Heat Index

30 million

Number of people who live in extreme heat today (above 85 degrees mean annual temperature)

2 billion

Number of people who are likely to live in extreme heat in 2070

1 mile per year

Average speed at which land animals are moving to higher, cooler latitudes

2.5 miles per year

Average speed at which malaria-carrying mosquitoes are moving to higher, cooler latitudes

210 million

Increase in number of people facing acute food insecurity since 2019

21%

Loss in global agricultural production in last 20 years due to climate-driven heat and drought

250,000

Annual worldwide deaths from firearms

489,000

Annual worldwide deaths from extreme heat

THE HEAT WILL KILL YOU FIRST

Fuckin' heat…I…oh, man, I just…can't…fuckin'…
make it!

—Michael Herr, *Dispatches*

PROLOGUE: THE GOLDILOCKS ZONE

WHEN HEAT COMES, it's invisible. It doesn't bend tree branches or blow hair across your face to let you know it's arrived. The ground doesn't shake. It just surrounds you and works on you in ways that you can't anticipate or control. You sweat. Your heart races. You're thirsty. Your vision blurs. The sun feels like the barrel of a gun pointed at you. Plants look like they're crying. Birds vanish from the sky and take refuge in deep shade. Cars are untouchable. Colors fade. The air smells burned. You can imagine fire even before you see it.

In the summer of 2021, weathercasters in the Pacific Northwest warned people that a heat wave was on the way. Workers in Washington's Yakima Valley were summoned to cherry orchards at 1 a.m. so the ripe fruit could be picked before it turned to mush. Air-conditioning contractors were deluged with calls. Electric fans sold out at Home Depot and Lowe's. The Red Cross activated its heat alert network,

blasting out warnings to people to drink water and check on family and friends who lived alone. Libraries and churches set up cooling centers for the homeless or anyone who needed refuge. In Portland, Chris Voss, the emergency management director for Multnomah County, decided to open the Oregon Convention Center, which was capable of providing a cool retreat for hundreds of people. "What's coming is not just uncomfortable heat," Jennifer Vines, the lead health officer for the region, advised Voss. "This is life-threatening heat."

Nevertheless, the heat hit with a force that few people anticipated. The Pacific Northwest, after all, has long been seen as a climate refuge. It was the place you moved to if you wanted to live somewhere that was "safe" from climate change. There are beaches and lakes and stately trees and volcanic soil where anything grows, from blueberries to boxwood to grapes that are crushed into world-class Pinot Noir. There are glaciers in the Cascades and lush temperate rain forests in Olympic National Park and more than a few fragments left of the Edenic paradise that pulled so many settlers over the Oregon Trail. In the 1970s, Steve Jobs picked apples on a farm in the region and loved it so much he named a computer company after it. Heat wave? No big deal. This was not Phoenix, where heat owns the city. Or New Delhi, where heat is both a goddess and a demon. In the Pacific Northwest that summer, everyone might have known the heat was coming, but nobody thought it would be a searing, ghostly force that would melt asphalt and kill loved ones and force a new reckoning with the world they live in.

The heat wave had been born over the Pacific a week or so earlier. Atmospheric waves wobbled across the Northern Hemisphere, creating a high-pressure lid that allowed heat radiating up from the ocean to gather beneath it. As this pile

of heat drifted to the coast, it grew quickly in size and intensity (land reflects and amplifies heat much more efficiently than water), creating what scientists called a heat dome. In a twenty-four-hour period, the temperature in downtown Portland jumped from 76 degrees to 114 degrees, the hottest temperature in 147 years of observations.[1] Suddenly, the ferny salamander-land of the Northwest felt like the hard-baked steel and sand of Dubai.

Ice, nature's most exquisite thermometer, registered the heat first. The last of the winter snow in the Cascades vanished from shady hollows in the forests and atop the glaciers near the peaks. With the protective snowpack gone, the blue glacial ice itself began to melt, rushing down streambeds and canyons in a swirl of silty gray water, carrying ancient sediment from before the fossil fuel age, before books, before the pyramids. The rush of meltwater flooded roads and towns as it rolled down to the rivers and out to the sea. In the Columbia River, which is the largest river in the Northwest, crisscrossing seven states and covering over 250,000 square miles, the wash of sediment was so enormous that satellites circling the Earth photographed a gray plume flowing several miles into the Pacific.

