end President Obama jetted in to "show leadership" and "break the deadlock," but all he did was repeat America's standing offer—by 2020 we'll cut our carbon emissions 4 percent below 1990 levels, a pledge whose stunning weakness his aides continued to blame on the difficulty of getting anything tougher through Congress. Fearing a face-destroying collapse, Obama negotiated a brief "Copenhagen accord" with the Chinese that lacked any targets or time frame for emissions, and then the president jetted out of town, eager to beat a snowstorm descending on Washington. The next day virtually every newspaper in the world declared it a debacle. As Joss Garman put it in London's *Independent*: "It is no exaggeration to describe the outcome of Copenhagen as a historic failure that will live in infamy."

But as usual you didn't need words to make the point at all, because numbers would do. A team of computer jockeys from MIT and elsewhere formed a group called Climate Interactive and built, in the months before Copenhagen, a sophisticated software model that could instantly analyze any proposal and tell you what it would mean a hundred years down the road. Here's what they found: if you took every government pledge made during the conference and added it all together, the world in 2100 would have *more than 725 parts per million carbon dioxide*, or slightly double what scientists now believe is the maximum safe level of 350. Even if you took all the possible "conditional proposals, legislation under debate and unofficial government statements"—in other words, even if you erred on the side of insane optimism—the world in 2100 would have about 600 parts per million carbon dioxide. That is, we'd live if not in hell, then in some place with a very similar temperature.

So far we've been the cause for the sudden surge in greenhouse gases and hence global temperatures, but that's starting to change, as the heat we've caused has started to trigger a series of ominous feedback effects. Some are fairly easy to see: melt Arctic sea ice, and you replace a shiny white mirror that reflects most of the incoming rays of the sun back out to space with a dull blue ocean that absorbs most of those rays. Others are less obvious, and much larger: booby traps, hidden around the world, waiting for the atmosphere to heat.

For instance, there are immense quantities of methane—natural gas—locked up beneath the frozen tundra, and in icy "clathrates" beneath the sea. Methane, like carbon dioxide, is a heat-trapping gas; if it starts escaping into the atmosphere, it will add to the pace of warming. And that's what seems to be happening, well ahead (need it be said) of schedule. In 2007, atmospheric levels of methane began to spike. Scientists weren't sure where they were coming from, but the fear was that those tundra

and ocean sources were starting to melt in earnest. In the summer of 2008, a Russian research ship, the *Jacob Smirnitskyi*, was cruising off the country's northern coast in the Laptev Sea when the scientists on board started finding areas of the water's surface foaming with methane gas. Concentrations were a hundred times normal. "Yesterday, for the first time, we documented a field where the release was so intense that the methane did not have to dissolve into the sea water but was rising as methane bubbles to the sea surface," one of the scientists e-mailed a journalist at the *Independent*. "These methane chimneys were documented on an echo sounder and with seismic instruments."[49] The head of the research team, Igor Semiletov of the University of Alaska in Fairbanks, noted that temperatures over eastern Siberia had increased by almost ten degrees in the last decade. That's melting permafrost on the land, and hence more relatively warm water is flowing down the region's rivers into the ocean, where it may in turn be melting the icy seal over the underwater methane. The melting permafrost is also releasing methane on land. "On helicopter flights over the delta of the Lena River, higher methane concentrations have been measured at altitudes as high as 1,800 meters," reported Natalia Shakhova, of the Russian Academy of Sciences.[50] In recent winters scientists have reported that far northern ponds and marshes stayed unfrozen even in the depths of winter because so much methane was bubbling out from underneath. "It looks like a soda can is open underneath the water," one researcher explained.[51]

That's scary. Scarier even than the carbon pouring out of our tailpipes, because we're not directly releasing that methane. We burned the coal and gas and oil, and released the first dose of carbon, and that raised the temperature enough to start the process in motion. We're responsible for it, but we can't shut it off. It's taken on a life of its own. One recent estimate: the permafrost traps 1,600 billion tons of carbon. A hundred billion tons could be released this century, mostly in the form of methane, which would have a warming effect equivalent to 270 years of carbon dioxide emissions at current levels. "It's a kind of slow-motion time bomb," said Ted Schuur of the University of Florida in March 2009. At a certain point, he added, "the feedback process would continue even if we cut our greenhouse emissions to zero."[52]

We don't know if methane release has begun in earnest yet, or the exact threshold we'd need to pass. But there are dozens of such feedback loops out there. Peat covers about 2 percent of the planet's land surface, mostly in the far north—think moors, bogs, mires, swamp forests. They are wet places filled with decaying vegetation, a kind of nursery for what in many millennia could become coal. Because they're wet, they're very stable; the plants decompose very very slowly, so peatlands make a perfect "sink" for carbon, holding perhaps half as much as the atmosphere. But say you raise the temperature and hence the rate of evaporation; the water table starts to fall, and those swamps start to dry out. And as they do, the carbon in all that decaying vegetation starts to decompose more quickly and flood into the atmosphere. A 2008 study found, in fact, that "peatlands will quickly respond to the expected warming in this century by losing labile soil organic carbon during dry periods." How much? Well, peat bogs worldwide hold the equivalent of sixty-five years of fossil-fuel burning, and the expected warming will dry out enough of them to cause the loss of between 40 and 86 percent of that carbon.[53] It's as if we'd conjured up out of nowhere a second human population that's capable of burning coal and oil and gas nearly as fast as we do.

