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AARON MILLAR

GREATEST WONDERS OF THE WORLD

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INTRODUCTION

Wonder is fine dining for the soul. There is no other animal on Earth, as far as we know, that can marvel at the planet like we can, that feels awe and humility, that is moved to tears by the sheer beauty of a sunset or the magnificence of the stars at night. Wonder is what makes us who we are. It drives us to explore, question and connect. And it is that impetus, to fill the world with all the possibilities of our imagination, which has carried us so far. Wonder is the pure joy of being alive. But we must nourish it for it to thrive. If this book aspires to one thing, it is this: live life to the full, celebrate your world and feed your spirit well.

Each wonder in this book is superlative in its own right: the largest, deepest, tallest, most audacious, beautiful, complex and awe-inspiring things on the planet. Some are man-made, some are natural; there are wildlife spectacles and human spectacles too. Many have never been included in a major compendium before. These are wonders not just of our past, but our future, too: the Large Hadron Collider, the most complicated machine ever built; the International Space Station, the greatest international peacetime collaboration in history; the Rio Carnival, the biggest party on the planet.

I hope to take you on a journey. I want you to feel what it's like to stand beneath the sweaty heat of the tallest waterfall on the planet or float on your back on the deepest lake in the world, 5,000 feet of darkness screaming up beneath you. I want to walk you up the freezing face of the tallest mountain on Earth; I want you to see 30,000-year-old cave paintings by our primitive ancestors and hear the thunder of a million wildebeest chasing rainbows across the Serengeti. Each wonder has a unique story to tell, each has mysteries hidden within.

But this is not just a list of sights; it's also a road map for discovering the greatest experiences of your life. I hope you'll travel

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with me: from your armchair, your commuter train, the pillow propped up on your bed. I hope you'll feel something of that spark of wonder as you read this book. But I also want to give you all the information that you'll need in order to follow that spark from these pages into the world for real. So, at the end of each chapter, I'll also tell you the best ways to visit these wonders for yourself and reveal the insider tips that will help you get the most out of your experience. From how to hear the 'sound of infinity' in the Taj Mahal to where you can swim up safely to the thundering edge of Victoria Falls.

Socrates said 'Wisdom begins in wonder'. Studies have shown that awe creates empathy and altruism; that it helps us connect with others and the world around us in meaningful and lasting ways. The experience of wonder is not just a fleeting passion; it is a seed from which the best things in life grow. And that's important. Because the more you look for wonder in the world, the more the wonder of the world becomes a part of you.

Wonder transcends all boundaries, nationalities and beliefs. It is a conduit to our past, our future and a sense of something greater than ourselves. It is the stuff that makes life worth living. But most of all, wonder is inside us, every time we look in awe at the world and realise that we are a part of that world too. Explore, dream and feed your soul well.

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THE 50 GREATEST WONDERS OF THE WORLD

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NORTH AMERICA

BRISTLECONE PINES, CALIFORNIA

Bristlecone Pines are the oldest living organisms on Earth. When the first stones of the Great Pyramids were being laid, Methuselah – the name given to what is perhaps the most ancient of these trees at more than 4,800 years old – already had its roots in the ground. They pre-date the birth of Christ, the fall of Troy, the invention of the alphabet.

But these remarkable trees are more than just gnarled wood and endurance. Written in the rings of their twisted, wind-battered trunks are the chronicles of their long life. And discovering those stories has led to surprising breakthroughs in our understanding of climate change, forest ecology and even the history of our own civilisation.

Adversity is their friend. Should they be nurtured with water and shelter they simply grow faster and die young. But give them an arid climate, exposed to the wind and cold, one that is too harsh for insects, disease and competition from other plants, and they will simply go on indefinitely. The oldest grove, where Methuselah itself is found, is more than 10,000 feet up in the parched White Mountains of California. Living branches are covered in thick green needles, which themselves survive for a staggering 40 years. The trees grow squat, to no more than 60 feet. As they age they thicken instead, spinning with each inch to strengthen their grain. And no two are alike. Each one has been whipped smooth by the endless scour of windswept sand and ice, like skeletal sculptures twisting up from the earth.

BRISTLECONE PINES, CALIFORNIA

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Photo: Rick Goldwasser

But it's the tenacity with which they cling to life that is most impressive. Scientists have recorded trees, entirely encased in dead wood, with less than 10 per cent still alive. A tiny sliver of bark connected to root will sustain a Bristlecone for centuries. And

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despite often being more dead than alive, the living parts of even the oldest trees have the health and vitality of newborns. Peer into their rings and the wood they produce on their thousandth birthday is as fresh and untainted by age as a sapling. Even in death they can remain standing for millennia.

But despite Methuselah's prodigious age, it is not, in fact, the oldest tree that has ever been recorded. That now infamous story belongs to a young geographer, who in 1964 while taking core samples got his borer stuck in a tree. To retrieve it, and salvage his research project, he cut it down. That tree, now named Prometheus, he later discovered, was around 4,900 years old, meaning he simultaneously found and killed the oldest living thing in the world.

But however inspiring it is to be in the presence of such antiquity, in the end it's what we're taught that matters most. Dead Bristlecone Pine wood can remain intact in the cold, dry climate of the White Mountains for thousands of years. Using a combination of living and fallen trees, scientists, beginning with Edmund P. Schulman, who discovered Methuselah in 1957, have now pieced together a continuous tree-ring chronology that extends back almost 10,000 years – to the end of the last ice age. Because the trees tailor their growth to temperature, their rings are like a thermometer frozen in time. By reading between the lines, literally, we can glimpse into the environmental conditions of our past and uncover patterns of climatic change that may help us predict the future. And it's not all good news: over the last 50 years Bristlecone rings have grown fatter than at any other time in the last 3,700 years. Our world, according to these old trees, is rapidly warming.

Bristlecone Pines are also known as the tree that rewrote history. For many years, scientists have used a technique called radiocarbon dating to establish a timeline for archaeological events. But the process needed calibrating. By correlating the amount of carbon-14 in samples of individual Bristlecone tree rings with existing radiocarbon data, scientists discovered that many previous historical estimates were wrong. Ancient artefacts found in Europe turned out to be 1,000 years older than previously thought; established theories of cultural diffusion were suddenly refuted; the development of civilisation itself was redrawn.

But perhaps we shouldn't be surprised at such wisdom. Bristlecone Pines were here when the first Native Americans spread

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across the continent; they stood sentinel to the rise and fall of Rome, Greece and the Incas. To be near them is to touch the resonance of that deep longevity with our own hands – as if our fingers might grasp a concept our minds could never fully comprehend. But they ask questions of our future too. The weathered old Pine that was a mere sapling when the Pyramids were built lived to see the atom split and man walk on the moon. But what of the tree that is just now taking root? What new secrets will be written, 5,000 years from now, in the rings of the oldest living thing on Earth?