In streams and rivers, migrating salmon immediately sensed the changes in water temperature. They had spent three or four years in the cold, salty Pacific and now were swimming upstream in freshwater back to where they were born to lay eggs and begin the cycle anew. The salmon's journey is one of the great wonders of nature. But it is also a fragile one. Warm runoff in the rivers—shallow water can heat

[1] Unless otherwise noted, all temperature references in this book are in Fahrenheit.

up quickly as it flows down out of the mountains—made it difficult for the struggling salmon to breathe (the warmer the water, the faster oxygen molecules vibrate with kinetic energy, allowing them to flee their molecular bonds and escape into the air. "It leaves fish feeling like they are breathing with a plastic bag over their heads," one wildlife biologist told me). Their iridescent silvery skin broke out in red lesions. Cottony puffs of fungus grew on their backs. Some escaped to cooler tributaries. But tens of thousands of others, exhausted and suffocating and literally disintegrating in the warmth, became meals for other fish or washed up on the riverbanks, where they were picked apart by racoons and eagles.

In the mountains and valleys, every plant and tree was assaulted by the heat, rooted in place and unable to move, creators of shade that were themselves unable to seek refuge. As the temperature rose, they struggled with the heat just as humans do, trying to preserve water while the sun and the heat sucked it out of the soil and the flesh of their leaves and trunks. All across the Pacific Northwest there was a great clenching as the plants closed the pores on the undersides of their leaves, in effect holding their breath, hoping the heat would pass quickly. Blackberry and blueberry plants drank the moisture out of their own fruit, leaving it dry and withered on the stalk. On broadleaf trees like ash and maple, leaves brittled and curled. As temperatures rose, some of the most sun-exposed trees opened their pores, desperately trying to cool off by sweating. Their roots worked to pull water out of the dry soil, but instead sucked air bubbles into the veins that ran up their trunks, causing them to rupture. If you'd had the right kind of microphone, scientists say, you could have heard the trees screaming.

In the mountains, bighorn sheep headed for higher

elevations. Doves rested on shady branches and opened their wings to aerate their bodies. And like dogs, they panted. Baby hawks, hot and fuzzy in their nests, faced the choice of overheating with their siblings or jumping out before they were ready to fly. Many jumped. Dozens of fluttering, broken bodies were found by hikers and taken to wildlife rehabilitation centers.

For some animals, however, these were good times. Caterpillars basked in the heat to kill pathogens in their bodies. Maggots hatched in the mouths of the dead salmon on the riverbanks. For pine bark beetles, an invasive species that is decimating western forests, the heat was like guzzling Red Bull. Their metabolism revved up, their appetite grew, and they moved like a marauding army through thousand-acre stands of Jeffrey pines.

In the cities and suburbs, air-conditioning units whirred. Overloaded power lines hummed and sagged. In the grid control centers, dispatchers sent urgent messages to power companies, who fired up idle natural gas plants, which can quickly generate electricity (and profits) during desperate times. In Oregon's Multnomah County, outdoor sporting events and concerts were canceled. Volunteers made thousands of calls to check in on disabled people and senior citizens. In Vancouver, British Columbia, police answered a surge of calls from people with difficulty breathing or in cardiac arrest. Sirens wailed and hospital emergency rooms were crowded with panting, red-faced people. Desperate to lower their body temperatures as quickly as possible, doctors filled body bags with ice and zipped them inside.

Vivek Shandas, a professor of urban studies and planning at Portland State University, drove around in his Prius with his eleven-year-old son, Suhail, measuring the temperature in

different parts of the city. In Lents, one of Portland's poorest neighborhoods, where trees are few and concrete is plentiful, Shandas measured an air temperature of 124 degrees, the highest temperature he had ever recorded in fifteen years of chronicling heat. "When I stopped and opened my car door, the first thing I felt was my eyes burning," Shandas recalled. "My skin was on fire. It just feels like you're melting." He drove to Willamette Heights, a tree-lined suburb with parks and lots of greenery where the median house price is about $1 million. He measured the air temperature again: 99 degrees. In a heat wave, wealth can afford twenty-five degrees of coolness.

