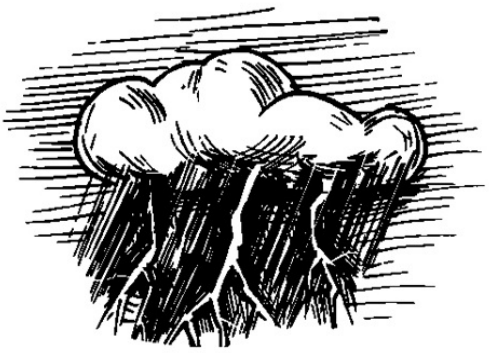

YOUR CHANCE OF BEING HIT BY A LIGHTNING BOLT OVER THE COURSE OF A LIFETIME IS ONLY 1 IN 600,000.

THE FAHRENHEIT SCALE IS CONSIDERED ANTIQUATED BY SCIENTISTS, WHO USE THE CELSIUS SCALE INSTEAD.

A CRASH COURSE IN UNDERSTANDING THE WEATHER

WEATHER 101

FROM **DOPPLER RADAR** AND **LONG-RANGE FORECASTS** TO THE **POLAR VORTEX** AND **CLIMATE CHANGE,** EVERYTHING YOU NEED TO KNOW ABOUT THE **STUDY OF WEATHER**

IN THE WINTER OF 1780 THE POTOMAC RIVER FROZE OVER SO SOLIDLY THAT IT WAS POSSIBLE TO WALK ACROSS IT.

CIRRUS CLOUDS GENERALLY MOVE FROM WEST TO EAST AND OFTEN PREDICT AN APPROACHING LOW-PRESSURE SYSTEM, WHICH IS A GOOD HINT TO GO FIND AN UMBRELLA.

KATHLEEN SEARS

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Adams Media
New York London Toronto Sydney New Delhi

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INTRODUCTION

Lightning. Supercells. Blizzards. All of it's weather, and all of it affects your life. But what exactly *is* weather?

It's one of the most complicated and difficult-to-predict systems in existence. Since the beginning of the human race, people have tried to understand it in order to benefit from good weather and protect themselves from bad. Today's scientists have come a long way in predicting major weather events, but they still can't make accurate long-term forecasts.

This is despite the fact that there's a lot of information today about the weather: it's on television, on the radio, in newspapers, blogs, vlogs, and on *YouTube*. That's why many people want to know more about how weather works.

In *Weather 101* you'll find out such things as:

- The causes of storms such as hurricanes and tornadoes
- What the different kinds of clouds mean
- What terms like "high-pressure front," "the jet stream," and "El Niño" mean
- How to stay safe in a storm

Weather 101 will also tackle issues like pollution, acid rain, damage to the ozone layer, and climate change. The more you learn about the weather, the stranger things you'll find: from supercells to exotic lightning forms (called sprites, elves, and blue jets), from polar vortices to microbursts. Scientists have developed sophisticated devices to study and measure all these things and more; including not only instruments here on Earth but also weather satellites that can look at atmospheric changes from space. All of this helps them understand the complexity and ever-changing nature of weather systems—and relay this information to you so you can plan accordingly: everything from your vacation to when to start your drive to work in the morning.

If you're fascinated by the range of global weather patterns, if you want to learn about important weather-related disasters, or if you just

want to know how to cope with the weather in your area, you'll find the answers to your questions in *Weather 101*.

Knowing more about the weather isn't just important—it's *essential* in our rapidly changing world. It's time to get started.

WHY DO WE HAVE WEATHER?

Something We All Have in Common

"Don't knock the weather; nine-tenths of the people couldn't start a conversation if it didn't change once in a while."

—Kin Hubbard, US journalist, humorist

Simply put, weather is what's going on in the atmosphere in any one location at a particular time. Understanding weather allows us to plan our day, our vacations, and our crops. And it's a handy conversation starter.