WHERE: Ancient Bristlecone Pine Forest, White Mountains, California.

HOW TO SEE IT: The identity of Methuselah is kept secret in order to protect the tree from damage, but it can be found, along with dozens of other ancient Bristlecones, 10,000 feet up, somewhere in the Schulman Grove. For the best view, hike the four-mile Methuselah Trail from the Grove car park. Don't miss the Patriarch Grove as well, an otherworldly landscape of moon-like rock and desolate trees, eleven miles (and 1,500 feet in altitude) further up a dirt track.
www.fs.usda.gov/main/inyo/home

TOP TIP: Come at dusk when the setting sun makes the tannins of the trees glow bright red, orange and amber.

TRY THIS INSTEAD: The most ancient trees are found in California, but at more than 3,000 years old the Bristlecone Pines at Great Basin National Park in Nevada are no spring chickens either. A three-mile hike leads to a spectacular grove nestled on the side of Mount Wheeler.
www.nps.gov/grba/index.htm

THE GRAND CANYON, ARIZONA

There are few landscapes more inspiring and worthy of wonder than the Grand Canyon. At 277 miles long, a mile deep and up to eighteen miles wide, this kaleidoscopic red rock gorge of the Colorado River is nature at its most dramatic, humbling and unfathomably large. The

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poet Harriet Monroe called it ‘the abode of gods. It made a coward of me’. To stand on its rim is to grasp, in an instant, the insignificance of our short lives and, yet, the unimaginable beauty to which we bear witness.

It’s not the biggest canyon in the world. Tibet’s Yarlung Zangbo Grand Canyon is more than 30 miles longer and more than three times as deep. There are gorges in Peru whose walls would tower above it. But it’s surely the most spectacular. Amber rock spires rise up from the snaking Colorado River like stone totems. Brush-stroked cliffs of gold, orange and crimson shift with shadows and the changing mood of the day. Everything is stripped bare – like peering into the sinews of the Earth. At dawn, silence sullens the pink temple-buttes. At dusk, the rocks glow like embers of a great fire. This is a landscape of myths, as big as giants, too vast and uncontained to be real. On a clear day you can see for 100 miles and still only take a fraction in. And the more you look, the more you feel like you might simply float away.

But what makes this canyon Grand is more than just enlightening views. Written within its sheer 5,000-foot walls is the most complete geologic record on the planet. Nearly 2 billion years of natural history, close to 40 per cent of the Earth’s entire lifespan, is engraved in these narrow cliffs – from the formation of the first life forms, through the evolution of plants, fish and amphibians, to early mammals and finally us. It’s like a photocopy of time itself, a panorama of the past etched into stone.

But the Grand Canyon itself is a relative newbie. The Colorado River began carving into the bare rocks of the Colorado Plateau about 6 million years ago, descending 2,000 feet in its journey through the Canyon, gathering speed and tearing up boulders that scoured the exposed chasm like a knife. In times of extreme flood the river flows at 300,000 cubic feet per second – the equivalent of a skyscraper of water rushing through the gorge every single minute. At the close of the last ice age, as the glaciers were melting in the Rocky Mountains, there might have been three times that force.

As the river cut down into the Earth’s crust, it exposed layer upon layer of much older rocks, gradually revealing the tapestry of geologic time that we see today. From the Kaibab limestone at the top, laid down some 260 million years ago by an inland sea, through sandstone and shale to granite and Vishnu schist, formed 1.8 billion

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years ago, and now exposed at the river's bed. Each layer tells its own story: desert becomes sandstone, mud becomes shale, the skeletons of sea animals harden into limestone. Reading into the rocks we can see oceans advance and retreat, mountains rise and fall, deserts form and disappear. Fossils are everywhere: 500-million-year-old ocean-dwelling trilobites, footprints of scorpions, centipedes and dragonfly wings. But no dinosaur bones: even the most recent of these old stones were laid down before their time.

THE GRAND CANYON, ARIZONA

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Photo: Martin Wahr

And there's more than just rocks too. Within the Grand Canyon National Park there are sandy beaches and emerald pools, waterfalls and rapids surrounded by hanging gardens of honey mesquite, orchids and coyote willow; above the desert scrub and cacti, there are swathes of sagebrush and juniper and then higher still rich forests of ponderosa pine, spruce-fir, aspen and oak. Five of America's seven life zones are stepped into the Canyon's mile-high elevation.

There's history too. The first Westerner to set eyes on the Grand Canyon was the Spaniard García López de Cárdenas in 1540. John Wesley Powell survived a three-month ordeal rafting through it in 1869. But the true discoverers of the Canyon were the Native Americans who lived here for thousands of years before Europeans arrived. Petroglyphs colour the chasm walls, there are food stores cut high into the cliffs, 2,000-year-old split-twig figurines – willow branches carefully folded into animal shapes – have been found placed ceremoniously in remote caves. The oldest artefacts here date back almost 12,000 years – a continuous record of human habitation. Even the walking paths we use today were once native hunting trails and the two biggest tribes, the Hualapai and the Havasupai, still reside on reservations in and around the Canyon. For them, it is a sacred place. And it's become a sacred place for us too.

The writer J.B. Priestley said that the Grand Canyon is not 'a beauty spot, but a revelation'. Some landscapes leave an imprint on the soul. The Grand Canyon is the abode of the gods, a chronicle of deep time, a view that may just change your life.

WHERE: Grand Canyon National Park. The South Rim entrance is about 70 miles north of Flagstaff, Arizona.

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HOW TO SEE IT: The south rim is where 90 per cent of visitors go, so escape the crowds at the remote north rim, 44 miles south of Jacob's Lake, or by hiking, rafting or taking a mule trip into the canyon itself – a unique perspective that few visitors get to see.
www.nps.gov/grca/index.htm

TOP TIPS: One of the best places to watch the sunset is Hopi Point, but in the summer months it can get crowded. For a less congested view try Yaki and Pima Points on the south rim instead. On the north rim, many rangers recommend Point Imperial for a breathtaking, and crowd-free, sunrise.

TRY THIS INSTEAD: Antelope Canyon, just two hours north of the Grand Canyon in the Navajo Reservation, is one of the most spectacular slot canyons in the world. At the start and end of the day, the swirling red, pink and bright orange colours of the rock are mesmerising. Use an authorised Navajo guide to explore inside the narrow canyon walls.
www.navajonationparks.org

MAUNA LOA AND KILAUEA, HAWAII

Mauna Loa is the largest active volcano on Earth. Located in Hawai'i Volcanoes National Park, on the 'Big Island' of Hawaii, its gentle slopes belie its staggering enormity. More than 60 miles long and 30 miles wide, taking up roughly half of the island, it fills approximately 19,000 cubic miles of solid rock – 3,200 Mount St Helens could fit within its enormous frame. From sea level it rises to 13,680 feet, but its flanks continue underwater for a further 16,400 feet, and then depress the sea bed a further five miles down. The total height of Mauna Loa, from the start of its eruptive journey to its crater, is roughly 56,000 feet – almost twice the height of Mount Everest.