Nobody knows for sure how many people died during the seventy-two hours of extreme heat in the Pacific Northwest. The official count was 1,000, but heat is a subtle killer and doesn't always make it onto death certificates. The actual number is likely far higher. Whatever the true toll was, it certainly included Rosemary Anderson, sixty-seven, whose neighbor had texted her, "Good night, sleep tight, may you find lots of angel wings upon your pillow," the night before she was found dead in her house, where the indoor temperature measured 99.5 degrees. It also included Jollene Brown, sixty-three, who lived alone in an apartment a few miles away from Anderson, who was found by her son Shane sitting in her La-Z-Boy rocker with one foot on the footrest, one foot on the floor, as if she'd been about to stand up but couldn't because of the wall of heat in her tiny un-air-conditioned living room. As with most heat waves today, the people who died first were elderly folks who lived alone, or who were too poor to afford air-conditioning, or who had a medical problem that left them vulnerable. In this sense, a heat wave is a

predatory event, one that culls out the most vulnerable people. But that will change. As heat waves become more intense and more common, they will become more democratic.

Even before this heat wave hit the Pacific Northwest, the forests were burning, dried to tinder by years of rising heat and declining rainfall. But in British Columbia, the heat brought something like spontaneous combustion to Lytton, an old mining camp (pop. 250) at the confluence of the Fraser and Thompson Rivers where First Nations people have lived for thousands of years. In the 1970s, the town was reborn as a whitewater rafting mecca due to its proximity to the spectacular flow of water through the black granite walls of Thompson Canyon. On the third day of the heat wave, temperatures in Lytton reached an unholy 121 degrees. Lorna Fandrich remembers looking out the window at the Chinese history museum in town—an institution she and her husband founded to commemorate and honor the Chinese workers who built the railroad and worked in the mining camps—and seeing leaves dropping off a tree, as if it were an autumn day, though it was only June. "I thought, *How strange,*" she said later. Then wind kicked up and a spark jumped out from the steel wheel of a passing freight train. Within minutes, the town was aflame. Mayor Jan Polderman raced his Honda minivan through the village, begging skeptical residents to flee. He picked up one of the last stragglers, a man running down a road with his cat in a cage.

Jeff Chapman, who lived with his parents outside of town, was just starting to cook dinner when he saw the smoke and fire approaching. "Ten minutes later, our house was fully engulfed," he said. "There was nothing we could do. We had nowhere to go." As the blaze swallowed the house and the trees around it, Chapman rushed his parents, who were both

in their sixties, into a trench that had been dug a few days earlier to repair a septic system. It wasn't big enough for all three of them, so he grabbed a sheet of metal roofing nearby and laid it over them. Then he took refuge on some nearby railroad tracks, hoping the fire would pass.

That's when the power line crashed down across the trench where his parents were sheltering. "I knew my parents were in that hole and I'm watching the house burn and I'm thinking, *Oh my God*." Chapman survived the inferno. His parents did not.

A few days later, as if by some miracle, it was blue skies and cool weather again in Lytton. The entire town was smoldering, burned to the ground. A few pieces of porcelain pottery survived in the ashes of the Chinese history museum. Douglas fir trees on the edge of town looked like black spears. There were grief and horror about what had happened, and vows to rebuild. Meanwhile, out on the coast, limp starfish and the shells of mussels and clams washed ashore by the millions. Chris Harley, a zoologist at the University of British Columbia, estimated that the three-day heat wave killed more than a billion sea creatures.

But as June came and went and summer turned to fall, life went back to normal, and the memory of the heat wave faded, as memories of heat waves always do, until they become like the fleeting images of a nightmare you're not quite sure you had. Or a future you don't want to imagine.