At the same time that we're triggering new pulses of carbon into the atmosphere, we're also steadily weakening the natural systems that pull it out of the air. Normally—over all but the

last two hundred years of human civilization—the carbon dioxide level in the atmosphere remained stable because trees and plants and plankton sucked it up about as fast as volcanoes produced it. But now we've turned our cars and factories into junior volcanoes, and so we're not just producing carbon faster than the plant world can absorb it; we're also making it so hot that the plants absorb less carbon than they used to. In a 2008 experiment, scientists carved out small plots of grassland and installed them in labs where they could heat them artificially. "During this anomalously warm year and the year that followed, the two plots sucked up two-thirds less carbon than the plots that had been exposed to normal temperatures," the researchers reported.[54] The same thing may be happening at sea, where in January 2009 scientists "issued a warning" after finding "a sudden and dramatic collapse in the amount of carbon emissions absorbed" in fast-warming areas of the Sea of Japan.[55] Imagine that you desperately need to bail out your boat, but you find that your buckets are filled with holes that keep getting larger. "Fifty years ago, for every ton of CO_2 emitted to the atmosphere, natural sinks removed 600 kilograms. Currently the sinks are removing only 559 kilograms per ton, and the amount is falling."[56] Those are big holes.

So far I've written more about causes than effects; before long we'll begin to see how these new realities play out, how they build on each other in a crescendo of cascading consequences. But here, toward the start, I want simply to establish the bottom line. We're changing the most basic dynamics of the only world we've ever known.

The only truly crucial question that human beings ask is: "What's for dinner?" Or, for much of human history, "Is there any dinner?" At an international meeting in Poland in December 2008, Martin Parry, one of the cochairs of the Intergovernmental Panel on Climate Change, gave a talk that began like this: "The 2008 food crisis is the largest impact of climate change so far. It was caused partly by the poorly-thought-through switch to biofuels as a way of combating climate change, and partly by the drought in western Australia, which local scientists have identified as having been caused by climate change." The result, Parry said, was that in 2008, 40 million people had been added to the list of those "at risk of hunger," taking the total to 963 million, or one-sixth of the world's population.[57] That is, in one year climate change had managed to turn 40 million people—more than the population of California—hungry. Not "this could happen." This happened. And in 2009 the number topped a billion.[58]

In January 2009, a team analyzing twenty-three climate models told us about the future. They compared the expected new temperatures by century's end with what we know about wheat and corn. They found that it will routinely get so hot that the crops will grow much less vigorously; wheat yields could easily fall 20 to 40 percent, on a planet that's expected to host 3 billion more people. We've already begun to see this in action. In 2003, France had the kind of heat wave that will become the new normal as the decades roll on. Not only did thirty thousand people die because of heat stress, but corn production fell by a third, fruit harvests by a quarter, and wheat by a fifth. The jovial notion that we'll compensate by simply moving farther north eventually becomes absurd. "You can't move that far north because all you end up with is pretty infertile tundra," one of the researchers, the University of Washington's David Battisti, pointed out. "When all the signs point in the same direction, and in this case it's a bad direction, you pretty much know what's going to happen," he said. "You are talking about hundreds of millions of

additional people looking for food because they won't be able to find it where they find it now."[59] The chief scientist at the U.S. State Department said recently that its analysis foresees famines severe enough to affect a billion people at a time in the next few decades; Britain's chief scientist said in the spring of 2009 that "a perfect storm" of food and water shortages could hit by 2030.[60] Here's the Stanford University researcher Rosamond Naylor, who conducted some of the most recent calculations: "I think what startled me the most is that when we looked at our historic examples there were ways to address the problem within a given year. People could always turn somewhere else to find food. But in the future there's not going to be any place to turn."[61] It doesn't get any more basic than that.

Or maybe it does get more basic, since we're not the only species involved. Often, speaking to audiences, I'll find people who have moved to a zone of spooky calm: yes, they say, human beings may do themselves in, but "the planet" will survive. That's true in some sense, at least until the sun explodes, but it won't be anything like the planet we've known. We're hard at work transforming it—hard at work sabotaging its biology, draining its diversity, affecting every other kind of life that we were born onto this planet with. We're running Genesis backward, decreating. Melt the Arctic, for instance, and you wreak havoc with the region's phytoplankton, "the crucial nutrient at the base of the food web on which marine life depends."[62] In the far South, a 2008 study noted, three-fourths of big penguin colonies may soon disappear.[63] I've stood in the middle of these rookeries, a hundred thousand mating pairs shrieking, their babies demanding food. It's the greatest example of fecundity I've ever seen—you can smell them miles away. They define the insane abundance of the world we've known, and their absence will help to define the new world we're creating.