And it's still active. Since 1843 there have been 33 eruptions. The last was in 1984 when lava flows reached within four miles of the town of Hilo, forcing many residents to evacuate. When that happened, molten magma seeped through cracks in the Earth's crust and fireworked into the air, iridescent rivers of fire drained like spilt

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honey to the sea. Over the last 3,000 years Mauna Loa has erupted roughly every six years. She's been taking a nap for the last 30 years or so, but not for long.

The entire region is part of the Pacific Ring of Fire – a 25,000-mile band of intense seismic and volcanic activity stretching from the south-western tip of South America, upwards along the North American west coast and across to the eastern edges of Asia and Australia. Within its belt there are thought to be 452 volcanoes – the most active and deadly ones in the world.

But however big Mauna Loa is, or impressive her eruption will one day be, her sister still steals the show. Kilauea, just 25 miles east, is widely regarded as the most active volcano in the world. It's been erupting near continuously since 1983 – one of the longest running eruptions in history – and has covered nearly 40 square miles of the island in its lava flow. Right now, as you read this, it is more than likely bubbling an enormous cauldron of fire like some giant witch's brew.

Or more accurately, a goddess. Legend has it that Kilauea's smouldering crater is the home of Pele, the Hawaiian goddess of volcanoes. In local dialect her name is 'Ka wahine 'ai honua', the woman who devours the land. Eruptions are an expression of her fiery temper, and her longing to be with her love. But beware of the curse: it is said if you remove volcanic rocks from her island home, she will inflict bad luck upon you. Whether you believe the legend or not, hundreds of pieces of lava rock are mailed back to the island each year from travellers who claim to have suffered misfortune since they took a souvenir home.

But volcanoes are more than mere destruction. They are creators too. More than 80 per cent of the Earth's surface above and below sea level was formed by volcanic activity. Hawaii's islands are themselves the product of countless volcanic eruptions – and Kilauea and Mauna Loa are adding landmass to the chain every year. Gas from ancient eruptions may also have been instrumental in forming the first molecular building blocks of biology. Their fires may have warmed the primordial soup.

Volcanoes are testaments to the origin of the Earth. But they are also a reminder that those same forces are still shaping the planet today. The world is in a constant state of flux. Cycles of violence and creation have been spinning for aeons and will continue to do so

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long after we're gone. Mauna Loa and Kilauea are windows into the inner workings of the world – the largest and most active volcanoes on Earth, side by side, like sisters, fiery goddesses that will roar again one day.

MAUNA LOA AND KILAUEA, HAWAII

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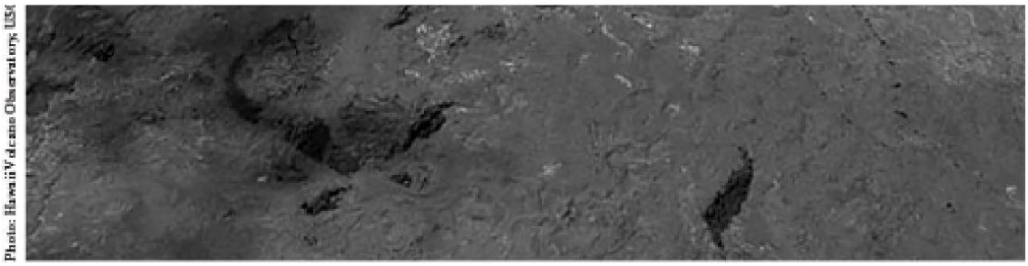

WHERE: Hawai'i Volcanoes National Park, Big Island, Hawaii.

HOW TO SEE IT: Take the Crater Rim Drive, or Chain of Craters Road, for the best lookouts into the Kilauea crater and other volcanic hot spots in the park. Then, if conditions permit, arrange for a private guide to show you where the lava flows into the Pacific Ocean – one of the most spectacular ways to see the world's most active volcano at work. For a true adventure camp at the summit cabin of Mauna Loa, but be prepared for a long hike, unpredictable weather and altitude sickness. The Mauna Loa Trail and the Observatory Trail are two of the most popular ways up. Register at the Kilauea Visitor Centre before setting off. March to November is the best season.
www.nps.gov/havo/index.htm

TOP TIPS: Come at night to see Kilauea's crater fire bubbling in the dark. Check the Hawaiian Volcano Observatory website for regular updates on Mauna Loa's eruption status.
http://hvo.wr.usgs.gov

TRY THIS INSTEAD: Iceland is one of the most volcanically active countries on Earth, with regular eruptions roughly every three to four years, some of which can be observed first hand. Or for something a little different, try going into a volcano itself. Thrihnukagigur Volcano has a hollowed out 400-foot deep magma chamber and is the only volcano in the world that you can explore inside.
www.visiticeland.com
www.insidethevolcano.com

METEOR CRATER, ARIZONA

Fifty thousand years ago a pinpoint of light appeared in the sky

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above what is now northern Arizona. Passing through the Earth's atmosphere it grew into a brilliant fireball, brighter than the sun, hurtling towards the ground at 26,000 mph – more than 30 times the speed of sound. The meteorite weighed 300,000 tonnes and was more than 150 feet across. As it struck the Earth it exploded with a force greater than 20 million tonnes of TNT – 1,000 times more powerful than the atomic bomb that destroyed Hiroshima. Shock waves swept across the plain, levelling forests and flinging mammoths, giant sloths and mastodons through the air. The ground melted instantly on impact. Earthquakes rippled across the land. A dense cloud of molten hot iron, nickel and burning pieces of rock rained down like a fiery mist.

This meteor crater may not be the largest in the world: that honour belongs to Vredefort Crater in South Africa, at 186 miles across, and more recently a still-to-be-confirmed discovery in the Warburton Basin of Australia, at 249 miles across. But most craters erode and gradually disappear over time: Vredefort is best seen from space, the Australian impact site was detected underground. This one is different. The high desert landscape that surrounds the crater has preserved the impact site in near perfect condition. It's like watching that moment of destruction, frozen in time.

The size alone is staggering. The crater reaches 550 feet deep, the equivalent of a 60-storey building, and over 4,000 feet wide. But perhaps most remarkable of all is the fact that somewhere underground there are microscopic fragments of rock and metal that originated in the depths of space. Being here is awe-inspiring, but a little frightening too. Asteroids have bombarded the Earth for aeons, and will continue to do so. Scientists estimate that dozens pass closer than our moon, undetected, every year. In 2015 one enormous, 1,800-foot wide killer passed within 300,000 miles of Earth – a hair's breadth in astronomical terms. The question is when, not if, a meteor will strike again.

