Dædalus

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Inside front cover: Charles-Guillaume Manière achieved the distinction of *maître horloger* in 1778, though this striking masterpiece (now the property of the English Crown) dates from the early nineteenth century. The present moment is indicated by the point of the scythe on the globe clock. The knife-edge confrontation between a scythe-wielding father time and a muse, madly at work, who gives him pause, seems to suggest a sculptural invocation of the classical theme *ars longa vita brevis.* See David S. Landes on *Clocks & the wealth of nations,* pages 20 – 26. Photograph from The Royal Collection © 2003, Her Majesty Queen Elizabeth II.

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Dædalus is designed by Alvin Eisenman

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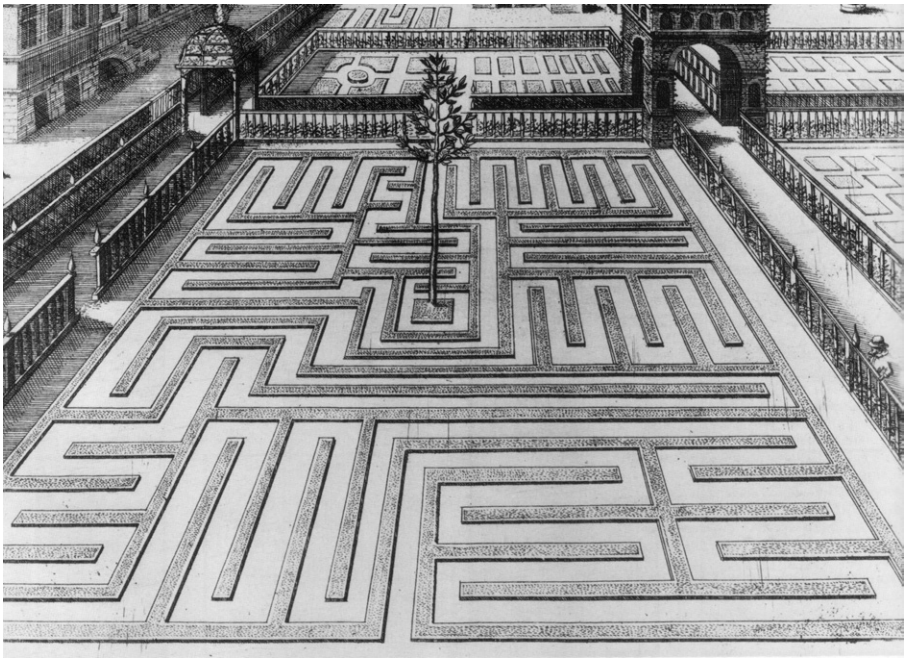

Design for the hedge maze is by Johan Vredeman de Vries, from *Hortorum viridariorumque elegantes et multiplicis artis normam affabre delineatae* (Cologne, 1615).

Dædalus was founded in 1955 and established as a quarterly in 1958. The journal's namesake was renowned in ancient Greece as an inventor, scientist, and unriddler of riddles. Its emblem, a maze seen from above, symbolizes the aspiration of its founders to "lift each of us above his cell in the labyrinth of learning in order that he may see the entire structure as if from above, where each separate part loses its comfortable separateness."

The American Academy of Arts & Sciences, like its journal, brings together distinguished individuals from every field of human endeavor. It was chartered in 1780 as a forum "to cultivate every art and science which may tend to advance the interest, honour, dignity, and happiness of a free, independent, and virtuous people." Now in its third century, the Academy, with its more than four thousand elected members, continues to provide intellectual leadership to meet the critical challenges facing our world.

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D. Graham Burnett

Mapping time: chronometry on top of the world

At dawn on the 9th of June, 1873, the sturdy Victorian ocean naturalist C. Wyville Thomson swung his elegantly bearded person down from the deck of the British research vessel *Challenger*, berthed in the Bermuda dockyards, and made his way aboard a diminutive steam pinnace for a day trip on the island. After churning around to Mount Langton to pick up the governor, the shore party of collectors and dignitaries (with a 'native fisherman' in tow as guide and a photographer along in the service of posterity) made for Harrington Sound, rowed ashore, and hiked up to the Walsingham Caves for an afternoon of learned spelunking in the deep and winding limestone caverns. The cool reaches of this geological attraction would provide welcome respite from the midday tropical sun, to be sure, but Wyville Thomson had more than comfort on his mind: the belly of Bermuda, he believed, secreted a rare device – a kind of earth clock, an hourglass for planetary time.

For it happened that more than fifty years earlier, the commanding officer of the North American and West Indian station, Sir David Milne, had spent several days in Walsingham indulging his petrological curiosity by carefully severing an eleven-foot stalagmite from its moorings on the cave floor, and arranging for it to be returned to the British Isles – yet another strange fruit plucked from the colonial periphery to be enjoyed in metropolitan institutions of philosophical cultivation. This calcareous obelisk had thus found its way to a new, cool, dark cave across the Atlantic – the Museum of the University of Edinburgh, where Thomson (the Regius Professor of Natural History) would later ponder its bulk and consider the manner and pace of its formation. Between 1819 and 1873 such ponderings had grown urgent, since the age of the earth had burst into one of the most contested questions in science. Genesis, evolution, Darwin, even thermodynamics lay in the balance. So it is perhaps less strange to learn that in 1863, four years after the publication of Darwin's *Origin of Species*, the Walsingham Caves saw the visit of another

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pith-helmeted colonial administrator, Sir Alexander Milne, who, acceding nepotistically to his father's post in the West Indies, made a pilgrimage to his stump as well, the better to follow in his footsteps, and to report on the passage of time. There, on his elbows and knees, pocket watch in hand, Milne junior timed the soft splats falling from the ceiling of the cave and landing on five separate points where the stalagmite had once been. One drip fell at the rate of five drops a minute, he reported, another between three and four, the rest slower still. He identified two new knoblets that had come into being over the intervening forty-four years, along with a little mineral slick to one side – a total of five cubic inches of matter. It was Alexander Milne's brother David, back in Scotland, who did the math, and decided that at this rate their father's three-and-a-half-ton prize represented something like six hundred thousand years of subterranean accumulation.

To this same site, then, came Wyville Thomson and his party the following decade, and they also drew their watches in the lantern light: "The two drops were still falling," Thomson reported, "but apparently somewhat more slowly, one not quite three times in a minute, the other twice." The three other drips continued to feed their little slick deposit, though the party "could not determine that the bulk of the new accumulation was perceptibly greater than when it was measured by Sir Alexander Milne." If this geochronometer was ever to be of real use, what Thomson needed was some more definite record of the current form and magnitude of the lumps. Out came the photographer's equipment, and the blue-white brilliance of burning magnesium made the Walsingham Caves, briefly, brighter than a Bermuda noon. But Thomson despaired: "We were very anxious to carry away with us a permanent record of the present condition of the stump of the stalagmite, and we twice tried to photograph it," but the conditions foiled the photographer, and spoiled his exposures.

Thomson, however, would not be denied: "It then occurred to us that it might be possible to take another slice from the column, showing the amount of reparation during half a century, as an accessory and complement to the Edinburgh specimen." Hammers and chisels again went to work in Walsingham, with the aim of producing yet another crate for the Edinburgh Museum; another crate, containing yet another piece in the jigsaw puzzle of time.[1]

There is something strangely compelling, I think, about this crate. Granted, it would solve none of the pressing chronoscientific questions of the day. It would not help sort out if Lord Kelvin's much reduced timescale for the formation of the earth (grounded in his physics of cooling bodies) was right, and it would not settle heated disputes among geologists and paleontologists about the dating of cave remains. In fact, it is not even clear (to me, anyway) that this crate ever made its way to the museum in Edinburgh; it may have, but it may also have wound up forgotten on the docks in Bermuda, or in the office of the superintendent of the shipyard, Captain Aplin, who arranged for the stonecutting tools and the men to wield them.

But this slice of lost stalagmite merits a moment's thought nevertheless. For here was a specimen chosen for what it might tell about the timeline of the planet's history, the sequential ages of geological time; chosen because it was the

1 The story of the Walsingham stalagmite can be found in C. Wyville Thomson, *Voyage of the 'Challenger,' Volume I: The Atlantic* (London: Macmillan and Co., 1877), 322 – 328.

frozen stuff of a chthonic water clock dripping in a smooth quartz bowl of middle earth. And yet, this small artifact of the relentless passage of timeline time was something quite different too, since, keystone-like, it served to close a set of looping arches that spanned space and time: falling into place, it promised to close the gaps between geological time and human time, between 1819 and 1873, between Milne *père* and Milne *fils*, between now and then, Edinburgh and Bermuda, here and there, metropolis and colony. The scientific investigation of linear time cut a divot in the floor of the Walsingham cave, but the redoubled scar in the stone powerfully symbolizes how the workings of human memory continuously tangle that timeline time into a knotty skein – producing folds, juxtapositions, curious singularities.

The crate contained another piece in the jigsaw puzzle of time. But did the piece fit? I imagine the stalagmite-in-exile reunited with this now rootless sliver of its trunk. The fragments do not fit, of course. There is a remainder, a calcareous accretion that holds them apart. Is there a lesson in this? Perhaps. We set out, at great effort, again and again, to put the pieces of time together; but time itself, it seems, forever holds those pieces apart.

This issue of *Dædalus* draws together a shipload of pieces in the puzzle of time. From Heraclitus to Einstein, from Faulkner to fifteenth-century Namibia, from cognitive science to the apocalypse, these ten essays invite reflection on what time is and what it has meant and still means. Does the origin of time lie in language, as J. Hillis Miller suggests in "Time in literature"? Or could we say, with Danielle Allen, that time – a condition of possibility for human justice – is born of the need to put both halter and yoke on anger, the furious beast that strains to trample every social form? And what to make, then, of a physicist like Thomas Gold, who reminds us that without the particular configurations of astrophysics, it is not clear that time would exist at all? Or of a biologist like Michael Rosbash, who points out that if several of our deep biochemical pathways were slightly different, it is not clear we would miss it?

Do these pieces fit? The reader must turn them in the mind to find reflecting facets, to hold them together, to measure the remainder.

Let me add a piece myself. In an interview published in the early 1990s, the French philosopher Michel Serres offered a striking parable for the timescape of modernity, a story about the collective conception of time that shapes our sense of who we are. Gesturing at the history of cartography, Serres recalled the quirky world maps of the medieval period. These geometrical disks strike the modern viewer as wholly fantastical, since they gathered up the known world and arranged it with care around a powerful centering point: Jerusalem. We laugh, Serres pointed out, at this and every other ancient cosmography that tried to place humanity in the heart, middle, and origin of everything. And yet, he went on to argue mischievously, are we not the victims of a comparably narcissistic delusion? If Mercator and Copernicus dramatized that human institutions are not at the center of space, the deep cognitive structures of modernity have offered us a consolation of considerable power: now, at this moment, we are continuously reassured, we stand at the *summit of time*.

The idea of progress makes us this guarantee. As Serres put it, "we conceive of time as an irreversible line, whether interrupted or continuous, of acquisitions and inventions." And therefore,

continuously abreast of the past, "it follows that we are always right, for the simple, banal, and naïve reason that we are living in the present moment." From our vantage point at the center of this temporal *mappamundi* we can survey history, secure in the knowledge that we are not only right, but "righter than was ever possible before."[2] Moreover, we are guaranteed always to occupy this enviable seat, since each moment simply lifts us higher over all that has come before. By these lights, if one dreams Serres's strange dream for a moment, our dominant theories of knowledge – our accounts of how we know we are right in politics and in science; our sense that our truths are the best truths – suddenly seem to be dependent on a very particular (even peculiar) cartography of time. Who made time into the hill we are always atop? Will those who come after someday look back at us – secure in our sense of being forever astride our yesterdays – and laugh, just as we are tempted to chuckle at a *mappamundi* with the Old Temple at its navel? It is a puzzling thought.

Who made time into the hill we are always atop? This is a deep and difficult question, and reasonable thinkers have lain the idea of progress on different doorsteps. Anthony Grafton's essay in this volume, "Dating history," takes up this very issue, and reminds us that even as those old TO maps were being replaced by the cartographies of Mercator and Johann Schott, a similarly revolutionary project – technical chronology – was rearranging the temporal framework of the universe in an equally radical way. This story is much more than a forgotten episode in the history of eccentric learning, since it is, in the end, a watershed moment in the creation of history itself, both history as a practice, and history as a product of this practice. As Renaissance chronologers like Scaliger organized antiquity along the axis of time, they were putting the presiding authorities of the classical tradition *in the past*. It was not a simple business, but here, surely, was the hill of time abuilding, and men scrambling to the top, even as they heaped the dirt under their feet.

If it was these early practitioners of a 'science of time' who served as architects, builders, and earliest summiteers of the hill of time, it was the robed claque of professional historians who became its surveyors, custodians, and dedicated gardeners. And in this club the historians of science and technology have long held a special place where the problem of progress is concerned. For theirs was an enterprise, at least in its inception, exactly dedicated to showing just how high the hill had grown, an enterprise that could dramatize temporal progress, stage by stage, in a pageant of new truths overcoming old errors on the way to the present. These historians might have walked down the hill, but they did so in order to show the colorful and treacherous path back up to the Olympian heights of modernity.

If the field of the history of science has changed in the last decades, many of its most satisfying narratives still hail from this era of the mountaineers. One of the very best stories they brought up the slopes was the story of timekeeping itself. This was a story of progress if there ever was one – perhaps the ultimate tale of how humanity had literally 'climbed the hill of time.' And a compelling story it remains: Once upon a time, human beings reasoned the passage of time by

2 The interview was published in English as Michel Serres and Bruno Latour, *Conversations on Science, Culture and Time*, trans. by Roxanne Lapidus (Ann Arbor: The University of Michigan Press, 1995). For the section on modern conceptions of time, see pages 48 – 51.

the loose organic cycles of the years, the seasons, the moons, and the days. Time was the passage of the sun in the sky: a sweep each day, a seesaw procession each year. The invention of timekeeping devices – hourglasses, water clocks, graduated tapers – made it possible for early civilized people to begin to control and standardize the units of time, and in doing so to coordinate their lives. But the great step came sometime around the turn to the fourteenth century – say, between 1270 and 1330 – when someone (we can't say who!) somewhere (in Europe, we think, but we can't say where!) hit upon the ticking heart of a true mechanical clock. This heart, called an 'escapement,' consists of a clever arrangement of swinging paddles set beside a toothed wheel shaped like a crown. The wheel would like to spin free, driven by a falling weight, but the weight cannot fall free (and the wheel cannot simply spin) because those deftly balanced paddles kick the wheel's teeth, stopping it for a moment, before letting it go – but just for a moment, only to stop it again: block, unblock, and block again; block, unblock, block. Instead of the weight dropping to the floor in a whir, it lowers itself by tiny steps: tick, tock, tick, tock; and the wheel turns, slow as the plodding of the seconds.