WHY IT'S A BIG DEAL

In fact, weather is a complex and dynamic process driven by the Sun; the earth's oceans, rotation, and inclination; and so many other factors that many of its mysteries still remain unexplained. Being prepared for what the weather brings can be as simple as turning on the TV to catch the latest forecast before heading for the beach, or as complicated as examining long-range forecasts to decide which crops to plant. Weather constantly affects people in small ways, but weather can also have major consequences when hurricanes or tornadoes threaten their well-being and livelihoods, or even their lives.

The weather can even affect your health, especially during extremes in temperature or precipitation. If you're not dressed properly in cold weather, you can fall victim to hypothermia, which occurs when the body's core temperature drops below the point where things function normally. The flip side of hypothermia is hyperthermia, where the body's core temperature rises too high. Hyperthermia can cause heat exhaustion or even heat stroke, which can be fatal.

A Cold? Or Allergies?

During the summer, a stuffy nose and postnasal drip may have you convinced you're suffering from a cold. But the same symptoms may be due to allergies. Remember that colds last an average of three to seven days, while allergic reactions can go on for ten days to several weeks. If you're still miserable after a week, chances are you've got allergies.

Weather can also affect your health in less obvious ways. Long spells of gray winter weather can lead to seasonal affective disorder (SAD), a malady that causes depression and a debilitating lack of energy; it's thought to be caused by lower light levels during the winter as the days become shorter and the Sun rises lower in the sky. Many arthritis sufferers complain of worsening symptoms when atmospheric pressure falls, and there is a statistical rise in the number of heart attacks after abrupt weather changes such as passing storm fronts.

THE BIG PICTURE

On a larger scale, weather plays a big role in the economic health of every nation on Earth. A timely soaking rain can rescue a crop from ruin, while a sudden torrential cloudburst can wash it away. And farmers aren't the only ones at risk; those who depend on natural gas for heat often watch in dismay as a particularly cold winter sends prices skyward. Hurricanes can drive tourists away from areas that depend on a regular influx of visitors for their livelihoods. Even a gentle phenomenon like fog can result in disaster, as the captains of the *Andrea Doria* and the *Stockholm* learned one fateful July night in 1956. And during the Dust Bowl of 1936, one of the hottest and driest summers ever recorded, more than 15,000 people died of malnutrition and dust-related diseases.

Ancient Hurricanes

Scientists look for evidence of ancient hurricanes in a branch of science called paleotempestology. Evidence of past storms can be found in coral skeletons, sediments from the ocean bottom, and even in caves, where stalactites retain the chemical signatures of abrupt cloudbursts caused by tropical cyclones.

With a growing realization of the weather's importance and so much weather news readily available on TV and the Internet, it's no wonder that

interest in the subject is soaring. It seems that almost every day a weather disaster is happening somewhere in the world. Yet it’s important to remember that extreme weather events, from droughts to hurricanes, have been happening for millennia, long before there were cameras to record them or buildings and people to get in their way.

One of the reasons weather is so compelling is because it is universal: snow falls just as heavily on poor neighborhoods as it does in well-to-do suburbs, and a flash flood can destroy both mansions and shacks with equal force. Weather is the one thing everyone has in common.

WEATHER AND CIVILIZATION

A Historical Force

Ancient people did their best to understand and predict the weather. Lacking modern scientific instruments, early civilizations observed nature and kept records of the seasons. They understood how important the Sun was for growing their crops, which explains why many ancient cultures worshiped sun gods. In Mesopotamia the Babylonians counted on the weather gods Hadad and Marduk to bring them good harvests. The Hittites left the weather-producing chores to their primary deity, Teshub; while in Greece, a violent thunderstorm meant that the weather god Zeus was throwing a thunderbolt tantrum.

As far back as 1800 B.C., Hindus in India counted on their weather god, Indra, who carried a lightning bolt, to command the weather from his perch atop a large white elephant. In Scandinavia, Norse god Thor protected farmers and serfs from weather disasters.

EARLY FORECASTS

Around 580 B.C., the philosopher Thales of Miletus is said to have issued the very first seasonal crop forecast based on past olive harvests. According to legend, Thales was so confident of his forecast that he reserved the use of all the olive presses in his area before the harvest and made a tidy profit leasing them back to farmers when the bumper crop arrived.