The changes could hardly be more fundamental. For instance, a team of scientists showed recently that all manner of animals are likely to shrink, literally, as temperatures climb. Larger animals have a lower ratio of surface area to volume, so they retain heat more easily and do better in cooler climes, whereas smaller species radiate heat more easily. "It makes sense to be bigger when it's colder," says Wendy Foden, a biologist at the World Conservation Union. "As the world gets warmer, species will shrink."[64] In July 2009, researchers in fact found that Scottish sheep had been shrinking three ounces a year for two decades because of warmer temperatures; the same with red-winged gulls and certain crustaceans. "Whether in the future we're going to get miniature bonsai sheep I have no idea," said a biologist at Imperial College in London.[65]

And as the world gets warmer, it also gets steadily simpler. "From Peru to Namibia to the Black Sea to Japan . . . massive swarms of jellyfish are blooming," researchers said in 2008, "closing beaches and wiping out fish, either by devouring their eggs and larvae, or out-competing them for food." In the Sea of Japan, 500 million Nomurai jellyfish—each more than two meters in diameter—are clogging fishing nets; a region of the Bering Sea is so full of jellies that it's been renamed "Slime Bank." "Jellyfish grow faster and produce more young in warmer waters," one researcher explained.[66] The fish and whales that remain live in a world changing as fast as ours, in every way. New studies show, for instance, that as seawater grows more acid, it absorbs less sound, making the whole ocean noisier. As one scientist put it. "It's the cocktail party effect."[67] Meanwhile, scientists reported in October 2009 that "as sea temperatures have risen in recent decades, enormous sheets of a mucus-like material have begun to form" in the world's seas. Some of these "blobs" are two hundred kilometers long, carry high levels of

E. coli bacteria, and often "trap animals, coating their gills and suffocating them."[68]

Here's all I'm trying to say: The planet on which our civilization evolved no longer exists. The stability that produced that civilization has vanished; epic changes have begun. (My favorite bleak headline, from *USA Today* in May 2009, describes a new study from the American Meteorological Society: "Global Warming May Be Twice as Bad as Previously Expected.")[69] We *may*, with commitment and luck, yet be able to maintain a planet that will sustain *some kind* of civilization, but it won't be the same planet, and hence it can't be the same civilization. The earth that we knew—the only earth that we ever knew—is gone.

If that stable earth allowed human *civilization*, however, something else created *modernity*, the world that most of us reading this book inhabit. That something was the sudden availability, beginning in the early eighteenth century, of cheap fossil fuel. An exaggeration? One barrel of oil yields as much energy as twenty-five thousand hours of human manual labor—more than a decade of human labor per barrel. The average American uses twenty-five barrels each year, which is like finding three hundred years of free labor annually. And that's just the oil; there's coal and gas, too.[70] It's why most of the people reading this book don't do much manual labor anymore, and why those who do use machines that make them hundreds of times more powerful than their forebears. It's why we're prosperous, why our economies have grown. It's also, of course, why we have global warming and acid oceans; in essence we've spent two hundred years digging up all that ancient carbon, combining it with oxygen for a moment to explode the pistons that take us to the drive-through, and then releasing it into the atmosphere, where it accumulates as carbon dioxide. That cloud of carbon is nothing more than a ghostly reflection of the pools of oil and veins of coal where it once dwelled—each gallon of gasoline represents a hundred tons of ancient plants.[71] All day every day we burn coal and gas and oil, from the second we make the coffee till the second we turn out the lights. (And is the furnace still running? The air-conditioning?) If an alien landed in the United States on some voyage of exploration, he might well report back to headquarters that we were bipedal devices for combusting fossil fuel.

Which is why it's unlucky in the extreme that at precisely the same moment that we've destabilized the climate that underwrote civilization, we've also started to come up short on the fossil fuel that underwrote modernity. The two phenomena (very much intertwined) have struck us with the same uncanny speed. Just as a few scientists began warning a generation ago about rising temperatures, so a tiny band of geologists began fretting about dwindling oil supplies. In 1956, two years before the first carbon dioxide monitor was installed on Mauna Loa, a petroleum geologist named M. King Hubbert first predicted that U.S. oil production would reach its zenith between 1965 and 1970. He was spot-on—but nobody worried too much, because so much oil was flowing in from the great fields of the Middle East. In recent years, however, there have been troubling signs that those fields, too, are starting to dwindle, and clear evidence that no new fields big enough to make up for their decline have been discovered. "Peak oil" began as a fringe idea—just like climate change—but in recent years more and more establishment figures have signed on to the idea that we may really be reaching the point where the amount of oil we can wrest from the planet will go down, not up.

The debate ended on November 12, 2008. If you didn't notice,

blame post-Obama hangover or the ragged fear (and low oil prices) that came with the height of the financial crisis. November 12 was the day the Bush administration decided to stop buying up toxic assets and instead just recapitalize the banks, and the day that Obama named his transition team. But the real news that day, the data that rewrote the history books, came from the International Energy Agency, which published its long-awaited World Energy Outlook. The IEA defines conservative—it's the group set up by rich nations in the wake of the oil shocks of the 1970s to maintain a steady supply of energy. And their economists had always insisted that there would be a growing supply of oil for decades to come. No problem, no problem, no problem. Plenty of oil.

This time around, the tune changed markedly. First, said the IEA, production in current oil fields is falling by about 7 percent a year, a figure that will rise steadily to 9 percent over the next few decades. In other words, the level of oil in these giant fields has dropped far enough that we can no longer get as much as we used to. Never mind fueling the growing Asian thirst for oil; simply running in place would mean finding four new Saudi Arabias by 2030. But since demand *will* keep rising in Asia (92 percent of American adults own cars, compared with 6 percent of Chinese) and elsewhere, staying abreast will mean finding *six* new Saudi Arabias—or a new Kuwait—every year. The IEA put it in dollar figures: keeping up our oil economy will require $350 billion in exploration and investment every year through 2030. That's compared with a total of $390 billion that the world spent on those items in the whole period of 2000–2007, when the economy was booming.[72] And even the IEA's gloom may well have been too optimistic. A few weeks later, Merrill Lynch energy analysts, using new numbers for non-OPEC oil fields, calculated that we'll need *ten* new Saudi Arabias by 2030.[73] As the former