Not that those seconds were all exactly alike, at least not at first. The earliest mechanical clocks swung those precious paddles with a certain erratic charm, since the paddles were affixed to the axis of a T-shaped bar called a *verge and foliot*. The name itself suggests that the device could not be made to behave with perfect regularity: etymologies offered for the term 'foliot' have suggested that it hails from the root word for 'lunatic' or 'madwoman' (as in, "the thing swings back and forth like a nut"), or perhaps from the word for 'leaf' (as in, "it trembles like a leaf"). Suffice it to say that the swinging arms of the foliot beat no natural pulse.

But the basic structure of the mechanical clockwork had been defined, and medieval towns vied for glory in the erection of public clocks, the better sort of which showed the paths of the planets on their dials and sounded the hours on giant bells. The very gaudiest set those bells ringing with the hammer strike of well oiled jack-work automatons, which creaked into action in elaborate mechanical masques. Many of these clocks survive, jacks intact, but few retain their original escapements, since those were upgraded long ago: in the seventeenth century, thanks to the work of Galileo (and Christian Huygens), the verge and foliot met its demise; and those same paddles that kicked the slowly turning wheel of time into a regular beat found their way onto the shaft of a *pendulum,* whose swings gave a new rhythm to the mechanical timekeeper. Within a few years, the error of the best mechanical timekeepers went from something like twenty minutes a day, to something closer to twenty seconds.

The effect was profound, since these new devices were precise enough to reveal in detail curious irregularities in the natural cycles of earthly and celestial time. Take the 'day,' for instance. One might think that the period of time from noon to noon marks an unchanging unit; more light in the summer, more dark in the winter, but always in sum the same period. An astronomer will tell you different. By the seventeenth century this and other quirks of the natural order could be measured and plotted with considerable accuracy.

A remarkable thing had happened. A device that had started out as a mechanical model of day and night, and hence of

the relationship between the earth and the sun (for this is what the hands of a clock really are – a model of the dynamics of earth and sun), had gradually outstripped its original: new sundials had to be equipped with correction tables, allowing the user to convert shadow time to clock time, this newly abstract and unworldly ticking. It is no exaggeration to say that human beings suddenly found themselves correcting the sun – a small correction to be sure (never more than a few minutes), but one with large implications. For ticking there on the wall was a product of human ingenuity that had, in a sense, surpassed the heavens. It is as if the shadows on the wall of Plato's cave reached back to nudge the source of light and truth back into place; as if Phaëthon took up the reins and drove the chariot better than Apollo. The relationship between the celestial realm and mechanical art, between heaven and earth, would never be the same.

A clock that could be used in these ways was a scientific instrument, an essential tool of the cosmos-encompassing astronomical researches of the seventeenth and eighteenth centuries. Indoor types tinkered with the mathematics that described such fine devices and their workings: if in the mid-sixteenth-century clock craftsmen had worked out the curve representing the force of an unwinding spring, they did so not with graph paper or numbers, but rather with files and wooden blocks, as they shaped the cone-shaped cog (called a *fusée*) that compensated for the uneven driving power of the earliest spring clocks. That cog was nothing less than the reification of a sophisticated dynamical analysis. But by the seventeenth century, as the historian of mathematics Michael Mahoney has shown, clockmaking mathematicians were actually doing that analysis on paper, and discovering whole new areas of geometry (and physics) by watching those same springs, swings, and cogs.[3] Head and hand met in the backrooms of the clockmaker's shop, at the bench and the forge.

Meanwhile, outdoor types made their own use of these powerful new devices. Carefully cased and padded, such 'regulators' made their way around the world with the naturalist voyagers of Enlightenment learning, revealing strange things as they went. For instance, even the best clocks seemed to run at slightly different speeds in different places on the planet. These worrying observations would lead natural philosophers to revise their understanding of the shape of the earth, and the forces that gave it form.

Nor was that all. As David Landes points out in his essay in this collection, "Clocks and the wealth of nations," a new type of highly resilient (and breathtakingly accurate) timekeeper – the true 'chronometer,' developed in the late eighteenth century – would up the ante of mechanical magic even as it provided a handy solution to the oldest problem in navigation and cartography: the longitude.[4] These newly compact instruments could ride out a six-week voyage slopping on the high seas while maintaining time to within a second or two a day: accuracies of 99.999 percent and better. They were, in their day, the most otherworldly devices ever made by the hand of man. Otherworldly in a very real sense: each was its own little autono-

3 See, for example, Michael Mahoney, "Huygens and the Pendulum: From Device to Mathematical Relation," in E. Grosholz and H. Breger, eds., *The Growth of Mathematical Knowledge* (Dordrecht: Kluwer Academic Publishers, 2000), 17 – 39.

4 For a brief description of how a clock makes it possible to measure longitude, see page 45 in this issue.

mous world, a universe to itself. This fact was not lost on the English mechanical genius John Harrison, who first pushed chronometrical precision into this ethereal realm. For decades he labored to produce a clockwork that would be impervious to the vicissitudes of the swirling world of dirt and change: his devices would continuously compensate for every perturbation in the conditions of this fallen, messy planet – swings in temperature, in pressure, in orientation. Regarding his creation, after enumerating its fine balances and countless defenses, he was moved to declare: "In short, it is a little world of itself, independent of the difference of gravity, heat, or cold of this our Globe."[5]

A world of itself. It is a tempting idea. An idea consistent with that powerful narrative in the historiography of time science: the story of how time 'left the earth' in the march to modernity. Once upon a time, sun and season, heat and cold were not obstacles to time-telling, they were *exactly the way that people reasoned what the time was*. The medieval peasant watched for hoarfrost and night herons; but Captain Cook, aboard the *Resolution*, peered into a gimbaled box, which, inured to heat and cold, place and position, simply told the time, a world unto itself.

But of course, in another sense, such devices could never leave the world; on the contrary, they stayed right here among us, and transformed it. Their austere and independent workings were inscribed with human significance at every tick. Not least aboard the *Resolution*: it became immortal legend that when Cook fell dead in the Hawaiian surf on February 14, 1779, his faithful chronometer, K1 – back on board the ship – stopped ticking forever, in a mystical manifestation of mechanical sympathy.

Such a braiding of machines and men, meaning and mensuration, should not surprise us. For even as timekeeping precision climbed the curve of progress to an asymptotic plateau beyond the soil, sun, and stars, the devices that performed these feats remained potent worldly objects. After all, as Peter Galison reminds us in this volume, there is eternally a propinquity between things and thoughts, and the clock was a perennial philosophical machine, a machine to *think*, as much as it was a machine to use. Those verge and foliot medieval clocks did more than tell the time of vespers in the village or merely toll the working hours out into the fields; they provided a new way to think about what nature was and how it worked. If that elaborate tower clock could coordinate the swinging motions of the planets and stars on its baroque dials, what made us sure that a similar clockwork was not behind the swinging of the originals, out there, moving against the black sky? Newton wondered as much. And what about that mechanical jack, hammering the bell? If it walked like a duck and talked like a duck, what made it not a duck? Or what made a duck something other than a particularly intricate jackwork? Viscount Bolingbroke may have doubted – wryly, with patrician comfort – that his villagers would ever confuse the parish clock with the town bull, but Descartes, listening to his cat squeak like a wagon wheel, was not so sure.

Such musings touched the heavens. Was God, in the end, perhaps the finest watchmaker of all? A clockwork nature called for a clockwork natural theology, a notion still vigorous (and contested) in the nineteenth century, when the celebrated Anglican divine William Paley

5 Quoted on page 217 of William J. H. Andrewes, "Even Newton Could be Wrong," in Andrewes, ed., *The Quest for Longitude* (Cambridge, Mass.: Collection of Historical Scientific Instruments, Harvard University, 1996).

D. Graham Burnett on time

opened his treatise on God and Man with a clockwork encounter: He asked his readers to imagine a sojourner upon a heath who, walking through the emptiness, stubs his toe on a pocket watch. From this encounter, Paley assures us, our solitary walker could be sure of one thing: a man – a thinking being – has been this way. And yet, Paley went on to suggest, we stub our toes on rocks, twigs, and turtles in any field. Can we not, looking at these, be absolutely certain that some fine intelligence passed this way before us? Otherwise, who made these 'works'? Moreover, does the turtle not surpass the watch (in complexity and craftsmanship) by precisely that measure that the Divine Artificer surpasses man?

In these ways and many more, the clock – the concrete referent in the dominant metaphor of a 'clockwork universe' – served as a potent conceptual tool for thinking about the workings of nature, even as it was also a powerful practical tool for investigating those same workings. And none of this was static. As the actual clocks changed through time (gaining new parts and new capabilities) the elaborations and implications of the clockwork metaphor changed in step: new bits of clocks, like the compensator or the precision-enhancing *remontoir,* offered new dimensions for thinking about the (clockwork) universe, in much the same way that in our own day – as Jennifer Groh and Michael Gazzaniga show in their essay here – new developments in computing have implications for how we think about our (computer-like?) brains.

To see this dynamic at work, take, for instance, the nineteenth-century earth science of the American naval astronomer and hydrographic innovator Matthew Fontaine Maury. Hailing from the fallen-on-hard-times branch of a large and distinguished Virginia family, Maury decided as a boy to cast his meager bread upon the waters, joining the nascent U.S. Navy in 1825, at the age of nineteen. Largely an autodidact, Maury rose to be the first superintendent of the U.S. Naval Observatory, and is often remembered now as the 'founder of oceanography.' As a midshipman and navigator plying the seas in naval and merchant vessels in the first decades of the nineteenth century, Maury had much contact with the new technologies of timekeeping at sea. Later, in the midcentury, as he put his hand to the defense of a new kind of sea science, he reached for the chronometer as a way to make sense of the oceans. And his visionary "Physical Geography of the Sea" needed chronometers as both practical and conceptual tools. Practically, Maury's sea science depended on an extended network of global informants, continuously making and reporting observations about the physical conditions of wind and water throughout the world's oceans. As the century unfolded, chronometrical navigation would make such a system viable, since it enabled observers reliably to correlate their data with specific sites on the trackless wastes of the sea. Plotted to their chronometer-derived coordinates, these data would make the earliest large-scale oceanographic models possible. Standard histories of oceanography seldom fail to acknowledge the field's debt to the chronometer.

But Maury needed the chronometer as more than an instrument. A true sea science demanded a sea that had an inner order that could be revealed – a sea of patterns and workings, a rational sea, not a sea of unformed chaos and opaque looming. A real sea science therefore called for nothing less than a conceptual reinvention of the sea itself, traditionally

a brooding brew of mystery, moodiness, and fearsome unpredictability. Against these notions Maury repeatedly invoked a "clockwork ocean," whose inner workings were as regular and reliable as those of a great blue chronometer. Waves and cycles of salinity were, as he put it, "balance-wheels" in the mechanism, as was the equatorial cloud ring, which "like the balance-wheel of a well-constructed chronometer, affords the grand atmospherical machine the most exquisitely arranged self-compensation"; the Antarctic served as a "regulator" in the thermodynamics of oceanic currents; and, expanding the clockwork analogy, he argued that the Gulf Stream "acts like a pendulum, slowly propelled by heat on the one side, and repelled by cold on the other." "In this view," he continued, "it becomes a chronograph for the sea, keeping time for its inhabitants, and marking the seasons for the great whales; and there it has been for all time vibrating to and fro, once every year, a great self-regulating, self-compensating liquid pendulum." Pushing beyond the waters, Maury went so far as to suggest that the sea was itself nothing less than the main driver in the whole geophysical clockwork of sea, land, and air. For those who took up this new study, Maury promised, "the sea, with its physical geography, becomes as the main-spring of a watch; its waters, and its currents, and its salts, and its inhabitants, with their adaptations, as balance-wheels, cogs, and pinions, and jewels in the terrestrial mechanism." Maury's rich language, his meticulous elaboration of the metaphor, suggests how, in the nineteenth century, new clocks facilitated new thinking as well as new doing.[6]

But there may be a deeper point here as well. The chronometrical sea was, above all and crucially, a *rational* sea. Human efforts to conceive the workings of the sky – the original 'rational' phenomena presented by nature – yielded the earliest clocks, and in time refined clocks made it possible to reconceive the sea – long invoked as the consummately 'irrational' face of nature – as a sky-like place: a formal system that would yield to metrical and mathematical analysis. A sea that behaved like a clock was a sea amenable to science. A chronometrical sea was a rational sea, a sea of ratios, a sea ready to come under a *mathesis universalis*. Here Maury's chronometrical sea science intimates the degree to which the chronometer had come, in the Victorian age, to embody nothing less than rationality itself.

Was the chronometer a Victorian 'theory machine'? A way to think about thinking and being in the nineteenth century? The argument can be made. In January of 1841 another hard-luck young man of good breeding took passage to the Pacific to try a life at sea. By the time the youthful Herman Melville signed on for a sperm-whale cruise aboard the *Acushnet*, Maury had given up life on the decks for life at the desk, but the two men had more in common than youthful wanderlust: Melville's cousin Thomas had been Maury's shipmate aboard the *U.S.S. Vincennes* in 1827 – 1830, on a voyage across the Pacific that stopped in the Marquesas and included a junket on wild and seductive Nukuhiva Island, where Herman would later jump ship. Maury's older brother, John, as it happened, had lived for almost two years as a beachcomber on Nukuhiva all the way back in 1812. On his visit there in 1829,

6 Matthew Fontaine Maury, *The Physical Geography of the Sea*, ed. John Leighly (Cambridge, Mass.: Harvard University Press, 1963 [1861]). In order, I refer to pages 212, 224, 423, 260, 403, 347, and 70; for a lengthy discussion of compensators in the "clock-work of the ocean" see also page 240.

young Maury was searching for evidence of his brother's stay; Thomas could not know then that his cousin Herman would give the island literary immortality in the novel *Typee* less than twenty years later.