The first real effort to gather all known weather information into one place was accomplished by the philosopher Aristotle around 350 B.C. In his essay “Meteorologica” the philosopher correctly guessed that the Sun put large masses of air into motion, and that water vapor could condense into clouds. But Aristotle was hamstrung by his era’s notion that everything was made of four elements: fire, water, air, and earth. His attempts to force

those elements to agree with the realities of nature limited his investigations. The other fallacy of his time was the belief that the earth was the center of the universe, which made it impossible to correctly explain the origin of the seasons.

Naming a Science

Aristotle's largest contribution to weather science was the term "meteorology," which we still use today. The word comes from the Greek *meteoros*, which means "high in the sky." In Aristotle's day anything falling from or appearing in the sky (like rain or clouds) was called a meteor.

False Tales

Some people still depend on folklore for weather safety, but many of the beliefs that have been passed down through the generations are misconceptions. For instance, some still insist the major danger from a hurricane is the wind, when most victims actually die in storm-spawned flooding.

Aristotle's pupil Theophrastus picked up his teacher's work, writing a journal called *On Weather Signs* that noted how nature can often be used to forecast the weather. He also established a link between the weather and certain kinds of illnesses, and was the first person in recorded history to identify sunspots.

For the next 2,000 years, the science of meteorology went dormant. Without accurate instruments to predict developing weather conditions or even measure the basic elements, weather forecasters leaned on folklore or nature for advice on planting crops and avoiding weather disasters.

LEARNING TO PREDICT THE WEATHER

Evolution of a Science

Things started falling back into place in the sixteenth century when Nicolaus Copernicus appeared on the scene. In 1543 he presented the theory that the Sun, not Earth, was at the center of the universe. Although still incorrect, his theory at least made room for an explanation of the seasons, and he correctly deduced that Earth rotated on its axis once a day and made the long trip around the Sun once each year. This was a scandalous and shocking idea at the time, because it contradicted religious dogma and suggested that man was just a part of nature, instead of being superior to it.

Leonardo da Vinci was fascinated by the weather. He noticed that a ball of wool weighed more on a rainy day than on a dry one, and further experiments led to his invention of the hygrometer, a device to measure the amount of water suspended in the air. Da Vinci wasn't content to measure the air's water content; he also invented the anemometer, which measures wind speed.

Even though the air's moisture level and speed now could be measured, for most of the sixteenth century no one could tell you how hot it was, because there were no thermometers yet. Enter Galileo Galilei, who remedied the thermometer shortage in 1593.

Galileo called his invention a thermoscope. It consisted of a long-necked glass bottle that was placed, upside down, into a vessel containing water. When the bottle was heated slightly, usually by the warmth of the experimenter's hands, the air inside expanded and the water was pushed downward. When the bottle cooled, the air contracted and the water rose back up into the neck of the bottle. Unfortunately, the thermoscope had no degree markings and was useless for determining temperature, but it paved the way for the more accurate versions to come.

THE PRESSURE INTENSIFIES

Now one could tell how humid it was and how fast the wind was blowing, and could get a vague idea of the temperature. But what about the air pressure?

Evangelista Torricelli, a student of Galileo's, created the first mercury barometer to measure atmospheric pressure in 1644, completing the list of instruments needed to develop an accurate weather forecast.

Verifying a Vacuum

Aristotle's contention that "nature abhors a vacuum" could be debated but not tested until Torricelli created one inside his mercury barometer. Catholic Jesuits, alarmed by this breach of faith, theorized that the mercury was being held up by invisible threads. But by then there was no stopping the weather revolution.

A French mathematician, Blaise Pascal, theorized that if air had weight, it should exert less and less pressure the higher you went. In 1648 he convinced his brother-in-law, armed with one of Torricelli's barometers, to climb almost 5,000 feet up a mountain. Sure enough, the higher he went, the lower the mercury sank.

The first recorded weather observations in the New World were made by a minister named John Campanius Holm in 1644 and 1645. Some people consider Holm, who lived in the colony of New Sweden near Wilmington, Delaware, to be America's first weatherman. In fact the National Weather Service gives an award in his name to outstanding volunteer weather observers each year.