CIA director and defense secretary James Schlesinger put it, "The battle is over, the oil peakists have won."[74]

On the old planet—the one with an Arctic ice cap, the one where hurricanes didn't strike Spain and Brazil, the one where jellyfish didn't bloom in great slimy clouds across the oceans—we had one Saudi Arabia and one Kuwait. They sat atop enormous pools of oil. Now, every day more so, they sit atop big empty holes. And there are no more Saudi Arabias, no matter how much money you have. So does modernity disappear along with the oil? It's a question worth asking, when six of the twelve largest companies in the world are fossil-fuel providers, four make cars and trucks, and one, General Electric, is, as its name implies, heavily involved in the energy industry. Just buying fossil fuel requires almost a tenth of global GDP, and almost all the other 90 percent depends on burning the stuff.[75]

Oil is also the mother of most petrochemicals and plastics. Richard Heinberg, the analyst who was one of the first to alert the world to the impending oil peak, once compiled a list of things made from oil that ran from computer chips, insecticides, anesthetics, and fertilizers, right through lipstick, perfume, and pantyhose, to aspirin and parachutes. "Without petrochemicals," Heinberg wrote, "medical science, information technology, modern cityscapes, and countless other aspects of our modern technology-intensive lifestyles would simply not exist. In all, oil represents the essence of modern life."[76] That we've wasted it so mindlessly is depressing. (From the mid-1980s on American automakers stopped worrying about efficiency and instead concentrated on torque; as a result, by 2002 the average American car would go from zero to sixty in 10.5 seconds, a dynamic 3.5 seconds faster than a generation earlier.)[77] But it's also understandable. Again: cheap energy is not a useful part of our economy. It *is* our economy. "Before 1850 most Americans didn't even know coal could be burned," writes Paul Roberts. "Yet by 1900 U.S. mines were outproducing those in England. What were people using all this extra energy for? Mainly people were manufacturing more things: more textiles, more machines, more food and ale, more paper. The pattern was clear: the more you produced, the more energy you needed. And conversely, the more energy you used, the more things you produced."[78]

Because there was lots of it on that old planet, energy was cheap. You've seen the pictures—the early oil strikes where the fields were under such high pressure that as soon as you punctured them with a drill the crude would spew into the air. It was, more or less, free for the taking. No more; what's left is in hard-to-get-at places and requires fantastic technical skill. Norway's Troll A platform in the North Sea, for instance, is the largest man-made structure ever moved: each of its three concrete legs is 994 feet long with an elevator that takes nine minutes to travel from the seabed to the drilling platform above. (To celebrate its tenth anniversary, a Norwegian pop idol sang a concert at the bottom of the elevator shaft, the deepest musical performance in history.) All of which means that drilling oil is getting progressively more expensive, not just in dollar terms but, more important, in what economists call "energy return on investment," or EROI. If the EROI on an oil well is 20:1, you get twenty units of energy out for every unit you put in. Twenty to one is pretty good—a lot better than, say, taking Canadian tar sands and melting them down to get usable oil. That might produce an EROI of 5.2:1 by some recent estimates. Corn ethanol for oil? Once you've figured in all the energy it takes to grow the stuff and process it, you're lucky to break even.[79] Charles Hall, a professor at the State University of New York, argued recently that "to offer any remotely viable contribution to society, a liquid fuel should not be dependent on subsidies from petroleum and should have an EROI of at least 5:1." Solar panels:

somewhere between 2.5 and 4.3:1, at least for now.[80] Which is not to say that solar panels are a bad idea—this book is being written with juice flowing straight from my roof. Only that they won't replace fossil fuels straight up.

We got a taste of that in the remarkable spring of 2008, as oil prices started to rise through the roof. Economies were strong, demand was rising—and there was no new supply to meet it. Paul Roberts pointed out in 2004 that six of the last seven global recessions had been preceded by spikes in the price of oil, and now we can safely make that seven of the last eight. Economic historians will long debate exactly why the economy keeled over in the fall of the year, but collapsing home prices seem to be the most basic answer. And they collapsed not just because of mortgage fraud but also because people began to take note of reality: in a world where four-dollar-a-gallon gas was even a possibility, who wanted a starter castle ninety minutes from work? "As oil prices started to bite, the new housing built in distant suburbs and even more remote 'exurbs' became less viable for commuters," wrote the oil analyst Phil Hart.[81] Between 2004 and 2008, when gas prices rose past two dollars to their eventual peak, the three cities with the largest declines in housing prices were the entirely auto-dependent Las Vegas, Phoenix, and Detroit; Portland, Oregon, the bike-and-trolley capital of the country, saw the largest rise in home value.[82]

But it's not only transportation. Since oil is in everything, its price affects the entire economy. In the spring of 2009, a University of California economist reported that "nearly all of last year's economic downturn could be attributed to the oil price shock"; despite his data, he reported, "it was a conclusion he didn't quite believe in himself," except that each of the previous run-ups in oil prices—1973, 1979, 1990, even 2001—also corresponded with recessions.[83] Once the economy collapsed, of course, oil prices

collapsed with them; we went back to consuming a little less than the planet was capable of producing. But should the economy recover, oil prices will almost certainly bounce right back. As the financier George Soros, who made a pile betting on the rise and fall of oil in 2008, wrote that autumn, "any relief will be temporary."[84]

In fact, one all-too-likely result of peak oil will be even more use of our most abundant fossil fuel, good old coal. And the certain result of using more coal will be . . . more global warming, since it's the dirtiest of all the fossil fuels, producing twice the carbon dioxide of oil. As James Hansen and his NASA team pointed out, any increased reliance on coal is enough to guarantee that we'll never get back to 350. Cue doom.