Like Maury, then, Melville spent his youth in the chronometrical world of global navigation, and, strikingly, he too would place this new clockwork system at the heart of his later writing. Book XIV of his sprawling, cloying, and finally maddening *Pierre, or The Ambiguities* contains a half dozen of the most remarkable pages ever written on timekeeping, in the form of a fragmentary pamphlet that falls into the hands of the novel's eponymous hero. "Chronometricals and Horologicals," authored by the shadowy sage "Plotinus Plinlimmon," offers a worldly sermon on time, space, and the soul – a sermon that uses the chronometer as an instrument for nothing less than the transvaluation of all values. At the heart of this strange embedded narrative lies a cumbrous allegory. As Plinlimmon puts it:

> It seems to me, in my visions, that there is a certain most rare order of human souls, which if carefully carried in the body will almost always and everywhere give Heaven's own truth, with some small grains of variance. For peculiarly coming from God, the sole source of that heavenly truth, and the great Greenwich hill and tower from which the universal meridians are far out into infinity reckoned; such souls seem as London sea-chronometers (*Greek*, time-namers) which as the London ship floats past Greenwich down the Thames, are accurately adjusted by Greenwich time, and if heedfully kept, will still give that same time, even though carried to the Azores.

Describing the actual process by which world shipping was regulated – merchant and navy vessels embarking on global voyages would set their chronometers by the daily fall of the 'time-ball' atop the Greenwich Observatory, which presided over the lower reach of the Thames docklands – Plinlimmon reimagines the divine *soul* (not merely the body) as a clockwork device. Thus regulated to keep 'God's time,' virtuous spirits can make their way through the world and remain 'true' to a distant and divine standard. They may require, as any chronometer would, periodic adjustments, and – playing out the allegory in technical detail – Plinlimmon suggests they ought to be 'rated' so their particular behaviors can be continuously corrected. But still, such souls can, with attention, emulate Christ, who "was a chronometer; and the most exquisitely adjusted and exact one, and the least affected by all terrestrial jarrings, of any that have ever come to us."

Moreover, like Christ, all 'chronometrical' souls will find themselves in the same worldly bind:

> Now in an artificial world like ours, the soul of man is further removed from its God and Heavenly Truth, than the chronometer carried to China, is from Greenwich. And, as that chronometer, if at all accurate, will pronounce it to be 12 o'clock high-noon, when the China local watches say, perhaps, it is 12 o'clock midnight; so the chronometrical soul, if in this world true to its great Greenwich in the other, will always, in its so-called institutions of right and wrong, be contradicting the mere local standards and watch-maker's brains of this earth.

To work from one's chronometer is thus to be out of sync – usually ridiculously so – with the 'horologicals,' to be out of sync with local norms and ways of life. Only on the fine line of the prime meridian, on that "great Greenwich hill

and tower" of the celestial seat, will chronometrical time be the 'right time.' Elsewhere, living by Greenwich time will make a chronometrical soul "guilty of all manner of absurdities: – going to bed at noon, say, when his neighbors would be sitting down to dinner."

At stake, finally, is nothing less than the very existence of absolute principles in moral life. Melville the beachcomber – that amphibious sailor who had by this time already made his way inland on notorious Nukuhiva, and who, confronting the terrifying 'Typee,' wondered how to reset his ethical ticker to a 'savage' local time – lets Plinlimmon play out the dark meaning of the lecture:

> In short, this Chronometrical and Horological conceit, in sum, seems to teach this: – That in things terrestrial (horological) a man must not be governed by ideas celestial (chronometrical).... A virtuous expediency, then, seems the highest desirable or attainable earthly excellence for the mass of men, and is the only earthly excellence that their Creator intended for them. When they go to heaven, it will be quite another thing. There, they can freely turn the left cheek, because there the right cheek will never be smitten. There they can freely give all to the poor, for *there* there will be no poor to give to. A due appreciation of this matter will do good to a man.

Here are the clocks and maps not of a physical relativity (that will come later with Einstein and Poincaré), but of an equally radical ethical relativism.

If not something more extreme – since it cannot have been lost on an educated salt like Melville that every nation set its chronometers to its own prime meridian: the French to Paris, the Spanish to San Fernando, the Americans to Washington. Even the *absolutes* of those chronological souls, by these lights, were perfectly arbitrary. Plinlimmon would seem to be offering a kind of antinomian horology at worst, at best an unctuous pragmatism of local mores.

And yet, there is a suggestive promise that the conceit, if rightly understood, offers something more, perhaps something less bleak. As Plinlimmon hints, "And yet it follows not from this, that God's truth is one thing and man's truth another; but – as above hinted, and as will be further elucidated in subsequent lectures – by their very contradictions they are made to correspond."

"By their very contradictions they are made to correspond." What can this gnomic conundrum possibly mean? Since the text in question is a fragment, the reader of *Pierre* shuffles in vain for an account of this reconciliation of oppositions, this transcendental deduction. Still, the vehicle of the allegory may carry us to a solution: for to anyone familiar with the actual operations of mid-nineteenth-century navigation, it is a simple matter of geometry to make horological and chronometrical contradictions 'correspond.' That is to say, the difference between Greenwich time and local time is a way of *orienting oneself in space*, of knowing where one is, and how one is heading. Does Melville want us to think of moral principles in this way? As a means to find our way home? Is this, ultimately, the function of the chronometrical soul?[7]

From the natural theology of Paley's wanderer and his watch, to the meanderings of Melville's chronometrical spirit, adrift on the high seas, the technologies of timekeeping ticked away in the heart of Victorian metaphysics and theology, even as they ticked in earnest

7 In the Northwestern-Newberry edition of *Pierre*, "Chronometricals and Horologicals" runs from pages 210 – 215. See Herman Melville, *Pierre, or The Ambiguities*, ed. Harrison Hayford, Hershel Parker, and G. Thomas Tanselle (Ev-

in the church towers of Victorian Britain. And as if in syncopated echo of Plinlimmon's tale, even those steeple clocks did not tick together. As the railways extended London time throughout England in the 1850s, a real chronometrical schism split the isle: high church bells still rang local hours; the nonconformist places of worship switched to Greenwich time. Chronometricals and Horologicals indeed.

One reading of "Chronometricals and Horologicals" sees the tale as a parable of nineteenth-century theosophical chronometry. And this cannot be wrong. And yet, it is not clear that this reading is enough. For one could begin again, at the beginning, and survey the world from the top of time – from atop Melville's "great Greenwich hill and tower." From here we can watch the sails open for the east, for China, Java, Africa, and India, places that are out there beyond the sea, yes, but even more importantly, places that are *not in our time*: not in our time chronometrically speaking, to be sure, as Melville reminds us; but not in our time in a deeper way too, since in the colonial imagination the 'out there' was almost always a 'back then.' In this sense London marked the prime meridian in a cultural cartography too – a global chronocultural geography. If there was a metaphysics of the chronometer in the age of empire, might we not be obliged to acknowledge that there was a geopolitics as well?

This observation extends beyond the straightforward fact that the clocks of the nineteenth century were tools for the creation of the maps of empire, though they were emphatically that: Darwin's ship the *Beagle* carried no fewer than twenty-two chronometers aboard as it fulfilled its admiralty duty, charting the South American coasts for the improvement of British shipping, while showing the Union Jack from Bahia to Valparaiso and beyond. The *Beagle* and its countless sister ships were chronometrical souls, and they kept Greenwich time (and paraded Greenwich mores) in the horological Chinas and Nukuhivas of the expanding European empires.

But the geopolitics of timekeeping meant more than this. For even as those brass Frodsham and Arnold chronometers helped bully colonial explorers keep track of where they were on sea and on land (as they made their maps and used them), these same ticking devices helped such men keep track of where they were in the history of civilization: they came from atop the hill of time, and could show this to the feathered and benighted people of the horological realms by opening a gimbaled mahogany box.

Such scenes were the stock-in-trade of Victorian exploration. The French gorilla-hunting swashbuckler Paul du Chaillu would write of how awed Africans contemplated his timekeeper in wonder and amazement and decided that it must be his "guardian spirit." If his onlookers actually asserted something like this, they were, of course, not far off. And such tales were legion. After showing his watch and other instrumental accoutrements to the native people he met, the British explorer Lovett Cameron quoted (ventriloquized?) their ejaculations of Anglophilia: "Oh these white men! They make all these wonderful things and know how to use them! Surely men who know so much ought never to die!"[8]

Indeed, so they all hoped. And if they did not die under the tropical sun, they

anston and Chicago: Northwestern University Press and The Newberry Library, 1971).

8 Both stories are told in Michael Adas, *Machines as the Measure of Men* (Ithaca, N.Y.: Cornell University Press, 1989), 159.

packed up and went back to the future, whence they were increasingly sure they had come. They left the past behind, in Africa, the Amazon, and elsewhere – primeval places, filled with primeval peoples at different stages in the evolution of civilization.

These scenes of chronometrical encounter were by no means new to the nineteenth century. Mechanical timekeepers had served European voyagers as a way to put themselves on the map culturally, long before such devices were adequate to put them on the map geodetically. Nowhere was this sort of timekeeping more important than in the early-seventeenth-century encounters between the China of the Ming dynasty and the Jesuit missionaries who set out for Peking to convert the middle kingdom. As Father Ricci liked to tell the story, it was the promise of receiving a gift of 'self-ringing bells' that finally seduced the reclusive emperor and gave the brethren a way around the meddling eunuchs of the imperial palace. The results entered the providential hagiography of the order: the emperor, instantly besotted with this fine new toy, obliged his supercilious mathematicians to sit at the feet of these clever foreigners and to learn the regulation and maintenance of this remarkable device. Soon thereafter, he insisted upon having a clock with him at all times, and within a year a section of the Forbidden City was being remodeled to accommodate a large tower clock. By 1730, a French missionary to the court would report that "The Imperial Palace is stuffed with clocks…watches, carillons, repeaters, organs, spheres and astronomical clocks of all kind and description – there are more than four thousand pieces from the best masters of Paris and London."[9]

Recently, after presenting a lecture on science and colonialism, I was approached by a distinguished senior gentleman who wanted me to explain why the Chinese never had a scientific revolution. This question – often known as the Needham Problem, after the great Cambridge sinologist and Marxist historian of science, Joseph Needham – has long been the sixty-four-thousand-dollar question for the historian of science. If in recent years developments in the historiography of the European 'scientific revolution' have somewhat put the question aside (we are no longer so sure we know exactly what that revolution was, so it makes it tough to ask why the Chinese didn't have one), it remains a hard problem on which much distinguished work has been done. I began to offer my questioner a sense of how one might go about answering his question, but he cut me off briskly. As it happened, he already knew the answer, and wanted to tell me: "The Chinese emperor," he explained, "had this huge, locked closet where he kept all the clocks of the kingdom, and he wouldn't let anyone else see them or study them. He hoarded them because he was afraid of what the people would do if they got any science."

Now this isn't right. By the early eighteenth century there was a proper trade in European timepieces through Canton, and by the 1820s a whole international European subindustry had arisen, linking London and Geneva, wholly for the purpose of supplying a distinctive kind of watch to the burgeoning China trade.[10] But my interlocutor was not to

9 Quoted in Carlo Cipolla, *Clocks and Culture 1300 – 1700* (New York: Collins, 1967), 86. There is a rich and detailed literature on timekeeping and European encounters with China. For an introduction see Chun-chieh Huang and Erik Zürcher, eds., *Time and Space in Chinese Culture* (Leiden: E. J. Brill, 1995).

10 This industry is discussed by David Landes, *Revolution in Time* (Cambridge, Mass.: Harvard

be budged: authoritarian tyranny and technophobia had, as far as he was concerned, consigned China to the dustbin of history. For him, they got stuck in the Middle Ages.

This view, which glosses over both the history of timekeeping in China and a complex story of cross-cultural exchange, nevertheless has a long scholarly pedigree, one that can be traced right back to some of those very eighteenth-century Jesuits who attended at court in Beijing. Put aside its merits. Most striking is the way this view places the chronopolitics of modernity in high relief. For what does it mean to say that other people, manifestly our contemporaries, are best understood as living in our past?

In an influential essay published in 1983, *Time and the Other*, the Dutch anthropologist Johannes Fabian undertook a sweeping critique of precisely this temporal cartography, which he called 'allochrony.' If Serres's parable probed how moderns came to think of themselves as perennially atop some abstract mountain of time, Fabian would ask us to see that this mountain was quite literally mapped onto the globe in the age of European overseas adventuring. London, Paris, Berlin – these metropolitan centers were atop that hill, which is to say that they were in the present, but the farther one went from downtown, the farther back in time one could venture. From the 'serfs' of neighboring Ireland all the way to the 'natural men' and (even better) 'natural women' of Tahiti. Out in space meant back in time. Reading movement in space was the job of a navigator or geographer, but reading this subtle movement back through the ages of humanity, this was the task of that paradigmatic figure of Enlightenment learning: the philosophical traveler.

For Fabian, then, modernity was born when the timeline time of Grafton's chronologers was spatialized into a vast, globe-encompassing geochronocultural tableau, a concentric secular cosmology that gathered the peoples of the world into a new *mappamundi* with the great cities of Europe cast as the new Jerusalem, the origin and apex of civilization, the only part of the planet that was actually *modern*. Here was a powerful new way to make sense of the flood of discontinuous, fragmentary, and destabilizing evidence about human origins and human habits that was pouring into the learned societies of those cities. Here, for Fabian, was the birth of the human sciences, particularly anthropology, which grounded itself in this new cosmology of modernity, grounded itself in the original sin of hegemonic ambitions, the "denial of coevalness."[11]

That a map of time enabled travelers to orient themselves and plot others throughout the age of empire – this, I think, cannot be denied. Whether, as Fabian suggests, allochrony remains a "vast entrenched political cosmology" such that contemporary geopolitics has its ideological foundation in, as he would have it, a "flawed chronopolitics" – this remains a contentious thesis, but not an absurd one. Talk with some undergraduates about the non-Western world and use a stopwatch to time how long it takes before they invoke allochrony as a way to make sense of others. Or, perhaps more tellingly, listen to the evening news.

University Press, 1983), 268. See also Catherine Pagani, *Eastern Magnificence and European Ingenuity: Clocks of Late Imperial China* (Ann Arbor: University of Michigan Press, 2001).

11 Johannes Fabian, *Time and the Other* (New York: Columbia University Press, 1983). He takes the eighteenth century to mark the installation of this idea; but the roots run deep.