OPPOSING SCALES

Have you ever wondered why the United States uses a method of measuring temperature that's different from the one used by the rest of the world? Blame Daniel Gabriel Fahrenheit, a German instrument maker who, in 1714, came up with the temperature scale that bears his name. He based his system on the difference between the freezing point of water and his own body temperature. Sound arbitrary and confusing? Indeed.

Celsius Preferred

The Fahrenheit scale is considered antiquated by scientists, who use the Celsius scale instead and wish everyone else would too. Old habits die hard—it'll probably be some time yet before everyone's on the same page temperature-wise.

Not content to leave well enough alone, Swedish astronomer Anders Celsius proposed another method. He divided the freezing and boiling points of water into equal degrees, which he called the centesimal system. Celsius decided the boiling point of water would be 0°, and the freezing point would be 100°. That must not have made any more sense at that time than it does now, because after his death, the scale was turned upside down, creating the measuring system still used today.

In 1793, Englishman John Dalton wrote a book called *Meteorological Observations and Essays* in which he advanced the theory that rain is caused by a drop in temperature, not air pressure. Taking the next step, he realized in 1802 that temperature actually affects the amount of water vapor the air can hold, a concept now called relative humidity.

WEATHER AND WARS

When the Military Drove Forecasting

Looking back through the history of warfare, it's evident that weather has played no small part in effecting both victories and defeats. The winter of 1777–1778 was no exception, and General George Washington's Continental Army learned that the weather can be more deadly than any mortal enemy.

After being defeated by the British Army in two major conflicts, Washington's troops marched to Valley Forge, Pennsylvania, 25 miles northwest of Philadelphia, in December 1777. The army of about 11,000 men had little to eat and inadequate clothing, and lived in tents while they set to work building huts in which to weather the coming winter.

By all accounts, that winter was unusually severe. Conditions got so bad that Washington wrote at one point, "For some days past there has been little less than a famine in the camp. . . . Naked and starving as they are, we cannot enough admire the incomparable patience and fidelity of the soldiery, that they have not been, ere this, excited by their suffering to a general mutiny and desertion."

FORGING A VICTORY

Although a few soldiers did desert, the ones who stayed were fiercely loyal to Washington. By the spring of 1778, nearly a fourth of the soldiers had died of smallpox, typhoid fever, malnutrition, and exposure to the severe cold, but the remaining troops were hardened by the experience. In May 1778 word came of the new alliance between France and the United States, and the worst was over. Valley Forge marked the turning point in the war, and soon Washington and his men were chasing the British from Philadelphia.

Across the Frozen Potomac

The winter of 1780 was one of the worst on record. On the coast of Delaware's Delmarva Peninsula, ice formations towered 20 feet high, and the Potomac River froze over so solidly that it was possible to walk across it.

The French helped save the day at Valley Forge, but ended up with problems of their own years later during Napoleon's invasion of Russia and one of the largest weather-assisted routs in history.

WEATHER: RUSSIA'S SECRET WEAPON

In 1812, Napoleon controlled nearly all of Europe and had set his sights on Russia as his next conquest. In June of that year he crossed the Russian border with 600,000 troops and more than 50,000 horses, planning to march all the way to Moscow, living off the land along the way. The Russians had other ideas: as they retreated before the advancing French horde, they burned fields and destroyed houses, leaving little for the French to eat. Dry, hot conditions prevailed all the way to Moscow, and upon arriving there on September 14, the exhausted French troops found the city all but abandoned, its supplies depleted and much of its shelter destroyed. More than 20,000 troops had died of disease and exhaustion on the way, but the worst still lay ahead: winter was coming.

In the middle of October, with no offer of surrender from the tsar, Napoleon finally ordered a retreat. He had waited too long. As the weary troops turned toward home, an early and unusually cold air mass descended over them, and the weakest soldiers began to die.

Germans versus Russians

The weather has been Russia's ally in repelling foreign invaders throughout recorded history. In 1242 the pope sent German Teutonic Knights to take control of Russia and convert its people to Roman Catholicism. But Russian troops were more accustomed to the severe winter conditions and defeated the Germans on the frozen channel between the Peipus and Pskov Lakes in what became known as the "massacre on the ice."