These are the kinds of traps we fall into on this new planet. We can't burn more oil because it's running out. The stuff we can still find to burn triggers even more global warming. The most vicious of cycles.

We know, definitively, that the old planet "worked." That is, it produced and sustained a modern civilization. We don't know that about the new one.

The traditional way of imagining the effects of climate change is simply to list disparate data points—to go around the world inventorying the items that one scientist or another has managed to model and predict. In a sense, to list the symptoms. So:

- Engineers in Dublin are convinced that higher tides caused by climate change are eroding the famous O'Connell Bridge that spans the River Liffey at the foot of the Irish capital's main thoroughfare.[85]
- A state of emergency was declared in the Marshall Islands late on Christmas Eve in 2008, as widespread flooding displaced

hundreds of islanders, the third time in two weeks that powerful storm surges had swamped the main cities of Majuro and Ebeye, each of which sits less than three feet above sea level. The floodwaters not only damaged houses and roads but also destroyed cemeteries.[86]

- "Tick drags" across my home state of Vermont are finding these agents of Lyme disease alive in the forest even in January and February. In the spring of 2008, the state entomologist Jon Turmel found thirty to forty ticks on his pant leg after walking twenty feet along the Connecticut river valley in the village of St. Johnsbury. He described the tick population in the area as "extreme." Indeed.[87]
- The residents of Ocean Isle Beach, North Carolina, are spending as much as thirty thousand dollars each to place giant sandbags in front of their homes in an effort to ward off the ocean. "There used to be a street in front of our house, and then a row of cottages," says Lisa Schaeffer. After Tropical Storm Hanna her home stood just five yards from the sea.[88]
- Along the Yukon River in Canada, warmer water has made Chinook salmon "more susceptible to the parasite *Ichthyophonus*. Subsistence farmers must now catch 150 salmon to yield 100 usable ones," according to a Natural Resource Defense Council study.[89]
- Reduced winter ice cover means that evaporation will proceed year-round, and hence the water level in Lake Erie could fall between three and six feet in the next seventy years, making shipping difficult (for every inch the lake drops, a commercial ship must leave behind 270 tons of cargo) and shifting the shoreline several miles in Sandusky Bay.[90] Moreover, the range of the official Ohio state symbol, the buckeye tree, may shift north, out of the state entirely and into the territory of its college football archrival, Michigan.[91]

- A Harvard study found that ragweed grows 10 percent taller and produces 60 percent more pollen as the temperature warms.[92]

The other time-honored method for communicating this kind of news is to find individual victims and share their stories, in the hope that narrative will accomplish what statistics can't. We don't pay much attention to poor people, so it can astonish us to read stories of just how hard life has become, like the ones John Vidal collected for London's *Guardian* in the fall of 2008.

- "Juan Antonio's eyes are full of tears," Vidal reports. "If good rains do not come, he says, he will pack his bag, kiss his wife and two children goodbye, and join the annual exodus of young men leaving hot, dry, rural northeast Brazil for the biofuel fields in the south." Droughts in the region are longer and more frequent now than in the past. "Climate change is biting," a Brazilian agronomist named Lindon Carlos tells him. "It is much hotter than it used to be and it stays hotter for longer."
- "It's far warmer now," says one Bangladeshi villager in the Deara district, whose only name is Selina. "We do not feel cold in the rainy season. We used to need blankets but now we don't. There is extreme uncertainty of weather. It makes it very hard to farm and we cannot plan. The storms are increasing and the tides now come right up to our houses."
- "Tekmadur Majsi farms in the upland Nepali village of Ketbari," Vidal writes. "Small floods once a decade or so are routine, but now they've grown larger and more common." Majsi is not hopeful for the future. "We always used to have a little rain each month, but now when there is rain it's very different. It's more concentrated and intense," he tells the reporter. "It means crop yields are going down."[93]

Vidal's reporting is not unique. Eliza Barclay of the *Miami Herald* traveled to the Cordillera Blanca, eleven thousand feet up in the Peruvian Andes, where she met a man named Gregorio Huanuco, who farmed as his ancestors had for generations. In 1990 Huanuco began to notice change: "a battering hailstorm, two months without rain, a warm winter. Then the quirky weather became more consistent and other oddities began to appear: rats nibbling away at his cereal crops and a fungus blanketing his potatoes." Huanuco's way of life was slipping away. "Before we planted all year long, any month we wanted to," he said. "Now we only get water a few times a year and so we cannot plant as much, and the pests and diseases keep coming."[94]

Or consider what Ben Simon, a reporter for Agence France-Presse, found on the slopes of Mount Speke, one of Uganda's highest peaks. The snowcap was almost gone, and farmers trying to eke out a living have to climb farther up the hill each year to find a climate cool enough to grow their beans. He quoted Nelson Bikalnumuli: "People just keep moving up, up, up. I fear soon we may be on top of each other."[95]

In Haiti, where an unprecedented four fierce hurricanes hit in quick succession in 2008, Marc Lacey of the *New York Times* found a mother living with her six children on a roof in the city of Gonaïves. "At the main cathedral, the water rushed in the front door, toppling pews and leaving the place stained with mud and smelling of sewage," he reported. "Upstairs, dozens of people have taken refuge, huddled together on the concrete floor. When a visitor arrived, they rubbed their bellies and pleaded for nourishment."[96]