METEOR CRATER, ARIZONA

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Photo: Dave Solis

But the crater is impressive for other reasons too. Its story begins when a local miner named Daniel Barringer heard tales of an enormous cavity in the Earth where pieces of metal could be found. Up to that point the scientific community were convinced the crater

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was caused by a volcanic eruption. But Barringer was beset by the idea that underneath that giant hole was a meteorite that contained enough iron to make its finder one of the richest men in the world. From 1903 to his death in 1929, he drilled, experimented and rallied the scientific community around his theory. But to no avail. It was only in 1960 when planetary scientist Eugene M. Shoemaker discovered two rare forms of silica on the site, coesite and stischovite, both of which do not occur naturally on Earth and can only be created through exposure to extremely high pressure, that Barringer's theory was finally vindicated.

It was a groundbreaking moment in scientific history, the first time a meteor crater had been conclusively discovered on Earth. It helped explain the large round craters that had been observed on the moon. It weighed in on theories about the extinction of dinosaurs, and became a vital stepping-stone in trying to understand the dynamic interplay of gradual and cataclysmic forces that have shaped our planet.

And Barringer's Crater is still aiding scientific discovery today. NASA astronauts use it for training. Interplanetary robots test their mettle on its rocky curves. And, by examining the gullies caused by erosion, it's teaching scientists how to better search for water on Mars.

But, perhaps, most amazing of all is just being there. To see, with your own eyes, the unfathomable forces that forged our world. To touch a direct line to the stars. Barringer's Meteor Crater is a stark reminder of the awesome power of the universe and our own fragility within it. Look up: you never know, that pinpoint of light might be hurtling towards us again soon.

WHERE: Near Winslow, northern Arizona.

HOW TO SEE IT: Take the guided rim tour for the best views and background on the impact site.
www.meteorcrater.com

TOP TIP: Stick around after the sun sets for dark skies and world-class stargazing.

TRY THIS INSTEAD: Wolfe Creek National Park in Western Australia is home to the second largest meteor crater in the world

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where fragments of a meteorite have been collected. It's also been extremely well preserved. Only accessible in the dry season, May to October, 93 miles south of Halls Creek via the Tanami Road.
https://parks.dpaw.wa.gov.au/park/wolfe-creek-crater

GIANT SEQUOIAS, CALIFORNIA

The General Sherman Tree, a Giant Sequoia found in the southern range of California's Sierra Nevada Mountains, is the largest living thing on the planet. At 52,500 cubic feet it's big enough to hold a concert for more than 2,000 people and still have enough room to wiggle. It weighs 2.7 million pounds. It stands 275 feet tall. Its branches can reach seven feet in diameter. Its bark can be more than two feet thick. It would take eighteen people linking fingertips at full stretch to circle it. They call it the General for a reason: it commands respect.

But General Sherman is just one tree. The Giant Sequoias themselves are the real wonder. John Muir, the legendary environmentalist and founder of the Sierra Club, called them 'the God of the woods'. Dark reddish-brown bark, blanketed in branches of evergreen needles, stretch up hundreds of feet, from a thick base to a bushy crown. They are the colossi of the living world. To walk among them is to have your neck craned, your ego levelled and your eyes filled with awe.

But there's not many left. Vast forests of Giant Sequoias, and their cousin the Redwoods – often confused, but distinct and equally impressive trees – once covered the entire northern hemisphere. The oldest known fossil records date them back to the time of dinosaurs. They look like giants because they come from a time of giants. To stand beneath them is to be dwarfed not just by their size, but by another era entirely.

Now Giant Sequoias can only be found along a thin 260-mile long, 15-mile wide corridor on the western slope of the Sierra Nevada. They are prodigious growers, but they are picky, requiring just the right amount of heat and cold to survive. Truly enormous trees, like General Sherman, also require thousands of gallons of water each day. Since the Sierra generally has dry summers this moisture is provided from the snowpack that accumulates higher in

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the mountains over the winter months and then soaks into the ground in spring. In this narrow band of life, usually between 5,000 and 7,000 feet in height, there is enough snowmelt to provide ample water, while at the same time not being too high and too cold in winter, nor too low and too warm in summer.

They owe their enormous size to their resilience. They are simply too big to blow over. Their thick bark is rich with tannins, which helps protect, and insulate, them against fire, insects and disease. And should a branch or two get burnt off, they have the unusual ability to simply sprout a new one. As much as 95 per cent of a Giant Sequoia's foliage can be decimated through fire and yet they can carry on growing for centuries. Which they do: many of the largest living Sequoias today are thought to be between 2,000 and 3,000 years old. Muir called them: 'near immortal' and he was nearly right. They're big, simply because nothing can take them down.

But their greatest threat today is man. Native people lived among these trees for more than 8,000 years without cutting a single one down. Then, in the mid-19th century, the gold rush came. The first official record of a Sequoia sighting was in 1852 by Augustus T. Dowd. That old tree, now named the Discovery Tree – the remains of which can still be seen in Calveras Big Tree State Park – was cut down a year later. Its stump was so large that it was used as a dance floor. Historical sketches depict couples in ball gowns and tuxedos prancing improbably on top of an enormous felled tree. But, thankfully, the wood of these giant trees was generally too brittle for full-scale construction projects and by the 1920s the logging of Giant Sequoias had largely stopped.

But a new threat has now emerged. Giant Sequoias are on the front line of climate change. Drought, increasing temperatures and decreasing levels of snowpack are all bad news for these forest giants. If we don't act quickly the next generation of colossi may never crane our necks and fill our eyes with wonder.