Fabian considered his analysis an intervention in what he called "the scandal of domination and exploitation." He believed that he was revealing the ideology of time that had undergirded, and finally authorized, the attitudes and practices that led Europeans and their Creole descendents to claim, by the opening of the twentieth century, territorial sovereignty over some 85 percent of the terrestrial globe.

But does his observation add anything to the history of time's science? That story of progressive precision, of fine clockwork? That story that takes us from the rough-and-ready judicial water clock in Athens to atomic clocks so fantastically precise that they can reveal changes in the speed of the spinning earth when the winds blow, and when the spring sap rises in the trees?

Perhaps. For a long while (as Needham's Problem suggests), scholars in the history of science and technology have been interested in the problem of European exceptionalism. They have asked, for instance, why the Chinese did not immediately take up the larger astronomical and cosmological significance of precision clockwork. What impedimentary aspect of their culture or character could be held responsible for the way that they held these devices in the realm of baubles and playthings? But perhaps we would do well to reconsider this question and others like it in light of Fabian's chronopolitics: if clocks went into the world, at least in part, to show non-Europeans that they were in the past, then these tickers were not simply useful tools, scientific instruments, or symbols of the clockwork universe – they were also agonistic instruments. Little boxes that measured not merely time, but men; and which were always wound up to do battle on foreign shores. And one might build large closets for such troublesome devices.

Deep in the Walsingham cave, in Bermuda, watch in hand, as the native guide looked on, C. Wyville Thomson and his party tried to get to the bottom of time. Pickaxes poised, they were ready to dig, if necessary, to get there. All the while, though, they knew exactly where they stood in history: they were men of science, from Victorian England; they had set their chronometers at Greenwich, that towering hill. Getting to the bottom of time would only tell them what they already knew: they stood at the leading edge of knowledge, they were astride the past.

Who made time the hill we are always atop? And who sold plots on the terraced slopes to the people of the Caribbean, to the Pacific Islanders, to the whole 'family of man'? At what cost?

I have sketched two stories in this essay: one, the story of how, with clocks and rocks, human beings tried to get to the bottom of time – to grasp, hold, and show what it really was; the other, the story of how, with maps and memory, human beings managed to get to the top of time – to mound up the hill of the past and summit it. Do these two stories fit?

Between them comes something else. An accretion, a flow, the sand that slips through the skylight of the hourglass, and makes that little hill, from its base to its ever-sliding tip. Between the bottom of time and the top comes the remainder. Time itself. Which we have not caught. Which does not fit.

What would it be like to let this sand fall into our hands, and neither to dig nor to climb? I do not know.

David S. Landes

Clocks & the wealth of nations

A recent novel by Dai Sijie, *Balzac et la petite tailleuse chinoise*,[1] tells of the impact of an alarm clock imported into a Chinese farm village:

> Before, in this village, there had been neither alarm, nor watch, nor clock. People had always lived by the rising or setting of the sun.
>
> We were surprised to see how the alarm assumed a veritable power over the peasants, almost sacred. Everyone came to consult it, as if our house were some kind of temple. Every morning the same ritual: the chief strode around our house, smoking his bamboo pipe, as long as an old rifle. He did not stop looking at the alarm. And at 9 o'clock precisely, he gave a long, deafening whistle, to send the villagers off to the fields.
>
> – It's time, you hear me! he shouted out to the houses around. It's time to work, you good-for-nothings! What are you waiting for?

Almost all cultures and civilizations have concerned themselves with time, if only to give cues and set bounds to social and religious activity. To these ends, they have relied principally on repetitive natural phenomena – on the movements and changing lineaments of heavenly bodies. Such clues are not regular in occurrence nor identical from one to another point of observation. They are sufficiently so, however, for most practical purposes.

The more technologically advanced societies have gone beyond passive observation to create instruments of time measurement – what we call clocks. These initially relied on the observation and measurement of an artificially created regularity – a gravity-driven falling column of water or sand, for example. Such instruments can provide a fairly accurate measure, though they do not afford identical comparisons among themselves and require painstaking attention by way of refilling the chamber and restarting the process. Resetting the clock requires an accurate standard that takes account of seasonal variations, and, insofar as this standard may be the

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1 Dai Sijie, *Balzac et la petite tailleuse chinoise* (Paris: Gallimard, 2000).

sky, may require such associated tools as a telescope and a little bit of luck in the way of good visibility.

It was this uncertain visibility that may have pushed European time-watchers to invent a mechanical clock. In any case, the Europeans early on sought to invent a machine that would keep time of itself and continue to do so even during moments of rewinding; that would depend, in other words, as little as possible on celestial indicators. The critical innovation turned out to be the principle and technique of oscillation – of coming and going, *va-et-vient* – a combination whose regularity combined with repetitiveness to provide countable time units. It found realization in the thirteenth century. From then on, and simply because one civilization had invented mechanical clocks and the other had not, West diverged from East, Europe from Asia.

This divergence found expression and consequence, first, in the making of timekeepers; and second, in their use.

As to the making: the accuracy now lay in the instrument itself, which had to be built to appropriate standards. This meant that every part had to be cut to the utmost precision, which in turn called for tools and measures unimagined before. The effect was felt not only in clock-making but also in other branches of manufacture, including those not yet known. Where once what mattered was the craftsman's feel for his work and tools, now standards could be set in advance and were subject to external prescription and judgment of performance.

As to the use: temporal precision had to matter. It came early to matter in Europe for its own sake; application came later. Elsewhere, time continued either to be a visual function, available to all, or the prerogative of an authority that dictated accuracy from above.

China is an excellent example of the differences that emerged between Europe and Asia. This was a civilization that esteemed timekeepers and built good water clocks (klepsydras) to this purpose. Students of the history of Chinese technology and invention have long boasted of Chinese precocity and originality, and sought to explain subsequent Western leadership as the result of copycat emulation, citing such items as paper, printing, porcelain, and gunpowder. Timekeeping has challenged this model. It is not only that the mechanical clock is so much better an instrument than the klepsydra. It is that even when Europeans brought the clock to China, as gift, bribe, and boast, the Chinese, who loved it, never really learned how to make it. In matters of technology, early modern Europeans were simply much better students.

The Europeans also took temporal accuracy much more seriously. For the Chinese, this was not a problem, because the hour was what the authorities said it was. They did have access to celestial indicators: the positions of planets and stars, the sky map. But barring egregious discrepancies, the pursuit of such information was more trouble than it was worth, especially to potential astronomers who had little to gain from diligence. We have here from the eighteenth century an informative set of letters from a Jesuit missionary, P. Parennin, to the director of the Académie des Sciences in Paris.[2] His first point: that good observations brought little gain or recompense to those who made them. They might rise to honor in the Mathematical Tribunal, but such advance brought little

2 In Isabelle and Jean-Louis Vissière, eds., *Lettres édifiantes et curieuses des Jésuites de Chine 1702 – 1776* (Paris: Éditions Desjonquères, 2001), 180 – 188; based on the edition of 1819.

income, the less so as Mathematics was subordinate to the Tribunal of Ceremonies. Even worse, the risk outweighed the profit, as a mistake could cost a year or two of salary.

As a result, the instruments needed for accurate observation, the eyeglasses and water clocks, were simply neglected and abandoned. Nor did the authorities impose their use:

> The palace of the Emperor is well equipped in this respect, and these instruments are [often] the work of Europe's best craftsmen; but the emperor Cang-hi [Kangxi] who has had the astronomical tables corrected and has equipped the [Peking] observatory with so many beautiful instruments, and who besides knows better than anyone how much eyeglasses and clocks are necessary to exact observations, has never ordered his mathematicians to use them. No doubt these last have been strongly opposed to these inventions and have made much of the nation's attachment to older ways – a position where they are guided only by their own interest. We have every reason to fear that with a change in dynasty, the older Chinese instruments, once relegated to the scrap furnace, will reappear with honor, and that those devices that have usefully replaced them will be sent to the foundry, the better to erase their very memory.

Meanwhile, the Europeans found new ways to use time. Where other societies saw it as a clue to banal everyday work schedules, the Europeans, who also used it that way, integrated it into other activities and changed them completely. Take sailing and navigation: the very performance that brought the Europeans around Africa into eastern waters depended on knowledge of latitude, and latitude calculations made use of calendrical data on the timing of the positions of celestial bodies, times eventually assembled in tabular form (ephemerides and almanacs).

Why was latitude so important? Because of the special conditions of navigation in the south Atlantic. The original assumption of Portuguese sailors heading southward was to hug the western coast of Africa, using it as guide, shelter, and source of provisions in traditional coasting fashion. The trouble was that this was a singularly barren and inhospitable coast, marked by countervailing winds and currents, so that this prudent recourse to established navigational technique entailed long voyages – so long as to threaten the health and survival of the crew.

Appropriate procedure called for navigational avoidance, for sailing west with wind and currents – as far west as the coast of what came to be called Brazil or South America – and then, after swinging south, for picking up the powerful eastward antarctic stream that would carry the vessels swiftly past the southern point of Africa into eastern waters. To do this, however, required a knowledge of latitude, and this called for frequent time readings. Initially these were based on celestial observations at intervals – an approximate but roughly satisfactory procedure. Over the years and decades, however, navigators learned to use clocks. Not the klepsydra, for that was a timekeeper that worked only when kept still. But the weight-driven mechanical clock was another matter and in the higher spring-driven chronometer form of the eighteenth century it made possible the calculation of longitude. Together with latitude this made it possible for European navigators to locate themselves. It was time, then, in combination with navigational imagination

and courage, that opened the world. And so it was that the 'barbarians' came to Asia, and not the reverse.

The Chinese had in fact sent out larger fleets with larger vessels a half century earlier, and these had reached the east coast of Africa.[3] That is as far as they went, for their primary aim was to bring back specimens of wildlife unknown in China – giraffe, hippopotamus – and add them to the emperor's collections, in demonstration of his pretensions to universality. But this costly venture posed problems of etiquette once the captive beasts reached China: the emperor wanted to see his new giraffe, but the rules had it that the emperor could not, should not, go out of his way to see anybody or anything; he or it had to come to him. So the courtiers arranged for the emperor to take a walk in his park, where he 'chanced' to come upon a 'wandering' giraffe. Thus he saw his booty, and order was preserved.[4]

These early Chinese voyages preceded the European ones by half a century or more, but lacked serious motivation (read: greed). The Chinese court found the voyages inordinately costly, and not only never followed up, but banned further oceanic exploration. Thus the first Chinese vessel to sail around Africa into the Atlantic went in 1850 – 1851 to attend the Great Exposition in London. That was three hundred and fifty years after the first Portuguese vessels found their way into Chinese ports – one more evidence of the Chinese indifference to outsiders and opportunity.

Chinese contempt for most Western things has been traditionally summed up in the dismissive letter (rescript) of the Qianlong emperor (reigned 1736 – 1795) to George III of Great Britain, rejecting the British request of 1793 for trading rights and a permanent legation in Peking: "We have never set much store on strange and ingenious objects, nor do we need any more of your country's manufactures." The Europeans in an earlier period had certainly learned from China; the Chinese of the eighteenth century did not feel they had anything to learn.

The easy availability of good timekeeping instruments, at least to those who could afford them, reinforced the general interest in and pursuit of time. These instruments also provided endless opportunities for obsessive behavior.

The examples are many, and all of us know friends and acquaintances who pursue precision and promptness as a source of comfort and achievement. Let me offer an example from history: Gustav Krupp von Bohlen und Halbach, heir to the great German steel and armaments fortune, king of the family castle, worshiper of efficiency, concentration, above all, punctuality.

In a nation of clock-watchers, Gustav stood out. Breakfast at the castle was served exactly at 07:15 hours, and the guest who arrived a minute late found the doors locked. That morning meal was set to last fifteen minutes, when Gustav went out to his carriage or, from 1908, his limousine. The moment his feet left the ground, the vehicle took off.

3 Recent literature has credited China with wider navigational and exploratory priority, for example Gavin Menzies, *1421: The Year China Discovered America* (New York: William Morrow & Co., 2003). John Noble Wilford's review in *The New York Times Book Review* of 2 February 2003 questions Menzies' evidence, but he would have done better to ask, So what?

4 A parallel version of this story is told of King Louis XIV of France, like the emperor of China a ruler of unlimited pretensions. Which version came first, I do not know. To this day, the French are the self-styled representatives of higher civilization in a world of lesser specimens.

He kept a schedule book listing each day's engagements by the minute, including just so much time to prepare and verify the next day's schedule. Fifty minutes were allocated to dinner, unless there were guests, in which case dinner went precisely to 21:45. Then thirty minutes for evening toilette and small talk, and he and Bertha slipped into bed and dutiful union at 22:15.

By the same token, fixed times were reserved for play with the children. The favorite toy was a railroad, with its own schedules, which Gustav supervised with stopwatch in hand. Lunch guests were not allowed to come in their own cars; they or their chauffeurs might be late. They were fetched by Krupp drivers, who brought them to the castle at 13:29. A minute later they entered the reception room to chat, then sat to table at 13:40. The moment Gustav finished a course, all plates were removed. Slow eaters gave up what was left. Meal over at 14:15, coffee at 14:29. The coffee was served at a pre-set temperature, never too hot. Gustav felt that a craving for warmth was a sign of weakness, and yielding to one weakness would encourage others. At 14:30 precisely, guests stepped into the waiting limos and were whisked away.[5]

The contributions of mechanical timekeepers to sailing and navigation were spectacular, with major gains to route selection and related economies.[6] To land transport as well, particularly with the coming of the railroad. Less obvious initially was the gain to industry and manufacturing, particularly as a measure and test of performance and productivity. These were activities, after all, that proceeded in accord with human, traditional work rhythms, the more so as wages were often calculated by the piece, and buyers and employers had little or no advantage in speeding the work.

The adoption of mass-production techniques, however, changed the nature of labor performance and the principles of remuneration. The coordination of tasks made all the difference. Now it was important, nay crucial, to assign the work and provide the equipment in such ways as to permit smooth and uninterrupted progress – to clear space and bring tools and materiel to the right places at the right time. Also – and this was essential to wise decision-making – to measure and compare the relative productivity of one arrangement as against another. The ever-present stopwatch was the key to gains and costs.