Or perhaps you have a hard time identifying with poor peasants stranded in impoverished villages. Consider, then, the story of the MV *Nautica*, a stately liner of the Oceania Cruise company, in whose thousand-square-foot suites "every inch is devoted to your pleasure," with "euro-top mattresses," forty-two-inch plasma screens, wraparound teak verandas, and "a second bathroom for guests." (The ship's spa offers an "exotic lime and ginger salt glow with massage," or, more worryingly, an "exotic coconut rub and milk ritual.") Anyway, the *Nautica* set off on its thirty-two-day "Odyssey to Asia" in the summer of 2008 but had to scrap "three magical days in the capital of the former British colony of Burma," after Cyclone Nargis wrecked both the nation and its image. "Considering the destruction, we said, no, not a wise move to be scheduling a call there," one mate explained. But the compensating longer stay in Mumbai was scrapped, too, after terrorist attacks, and then cruising through the Gulf of Aden the ship was attacked by pirates who fired eight shots. "We didn't think they would be cheeky enough to attack a cruise ship," said Wendy Armitage of Wellington, New Zealand. So the *Nautica* reset course for the Maldives, where nothing bad happened.[97] Although the same month the liner was in port, the president of the Maldives announced that his low-lying nation was planning to save a billion dollars annually from its tourist income so that it could buy land and relocate the population to Sri Lanka or Australia before the ocean finally rose too high for its survival. "We will invest in land," he said to CNN. "We do not want to end up in refugee tents if the worst happens."[98] The Maldives weren't alone, by the way. A few months later the Pacific island nation of Kiribati announced a similar plan.[99]

The trouble with this endless collection of anecdotes, though, is that it misses the essential flavor of the new world we're constructing. Every individual problem, even if it's impossible to endure, is fairly simple and straightforward. The temperature rises, and the buckeye tree migrates north. The temperature rises, and the hurricanes get more frequent and you starve. The temperature rises, and the level of the ocean comes up and it floods your cemetery and you really can't live on your island anymore. The temperature rises, and even in the Mandara Spa on the Salon Deck, it's hard to imagine that "the nimble fingers of an able masseuse will soothe away all the cares of the world."[100] Simple, understandable.

In truth, though, our new planet is much more complex and interesting. It's not just that the things we used to do are getting harder; it's that these initial and obvious effects lead us into a series of double and triple binds that make *any* action hard. We don't really know where to turn, because the planet we now inhabit doesn't work the way the old one did. Sometimes the irony couldn't be clearer. We've already seen that the far North is melting fast. As the sea ice goes, the albedo, or reflectivity, of the Arctic changes, with the mirror of white ice replaced by sun-absorbing blue. And the permafrost melts, and the methane escapes, and peat bogs dry out and add to the load of carbon. But something else happens, too. All of a sudden you can start drilling for gas and oil in these places. The Arctic, by some estimates, may hold 20 percent of the planet's undiscovered reserves, not enough to hold off peak oil for very long but enough to guarantee one more pulse of carbon into the atmosphere.

Now try a slightly more complicated problem. We've been burning down rain forests for a long time to create cheap agricultural land in the Amazon, and that obviously puts carbon into the atmosphere. It was enough of a worry—remember all those "save the rain forest" concerts in the 1990s?—that Brazil started enforcing its conservation laws, and the rate of loss began to ebb. But as those holes grew beneath the Middle East, and oil became more expensive, the market for biofuels strengthened. All of a sudden soybean farmers started pushing deeper into the jungle; deforestation jumped 64 percent in 2008 as oil prices rose.[101] One observer reported watching "bulldozers operating like Panzer divisions leveling and burning forests."[102] Meanwhile, Britain's Meteorological Office released new research in November 2008 (the same week, in fact, as the IEA report on declining oil supplies), which showed that climate change was producing drier conditions over much of the region, making the rain forest more prone than ever to natural fires—within a decade much of southeast Amazonia would be in the zone of higher fire risk.[103] Those fires produce even more carbon, and by destroying the forest they also remove a natural sink for carbon. What is left behind is a hotter, drier clearing: African research shows that the daytime temperature in the soil above a cleared patch is eight degrees higher than in the nearby forest, and the humidity is 49 percent, compared with 87 percent in the forest.

Something like that appears to be what's happening across the tropics. In the Amazon, reports the researcher Peter Bunyard, "already we are seeing parts of the Basin drying out and forming savanna, with its drought-tolerant shrubs and grasses, in what may well be the beginnings of a savannizing process that could lead to desertification."[104] In normal times—that is, on the old earth—the Amazon managed to move water much farther inland from the oceans than the rain would normally fall. The first swath of jungle gets wet, and then transpires the moisture through its leaves, forming new clouds that produce new rainfall farther west—all in all, a series of six pulses that move the ocean's bounty all the way to the Andes. The energy involved is prodigious—the equivalent of 4 million or more atomic bombs' worth a day. The forest, in essence, is "a gigantic irreplaceable water pump," in Bunyard's phrase, which in turn powers much of the planet's current air circulation system, taking "energy out and away from the Amazon basin to the higher latitudes, to the more temperate parts of the planet. Argentina, thousands of miles away from the Amazon Basin, gets no less than half its rain courtesy of the rainforest, a fact that few, if any, of the Argentinian landowners are aware of. And in equal ignorance the U.S. receives its share of the bounty, particularly over the Midwest." In fact, studies show that rainfall over the Amazon Basin is paralleled, four months later, by spring and summer rain across the U.S. corn belt.[105]