GIANT SEQUOIAS, CALIFORNIA

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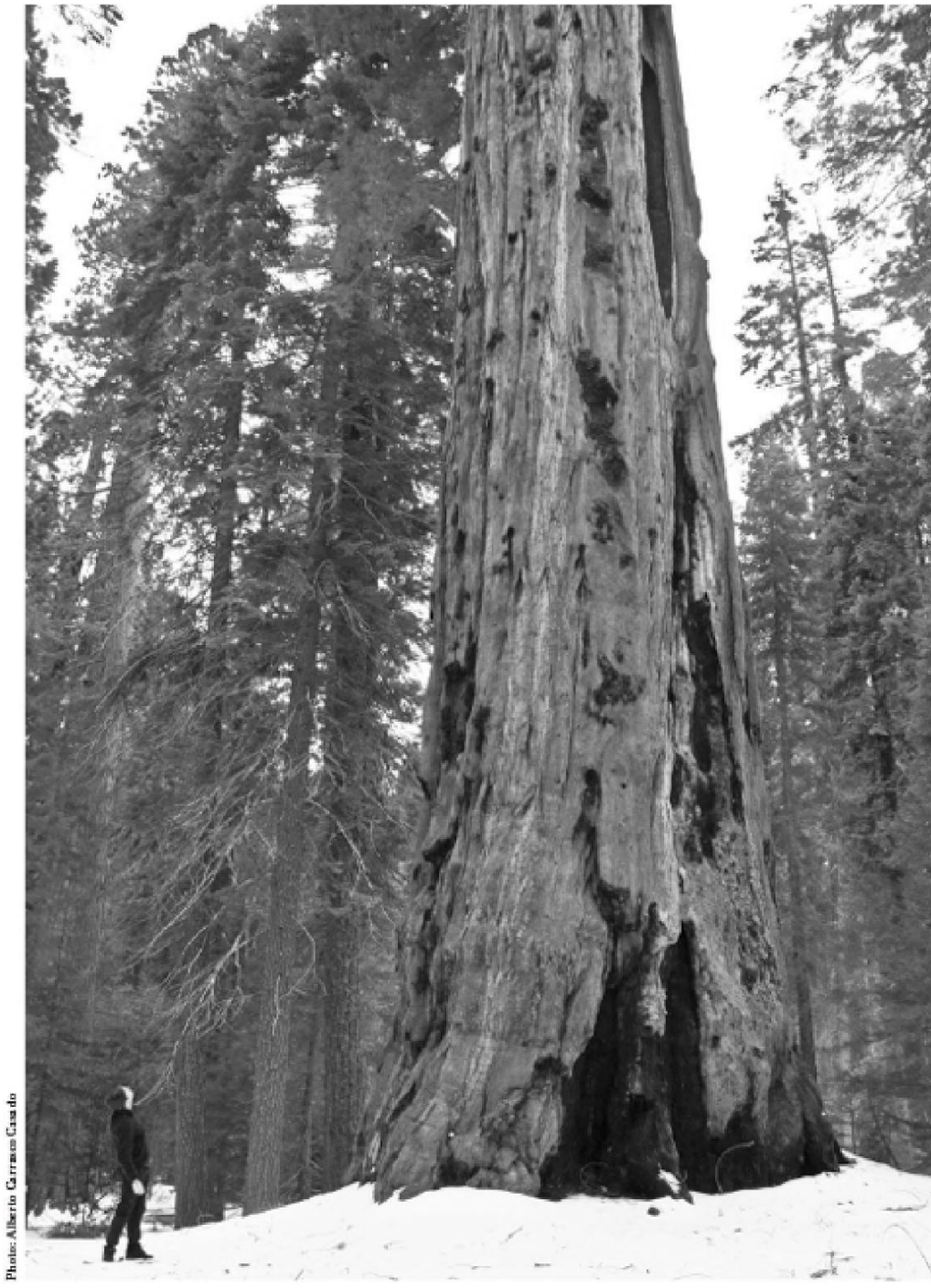

Photo: Alberto Carrasco Casado

WHERE: Sequoia & Kings Canyon National Park, near Fresno, California.

HOW TO SEE IT: The Giant Forest, a grove of Sequoias set within

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the national park, is the home of General Sherman and offers the best access to the biggest trees – including five of the ten largest on the planet.
www.nps.gov/seki/index.htm

TOP TIP: When photographing the giant trees, put a person in the frame to give the image a sense of scale.

TRY THIS INSTEAD: Coastal Redwoods, otherwise known as Giant Redwoods, are an equally impressive tree species. While Sequoias are the largest by volume, Redwoods are the tallest – with the current record standing at about 380 feet tall, or roughly the equivalent of a 35-storey building. They also require very specific climatic conditions and exist only in a narrow band along the Pacific Coast where coastal fog and a humid climate act like steroids on their growth rate. See them at Redwoods National and State Parks, and other reserves, along the Californian coast.
www.nps.gov/redw/index.htm

YELLOWSTONE GEYSER BASIN, WYOMING, MONTANA AND IDAHO

Covering 2.2 million acres of Wyoming, Montana and Idaho, Yellowstone, founded in 1872, is America's first national park and the inspiration for wilderness preservation everywhere. Grizzly bears, wolves, elk and bison make their home here. It is one of the last great wildernesses on the continent, a symbol of the boundless freedom of the old American West, and part of one of the most intact temperate ecosystems on Earth. But what makes Yellowstone a wonder of the world has nothing to do with that. It's what's happening below ground that counts.

In the early 19th century, when the first mountain men and fur trappers began returning from the far reaches of the still wild west, they brought stories home of a magical landscape where the Earth bubbled and giant fountains of boiling water exploded into the air. They were dismissed out of hand as myth. But following expeditions later that century, the reports were confirmed. Yellowstone really was magic. In fact, it's the largest active geyser basin on the planet.

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There are more than 10,000 hydrothermal features here, including the world's biggest concentration of geysers, more than 300, as well as the highest density of hot springs, mud pots and steam vents anywhere on Earth.

Old Faithful, named by early explorers for her clockwork eruptions every 90 minutes or so, is the star of the show: a giant plume of superheated water that erupts as much as 180 feet into the air. But its fame rests on its reliability. Giant Geyser nearby can reach 250 feet, but is infrequent. Steamboat Geyser, in the Norris Basin, is the world's tallest with eruptions up to 300 feet, but during its long dormant periods you may have to wait decades to see it.

But, in truth, the real wonder of Yellowstone is no particular feature by itself, but the geyser basin as a whole. Within the two square miles of the upper section alone there are nearly one-quarter of all the geysers on Earth. Thermal jets shaped like beehives and castle turrets, spouts that bubble like fountains or shoot like guns into the air. Walk around and you'll find super-heated pools of pure sapphire, boiling pots of gloopy, cinnamon coloured mud and scorching water tapestries of green, amber and gold.

Near to Old Faithful and the geyser basin is the Grand Prismatic Spring, the largest hot spring in the USA: dark blue, cyan and turquoise waters, 370 feet wide, ringed by layered lines of yellow, orange and deep red like a rainbow fallen to Earth. And then 50 miles further north is another wonder, the terraces of Mammoth Hot Springs, where mineral-rich water, heated deep underground, rises through cracks in the Earth and solidifies into multi-coloured travertine sculptures, like an enormous abstract art installation.

The aesthetics are mind-blowing, but what's truly amazing is that all these thermal worlds are alive. Microscopic bacteria and algae, called thermophiles, thrive in these extreme conditions, creating vivid colours as they feed in distinct, narrow bands of heat. Blue for archaea – an entirely new kingdom of life, discovered in the late 1970s, surviving at 93°C; yellow for bacteria at 75°C; green, algae at 60°C; orange, protozoa at 56°C. These are the artists of Yellowstone. They are among the most prevalent and least understood organisms on Earth. But they are helping us to solve some of the greatest mysteries of our time.

The key to unlocking the DNA code was discovered basking in Yellowstone's lower geyser basin. Viruses discovered in

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Yellowstone's thermal waters are helping in the fight against Aids, Ebola and other diseases. Advances in climate change science and oil and gas extraction are credited to Yellowstone's microbial world. And we are only just beginning: it is estimated less than 1 per cent of Yellowstone's thermophilic potential has been discovered.

