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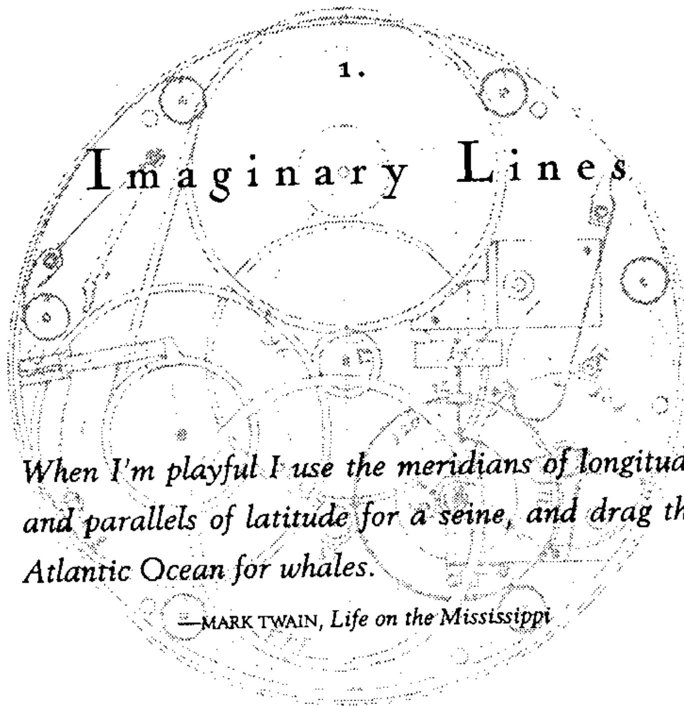


1.

Imaginary Lines

When I'm playful I use the meridians of longitude and parallels of latitude for a seine, and drag the Atlantic Ocean for whales.

—MARK TWAIN, *Life on the Mississippi*

Once on a Wednesday excursion when I was a little girl, my father bought me a beaded wire ball that I loved. At a touch, I could collapse the toy into a flat coil between my palms, or pop it open to make a hollow sphere. Rounded out, it resembled a tiny Earth, because its hinged wires traced the same pattern of intersecting circles that I had seen on the globe in my schoolroom—the thin black lines of latitude and longitude. The few colored beads slid along the wire paths haphazardly, like ships on the high seas.

My father strode up Fifth Avenue to Rockefeller

Center with me on his shoulders, and we stopped to stare at the statue of Atlas, carrying Heaven and Earth on his.

The bronze orb that Atlas held aloft, like the wire toy in my hands, was a see-through world, defined by imaginary lines. The Equator. The Ecliptic. The Tropic of Cancer. The Tropic of Capricorn. The Arctic Circle. The prime meridian. Even then I could recognize, in the graph-paper grid imposed on the globe, a powerful symbol of all the real lands and waters on the planet.

Today, the latitude and longitude lines govern with more authority than I could have imagined forty-odd years ago, for they stay fixed as the world changes its configuration underneath them—with continents adrift across a widening sea, and national boundaries repeatedly redrawn by war or peace.

As a child, I learned the trick for remembering the difference between latitude and longitude. The latitude lines, the *parallels*, really do stay parallel to each other as they girdle the globe from the Equator to the poles in a series of shrinking concentric rings. The meridians of longitude go the other way: They loop from the North Pole to the South and back again in great circles of the same size, so they all converge at the ends of the Earth.

Lines of latitude and longitude began crisscrossing our worldview in ancient times, at least three centuries before the birth of Christ. By A.D. 150, the cartographer and astronomer Ptolemy had plotted them on the twenty-seven maps of his first world atlas. Also for this landmark volume, Ptolemy listed all the place names in an index, in alphabetical order, with the latitude and longitude of each—as well as he could gauge them from travelers' reports. Ptolemy himself had only an armchair appreciation of the wider world. A common misconception of his day held that anyone living below the Equator would melt into deformity from the horrible heat.

The Equator marked the zero-degree parallel of latitude for Ptolemy. He did not choose it arbitrarily but took it on higher authority from his predecessors, who had derived it from nature while observing the motions of the heavenly bodies. The sun, moon, and planets pass almost directly overhead at the Equator. Likewise the Tropic of Cancer and the Tropic of Capricorn, two other famous parallels, assume their positions at the sun's command. They mark the northern and southern boundaries of the sun's apparent motion over the course of the year.