All of this is wildly complicated. It is perhaps enough to say that the Amazon is one of our planet's largest physical features, and it is far more vulnerable than we'd assumed, both to the onslaught of deforestation for food and biofuels, and to the changes in temperature that we've kicked off. The net result of the various forces, Bunyard says, will be a "much-diminished rainfall regime over the Amazon," with "rapid forest dieback and death." Oh, and as that happens, the decomposition of all the old forest "may well lead to more than 70 gigatons of carbon escaping as carbon dioxide into the atmosphere."[106] Instead of the "lungs of the planet" sucking in carbon and breathing out oxygen, the great green jungle turns into one more smokestack.

But the Amazon is far away, mysterious. You've more likely been to the high forests of the North American West, to the Rockies and the Sierras—probably driven the Road to the Sun at Glacier Park, or motored over Donner Pass. Certainly you've looked at Ansel Adams's photographs—this is our iconic idea of the wild. These ranges are also, like the poles or the Amazon, key natural features on which we depend. As the *Sacramento Bee* once described it, the Sierra is "a giant water faucet in the sky, a 400-mile-long, 60-mile-wide reservoir held in cold storage that supplies California with more than 60 percent of its

water, much of it when it's needed most: over the hot, dry summer months."[107] Already that snowpack has shrunk by more than 10 percent, with the forecast that it will shrink as much as 40 percent more by midcentury and as much as 90 percent by century's end.

But let's not speculate; let's just focus on what has already happened: "Temperatures have warmed during winter and early-spring storms," noted one study. "Consequently the fraction of precipitation that fell as snow declined, while the fraction that fell as rain increased." And when rain falls in the winter in the Sierras, bad things happen—the massive New Year's Day flood in 1997, for example, when rain fell as high up the mountains as eleven thousand feet and the ensuing deluge resulted in disaster declarations for all forty-six counties in northern California. California's four wettest winters on record have come since 1996; in 2008 the state's energy planners started conducting drills for dealing with epic floods that forecasters say are becoming ever more likely.[108] Something else happens when the snowpack melts early—the sun now has time to dry out the forest, guaranteeing a longer fire season and drier trees.[109] In fact, the average California fire season runs seventy-eight days longer than it did in the 1970s and 1980s; it used to start in June and end in September, but now the Forest Service hires firefighting crews in the middle of April, and they are often still working into November and December. Half the National Forest Service budget is now spent extinguishing fires: "The agency is no longer the U.S. Forest service but rather the U.S. Fire Service," one congressman complained.[110]

As with hurricanes, it's not just more fires but bigger ones. On average, large fires now burn four times as long as a generation ago, and in recent years three-quarters of the bad fires across the West came in years when the snow melted well ahead of schedule. "We're getting in a place where we are almost having a perfect storm" for wildfire, said one Forest Service official. And, of course, it all feeds back on itself. The Moonlight fire, in September 2007 near Lake Tahoe, burned for two weeks and in that time pumped an estimated 5 million tons of carbon dioxide into the atmosphere, the same as 970,000 cars driving for a year, the same impact as a coal-fired power plant. "The intensity of the fire was pretty spectacular," the incident commander told Tom Knudson of the *Sacramento Bee*. When it was over, even the soil was incinerated, making it hard for the conifer forest to return. Researchers now believe that more large fires will lead to thinner, scrubbier woods, and indeed, black oak, whitethorn manzanita, and other brush species are rapidly expanding across parts of the Sierra that once grew mostly pine. One result? Western forests, which are currently responsible for 20 to 40 percent of total U.S. carbon sequestration, may soon become a source of carbon dioxide, not a sink for the gas.[111] Another, just as depressing: the biggest trees, the largest living things on earth, are disappearing. A Yosemite study found in 2009 that the "density of large-diameter trees in the forest" has fallen by a quarter in recent decades. "These large, old trees have lived centuries and experience many dry and wet periods," one researcher said. "So it is quite a surprise that recent conditions are such that these long-term survivors have been affected." The decline could "accelerate" as the climate warms, the study adds.[112]

Let's move a few hundred miles east, to the spine of the Rockies, where trees are dying in incredible numbers. Partly it's chronic; heat stress and lack of water have doubled the "background mortality" of trees in the area.[113] But there's also acute trouble. By 2008 Wyoming and Colorado alone housed more than three million acres of dead trees.[114] In the next five years, Colorado expects to lose another 5 million acres—virtually every lodgepole pine larger than five inches in diameter. Farther north, in British Columbia, 33 million acres of lodgepole have already turned from green to rust-red, all dead. The culprit is the mountain pine beetle, Latin name *Dendroctonus*, which translates as "tree killer." Once the beetle drills into the bark, the tree gives off a white, waxy resin in an attempt to seal the insect in its hole. But the attacker can give off a pheromone that draws swarms of other beetles. Eventually the tree is overwhelmed.[115] "The scope and scale of the destruction is like nothing we have ever seen," says Jay Jensen, executive director of the Council of Western State Foresters. "We're seeing the end of some forests as we know them."[116]