But the greatest discovery of all may not even be on this planet. Astrobiologists from NASA, the people charged with finding out whether or not we are alone in the universe, are studying Yellowstone's extreme environments in order to better help them search for life elsewhere in the universe. By studying life in these extreme conditions, which mirror those of Mars, Europa and other planetary bodies, they can figure out what real extra-terrestrial beings might look like. Far from little green men, many scientists think they may look a lot like Yellowstone's geyser basin. That would be a story: the most alien environment on the planet helps to find the first alien environment off the planet.

YELLOWSTONE GEYSER BASIN, WYOMING, MONTANA AND IDAHO

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Photo: Flickr

But we may have to act quickly. Firing all this geothermal energy, just a few miles underground, is one of the largest active volcanoes in the world. The last time it erupted, 640,000 years ago, it was 1,000 times more powerful than the 1980 eruption of Mount St Helens. When, not if, it goes again, it will decimate the country and cover half the world in darkness and ash. For all its wonder, Yellowstone is a ticking bomb.

But that's also what makes it so special. Written on the walls of Old Faithful's visitor centre is a quote from the American painter Anne Coe, who called it 'the place where the centre of the earth finds an exit and gives us a glimpse of its soul'. This is the planet at its most primal, the birth of creation itself. It's more than just the largest geyser basin in the world; it's a glimpse into the engine of the Earth. And, perhaps, a peek at our future too – here and beyond the stars.

WHERE: Yellowstone National Park, Wyoming, Montana, Idaho.

HOW TO SEE IT: All of the major thermal features have raised boardwalks that are easy to navigate. But try getting off the main

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thoroughfare too: many of the remote geysers are only a short hike away.
www.nps.gov/yell/index.htm

TOP TIPS: Yellowstone in summer is crowded. Come in winter to have the geyser basin all to yourself. Download the NPS Yellowstone Geysers app to plan your visit around predicted eruption times.

TRY THIS INSTEAD: Rotorua, on the North Island of New Zealand, is also one of the largest geothermal areas in the world and filled with many of the same spectacles, colour and wonder as Yellowstone.
www.rotoruanz.com

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have found the remains of an even earlier pyramid too, where a snarling jaguar throne with jade eyes stares out from the darkness inside.

Nearby is the Temple of the Warriors, flanked by rows of pillars and statues of feathered serpents and the Osario Step Pyramid. But perhaps the most impressive part of the whole city is the observatory. Astronomy was central to Mayan existence. They believed that the sun, moon, planets and stars were gods and that by tracking their movements they could better understand divine influence upon the Mayan people. As a result, they spent much of their resources carefully charting the paths of celestial bodies and their degree of accuracy is astonishing. Using only the naked eye astronomer-priests were able to predict solar eclipses and equinoxes with pinpoint precision. They calculated the length of a year to be 365.242 days; modern measurements put it at 365.242198. The orbit of Venus was predicted to within two hours of a 584-day cycle. Their measurement of the lunar month differed from ours by less than nine seconds. Astronomy fuelled the growth of their culture, helping them to advance their agriculture, create calendars and develop highly sophisticated measurements of time.

Indeed, Chichén Itzá itself was built according to these profound astronomical observations. Each side of the great pyramid has 91 steps, add in the top step to the temple and that equals 365, one step for every day of the year. The number 91 is also the number of days that separate the seasonal phases of the solar cycle: spring, summer, autumn and winter. The pyramid itself would have acted as a kind of calendar with the interplay of light and shadows signifying key agricultural and ceremonial times of year. Indeed, one of the greatest spectacles of the entire region occurs at each spring and autumn equinox when the sun casts a shadow in the shape of a giant serpent that moves down the pyramid’s steps to align with an enormous sculpture of a snake head at the base of the temple.

But astronomy wasn’t their only achievement. They built complicated looms for weaving cloth; they produced the first rubber products 3,000 years before Goodyear received his patent; they established trade routes as far as South America and mastered complex farming and irrigation systems in even the most inhospitable of locations. And their written language was the most advanced in the region: an intricate system of about 800 different

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symbols, each one corresponding to a different syllable or word, which can be combined in almost infinite ways. Breaking the Mayan code took 200 years and was one of the greatest achievements of modern archaeology.

Given these astonishing achievements it would be easy to assume that the ancient Mayans were a peaceful people – philosopher kings more intent on deciphering the mysteries of the cosmos than chopping off each other's heads. But nothing could be further from the truth. War was a way of life at Chichén Itzá – and the violence extended inside the city walls as well as out. North of the Great Pyramid lies a series of sinkhole wells where victims were thrown in alive to appease the rain god. At the summit of the Temple of Warriors it's possible to touch the altar where they used to rip out the still beating hearts of sacrificial victims. And right in the centre of the city is Chichén Itzá's great ball court, the largest in Mesoamerica. Here players would attempt to throw a rubber ball, often stuffed with a human skull inside, through one of four twenty-foot high stone rings on each of the surrounding four walls. The stakes were enormous: the vanquished lost their heads as well as the game.

But however bloodthirsty their practices appear to us today, their achievements seem all the more remarkable for it. Inventors, astronomers, master builders: Chichén Itzá is more than just old stones; it's a testament to human ingenuity, intellect and imagination.

WHERE: Yucatán, Mexico.

HOW TO SEE IT: Day trips are organised from numerous popular resorts, including Cancún. But for the best experience stay overnight in one of the nearby towns. You'll be the first on site and will avoid the afternoon heat and daytripper crowds. Plus it's a great chance to experience some of modern Mayan culture too.
www.chichenitza.com

TOP TIP: To watch the shadow of the snake phenomenon, come the week before or after the equinox instead of the actual date itself. The crowds are a fraction as large and the spectacle is almost as good.

TRY THIS INSTEAD: Tikal in Guatemala is equally impressive,

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more atmospheric and has fewer visitors.
www.tikalnationalpark.org

MONARCH BUTTERFLY MIGRATION, MEXICO

The migration of the Monarch butterflies is one of the most astonishing journeys in the animal kingdom. Every autumn tens of millions of Monarchs travel from eastern Canada, across the USA, to their winter hibernation grounds in the Transvolcanic Mountains of Mexico. It's a journey of between 2,000 and 3,000 miles. For a creature that weighs half a gram, and measures about four inches, that's a preposterous distance. The comparative trip length for a 150-pound human would be more than 300 million miles – or roughly 700 round trips to the moon.

But the length of the journey is only part of the wonder. The truly baffling fact is that they do it across multiple generations, without a guide and without ever having been there before. The butterfly that departs from Canada will die before returning home. And so will its offspring. It will be left to the fourth generation, the great granddaughter of that original butterfly, to begin the migration anew next autumn. How millions of Monarchs find their way across a continent to the same specific twelve mountains every year, having never been there before and with no guide, is still one of the great mysteries of the natural world.