Ptolemy was free, however, to lay his prime meridian, the zero-degree longitude line, wherever he liked. He chose to run it through the Fortunate Islands (now called the Canary & Madeira Islands) off the northwest coast of Africa. Later mapmakers moved the prime meridian to the Azores and to the Cape

Verde Islands, as well as to Rome, Copenhagen, Jerusalem, St. Petersburg, Pisa, Paris, and Philadelphia, among other places, before it settled down at last in London. As the world turns, any line drawn from pole to pole may serve as well as any other for a starting line of reference. The placement of the prime meridian is a purely political decision.

Here lies the real, hard-core difference between latitude and longitude—beyond the superficial difference in line direction that any child can see: The zero-degree parallel of latitude is fixed by the laws of nature, while the zero-degree meridian of longitude shifts like the sands of time. This difference makes finding latitude child's play, and turns the determination of longitude, especially at sea, into an adult dilemma—one that stumped the wisest minds of the world for the better part of human history.

Any sailor worth his salt can gauge his latitude well enough by the length of the day, or by the height of the sun or known guide stars above the horizon. Christopher Columbus followed a straight path across the Atlantic when he "sailed the parallel" on his 1492 journey, and the technique would doubtless have carried him to the Indies had not the Americas intervened.

The measurement of longitude meridians, in comparison, is tempered by time. To learn one's longitude at sea, one needs to know what time it is aboard ship

and also the time at the home port or another place of known longitude—at that very same moment. The two clock times enable the navigator to convert the hour difference into a geographical separation. Since the Earth takes twenty-four hours to complete one full revolution of three hundred sixty degrees, one hour marks one twenty-fourth of a spin, or fifteen degrees. And so each hour's time difference between the ship and the starting point marks a progress of fifteen degrees of longitude to the east or west. Every day at sea, when the navigator resets his ship's clock to local noon when the sun reaches its highest point in the sky, and then consults the home-port clock, every hour's discrepancy between them translates into another fifteen degrees of longitude.

Those same fifteen degrees of longitude also correspond to a distance traveled. At the Equator, where the girth of the Earth is greatest, fifteen degrees stretch fully one thousand miles. North or south of that line, however, the mileage value of each degree decreases. One degree of longitude equals four minutes of time the world over, but in terms of distance, one degree shrinks from sixty-eight miles at the Equator to virtually nothing at the poles.

Precise knowledge of the hour in two different places at once—a longitude prerequisite so easily accessible today from any pair of cheap wristwatches—was utterly unattainable up to and including the era of pendulum clocks. On the deck of a rolling ship, such clocks would slow down, or speed up, or stop running altogether. Normal changes in temperature encountered en route from a cold country of origin to a tropical trade zone thinned or thickened a clock's lubricating oil and made its metal parts expand or contract with equally disastrous results. A rise or fall in barometric pressure, or the subtle variations in the Earth's gravity from one latitude to another, could also cause a clock to gain or lose time.

For lack of a practical method of determining longitude, every great captain in the Age of Exploration became lost at sea despite the best available charts and compasses. From Vasco da Gama to Vasco Núñez de Balboa, from Ferdinand Magellan to Sir Francis Drake—they all got where they were going willy-nilly, by forces attributed to good luck or the grace of God.

As more and more sailing vessels set out to conquer or explore new territories, to wage war, or to ferry gold and commodities between foreign lands, the wealth of nations floated upon the oceans. And still no ship owned a reliable means for establishing her whereabouts. In consequence, untold numbers of sailors died when their destinations suddenly loomed out of the sea and took them by surprise. In a single such accident, on October 22, 1707, at the Scilly Isles near the southwestern tip of England, four homebound British warships ran aground and nearly two thousand men lost their lives.

The active quest for a solution to the problem of longitude persisted over four centuries and across the whole continent of Europe. Most crowned heads of state eventually played a part in the longitude story, notably King George III of England and King Louis XIV of France. Seafaring men such as Captain William Bligh of the *Bounty* and the great circumnavigator Captain James Cook, who made three long voyages of exploration and experimentation before his violent death in Hawaii, took the more promising methods to sea to test their accuracy and practicability.

Renowned astronomers approached the longitude challenge by appealing to the clockwork universe: Galileo Galilei, Jean Dominique Cassini, Christiaan Huygens, Sir Isaac Newton, and Edmond Halley, of comet fame, all entreated the moon and stars for help. Palatial observatories were founded at Paris, London, and Berlin for the express purpose of determining longitude by the heavens. Meanwhile, lesser minds devised schemes that depended on the yelps of wounded dogs, or the cannon blasts of signal ships strategically anchored—somehow—on the open ocean.

In the course of their struggle to find longitude, scientists struck upon other discoveries that changed their view of the universe. These include the first accurate determinations of the weight of the Earth, the distance to the stars, and the speed of light.