Why is it happening? Because we've raised the temperature enough that the beetles can overwinter more easily. Milder winters since 1994 have reduced the winter death rate of beetle larvae in Wyoming from 80 percent per year to less than 10 percent.[117] You need stretches of thirty or forty degrees below zero up in the mountains to kill off the beetles, and that doesn't happen much anymore. (In Glacier National Park, for instance, only 25 of the 150 glaciers that were there in 1850 still exist, and all of them are shrinking rapidly.)[118] Meanwhile, hotter, drier summers have made trees weaker and less able to fight off the swarming beetles. And what is the result? All the obvious things: greatly increased fire risk, followed by mudslide and erosion. Dead trees falling on roads and toppling power lines. In Colorado and Wyoming, officials closed thirty-eight campgrounds so trees wouldn't drop on tents. And a kind of despair. "It's really something to see," a Utah state forester said. "You would be very surprised. It's hard to describe until you see it—it's just dead trees as far as the eye can see."[119]

Oh, and this you'd never guess: lots more carbon flooding into the atmosphere. A study in the journal *Nature* in the fall of 2008 offered this tally: during outbreaks of pine beetle infestation, "the resulting widespread tree mortality reduces forest carbon uptake and increases future emissions from the decay of killed trees." Since these outbreaks are "an order of magnitude larger in area and severity than all previous recorded outbreaks," the impact "converted the forest from a small net carbon sink to a large net carbon source."[120] Indeed, in early 2009 the Canadian government, which had long argued that its carbon-sequestering forests should count against its tar-sand burning in UN tallies of its carbon dioxide output, quietly dropped the claim. Now that the trees have died, timber companies want to log them off, but environmentalists have pointed out that that would in turn release much of the carbon stored in the peaty soils beneath the trees, igniting what one called a "carbon bomb." By some estimates, Canada's forests alone contain 186 billion tons of carbon, or the equivalent of twenty-seven years of global emissions from burning coal and gas and oil.[121]

Once trends like this get rolling, we can't slow them. We don't know how to refreeze the Arctic or regrow a rain forest. Here's what it looks like: in the last six years, as warming temperatures and drought have killed off the native vegetation that holds soil in place, windstorms have dumped twice as much dust across the American West.[122] In April 2009, after the biggest of the storms blew through Silverton, Colorado, one witness said the landscape "looked like Mars.... You could feel the dust, you could taste the dust." But as usual the damage reverberates. The storms drop huge quantities of dirt on the snowpack of the Rocky Mountains, darkening the white ice and significantly speeding up its melt. "It's effectively like turning the sun up fifty percent," explains one University of Utah professor.[123] The snowpack now melts "weeks earlier than normal," according to Scott Streator of Greenwire, which spells "disaster for thousands of farmers and ranchers in the region who depend on slowly melting snow to provide water" flows over the dry summer months.[124] "A lot of the water's gone by the time the crops need it," one researcher explained.[125]

So let's review. The planet we inhabit has a finite number of huge physical features. Virtually all of them seem to be changing rapidly: the Arctic ice cap is melting, and the great glacier above Greenland is thinning, both with disconcerting and unexpected speed. The oceans, which cover three-fourths of the earth's surface, are distinctly more acid and their level is rising; they are also warmer, which means the greatest storms on our planet, hurricanes and cyclones, have become more powerful. The vast inland glaciers in the Andes and Himalayas, and the giant snowpack of the American West, are melting very fast, and within decades the supply of water to the billions of people living downstream may dwindle. The great rain forest of the Amazon is drying on its margins and threatened at its core. The great boreal forest of North America is dying in a matter of years. The great storehouses of oil beneath the earth's crust are now more empty than full. Every one of these things is completely unprecedented in the ten thousand years of human civilization. And some places with civilizations that date back thousand of years—the Maldives in the Indian Ocean, Kiribati in the Pacific, and many other island nations—are actively preparing to lower their flags and evacuate their territory. The cedars of Lebanon—you can read about them in the Bible—are now listed as "heavily threatened" by climate change.[126] We have traveled to a new planet, propelled on a burst of carbon dioxide. That new planet, as is often the case in science fiction, looks more or less like our own but clearly isn't. I know that I'm repeating myself. I'm repeating myself on purpose. This is the biggest thing that's ever happened.

And the attempt to make it right usually makes things worse.

Sometimes the loops are almost comical. Versace is building a new hotel in Dubai, for instance, but the beach sand now gets so hot that guests burn their feet. Solution: a "refrigerated beach." As the hotel's founder explained, "We will suck the heat out of the sand to keep it cool enough to lie on. This is the kind of luxury top people want."[127]

Sometimes it's not shake-your-head funny but almost unavoidable. As more and more of Australia desertifies, the country could find itself "using 400 percent more energy to supply its drinking water by 2030 if the policy trend towards seawater desalination were to continue."[128]

And often—usually in the poor world—it's simply tragic. "Drinking water in Bangladesh is often full of salt as rising sea levels force water further inland," a Dhaka newspaper reporter wrote recently. That means women have to trek ever farther for a pitcher of clean water—sometimes several trips of several miles a day. "Some reports claim women and adolescent girls no longer have enough time and energy to carry out household duties like cooking, bathing, washing clothes and taking care of the elderly and infirm. It is even affecting their marriage prospects and family lives. Families who struggle to get clean water don't want daughters to leave their homes and marry elsewhere." Adolescent girls forced to drink increasingly saline water found their skin was "turning rough and unattractive," and "men from outside the area had no interest in marrying them."[129]

That's life on our new planet. That's where we live now.