The pioneer here was Henry Ford. He was a firm believer in the moral virtue of democratic transport and mass production, of cheap cars for the multitude. The flivver showed the way. And the demand for Model T's kept growing apace: 18,664 cars in 1909 – 1910, 34,528 in 1910 – 1911, 78,440 in 1911 – 1912. Some way had to be found to increase output without inflating prices, in short, to increase productivity. One technique was to move toward interchangeable parts. Henry and his engineers were constantly on the lookout for more accurate and precise machine tools, aiming at tolerances of one ten-thousandth of an inch. Any time they found a better tool, they scrapped all the old ones. The managers grimaced with pain, but went along because the boss and the engineers wanted it that way. In two years, by 1910, the

5 On all this and more, see William Manchester, *The Arms of Krupp* (Boston: Little, Brown, 1968), 251 – 254.

6 See William J. H. Andrewes, ed., *The Quest for Longitude* (Cambridge, Mass.: Collection of Historical Scientific Instruments, Harvard University, 1996).

careful filing and adjustment of inaccurate parts were done away with.

A second major innovation was the simplification and routinization of tasks, thanks to the use of a moving assembly line. The old way was to bring the workers to the work; now they brought the work to the workers. This process developed in three stages. First, teams of assemblers moved from fixed chassis to fixed chassis, or assemblers simply stayed with their chassis while others brought them tools and parts as needed. Average time (stopwatches had become indispensable tools): twelve and a half man-hours per chassis. Then came line production: a rope or cable winch pulled the chassis along while teams of assemblers moved with it, picking up parts from bins strategically placed along the way – jerky, irregular progress. Average time: 5 man-hours, 50 minutes. Then workers were placed in carefully calculated stationary positions along the way, while the moving chassis ran along at waist height and overhead carriers and gravity slides brought subassemblies as needed. Best time: 93 minutes. Henry rejoiced: "Save ten steps a day for each of 12,000 employees, and you will have saved fifty miles of wasted motion and mis-spent energy."[7] Output more than doubled in 1912 – 1913 and doubled again the next year, while the workforce actually fell.

Henry Ford, with the aid of a remarkable team of collaborators, had thus effected a revolution in production technology. In his autobiographical essay, *My Life and Work*, Henry conveys the impression that all the ideas and techniques went from him down. Nevins and Hill, observing the process from beyond and after, find this simplification erroneous: "seminal ideas moved from the bottom upward."[8] They stress the accidents of shrewd hiring; the readiness of Henry and supervisors to give gifted men their head; above all, the willingness to experiment (*always using watches*).

To be sure, the new technology posed a problem to labor morale. The work was dull and thus fatiguing, and the constant pressure to raise productivity pushed effort to ever-higher limits. Henry Ford's answer was to introduce a record daily wage. He did not want to base wages on output (piece wages) – the prevalent Detroit method – because he felt that productivity gains came from above; also because the Ford company was changing methods and procedures too fast to permit appropriate and timely recalculations. And of course, once the assembly line was introduced, piece wages would not have made sense: it was the speed of the line that set the level of output. But Henry wanted to be able to recruit a diligent, reliable workforce eager for high pay. The answer, voted January 1914, was the $5 day, two to three times the prevalent level. Not right away, of course: workers had to put in six months of training and adaptation at base-pay $2.34 before the new level kicked in as an implicitly conditional profit-sharing bonus.

Nothing did more than this pay raise to enhance Ford's reputation as a statesman of industry and a model of employer wisdom and generosity. Newspapers all over the country carried the story, and would-be workers lined up outside the factory gates by the thousands, far beyond the hiring possibilities of even an exploding company. One newspaper headline went so far as to invoke divine benediction: "God Bless Henry Ford."

7 Ibid., 109.

8 Allan Nevins with the collaboration of Frank Ernest Hill, *Ford,* vol. 1 (New York: Scribner, 1954 – 1963), 474.

It goes without saying that these methods were copyable and much copied. That has always been the supreme advantage of modern techniques of time measurement: the instruments are relatively cheap and widely applicable.

I would not want simply to say that time measurement and the mechanical clock made the modern world and gave the West primacy over the Rest. That they did.

But the clock in turn was part of a larger open, competitive Western attitude toward knowledge, science, and exploration. Nothing like this attitude was to be found elsewhere. Attitude and theme came together, and we have all been the beneficiaries, including those civilizations and societies that are now learning and catching up.

Vive l'heure! Et vive l'horloge!

Michael Rosbash

A biological clock

Time: why and how do living organisms harmonize with the fourth dimension of our world?

Many biologists have little interest in this question. They concentrate instead on the three-dimensional world, trying to understand how the proper size and shape of organisms are encoded and achieved, and how the human brain is wired. Although these matters are not completely divorced from temporal considerations – an organism must make the correct gene products in the correct sequence and at the correct stage of development – timing has received scant attention during the past thirty years or so in such fields as molecular and developmental biology.

In contrast, other biologists, working in such fields as neuroscience and evolutionary biology, regard the issue of time as urgent and inescapable. Consider the brain. There are very rapid temporal events, of intense interest to neurobiologists, on the millisecond (0.001 seconds) timescale. Here timing is everything, and information-processing in a neurobiological context does not work at all if events do not occur with proper speed and coordination.

Then consider the evolution of life on earth. It has taken three to four billion years for our species to emerge since primitive life-forms first arose in the primordial soup. The last 0.1 percent of this journey, approximately five million years, is the time since the last common ancestor shared between humans and our closest relatives, chimpanzees. It is generally acknowledged that many features unique to our species, like walking upright and sophisticated verbal communication, arose during this last tiny fraction of our planet's biological experiment. Yet even this 0.1 percent, or 5 million years, is a number that dwarfs the average human life span and comprises perhaps two hundred fifty thousand to five hundred thousand ape-human generations.

The incredibly slow march of evolutionary time and the very rapid events of neuronal firing are well beyond the experience or intuition of most if not all members of our species. The inability of people to achieve a comfortable relation-

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ship with these very large and very small numbers has almost certainly contributed to society's difficulties with mind-brain issues on the one hand and Darwinian evolution on the other.

No such difficulties attend the topic of my own area of biological interest: the circadian rhythms that regulate living organisms. These rhythms function on the much more familiar timescale of twenty-four hours. The name 'circadian' comes from the Latin *circa dia* and means 'about a day.' This is because circadian periods do not last *exactly* twenty-four hours but rather vary somewhat from organism to organism. These inexorable rhythms, due to the persistent beating of a biological clock in our brains and in other tissues, serve to coordinate many features of our behavior, metabolism, and physiology – even our sleep-wake cycle. Circadian rhythms are also present in plants and in most, perhaps all eukaryotic life-forms, i.e., complex organisms like us with a nuclear membrane. Bona fide circadian rhythms are even present in some photosynthetic bacterial species.

The relationship to photosynthesis is not coincidental, as circadian rhythms reflect an almost ubiquitous adaptation to the twenty-four-hour-day cycle. The rotation of the earth on its axis is the source of daily temperature as well as of light-dark cycles and is considered the oldest and most continuous feature of life on earth. Even the first organisms – perhaps the self-replicating molecules of the original RNA world that probably preceded cellular life – arose in the presence of a light-dark cycle much like the one we experience today. It was perhaps 20 percent shorter four billion years ago, which might contribute to the explanation of why circadian clocks are not precise twenty-four-hour timekeepers. Consistent with the loose relationship to a twenty-four-hour cycle, intrinsic period varies from species to species, from about twenty-two to about twenty-six hours.

The fact that there is a difference between the 'intrinsic period' of an organism and the actual twenty-four-hour cycle of the external world implies that circadian clocks are not solely light-driven. From a practical standpoint, it also implies that the intrinsic period must be measured under constant conditions, constant darkness or constant light along with constant temperature. This is to avoid the synchronization with the actual twenty-four-hour light-dark cycle that normally takes place.

It is generally acknowledged that the first person to recognize this organic phenomenon was an eighteenth-century French astronomer named de Mairan. He had been musing about plant rhythms, wondering what drove plants to extend their leaves during the daytime and retract them at night. Intuition suggests that this daily leaf movement rhythm should be light-driven, but in 1729 de Mairan elected to test this hypothesis. To perform the first free-running circadian experiment, he took a plant down to his basement (*la cave*), where there were constant conditions, i.e., no daily variations in light or temperature (good for storing wine). *Mirabile dictu*, the leaf movements continued unabated on a circa twenty-four-hour schedule, indicating that they were driven by an endogenous circadian clock rather than by light.

Many different kinds of experiments under constant conditions support this general conclusion, namely, that most organisms contain self-sustaining pacemakers at the heart of their circadian systems. Mice have periods of about 23.5 hours and rats about 24.5 hours under

constant conditions. Importantly, there are even differences between inbred strains of mice, indicating that quantitative features of the circadian system are under genetic control. (Much more about genetics and mutants below).

Under more normal light-dark conditions, animals sense light and especially the changes in illumination intensity that are normally experienced at dawn and dusk. Photoreceptors transmit these time-of-day signals through specific input pathways to their endogenous biological clocks. One or more of these photoreceptors provides a daily reset of these endogenous clocks and keeps them synchronized with the actual twenty-four-hour light-dark cycle of the external world. A one-hour delay remains a one-hour delay, day after day, and every day is the same as the day before. Otherwise put, circadian clocks run too fast or too slow, but they are reset at the same time every day by the very precise twenty-four-hour light-dark cycle. This general principle gives rise to an important relationship between period as measured in constant darkness and phase as measured under more normal light-dark conditions. An individual with a shorter period under constant conditions will usually manifest an advanced phase under normal conditions. This pertains to comparisons between species as well as between individuals of a single species – a mutant for example.

What are circadian mutants and how do they arise? It is important to appreciate that mutants in general (mutants of any characteristic and of any organism) are of two kinds. First, there are spontaneous mutants, oddballs that arise by chance. These are oddballs in the probability and statistics sense of the word, with no pejorative connotation implied. They might have one or more unusual circadian characteristics, which are genetic in origin, due for example to a fortuitous mutation in an important clock gene. (This is fortuitous for the investigator; not always for the individual, if we are considering humans.)

The second, larger category of mutants is induced. This is usually due to the feeding of mutagens to animals or bacteria, which causes a high frequency of DNA alterations and a concomitant high frequency of mutations. (Needless to say, this is not done with humans.) The strategy is then to screen the treated population for a mutant phenotype, a circadian abnormality for example, and verify that it 'breeds true' and is transmissible to subsequent generations. This 'forward genetics' approach (called 'genetics' before the more recent advent of recombinant DNA and 'reverse genetics') has been a mainstay of biological research for much of the twentieth century, both in microorganisms as well as more complex organisms like *Drosophila* (fruit flies). This canonical strategy was originally concerned almost exclusively with mechanisms of inheritance, i.e., how particular characteristics (phenotypes) are transmitted from generation to generation. This more descriptive field of genetics predominated during the first half of the twentieth century and presaged the Watson-Crick discovery of the structure of DNA in 1952 – 1953.

A more biochemical genetics, the study of gene expression, has predominated since that time. Especially over the past thirty years, this has given rise to an abundance of information about genes and their functions. The recent completion of the human genome DNA sequence, approximately three billion base pairs per person, is a particularly visible example of this progress. The worldwide effort to understand DNA and its expression has provided the world of molecular biology with a highly sophisticated

tool kit, culminating in the now rather straightforward ability to identify and sequence a mutant gene and identify the precise genetic lesion – the genotype responsible for the appearance or relevant characteristic(s) of the mutant organism – the phenotype.

It was against this general backdrop that Seymour Benzer decided in 1965 to apply genetic strategies in an effort to explain enigmatic behavioral problems like circadian rhythms and memory. Benzer had made a large contribution to the understanding of gene expression during the 1950s and early 1960s, and he had a fascination with behavior. Although studied for a long time in many organisms including insects, these problems like circadian rhythms and memory were almost intractable from a molecular standpoint. This is despite the fact that electrophysiologists and pharmacologists had been working successfully on the mechanisms that underlie the basic structure and function of neurons. There was still no obvious way to gain access to the genes and especially to the proteins that must constitute at least part of the biochemical machinery that lies at the heart of rhythms and memory. (Proteins are involved in just about everything biological.)

The genetics and molecular biology community was brimming with confidence after its remarkable success at providing mechanistic explanations for inheritance and the genetic code. As a consequence perhaps, Benzer and others found unsatisfying the descriptive (non-biochemical) approaches and explanations used in behavioral studies. With almost religious zeal, they believed that genetics was the path to enlightenment. This new approach to behavior also represented a paradigm shift for the field, as it went from being an end in itself to being a means to very different ends.

Understanding the 'mechanism of inheritance' was no longer the goal. Rather, the goal became understanding the biochemical underpinnings of behavioral biology. The research strategy was simple: isolating a mutant gene associated with aberrant circadian rhythms will identify the underlying biochemical cause of the behavior. For example, a mutant clock gene will encode a mutant clock protein (genes → RNA → protein; the central dogma of molecular biology), which can be mapped by traditional procedures and then used to further probe clock mechanisms.

The genetic approach that Benzer pioneered is not without controversy. Does the existence of clock genes (or memory genes, or sex-drive genes) mean that human behavior is hardwired by our genes, with no room for environmental influence? If we have behavioral genes, what room is there for free will and responsibility? Few people question the inheritance of height, hair color, or eye color from parents to children. Almost everyone seems to agree that tall parents are more likely to have tall children. (The genetics can be complicated, so the outcomes are statistical within a population, i.e., it doesn't always work in every case.) But the possible inheritance of brain characteristics (personality, sense of humor, and intelligence for example) raises hackles for almost religious reasons: the brain appears to be divine territory. On this issue, many neuroscientists stand firm and believe that all behavioral phenomena ultimately will have biochemical underpinnings. This does not negate the fact that the underlying mechanisms in many cases (e.g., complex reasoning, consciousness) may be very complicated and beyond our grasp for years and perhaps even decades.

It is important to understand that the possible inheritance of behavioral properties from parents to offspring in hu-

mans has little to do with the genetic strategies in model organisms designed to illuminate brain-behavior mechanisms. Researchers interested in human genetics – i.e., the possible inheritance of behavioral properties from parents – focus on the question: Are brain phenotypes that distinguish different human beings heritable? The question Benzer posed was: Can I identify behavioral genes in a model organism, and will they illuminate something fundamental (and hopefully ubiquitous) about the underlying mechanisms, even in humans? Attempts to answer the human genetics question rely on an uncertain principle and subtle analyses of phenotypic differences between individuals.