You probably think of heat on a temperature scale, either Fahrenheit or Celsius. You think of it as a gradual, linear thing, a quality of the air around you that moves up and down in increments, or that can be controlled by a thermostat. Seventy degrees is a little hotter than 68 degrees, which

is a little hotter than 65 degrees. The change of seasons also plays into this incremental perception of heat—winter gradually warms into spring, spring into summer. Yes, there are some days that are noticeably hotter or colder than others, but we crank up the air-conditioning or throw on a sweater. We trust it will pass and things will return to normal. Temperature is a merry-go-round that we are used to riding.

This sense of incrementalism also holds true with the climate crisis. The Earth is getting hotter due to the burning of fossil fuels. This is a simple truth, as clear as the moon in the night sky. So far, thanks to 250 years of hell-bent fuel consumption, which has filled the atmosphere with heat-trapping carbon dioxide (CO_2), global temperatures have risen by 2.2 degrees since the preindustrial era and are on track to warm by 6 degrees or more by the end of the century. The more oil, gas, and coal we burn, the hotter it will get.

Right now we're more than halfway to 3.6 degrees (2 degrees Celsius) of warming from preindustrial temperatures, which scientists have long warned is the threshold for dangerous climate change. The reports of the UN's Intergovernmental Panel on Climate Change are full of harrowing details of what might happen to our world with 3.6 degrees of warming, from collapsing ice sheets to crop-killing drought. But to nonscientists—which is to say, most humans on the planet—3.6 degrees of warming does not sound dangerous at all. Who can tell the difference between a 77-degree day and an 81-degree day? Then there are social media trolls who argue that extreme cold kills people and causes all kinds of weather-related problems too so maybe a hotter world isn't such a bad thing after all. Even the phrase "global warming" sounds gentle and soothing, as if the most notable impact of burning fossil fuels will be better beach weather.

The difficulty of understanding the consequences of heat is amplified by conventional notions of what it means to be hot. In pop culture, hot is sexy. Hot is cool. Hot is new. Websites publish "hot lists" of the latest books, movies, TV shows, and actors. Facebook started in Mark Zuckerberg's Harvard dorm as a hot-or-not website called Facemash, which ranked the attractiveness of Harvard women. Heat is an expression of passion—you feel hot for the guy at the bar or engage him in a heated debate. A person who is quick to anger is hot-blooded. Near the house where I live in Austin is a gym called Heat Bootcamp. Here, sweat is purifying, a sign of inner strength (a throwback to medieval times, perhaps, when heat was linked to masculinity through what philosopher Thomas Aquinas called "the elemental heat of the semen") . In Miami, one of the hottest cities in the US, where heat is a lethal threat to outdoor workers and where the city regularly floods due to rising seas caused by the melting ice sheets of Greenland and Antarctica, the basketball team is named, without irony, the Miami Heat.

In this book, my goal is to convince you to think about heat in a different way. The kind of heat I'm talking about here is not an incremental bump on the thermometer or the slow slide of spring into summer. It is heat as an active force, one that can bend railroad tracks and kill you before you even understand that your life is at risk. Scientists don't fully understand how fast this heat can move or where it will appear next (until it happened, a killer heat wave in the Pacific Northwest seemed about as likely as snow in the Sahara). But there is one thing scientists do know: this is a form of heat that has been unleashed upon us through the

burning of fossil fuels. In this sense, extreme heat is an entirely human artifact, a legacy of human civilization as real as the Great Wall of China.

The amount of heat generated by our consumption of fossil fuels is difficult to grasp: by one measure, the ocean absorbs the equivalent of the heat released from three nuclear bombs every second. And because CO_2 stays in the atmosphere for thousands of years, it's not going to cool off when we finally stop emitting CO_2 into the atmosphere. All that will do is stop the *increase* in warming. It will not reverse it. Until we figure out a way to suck massive amounts of CO_2 out of the sky, we will be stuck with a hotter planet.