Suddenly the weather turned warmer again, and roads that had been frozen solid turned into muddy quagmires. Streams and rivers that had been solid ice were now raging torrents, slowing the retreating troops even more. Then as quickly as the warm weather had arrived, it was replaced by

an even colder air mass, and thousands more died in the driving snow and subzero temperatures.

In early December, Napoleon’s troops finally crossed back over the border into Poland, but of the 600,000 fighting men who had invaded Russia just six months earlier, fewer than 100,000 remained. Half a million people had died in the Russian winter’s icy embrace.

WORLD WAR II

Weather's Important Role

From the very first battle marking America's involvement in World War II, weather played a major role. On November 26, 1941, a fleet of four aircraft carriers and several other ships under the command of Admiral Isoroku Yamamoto steamed away from Japan toward Oahu, Hawaii, twelve days and 4,000 miles away.

Most of the trip was very difficult, with high seas and cold, stormy winter weather, but the rough conditions helped the huge fleet avoid detection. When the ships finally anchored 220 miles north of Oahu on December 7, 1941, and prepared to launch a surprise attack on the US naval base at Pearl Harbor, America's entry into the war was certain.

THE ALLIES STRIKE BACK

For the next four months, most of the news coming from the Pacific theater was negative, with defeats at Bataan and Corregidor disheartening the American public and military alike. On April 18, 1942, commander Jimmy Doolittle and his squadron of sixteen B-25 bombers (still 200 miles from their intended launch point) took off from the deck of the brand new aircraft carrier USS *Hornet* and turned toward Tokyo, more than 700 miles away.

Forced to take off early after the fleet was sighted by a Japanese patrol boat, the B-25s lumbered off the deck of the USS *Hornet* in a light rain. The B-25s had been stripped of any unnecessary equipment in order to carry more fuel, but on the way to Japan, they encountered a 20-mile-per-hour headwind that accelerated their fuel consumption. Arriving over Tokyo, the Raiders loosed volleys of 500-pound bombs on war-industry targets and then turned north along the coast toward China, where they hoped to find refuge.

It soon became obvious that the bombers wouldn't have enough fuel to make it to the Chinese airfields due to the headwinds they had encountered earlier. The situation got even worse when they encountered fog over the East China Sea, followed by a hard rain. With visibility near zero, navigators were forced to rely on dead reckoning to chart their course.

Suddenly, the winds shifted and the bomber crews found themselves being propelled by a strong tailwind. Still unable to see through the storm and low on fuel, most of the planes were forced to ditch in the ocean. In the end all sixteen B-25s were lost, seven men were injured, and three were killed. Eight crew members were taken prisoner by the Japanese, and only four of them survived the war. But the raid not only gave American morale a huge boost after several crushing defeats, it also dealt a shattering blow to Japanese pride.

THE PLOESTI RAID

In the summer of 1943, Operation Tidal Wave was launched from a Libyan airfield against Nazi-held oil refineries in Ploesti, Romania. Once again the weather would have a marked influence on the outcome. To reach the target and return, the mission's 179 B-24 bombers would have to fly more than 2,400 miles in eighteen hours. The flight over the Mediterranean was uneventful, with beautiful weather and unlimited visibility. Then, on reaching land, the bombers encountered a bank of huge cumulus clouds over the 9,000-foot peaks of the Pindus Mountains. Flying blindly through the clouds at 12,000 feet, the planes became separated into two groups, neither one aware of the position of the other.

Because one bomber group arrived over the target well in advance of the second, the late arrivals suffered heavy casualties since the Germans had been alerted to their presence. Although most of the planes were able to drop their bombs, many important targets were missed in the confusion. Of the 179 planes in the mission, only ninety-nine returned to base, and fifty-eight of the surviving planes suffered severe combat damage.

THE BEGINNING OF THE END

The end of the Third Reich began with the Allies' Operation Overlord, a culmination of years of planning that aimed for the invasion of Europe and