The model organism genetic strategy, by contrast, uses an experimental sledgehammer to debilitate a key gene and hopefully create a striking phenotype, in every offspring from that original mutant. If the phenotype is robust and maps to a single gene, it should provide an entrée into what might otherwise be an intractable scientific problem. This strategy has proved to be a staggering success for biological clocks and learning and memory, and we now have a fairly sophisticated grasp of the relevant biochemical machineries.

Benzer and his student Ron Konopka first explored the genetics of circadian rhythms by studying fruit flies. Their research, published in 1971, resulted in the identification of the first clock gene. By mutagenizing and screening progeny for their locomotor activity rhythms (rhythms of rest-activity cycles, more or less the insect analog of our sleep-wake cycle) in constant darkness, they identified three types of circadian-rhythm mutants: a short-period mutant (nineteen-hour period), a long-period mutant (twenty-nine-hour period), and an arrhythmic mutant with no rhythms whatsoever. All three mutants were allelic, i.e., they were all due to mutations in the same gene, which they named *period*.

This was not only a landmark achievement, which kick-started the circadian rhythm field, but also unusually prescient. This first clock gene was identified several years before the first recombinant DNA papers appeared in the scientific literature, and a decade or more before the cloning of genes became a truly practical technology, even in sophisticated laboratories. In other words, the period mutants were identified and characterized by Konopka and Benzer well before the more complete molecular genetic vision was conceptualized, let alone realized. Although these mutants gave Konopka and Benzer as well as others an invaluable tool with which to manipulate the circadian system of flies, another thirteen years passed before the period gene was cloned and identified by molecular methods.

In the intervening years, Konopka continued to work on *Drosophila* clocks with traditional tools, as a faculty member at Caltech and then at Clarkson College. At the same time, I was doing molecular biology on completely unrelated subjects, first as a postdoctoral fellow in Scotland, and since 1974 as a faculty member at Brandeis University. I did not read or even hear about the Konopka and Benzer paper until the mid to late 1970s, from my friend, colleague, and ultimately long-term collaborator Jeff Hall. He was a contemporary of Ron Konopka in the laboratory of Seymour Benzer and continued to work on behavioral genetics and fly courtship after he took a faculty position at Brandeis, also in 1974. (Hall and Konopka remain friends to this day.)

Hall was also doing some work on circadian rhythms, because the period mutants had a pronounced effect on a particular aspect of fruit-fly courtship. In

1982, after the recombinant DNA revolution had transformed my laboratory as well as many others, Jeff Hall and I decided to apply these new technologies to the problem of circadian rhythms and clone the period gene. At that time, he was the *Drosophila* rhythm guru and I the molecular biologist, and we published our successful results in 1984. Importantly, the gene was identified by germ-line transformation, in which the phenotype of the mutant flies was altered by injecting cloned wild-type DNA. ('Wild type' is genetic patois for a normal, as opposed to mutant, individual or gene.) The phenotype was converted back to that characteristic of a wild-type strain, showing that the injected DNA contained the normal gene. Mike Young at Rockefeller University used a very similar strategy and published the same result at essentially the same time. This was the first transgenic rescue of a behavioral gene in any organism.

Unfortunately, this achievement was still not entirely satisfying. This is because a key aspect of the circadian system, the period protein (PER) and particularly its function, remained unknown. Both our laboratories at Brandeis and the Young laboratory at Rockefeller worked on the relationship of this gene to circadian rhythms during the next few years, which resulted in several significant advances. We both mapped the sequence of the complete protein and located the precise nucleotide changes responsible for the slow, fast, and arrhythmic alleles. However, knowing the DNA sequence still did not explain the function of the period protein. This is because it was a 'pioneer protein,' with no known relatives. In those early days of DNA sequencing, with only limited database information from different organisms, it was much more the rule than the exception that a DNA sequence did not reveal the function of a protein. (Although less problematic today, the function of perhaps 50 percent of human proteins is still uncertain.) This was the situation until 1988, when there appeared the sequence of a well-understood *Drosophila* protein with a clear relationship to the period protein. This relative was a known transcription factor, meaning that it functioned in gene expression to 'transcribe' DNA into RNA. Although the two proteins were not very close relatives and only a limited portion of the protein sequences was in common (and the region in common was itself of uncertain function), the similarity was unambiguous and inspired us at Brandeis to explore the following hypothesis: Perhaps PER itself was a transcription factor – and if it was, then perhaps the regulation of transcription was central to circadian rhythms.

In 1990, almost twenty years after the landmark Konopka and Benzer publication, we published the finding that period messenger RNA (mRNA) levels undergo circadian oscillations and that PER regulates the period and phase of its own mRNA cycling. In other words, the mRNA cycling was sensitive to the Konopka and Benzer mutations and paralleled the previously described changes in the behavioral cycle. (Remember: DNA → mRNA → protein; synthesis of mRNA using DNA as a template = transcription and synthesis of protein using mRNA as a template = translation.) Over the next several years, we expanded on this observation and showed that the fluctuations in period mRNA levels were largely transcriptional and almost certainly reflected a negative feedback loop, in which PER inhibits its own synthesis.

Then, in 1997, the field experienced another major breakthrough: the discovery of the mammalian period genes. For the first time, it became clear that

the same transcriptional feedback loop occurred in mammals – including human beings – and not just in fruit flies. This important finding unified the worlds of mammalian and insect rhythms and indicated that a very similar circadian machine operates in all complex animals. Indeed, almost all of the additional fruit-fly pacemaker components discovered in the past decade are conserved across species. These include proteins that contribute to important circadian posttranscriptional control mechanisms. (For the cognoscenti, this includes RNA and protein stability as well as protein phosphorylation.) The conservation of functional clock components echoes a major biological theme from DNA work in many fields over the previous two decades, namely, the same genes make the same proteins and do the same basic jobs in all complex animals.

In other words, circadian rhythms are ancient. These biological clocks existed many hundreds of millions of years ago – long before the evolution of insects and mammals.

Although there is a similar clockwork (the circadian quartz crystal) in all animals, the machinery ticking in plants and fungi appears quite different – from each other as well as from that in animals. Although there is a very limited relationship between a couple of animal clock genes and those in *Neurospora* (a type of bread mold and an important circadian clock model organism because of its genetics), it has long been generally believed that circadian rhythm genes are not truly shared among all three kingdoms: animals, plants, and fungi. A commonly articulated conclusion is therefore that circadian rhythms arose multiple times in evolution: animal clocks come from one beginning, and the clocks of plants and fungi from another (or from more than one). The situation contrasts with the protein synthesis machines of plants, animals, and even bacteria. They are so similar that it is universally accepted that protein synthesis arose only once in evolution and has been passed on to all contemporary organisms from a single common ancestor.

This multiple clocks hypothesis has to deal with the fact that the molecular design principles of these different clock systems are quite similar, i.e., they all involve the circadian regulation of different transcription factors. This points to convergent evolution subsequent to multiple origins as the explanation for the similar design plans.

But in my view, a still more attractive possibility is that key common elements – missing links between the systems – are as yet undiscovered, or insufficiently appreciated. Two recent studies have shown that the protein kinase CKII (casein kinase II; a kinase puts phosphate groups on other molecules) is a clock gene in *Drosophila*. As this enzyme had been previously implicated in the clocks of plants and *Neurospora*, it is the first clock component shared between all three systems and may reflect a common evolutionary origin for the circadian system in eukaryotes.

Because CKII plays a pivotal role in the response to ultraviolet radiation in organisms ranging from yeast to humans, it is possible that avoiding UV light was a major driving force in the early evolution of circadian systems. This idea is also based on other considerations, centered on light and its important relationship to circadian rhythms. Although sunlight is a primary source of energy for life on earth (via photosynthesis) and is important for vision, it also provides a critical temporal cue for circadian sys-

tems. Indeed, most organisms have evolved specialized photoreceptors for circadian light perception. In *Drosophila* and insects, the protein cryptochrome serves as a major circadian photoreceptor, whereas rhodopsins are the major visual photoreceptors (this is the same family of proteins that is used for visual photoreception in mammals, including humans).

Although mammalian cryptochromes may also be circadian photoreceptors, the evidence is stronger that they are important central clock components. Importantly, cryptochromes are close relatives of photolyases, which are blue light-activated DNA repair enzymes. This connection leads to the idea that the strong UV component of sunlight contributed to the selective pressure for the evolution of this specialized photoreceptor. Moreover, the blue light absorption maximum suggests that circadian photoreception may have evolved in an aquatic environment shortly after animal life first emerged, because only blue light can penetrate to substantial depths in water. This is related to the suggestion that diurnal fluctuations of some animals in the oceans (deeper in the daytime, more shallow at night) are to avoid UV irradiation. Early photolyases may then have signaled both the time to descend and especially the time to rise to the surface, a precursor of the circadian rhythm role played by their contemporary descendents, cryptochromes.

Drosophila cryptochromes function as photoreceptors within most if not all individual clock cells. This is related to the fact that the self-sustaining transcription-translation feedback loop that lies at the heart of the circadian system is cell-autonomous, i.e., it operates independently within the many circadian cells and tissues. A major factor keeping these individual clocks synchronized is their independent connection to the light-dark cycle, through the cell-autonomous function of this photoreceptor. Even within the fruit-fly brain, cryptochromes receive direct time-of-day information from sunlight and transmit it intracellularly to the clock machinery. They are therefore true deep-brain photoreceptors that bypass the eyes as a pathway for photic information.

In contrast, many mammals, including humans, have an opaque skull and must therefore use their eyes as the source of temporal as well as visual cues for the brain. Yet even in mammals it is virtually certain that separate molecules and even separate cells of the eye are used for circadian and visual photoreception. This is because the rods and cones, which house visual photoreceptors, are unnecessary for circadian photoreception. Only very recently have specific retinal ganglion cells, putative circadian photoreceptor cells within the retina, been identified. They contain a specialized photoreceptor (melanopsin), which transmits information to the circadian pacemaker region of the brain. This is a small part of the hypothalamus called the suprachiasmatic nucleus (SCN). It is the most important region of the mammalian brain for orchestrating the circadian programs of the entire organism. SCN cells contain a robust transcription-translation cycle, which relies on the eye for its photic information.

The importance of the retina to mammalian circadian rhythms has profound implications for many blind people. These individuals 'free-run' with an endogenous period characteristic of our species, slightly longer than twenty-four hours. As a consequence, they periodically move out of sync with the rest of the population and then have a myriad of physiological and behavioral difficulties. This is because they cannot perceive the actual twenty-four-hour light-dark

cycle that keeps most of us regular and 'on time.' The affected population is difficult to identify with vision tests, because of the photoreceptor division of labor mentioned above. Individuals with an intact melanopsin system are presumably able to 'see' circadian cues, independently of other visual difficulties. The blind population not only also underscores the importance of the eyes for the circadian system, but also indicates that other potential cues (temperature, noise, social interactions) do not have much influence on human circadian timing.

The circadian system also influences the human sleep-wake cycle. When circadian-blind individuals are out of sync with the twenty-four-hour light-dark cycle, they have trouble falling asleep at night and rising at a normal hour for work or school; for obvious reasons, they then experience excessive daytime sleepiness. These difficulties resemble some sleep disorders, which have long been interpreted as being circadian in origin. These include Advance Sleep Phase Syndrome (ASPS) and Delayed Sleep Phase Syndrome (DSPS).

Individuals with these disorders have a normal sleep drive, which just kicks in too early or too late compared to most of us and creates obvious conflicts with most of the human population. ASPS individuals become sleepy and fall asleep in the early evening, at perhaps 7 P.M. They then sleep a normal and restful seven to eight hours and rise at 2 – 3 A.M. DSPS individuals have trouble falling asleep until perhaps 4 A.M. and then want to sleep a normal eight hours until noon. ASPS individuals are therefore phase-advanced with respect to the light-dark cycle, and DSPS individuals phase-delayed.

Both groups are believed to have defective pacemakers, which run too fast or too slow. With normal ocular connections, however, they are reset every day by the normal light-dark cues and therefore maintain a constant but aberrant phase relationship with the external twenty-four-hour cycle and the rest of the circadian world. In some cases, this interpretation has been verified in a sleep lab, where the influence of the external light-dark cycle can be removed and the intrinsic period measured. This patient population therefore illustrates the important relationship between phase in a light-dark cycle and intrinsic period in constant conditions mentioned above. Fast or slow clocks have short or long periods, but these are normally masked by the daily reset from the external twenty-four-hour light-dark cycle.

It is interesting to note that the mutant fruit flies studied by Konopka and Benzer were similarly able to adjust their behavior. Although two of the circadian mutant strains were originally identified as period-altered in constant darkness, the mutant clocks nevertheless manifest perfect twenty-four-hour periodicity when exposed to a normal light-dark cycle. However, like people with ASPS and DSPS, the mutant fruit flies have phase-advanced or phase-delayed locomotor activity patterns under these conditions.

The link between human and fly clocks, as well as between sleep and circadian rhythms, has been further strengthened by the identification and characterization of a family with inherited ASPS. This unusual circumstance allowed researchers to identify the 'mutant' gene responsible for the inheritance of this sleep syndrome. It turned out to be a mutation in a human period gene, the ortholog of the original *Drosophila* clock gene. (An ortholog is a gene that looks the same and does the same job in another, distantly related organism.) The mutation is in one of the three

human period genes, which perform overlapping and similar clock tasks to the single fruit fly gene.

What lies ahead? From a practical standpoint, we may expect to see new classes of pharmaceuticals, better able to treat disorders of sleep and the problem of jet lag. From the standpoint of basic science, new molecules and principles will almost certainly be discovered. This is because there is a great deal that we still do not understand about circadian clocks and how they function. And only time will tell where modern biology will go in explaining how and why living organisms harmonize with the fourth dimension of our world.

Thomas Gold

Why time flows: the physics of past & future

"We have to assume that there exists a mathematical flow of time." These were Newton's words when he used time as an important coordinate in the laws of mechanics that he described so accurately. He seems to have understood that a separate assumption was implied, and that the flow of time was indeed a property of our universe.

We can measure time with great precision, so we might therefore believe, with Newton, that time in our universe flows with mathematical regularity. But our ability to measure time does not really account for another crucial aspect of our sense of the flow of time: namely, that it flows in one direction, from the past toward the future.

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We all know this with a high degree of certainty. What gives us this information?

Of course we sense the flow of time when we watch the hands of an ordinary clock move around in the clockwise direction. But why do they move in that direction?

It was the maker of the clock who designed it this way. He could have just as easily mounted the gearwheels so that the hands would turn the other way around. But he sensed, as we do, that time flows in one direction, and so we have all adopted the notation he had selected.