MONARCH BUTTERFLY MIGRATION, MEXICO

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Photo: Impaludi

Their journey begins at the end of summer. Drops in temperature, the angle of the sun and dwindling food sources activate certain genes within the Monarch's DNA that drive physiological changes, preparing the butterfly for its long journey ahead. Monarchs born at this time are entirely different from their mothers and grandmothers: their muscles are more efficient, their metabolic rate changes, they begin to store fat and lose the ability to mate. These are the migratory generation – the superheroes of the butterfly world. They live eight times longer than their parents or their offspring and travel ten times as far. The sole purpose of their existence is to reach the hibernation grounds in Mexico, survive the winter, and then mate so

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their offspring can complete the cycle.

They fly four to six hours a day, gliding between thermals for 20 to 30 miles, sometimes reaching thousands of feet in the air. Along the way they must avoid seas and storms, seek shelter from the cold and thread a geographical needle between river valleys and mountain ranges, in order to hit a roughly 50-mile gap that will take them to the specific forests where their great-grandparents roosted a year ago.

How they complete this amazing feat of navigation was a mystery for many years, but science now has some answers. In part they simply use the sun – their brains have a powerful in-built compass that is orientated towards the sun. Even on the cloudiest days they can lock on to it through the polarisation of light. The problem is the sun moves across the sky during the day. They can't just be following it blindly; something else is required. Recent studies have revealed that the Monarch's antennae also have an incredibly sensitive biological clock. That means they can correlate the relative position of the sun to the time of day. In effect, their brain is like a powerful time-compensated sun-compass. Just like Boy Scouts are taught to use their watch and the sun to find their way, Monarchs, by combining the information from their eyes as to where the sun is with the circadian rhythms in their antennae as to what time of day it is, can always find south.

But that only solves one mystery. At a crucial point in their journey they turn due east to reach their overwintering grounds. That means they must somehow know where to go, and when to turn, even though they've never been there before and no one's showing them the way. And the Monarchs begin from multiple locations and are able to adjust their route as required. They're not just following a compass heading, they're actively navigating a route as they go. No one has a conclusive answer to how this is done, but it is thought that it is some type of genetic memory – a kind of inherited GPS-like software with a pre-programmed destination built in.

Their arrival, usually around mid-October, is spectacular: millions of golden black butterflies cover the branches of the evergreen and oak forest like a thick orange coat, huddling together for warmth during the long winter. Locals once believed they were the angels of their ancestors coming home to visit because they usually appear around the Mexican Day of the Dead. Then, in spring, after their

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Photo: Marrissa Spiers

Limited human contact has helped too. For 60 years Vieques Island was the test ground for the US Navy until they pulled out in 2003, under pressure from the local population. As a result Mosquito Bay was spared development. Other bays haven't been so lucky. La Paguera, on the Puerto Rican mainland, has dimmed to near extinction from exposure to chemicals in boat fuel and pollutants on

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the skin of swimmers. Vieques is now growing in popularity. To keep this wonder shining bright, tourism is now strictly monitored and controlled, but the fate of the bay remains to be seen.

And it's important we keep these remarkable ocean fireflies safe, because they have a lot left to teach us. Although bays like this are rare, bioluminescence itself is not. In fact it's the primary communication tool of the deep ocean, used for everything from attracting a mate to warding off predators. It is one of the oldest fields of study too. Aristotle was the first to record detailed observations of bioluminescent creatures, including dinos, which he prodded with a fishing rod in order to watch them glow. Christopher Columbus referred to mysterious lights in the sea. And a young Charles Darwin marvelled at the luminosity emitting from the wake of the HMS *Beagle*.

The study of bioluminescence, in more modern times, has heralded radical breakthroughs in medical science too. A green fluorescent protein, found lighting up the bodies of a particular species of jellyfish, is now used by doctors as a kind of glow-in-the-dark torch into the molecular world. By attaching that protein to certain cells they can literally illuminate processes that had hitherto been invisible. Work is also underway to use bioluminescence to better map brain processes and help in the fight against cancer. But the future may bring more surprising developments too: research is being conducted to see if bioluminescent trees can be created to replace energy-draining streetlights, it's been suggested we may one day engineer crops that glow when they need water, bright bioluminescent sweets are not far from our supermarket aisles.

For now, though, perhaps it's enough just to be there, to see those living lights respond to your touch, to have the cosmos mirrored in perfect reflection. In a world where everything can be viewed at the click of a button, Mosquito Bay is unique. Videos don't do it justice. Photographs are poor imitations. You have to see it with your own eyes.

WHERE: Mosquito Bay, Vieques Island, Puerto Rico.
www.vieques.com

HOW TO SEE IT: Kayak tours are the best way to see the phenomenon, but electric boat tours are also available. Book with a

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licensed guide to help protect the bay.

TOP TIP: Time your visit with a new moon for the best viewing conditions.

TRY THIS INSTEAD: Laguna Grande bio bay in Las Croabas, Fajardo, on the Puerto Rican mainland, near the capital San Juan, is easier to get to and still offers a spectacular show. Or for an alternative bioluminescent experience try the Waitomo Caves on New Zealand's North Island. Thousands of glow-worms light up the cave walls like stars.
www.seepuertorico.com
www.waitomo.com

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SOUTH AMERICA

THE AMAZON RAINFOREST

The Amazon rainforest is the largest tropical rainforest on Earth. This vast expanse of almost 400 billion trees is nearly twice as big as India and more than twenty times the size of Great Britain. It covers 2.1 million square miles of Brazil, Peru, Ecuador, Bolivia, Colombia, Venezuela, Guyana, Suriname and French Guyana – roughly 40 per cent of the entire South American continent. If it was a country, it would be the ninth largest in the world.

But size is only part of its wonder. The Amazon is the most biodiverse place on the planet. Ten per cent of the world's known species live here – including an estimated 2.5 million types of insects, most of which have never been recorded. Twenty per cent of the world's oxygen is produced by its forest. One fifth of the world's fresh water is stored in its basin. The Amazon rainforest is more than a precious ecosystem, it is the lungs and life force of the planet itself.

At the heart of the forest is the Amazon River. Stretching more than 4,000 miles from the Peruvian Andes across the northern half of South America to the Atlantic Ocean in Brazil, it is the largest river by volume in the – ten times greater than the Mississippi and more than four times bigger than the Congo, the second largest on the list. It drains an area close to 3 million square miles, which collects an average of nine feet of rainwater a year. In the summer, snowmelt from the mountains raises the water level by more than 30 feet to flood the forest basin for twelve miles inland from the main channel.

The volume of that cumulative amount of water is staggering. Twenty-eight billion gallons of fresh water flow into the Atlantic every minute. Its daily discharge would be enough to supply New York City's fresh water needs for nine years. That immense pressure pushes the river 125 miles out to sea before it mixes with the saltwater of the Atlantic. Early sailors could drink freshwater straight out of the ocean before even setting sight on land.