As time passed and no method proved successful, the search for a solution to the longitude problem assumed legendary proportions, on a par with discovering the Fountain of Youth, the secret of perpetual motion, or the formula for transforming lead into gold. The governments of the great maritime nations—including Spain, the Netherlands, and certain city-states of Italy—periodically roiled the fervor by offering jackpot purses for a workable method. The British Parliament, in its famed Longitude Act of 1714, set the highest bounty of all, naming a prize equal to a king's ransom (several million dollars in today's currency) for a "Practicable and Useful" means of determining longitude.

English clockmaker John Harrison, a mechanical genius who pioneered the science of portable precision timekeeping, devoted his life to this quest. He accomplished what Newton had feared was impossible: He invented a clock that would carry the true time from the home port, like an eternal flame, to any remote corner of the world.

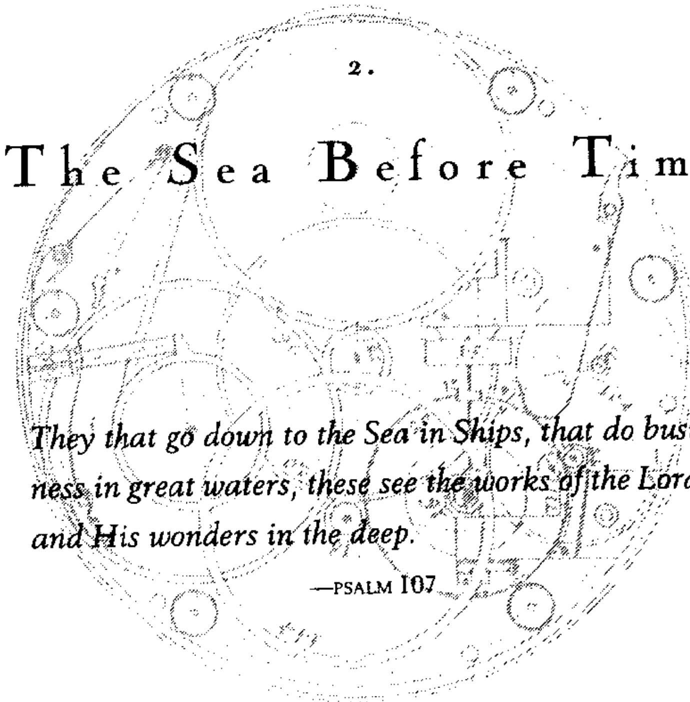
Harrison, a man of simple birth and high intelligence, crossed swords with the leading lights of his day. He made a special enemy of the Reverend Nevil Maskelyne, the fifth astronomer royal, who contested his claim to the coveted prize money, and whose tactics at certain junctures can only be described as foul play.

With no formal education or apprenticeship to any watchmaker, Harrison nevertheless constructed a series of virtually friction-free clocks that required no lubrication and no cleaning, that were made from materials impervious to rust, and that kept their moving parts perfectly balanced in relation to one another, regardless of how the world pitched or tossed about them. He did away with the pendulum, and he combined different metals inside his works in such a way that when one component expanded or contracted with changes in temperature, the other counteracted the change and kept the clock's rate constant.

His every success, however, was parried by members of the scientific elite, who distrusted Harrison's magic box. The commissioners charged with awarding the longitude prize—Nevil Maskelyne among them—changed the contest rules whenever they saw fit, so as to favor the chances of astronomers over the likes of Harrison and his fellow "mechanics." But the utility and accuracy of Harrison's approach triumphed in the end. His followers shepherded Harrison's intricate, exquisite invention through the design modifications that enabled it to be mass produced and enjoy wide use.

An aged, exhausted Harrison, taken under the wing of King George III, ultimately claimed his rightful monetary reward in 1773—after forty struggling years of political intrigue, international warfare, academic backbiting, scientific revolution, and economic upheaval.

All these threads, and more, entwine in the lines of longitude. To unravel them now—to retrace their story in an age when a network of orbiting satellites can nail down a ship's position within a few feet in just a moment or two—is to see the globe anew.



2.

The Sea Before Time

They that go down to the Sea in Ships, that do business in great waters, these see the works of the Lord, and His wonders in the deep.

—PSALM 107

"Dirty weather," Admiral Sir Clowdisley Shovell called the fog that had dogged him twelve days at sea. Returning home victorious from Gibraltar after skirmishes with the French Mediterranean forces, Sir Clowdisley could not beat the heavy autumn overcast. Fearing the ships might founder on coastal rocks, the admiral summoned all his navigators to put their heads together.

The consensus opinion placed the English fleet safely west of Île d'Ouessant, an island outpost of the Brittany peninsula. But as the sailors continued north,