As it happens, there is another feature of every clock that seems to show that time flows in one direction only, from past to future. This is the power source that drives the clock. It may be an ancient pendulum clock, whose sinking weight, after it has been wound, will supply the energy. Or it may be a spring-driven wristwatch that you have to wind up. Or a battery-powered device that uses an electric current to keep the clock going. The energy supplied by every such power source dissipates among the working parts. While the direction of movement of the clock hands was only an arbitrary choice, no clock can function without a concentrated energy supply that diffuses as time passes.

Could our conviction that time flows in one direction spring from a similar cause?

I raise the question because physics presents us with a dilemma: The detailed laws of physics nowhere define the direction of time's flow. The laws that control the motion of elementary particles or of any simple system like a collision between particles, or even of the orbits of the planets, are both time-symmetrical and deterministic. From a diagram showing any one of these actions in which time is given as one of the coordinates, it would not be at all clear in what direction time is flowing. Why then do we have this overpowering knowledge that allows us to distinguish the flow as one which we call from the past to the future?

The events of the past are not in doubt; but the events of the future we can only guess. That surely is one origin of the distinction between past and future, and therefore one reason why we all believe that the flow of time is asymmetrical. But can time-symmetrical physical laws explain the difference we feel between the past, which is certain, and the future, which seems uncertain? Why would the future not follow without fail from the present, just as the present seems to have followed without fail from the past?

The laws of physics may be time-symmetrical, but they are not always deterministic. Some of the laws of physics stipulate probabilities rather than definite certainties. Could probabilistic laws be the origin of the difference between past and future? Or can time-symmetrical, fully deterministic laws of physics explain what seems to be the time-asymmetrical behavior of all the matter around us and within us?

Only in the last forty years or so has it become fully understood that the superpositions of very many interactions between many particles can destroy the time symmetry that is in evidence for any simple event. The reason appears to be this: In order to make predictions with certainty, the initial conditions of any experiment would have to be known with perfect accuracy, as manifold interactions are involved in the events that follow. But since we live in a world of enormous complexity on the microscopic scale, a perfect knowledge of the initial conditions is in practice unattainable. We had previously understood that changes tend to go from order to disorder; we now understand that they may go on beyond that, from disorder to chaos. The chaotic state is one in which no relation to the initial conditions can be recognized anymore.

An example of planetary orbits can show this. The few planets maintain their orbits with great regularity, and we can make very good predictions where they will be at some time in the future. But if we studied the hundreds or thousands of minor planets, the asteroids, that are all subject to the same laws of motion as the planets, we would find that an error of the position of one, of the insignificant amount of a few meters, would grow to an error in the prediction of a few kilometers in a thousand years. The new calculations now would change the perturbations caused in other asteroids, which in turn would alter the predicted orbits of others yet. Eventually this would lead to such deformations of all orbits, that even the most precise determinations of all positions and velocities would not allow a calculation to find a unique initial condition of the whole system. Despite obeying deterministic laws, the system would have lost the unique relation to its starting condition.

Thermodynamics is the subject that deals with the consequences of the inter-

actions between very many particles. The laws of thermodynamics represent the statistical consequences of the laws of physics. But because our world is composed of so many particles, and because there are so many interactions between them, these statistical results bear great weight. It is only at this level, where the laws of physics are not deterministic, that the time asymmetry that we all experience appears.

Think of a cinematographic film, and think what it would have to show if an examination of individual frames were to reveal in what order they were taken. If the pictures showed us a car traveling along the road, we would say that it probably traveled forward, since we identify the front and the back of a car. But we could not be quite sure of our answer – it might have traveled along the road all in reverse. If we saw a person diving into a swimming pool we could answer the question with great certainty – it would seem impossible that the water would have expelled him up into the air, for him to land on the diving board above. Or if our strip of film showed an airplane running along a runway and taking off into the air, we would all be quite certain in which direction it was going. An airplane just could not take off going backwards.

What is so different about the airplane and the car? The car could run in reverse all right, and so could the aircraft. But the aircraft could not take off in reverse. Why is that? The reason is that the aircraft depends on the superposition of the motion of a huge number of particles of air, while the automobile only depends on the rotation of four wheels. If you had seen the car raising a dust cloud from the road you would also have recognized the temporal sense in which the film had been taken.

Think now of a filmstrip that records an erratic distribution of the balls on a pool table, and then shows the balls contracting into a regular triangle. You would know at once that the regular triangle was filmed at the beginning and not at the end of the strip.

In each case, the flow of time produces disorder from order, a diffusion of energy from a concentrated source, a low temperature from a high temperature. In each case, too, it is such diffusion that gives you time's arrow. Thermodynamics describes the processes that can occur freely in one sense of time, while they can occur in the opposite sense only in very restricted circumstances. Thus the transport of energy from a lower to a higher concentration is restricted, and it is then always only as a small fraction of an energy flow, with the major flow going in the opposite way. The overall effect of any device that generates mechanical energy from heat must always be to bring more heat energy to a lower temperature than the amount it converted to the more concentrated form of energy. This effect found a precise definition in a paper by a young French engineer called Carnot, already in 1824, a paper of great significance to the study of thermodynamics, and later of special import to Lord Kelvin's identification of the absolute zero of temperature.

It has been questioned whether a statistical definition of the apparent flow of time is compatible with Newton's demand for a uniform mathematical flow. Would such a flow not be erratic to the degree of the statistical fluctuations? How could we then measure time intervals with accuracies of better than one part in ten to the power thirteen? Would there not be differences in different locations at the same moment?

Physics provides us with many processes that consistently define intervals of time with very high precision. These intervals are not related to the direction

of the flow, just as the swing of the pendulum is unrelated to the direction in which we know time to be flowing.

It has also been suggested that the observable finite speed of light must surely define the direction of time's flow. The arrival of a light signal must surely be later than its emission. But again there is no proof. The relativity discussion defines the speed of light as just that speed for which you cannot define which event occurred earlier and which later; in other words, you cannot uniquely distinguish emission from reception. The details of the two physical processes are indeed seen to be exact images of one another: the same momentum recoil, the same energy exchange. So, again, this gives no information on our subject. If we were observing many events, like a burst of many photons from one locality and a dispersed arrival of them, we might again make a decision of probability on statistical grounds. It would seem improbable that many diverse locations had emitted photons just so that they would all arrive closely packed and simultaneously, and so we would guess that the concentrated event was emission and the diffuse event, reception.

The largest scale of the energy flows is that of the universe, and it dominates all others. Heat is generated at very high temperatures by the nuclear processes in the interior of stars, and from there begins a downhill flow to lower and lower temperatures. In the course of this flow of degradation, it may chance to encounter a heat engine that can produce a limited amount of free energy or higher temperature heat, but only at the expense of an even faster degradation of the rest of that energy. Our earth happens to be a particularly favorable place for such a sidestep in the overall energy flow, and our own livelihood is dependent on this fortunate circumstance. A very small fraction of the heat output of the sun is temporarily held up by our planet, and some fraction of this in turn is there converted by heat engines into a more concentrated form, such as the chemical energy plants derive from sunlight. This gives us the chemical energy of the food we eat, and, through that, of all the things we can do. The final destination of all the heat is the dispatch into the depths of space of the expanding universe, from which it does not return, or returns degraded from the initial millions of degrees to a temperature very close to the absolute zero.

It is the expansion of the universe that is responsible for this overall flow of heat from the high temperature of the stars to the low temperature of the background. If we did not have the expanding universe around us, with its ability to swallow up whatever energy is sent out by the stars, only to return a minute fraction, then this process could not occur. If the same amount of energy came back as went out, we would be living in a uniform temperature universe, and no sources of free energy would be available to us. With only uniform heat all around us there would be no criterion that would distinguish the flow of time from past to future. Our concept of time and its unidirectional flow could not exist in such a world.

Peter L. Galison & D. Graham Burnett

Einstein, Poincaré & modernity: a conversation

Newton, forgive me . . .

– Albert Einstein, *Autobiographical Notes*

D. GRAHAM BURNETT: Peter, in 1997 you gave a plenary session lecture at the History of Science Society meeting in La Jolla entitled "Relentless Historicism: Machines and Metaphysics." I have a vivid memory of the presentation, which was, I think, the first time you shared with the wider community of historians and philosophers of science your research on Einstein, relativity, and the material culture of time in the fin de siècle. And you turned a lot of heads. Your argument went something like this: At the heart of Einstein's watershed 1905 paper on special relativity – the paper that shook the foundations of Newtonian physics – lies a 'thought experiment' about clock synchronization and the 'problem' of simultaneity; there, talking about trains arriving in stations and observers watching their watches, Einstein posed what turn out to be insurmountable challenges to Newton's notion of absolute time (and absolute space). This we knew. But then the talk got juicy: you went on to point out that this thought experiment might not be *merely* a thought experiment, since the business of synchronizing time frames through space was more than just abstruse theoretical physics in the late nineteenth and early twentieth centuries. It was a perfectly real, quotidian, and central preoccupation of railway companies, nation-states, and military planners. The increasing speed of railway travel in the second half of the nineteenth century had made it necessary to codify 'time zones' around the world – zones of conventionalized simultaneity, where people would ignore local time (say, the 'noon' of the sun), and go by the noon on their clocks: a subtle change, but an important one, since it

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Peter L. Galison has just completed a new book, "Einstein's Clocks, Poincaré's Maps," that forms the basis of this dialogue. A Fellow of the American Academy since 1992, Galison is the Mallinckrodt Professor of the History of Science and of Physics at Harvard University. Galison's other books, including "Image and Logic" (1997) and "How Experiments End" (1987), explore the interaction between the principal subcultures of twentieth-century physics – experimentation, instrumentation, and theory – and also the cross-currents between physics and other fields.

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put people across the globe in temporal step. There was no other way to run a railroad. Moreover, the design and manufacture of electromechanical systems that 'distributed' this new coordinated time – networks of clocks running in sync – was a major precision industry. Looked at in the right way, Einstein's thought experiment bore an uncanny resemblance to a set of wholly practical experiments going on all around him – even under his very nose, as he earned his living in the Berne Patent Office reviewing exactly these sorts of time-distribution devices. That day in La Jolla you left us with a question: Could we really understand Einstein's 1905 paper without understanding the rise of international time conventions and the technologies of industrial time-synchronization? Now you have written a book, *Einstein's Clocks, Poincaré's Maps: Empires of Time,* which delivers on this question and expands your original insight. For readers to whom all this is new, would you start by describing how trains and clocks figure in Einstein's landmark publication?

PETER L. GALISON: Certainly. Perhaps the greatest success of nineteenth-century physics was the prediction (and subsequent demonstration) of the existence of 'electric waves.' Light was nothing other than such a wave. Suddenly the ancient science of optics became no more than a subfield of electromagnetism. At the same time, this thrilling finding brought with it a puzzle: Physicists of the late nineteenth century, very reasonably, thought that a wave had to be a wave *in something.* After all, waves at the beach are waves in water, sound waves are waves in air, and so on. But light could travel in a vacuum – that is, apparently through empty space. This led most everyone to suppose that there had to be a special all-pervading (and as yet undiscovered) substance – the 'ether' – permeating everything, everywhere, present even in a vacuum. But experimentalists had no luck finding this elusive medium. Einstein's famous 1905 paper on relativity begins here. Generalizing from failed attempts to 'see' the ether (or, more correctly, to see any evidence that the earth was moving 'through' it), Einstein decided to scrap the ether altogether, and to go after the problem of the propagation of light in a different way. First, he stipulated that *all* the laws of physics – including electricity and magnetism – were the same in any constantly moving frame of reference. Then he added a seemingly simple (and modest) second assumption: Light travels at the same speed no matter how fast its source is moving. To anyone thinking of ether this was not so strange: Move your hands at any reasonable speed through a room of still air; once you clap your hands the sound waves propagate through the room at the same speed – independent of the original motion of your hands. Maybe light was like that: a lamp moving in the ether simply excited light waves that radiated out at a single speed independent of the motion of the lamp. Yet these two reasonable starting assumptions appeared to contradict one another. Suppose lamps were flying this way and that at various speeds, but that in some frame the light beams from those lamps were all traveling at 186,000 miles per second, just the speed predicted by the equations of electrodynamics. Wouldn't those same beams of light appear to be traveling at *different* speeds when seen from a different, moving frame of reference? If that was so, then the equations of electrodynamics would only be valid in one frame of reference, violating Einstein's first principle. It was to resolve this apparent contradiction that Einstein made his single most dramatic move: he criticized the very idea

of time as it was usually understood. In particular, he relentlessly pursued the meaning of 'simultaneity.' Only by criticizing the foundational notions of time and space could one bring the pieces of the theory – that the laws of physics were the same in all constantly moving frames; that light traveled at the same speed regardless of its source – into harmony. And this is where the trains and clocks enter. Suppose, Einstein reasoned, that you wanted to know what time a train arrived in a train station. Easy enough: you see where the hand of your watch is at the time the engine pulls up alongside you. But what if you wanted to know when a train was pulling into a *distant* station? How do you know whether an event here is simultaneous with an event there? Einstein insisted that we need a simultaneity-fixing procedure, a definite system of exchanging signals between the stations that would take into account the time it took for the signal to get from one station to another. By pursuing this insight, Einstein discovered that two events that were simultaneous in one frame of reference would not be simultaneous in another. Moreover, since a length measurement involves determining the position of the front and back of an object *at the same time,* the relativity of simultaneity meant that *length* was relative as well. By removing the absolutes of space and time, Einstein restructured modern physics.

DGB: So what was at stake here was not only the universal ether, the substrate of the cosmos, but also *time* – that absolute, ever-unrolling, eternally immutable *flowing,* the Platonic time of which all worldly clocks were mere dilapidations. It was this time that Newton had understood was a necessary condition of his physics, and that he had placed beyond the realm of merely human investigation; it flowed in the "Sensorium of God."