And where the river flows, it breathes life. The Amazon is home to more than 420 types of mammals, 1,300 species of birds as well as

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hundreds of reptiles and amphibians. There are snakes that weigh 500 pounds, which could eat you whole, Jesus Lizards that can walk on water and glass frogs with translucent skin. And most of the Amazon is still undiscovered – we know less about the canopy of the Amazon rainforest than of the ocean floor.

And that's why it's so precious. Twenty-five per cent of all prescription drugs derive from ingredients found in rainforests, yet only 1 per cent of tropical plants have been studied for their medicinal potential. Cures for Aids, cancer and diseases we haven't even encountered yet are more than likely growing, right now, somewhere in that vast fertile basin. The Amazon is the medicine cabinet of the world and we've barely opened the door.

The keepers of this knowledge are the indigenous tribes that have lived there for thousands of years. The Amazon is the ancestral home of 1 million native Indians, from more than 400 tribes, each with their own distinct language, knowledge and culture. Many of those tribes have still never made contact with the outside world. There are people living in these forests today who have absolutely no idea of the universe beyond the trees.

THE AMAZON RAINFOREST

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empire stretched from the capital Cuzco in southern Peru across the western edge of the Andes from Colombia in the north through Ecuador, Bolivia and Chile to the tip of Argentina in the south. One single ruler, Topa Inca Yupanqu, is credited with expanding their reach by an astonishing 2,500 miles in just over twenty years. They flourished for little more than a century, from 1400 to their conquest by the Spanish in 1533. But in that brief flash they managed to construct a road network of more than 14,000 miles, subjugate over 10 million people, speaking more than 30 different languages, and become the largest civilisation of its time anywhere in the world. They built many cities during their reign, but Machu Picchu was their crown jewel.

MACHU PICCHU, PERU

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Photo: Albert Schmidt

Their work was stunning. The entire complex blends into the natural surroundings with exceptional harmony of design – as if it is an extension of the mountain itself. But it was also well made. Without iron or steel, the Incas used hard stones from the river to chip away at the white granite quarried on the mountain summit. They had no mortar so carved precisely shaped interlocking bricks instead, simply balancing one on top of the other. And their craftsmanship was so exquisite that to this day, 500 years later, a knife still can't be inserted between the blocks.

They had foresight too. In order to provide food for the population, they built over 700 terraces cut into the mountainside, where maize and potatoes would be grown. To feed this agriculture they needed a reliable source of water. So they built a system of highly advanced aqueducts that carried natural sources through the city via a complex series of canals and fountains. But the terraces also acted as a defence against landslides, literally gripping the city to the steep slopes. The foundations were constructed with multiple layers of topsoil, gravel and waste rock that aided in the drainage too. Without that forward thinking, 79 inches of rainforest downpours a year would have simply washed the city away.

The purpose of Machu Picchu, in such a remote and inaccessible location, was a mystery for many years. But it's now believed to have been a kind of royal retreat for the great warrior king Pachacuti Inca Yupanqui, the ninth ruler of the Incas. But it was also a sacred

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site and religious ceremony would have played a key role. The Incas worshipped the sun, moon, stars and planets and many of the buildings at Machu Picchu were constructed according to these astronomical functions. At summer solstice, for example, sunlight shines through a window of the Temple of the Sun, one of the most beautiful buildings of the entire complex, and aligns perfectly with a boulder in its centre and a nearby sacred peak. Nearby, the Intihuatana stone, a carved monolith to the west of the main plaza, would have functioned as a kind of solar clock and helped plan the timing of religious ceremonies. The truly remarkable thing is that the Incas managed to do all this and more without written language, or even the wheel, in the middle of one of the densest jungles on Earth.

But Machu Picchu is more than just the sum of its parts. In his diary, American explorer Hiram Bingham, the first Westerner to discover it in 1911, called it ‘an unbelievable dream’. That description is as apt today as it was more than 100 years ago. It is a place of awe and magnificence, a marvel of engineering and design. Here, perhaps more than anywhere else on Earth, nature and the vision of mankind blend seamlessly into something more powerful, and more beautiful, than each would be on its own.

WHERE: Urubamba, Peru.

HOW TO SEE IT: April to November is the best time of year, but avoid the busy months of June and July, when crowds are at their greatest. The majority of people travel from Cuzco to the nearest town Aguas Calientes and then take the train up from there. It’s essential to buy permits in advance. Tickets can be purchased at the official office in Cuzco or online at www.machupicchu.gob.pe. For something more adventurous, try the 26-mile Inca Trail, but altitude, steep climbs and extreme weather make it a challenging trek. And it’s packed: 75,000 people make the journey each year. Consider trying one of the alternative routes instead, such as the Lares or Salcantay Routes.
www.peru.travel

TOP TIPS: Get there for sunrise and stay for sunset. Hike up to Huayna Picchu for the best views of the site.

TRY THIS INSTEAD: Choquequirao is located nearby in Peru’s

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Sacred Valley. It's smaller and less dramatic, but receives a fraction of the visitors and is well worth a look.

ANGEL FALLS, VENEZUELA

Angel Falls is the highest free-falling waterfall on the planet. Pouring out of an immense flat-topped mesa, called a tepui, deep in the Guiana Highlands of South-east Venezuela, its total height is 3,212 feet – including a spectacular single drop of 2,647 feet. If you were standing on top of the Empire State Building in New York City, you wouldn't even reach halfway up this enormous cascade. Rivals are babes in its presence. The Angel is nine times taller than Victoria Falls in Southern Africa, eleven times more elevated than Iguaçu in Brazil, and fifteen times the height of Niagara in the USA. By the time the water reaches the Kerep River, at the base of the mountain, it has fallen so far that most of the flow is vaporised into a sheer mist that can be felt a mile away.

The indigenous people of the region, the Pemón, call her 'Kerepakupai-Meru' – 'the waterfall of the deepest place'. The name Angel comes from the first Western man to see it, an American aviator named Jimmie Angel, and his story is almost as spectacular as the waterfall itself. Legend has it that he was once a World War combat ace for the Royal British Flying Corps, that he helped a Chinese warlord create an air force in the Gobi Desert and worked as an aviation scout for Lawrence of Arabia. But legend also has it that Jimmie liked a good story.

What is undeniably true is that he was a gifted pilot and spent much of his life working in remote regions of Central and South America looking for gold, diamonds and oil. In the 1920s he met an American mining geologist, named McCracken, in a bar in Panama, who agreed to pay him $5,000 to fly to a remote location in Venezuela. The pair landed on a tepui mountain top and pulled a fortune in gold from a river on that plateau. Jimmie would spend the rest of his life trying to find that fabled lost river again. Indeed it was while searching for it in 1933 that he caught his first glimpse of Angel Falls. Convinced his lost river of gold may be feeding that enormous cascade, he returned soon after with his wife Marie and two Venezuelan guides to explore the top of the mountain.

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