This heat we are pumping into the sky is the prime mover of the climate crisis. The climate impacts you hear about most often, from sea-level rise to drought to wildfires, are all second-order effects of a hotter planet. The first-order effect is heat. It is the engine of planetary chaos, the invisible force that melts the ice sheets that will flood coastal cities around the world. It dries out the soil and sucks the moisture out of trees until they are ready to ignite. It revs up the bugs that eat the crops and thaws the permafrost that contains bacteria from the last ice age. When the next pandemic hits, the chances are good it will be caused by a virus that leapt from an animal that was seeking out a cooler place to live.

As a force, heat is mysterious because its effects are both slow and fast. Think of parched wheatfields, slowly dried out by months of heat that pulls moisture out of the ground and spits it into the sky. Then think of heat waves that are the cosmic equivalent of a bug zapper that kills you before you understand what's happening. Extreme heat penetrates every living cell and melts them like a Popsicle on a summer

sidewalk. It reverses evolution, driving entropy and disorder. It is the widening gyre that the poet W. B. Yeats wrote about[2], an extinction force that takes the universe back to its messy beginnings. Before there was light, there was heat. It is the origin of all things and the end of all things.

You don't need to be a Hollywood screenwriter to imagine how our world will be changed by extreme heat. A few things are self-evident.

As the temperature rises, it will drive a great migration — of humans, of animals, of plants, of jobs, of wealth, of diseases. They will all seek out cooler ecological niches where they can thrive. Some will fare better than others. Robins can migrate more easily than elephants. Poison ivy can move more quickly than an oak tree. Farmers who grow wheat have more options than farmers who grow peaches. And some creatures have nowhere to go. Polar bears in the Arctic can't migrate farther north. Frogs in Costa Rica aren't going to hop up to Canada.

Humans are better off than many plants and animals. With the help of technology, we can adjust to a lot of things. As one architect told me, "If you have enough money, you can engineer your way out of anything." And in some ways, he's right. If we can send photos through the air and drive a rover around on Mars, we can design new ways to live in hot places. You can see it happening right now in Paris and Los Angeles and many other cities around the world, where shade trees are being planted and streets painted white to deflect sunlight. Plant geneticists are developing new strains of corn and

[2] The opening lines of Yeats' "The Second Coming," written in 1919, soon after the end of World War I: "Turning and turning in the widening gyre/ The falcon cannot hear the falconer/Things fall apart; the centre cannot hold"

wheat and soybeans that can better tolerate high temperatures. Air-conditioning is becoming cheaper and more widely used. Communication from public health officials about how to protect yourself during a heat wave is improving. Clothing companies are developing new high-tech fabrics to reflect away sunlight and dissipate heat more quickly.

But even for the wealthy and privileged, adaptation to extreme heat has its limits. And the notion that eight billion people are going to thrive on a hotter planet by simply cranking up the air-conditioning or seeking refuge under a pine tree is a profound misunderstanding of the future we are creating for ourselves. In western Pakistan, where only the richest of the rich have air-conditioning, it's already too hot for humans several weeks a year. Planting a few thousand trees is not going to save them. In India, I talked with families who live in concrete slums that are so hot they burn their hands opening doors. Holy cities like Mecca and Jerusalem, where millions gather on religious pilgrimages, are caldrons of sweat. In the summer of 2022, nine hundred million people in China—63 percent of the nation's population—suffered under a two-month-long extreme heat wave that killed crops and sparked wildfires. "There is nothing in world climatic history which is even minimally comparable to what is happening in China," one weather historian declared.

In a world of heat-driven chaos, heat exposes deep fissures of inequity and injustice. Poverty equals vulnerability. If you have money, you can turn up the air-conditioning, stock up on food and bottled water, and install a backup generator in case there's a blackout. If things get bad enough, you can sell your house and move to a cooler place. If you're poor, on the other hand, you swelter in an uninsulated apartment or trailer with no air-conditioning or an old, inefficient machine

that you can't afford to run. You can't move somewhere cooler because you're afraid of losing your job and you don't have the savings to start over. "We're all in the storm, but we're not in the same boat," Heather McTeer Toney, the former mayor of Greenville, Mississippi, said during testimony before the US Congress. "Some of us are sitting on aircraft carriers while others are just bobbing along on a floatie."

Solomon Hsiang, an economist and climate scientist at the University of California, Berkeley, and the codirector of the research group Climate Impact Lab, calculates that each degree Celsius of warming will erase 1.2 percent of America's GDP per year, or about $300 billion. Heat lowers children's test scores and raises the risk of miscarriage in pregnant women. Prolonged exposure increases death rates from heart and kidney disease. When people are stressed by heat, they are more impulsive and prone to conflict. Racial slurs and hate speech in social media spike. Suicides rise. Gun violence increases. There are more rapes and more violent crime. In Africa and the Middle East, studies have found a link between higher temperatures and the outbreak of civil war.

The harshest truth about life on a superheated planet is this: as temperatures rise, a lot of living things will die, and that may include people you know and love. A study in *The Lancet,* a prestigious medical journal, estimated that 489,000 people worldwide died from extreme heat in 2019. That's far more than all other natural disasters combined, including hurricanes and wildfires. It is also more than the number of deaths from guns or illegal drugs. And those are only the deaths that are directly attributable to heat. There are also deaths caused by the heat-related amplification of ground-level ozone pollution (aka smog), or the smoke from wildfires in desiccated forests. The smoke can drift thousands of miles, lofting tiny

particulates into the atmosphere. When you inhale them, they can trigger a variety of health problems, from asthma to heart attacks. The toll is enormous: globally, between 260,000 and 600,000 people die each year inhaling smoke from wildfires. Smoke pollution doesn't only kill people near fires either. Wildfires in western Canada have been directly linked to spikes in hospitalizations three thousand miles away on the East Coast of the US.

Earth's history is full of wild temperature swings, driven by volcanic eruptions, meteor strikes, and geologic mayhem. There have been palm trees in the Arctic and two thousand feet of ice over New York City. But for the last three million years or so, while humans evolved, the climate has been relatively stable. Stable enough, anyway, that our ancestors could migrate, adapt, and thrive.

But those days may be over. The last time the Earth was hotter than it is today was at least 125,000 years ago, long before anything that resembled human civilization appeared. Since 1970, the Earth's temperature has spiked faster than in any comparable forty-year period in recorded history. The eight years between 2015 and 2022 were the hottest on record. In 2022, 850 million people lived in regions that experienced all-time high temperatures. Globally, killer heat waves are becoming longer, hotter, and more frequent. One recent study found that a heat wave like the one that cooked the Pacific Northwest is 150 times more likely today than it was before we began the atmosphere with CO_2 at the beginning of the industrial age. The ocean, which hundreds of millions of people depend on for their food supply and which has a big influence on weather, was the hottest ever recorded in 2022. Even Antarctica, the coldest place on Earth, is not immune. In March of 2022, a heat

wave invaded the ice-bound continent, pushing temperatures seventy degrees—*seventy degrees!*—above normal.

Extreme heat is remaking our planet into one in which large swaths may become inhospitable to human life. One recent study projected that over the next fifty years, one to three billion people will be left outside the climate conditions that gave rise to civilization over the last six thousand years. Even if we transition fairly quickly to clean energy, half of the world's human population will be exposed to life-threatening combinations of heat and humidity by 2100. Temperatures in parts of the world could rise so high that just stepping outside for a few hours, another study warned, "will result in death even for the fittest of humans."

Life on Earth is like a finely calibrated machine, one that has been built by evolution to work very well within its design parameters. Heat breaks that machine in a fundamental way, disrupting how cells function, how proteins unfold, how molecules move. Yes, some organisms can thrive in higher temperatures than others. Roadrunners do better than blue jays. Silver Saharan ants can run across superhot desert sands that would kill other insects instantly. Microbes live in 170-degree hot springs in Yellowstone National Park. A thirty-year-old triathlete can handle a 110-degree day better than a seventy-year-old man with heart disease. And yes, we humans are remarkable creatures with a tremendous capacity to adapt and adjust to a rapidly changing world.

But extreme heat is a force beyond anything we have reckoned with before. It may be a human creation, but it is godlike in its power and prophecy. Because all living things share one simple fate: if the temperature they're used to—what scientists sometimes call their Goldilocks Zone—rises too far, too fast, they die.