PLG: Just by demanding a conventional clock-and-signal-based *procedure* to fix simultaneity, Einstein was breaking with the Newtonian idea of time. For Newton, there was absolute, true, mathematical time that ticked ever-constantly the same way for all observers. Clocks – all kinds – were only pale reflections, approximations to this metaphysical temporality. But Einstein's departure from Newtonian time went further, since once Einstein's starting points are accepted, dramatic consequences follow. For instance, if a train travels through our station and the engineer and caboose driver flash their lanterns towards the center of the train (at what we in the station judge to be simultaneous moments), we can ask what happens in the train. We on the station platform say: The mid-train conductor moves *towards* the site where the engine driver had flashed his lantern and *away* from the site where the caboose tender had flashed her lamp. So (say we station-based observers) the middle conductor receives the engine flash first. Since by assumption the middle conductor measures the two flashes as moving at equal velocities from equally separated points of origin, he concludes – as night follows day – that the two flashes were *not* sent simultaneously. So the two flashes that were simultaneous in the station frame are *not* simultaneous in the moving one. Simultaneity is relative to a frame of reference; it is *not* absolute. From an apparently prosaic starting point about clocks, trains, and light signals, Einstein had smashed one of the very centerpieces of classical physics.

DGB: This is perhaps the Einstein of myth and legend, the knight-errant in the borderlands of metaphysics who

slays the last chimera of the crystalline spheres. A searcher in the realm of pure mind, he reconnoiters the Sensorium of God and finds it empty. But this image, you would remind us, is a distortion of Einstein's character, of what he thought he had done, and of his approach to problems as well, no?

PLG: Einstein, without any doubt, is the best-known scientist ever, and he occupies an astonishingly robust cultural place. He doesn't seem to come into and fall out of fashion as much as he is simply appropriated for new purposes with each generation. But one of the perennial features of Einstein-the-icon is the figure of the great mind living in a world apart, the ultimate loner. No doubt Einstein himself is in some measure responsible for this image, since, in later life, he reflected nostalgically on solitude, isolation, and creativity. For instance, he wrote wistfully of the lighthouse attendant, whose world could be that of undistracted thought. So we think of him as the person who could not quite navigate the physical world, and associate that incapacity with a romantic picture of scientific genius. This in turn leads to an odd rewriting of the way he lived his life and did his work.

DGB: Was the patent office Einstein's 'lighthouse'?

PLG: This has generally been the story – Einstein at the patent office is the genius at his day job: at best a source of bread and butter, at worst a distraction, but in some deep way irrelevant to understanding his science.

DGB: When did you begin to get a different idea of how the story might be told?

PLG: I was standing at a train station in northern Europe admiring a line of clocks that went along the platform. And I noticed that the minute hands were all at the same point – I could just see them all lined up. I thought, "These are wonderful clocks; isn't that impressive that they can make them to hold such regularity?" Then I noticed that the second hands were clicking in synchrony too, which was startling, and I thought, "These can't be that accurate – you can't have clocks running like this that are not synchronized in some way, or else they'd get out of phase." Suddenly I wondered if Einstein had paid attention to synchronized clocks in train stations. If he had, it would give a very tangible sense to that most famous of all scientific thought experiments in his 1905 paper. It would make his move towards a criticism of absolute time both figurative *and* literal. So I went back and I started poking around – and found myself in the midst of an absolutely immense literature on fin-de-siècle timekeeping and clocks. As you know, there was at the time an urgent technological problem of coordinating time along train tracks. More than that: in Europe the center of precision-coordinated timekeeping was Switzerland, and if all this industry was based in Switzerland they must have been processing patents right and left. I went to the patent office, and found myself surrounded by a huge number of patents with diagrams of clocks linked by signals. There were even proposals for patents and articles in the technical journals about clocks linked by radio waves. All this seemed extremely close to the kind of materialization of time that preoccupied Einstein. Of course, the clock factories and inventors had no interest in 'frames of reference' or in all

the 'physics of the ether.' But the importance of distributing simultaneity by electromagnetic means was clear to everyone. Here was a technical problem located in Switzerland, centered in Berne, and with ideas coming to a point in Einstein's patent office. It all seemed remarkable; and it is there that I began this work.

DGB: And yet Einstein certainly wasn't the only physicist at the turn of the century preoccupied with time . . .

PLG: Not at all. In fact, even as I worked on "Einstein in the Patent Office" (and prepared the paper you mentioned), I kept wondering, "Who else would have, should have, been in this mix? And who else from the physics community would have been concerned with ideas of simultaneity?" There is one other person who cared about simultaneity at least as much as Einstein – and earlier – and that was Henri Poincaré. He certainly saw that clock coordination was essential for defining what we mean by simultaneity.

DGB: Einstein may be a household name, but the same cannot be said for Poincaré.

PLG: I suppose household name, like time and simultaneity, is a relative concept. In France, Poincaré has long been a hero. Known for his innovations in the qualitative studies of chaotic systems, for his invention of the mathematical theory of topology, for his contributions to mathematical physics, and for his philosophy of conventionalism, Poincaré was without any question the most renowned French scientist of the late nineteenth and early twentieth century. And that, in France, meant he was an extraordinarily visible figure whose books about science, philosophy, and morality were best-sellers. He also wrote dramatically and often about the new theory of relativity to which he contributed importantly. Crucially for our understanding of his ideas of simultaneity, Poincaré was, beginning in the early 1890s, deeply involved in time-distribution networks.

DGB: At the Bureau des Longitudes?

PLG: Yes, where he would serve several terms as president. And this was crucial, because the astronomers and geographers of the Bureau were working intensively with the telegraphic transmission of time. This was not for domestic railroad use – or at least not in the first instance. Rather, these engineers and scientists were working at a much higher level of precision. They needed to determine simultaneity so distant observers could determine their relative longitude.

DGB: For cartographic purposes, since longitude measurements are measurements of time?[1]

PLG: Precisely. Their goal was to map the nation, the empire, and then much of the world. Specifically, they aimed to find points of reference – for instance, in North Africa, Senegal, Ecuador, and Vietnam – from which the further mapping of the interiors could proceed. Maps were important for extraction of

1 The earth rotates once on its axis each day, or 360 degrees every 24 hours, or 15 degrees every hour. Longitude is measured with respect to some arbitrary zero line – say, the meridian of Paris. So if we know that the sun is directly over our heads (it is noon where we are) and we get a telegraph message from Paris saying it was noon there an hour before, we know we are 15 degrees west of Paris.

ores, for military domination, for the cutting of roads, and the laying of railroad lines. Railroad lines brought in more cable, and therefore more mapping, and so on. All of this constituted a major technical program, a great national moment. And the timing is fascinating. Poincaré really became a public figure starting in 1887 or so. And by 1892 he was involved with the Bureau of Longitude, where he tackled problems of time conventions – from the decimalization of the hour to reconciling the longitude of the Paris and Greenwich observatories. I remember staring at these reports from the 1890s, trying to figure out what the Bureau's telegraphic time-finders were doing, and expecting that I'd find that – as in the case of Einstein's patent office – the fixing of simultaneity was a fairly crude affair. But this work was anything but crude! Instead, I saw that by the 1890s it was altogether routine for the astronomer-engineers to *take into account the time the electrical signal took to go from one place to another*. That, I thought – I had assumed – was exclusively a preoccupation of physicists and their 'relativity.' But it turned out that Poincaré's colleagues at the Bureau were precisely worried about this, and their concern is plain as day once you look at their data. Columns in the official reports are labeled: "time of transmission." The engineers even sent their time signals on round-trips to compensate for errors. The more I looked at it, the more specific the connections seemed. So in January 1898, when Poincaré wrote his famous philosophical article "The Measure of Time," introducing the simultaneity convention via the metaphor of telegraphic longitude finders, he had in mind an abstraction but also a concrete procedure. A procedure from next door.

DGB: So here, in a real material network of telegraphic transmissions (assembled for geodetic purposes), lies the whole schematic of 'relativistic' physics: As you put it in the book, "*simultaneity is a convention, nothing more than the coordination of clocks by a crossed exchange of electromagnetic signals, taking into account the transit time of the signal*." This is physics, but it is also technology at the turn of the century. And yet, in a way, Poincaré isn't the guy who 'gets' the physics of relativity. Or at least this is how he is usually remembered: He was so close, but he turned away from the more radical interpretation of his thinking, and the real discovery was left to Einstein, no?

PLG: What Poincaré first publishes, in January 1898, is the idea that in principle simultaneity is nothing other than the exchange of signals between clocks, taking into account the time of transfer between the clocks of the electric signal or of light. It is a philosophical point (published in the *Review of Metaphysics and Morals*) that is, on my reading, also deeply technological. Between 1898 and 1900 he doesn't apply the scheme to the physics – he thinks of the correction to Newtonian physics as being too small, just another longitude-finder's fix. And the reason that he says it's just another error is because that was how it was being treated by his colleagues in the Bureau of Longitude. Then, in late 1900, Poincaré was invited to speak at a gathering to honor H. A. Lorentz, perhaps the leading theoretical physicist of the day, and an innovator in the electrodynamics of moving bodies. He was also an admired friend of Poincaré's and a father figure to Einstein – so Lorentz was a looming figure in late-nineteenth-century physics. Poincaré, preparing for this event during a period when he was involved with the details of the Bureau (and still actively presenting the time coordination idea to philosophers), sud-

denly sees that he can reinterpret a purely mathematical idea of time in Lorentz's physics as a *physical coordination procedure*. In other words, Poincaré looks at the formal way that Lorentz has dealt with the problem, and he says to himself: "No! Really, this is just the telegraph problem that I had written about philosophically two years before!" From December of 1900, Poincaré put the time-coordination procedure into his *physics*. He writes about it, and he lectures about the philosophical significance of the physics of time coordination. So it works out that both Poincaré and Einstein were interested in the problem of the philosophical nature of time, the technical ways in which clocks could be set to distribute time, and the physics of how time should enter the theory of electrodynamics of moving bodies.

DGB: Still, physicists and historians of physics have spilled much ink on why Poincaré 'missed' being the first to develop Einstein's version of relativity – Poincaré was too conservative, he was too much the mathematician. In your book you try to put this question aside, and having situated both physicists in a broader story – a story about how simultaneity was *actually produced* at the turn of the century, as well as its technical and cultural resonance – you then return to their different perspectives in the conclusion. For there is still a question, isn't there? Given that they're both in this mix that you describe – both preoccupied with the "empires of time" in the realms of technology, physics, and even metaphysics – how is it that they come out of it with such different 'takes'? As I understand it, your answer would have us put aside the idea that Einstein was the 'modern' and Poincaré fell 'behind the times.' In fact, you even suggest at one point that we can hold them next to each other as representatives of "two modernities." Would you say a little more about this tempting idea?

PLG: In the years following 1905, Einstein and Poincaré were working on many of the same problems, both at the absolute top of the profession, both maintaining massive correspondence with many of the same colleagues and friends (including Lorentz). Both were deeply interested in the philosophy of science, both were writing on the side for popular audiences. These were scientists who in many ways were very similar, and yet they did not exchange a single postcard through the entirety of their lives – and neither ever even footnoted the other's work on space and time. It puts one in mind of the way that Freud treated Nietzsche: in some ways they were too close and too alien at the same time. It became unbearable for Freud to approach the work of his predecessor. On special relativity neither Poincaré nor Einstein ever argued with the other; they simply acted as if they lived in parallel but nonintersecting universes. Now Poincaré is often depicted as the reactionary who was too backward to absorb fully the radical thoughts of Einstein. That, I believe, is absolutely the wrong way of thinking about it. Both Einstein and Poincaré were concerned with a new and modern physics and a new and modern world. Poincaré wrote essays and gave many lectures about the new mechanics, always emphasizing the enormous novelty of these changes in physics. It simply is not possible to describe him as simply trying to conserve, to reinstate an older physics. But his idea of what needed to be changed was different. It was not Einstein's.

DGB: You characterize Poincaré as an 'ameliorist' at one point.

PLG: Yes, I think he is. In another context his nephew once said of Poincaré that he wanted to "fill in the white spaces on the maps." That really gets at something important. In much of his work, whether it was in mathematics (for instance in his discovery of chaos, where he literally made a new kind of map for mathematics, 'Poincaré maps'), or administration (for instance in his work trying to map and track the details of a mining accident), or geodetics (for instance in his directing the surveyors who were representing the surface of the earth), he was always trying to fix things, to fill things in, with a great faith in science. He was the ultimate Third Republic French savant – a believer in progress, a believer in using reason to make technical things work, a believer in improving the world and solving its crises. Poincaré saw himself as 'reforming' time to save Lorentz's extraordinary new theory.

DGB: And this comes out of his training as an engineer, no? Which is so important to the way you depict him …

PLG: Yes, Poincaré's modernism is exactly the modernism of the progressive, late-nineteenth-century engineer – somebody who faced all problems as solvable, from the social and political to the scientific and technical. He even played an important *technical* role in absolving Dreyfus when he reanalyzed the 'proof' that Dreyfus had authored an incriminating sheet of paper known as the 'bordereau.' Poincaré's modernism favored scientific-intuitive understanding (in mathematics as in the physics of the ether) and utterly avoided all reference to the spiritual or mystical. It was a modernism that expected the French to lead a rational and ultimately internationalist reformation of all manner of things from the standard meter on up. As far as Poincaré was concerned, physics had often faced crises – and in each instance had or could solve the difficulty by an application of a reparative reason. So it was with space and time. These concepts had to be fixed for physics to survive. Poincaré's own ideas about changing the time concept would, he hoped, repair the theory, just as space had been repaired by Lorentz's assumption that moving objects contracted in their direction of motion. But Poincaré kept the fundamental distinctions between 'true time' (in the frame of the ether) and 'apparent time' as measured in any other frame of reference. And of course he kept the ether – which he thought he needed for a productive, intuitive physics. So, for Poincaré, the reinterpretation of time was a necessary patch to keep Lorentz's theory working, one more idea in the kit of ideas that would fix the broken engine of physics.

DGB: And Einstein?

PLG: Well, Einstein had a different picture of what modern physics should be. Einstein had as his ideal neither a machine on which we would do repairs, nor a set of assumptions that would maximize our human convenience in assembling a theory. Instead, Einstein aimed for a reformulation of physics in which the order of theory itself would mirror the order of the world. If the world of phenomena showed no observable distinction between frames of reference then (so Einstein believed) neither should the theory: a symmetry in the phenomena should show up as a symmetry in the theory. 'Apparent time' and 'true time' were terms he would never utter. Einstein's ideal of a physical theory was thermodynamics, which began with two simple assumptions: first, that

energy was the same; and second, that the disorder of a system, the 'entropy,' always increased. From these starting points you went to town, deriving everything else from them. There was (as far as Einstein was concerned) a classical simplicity to thermodynamics: its two pillars supporting all the other elements of the edifice. And Einstein wanted, here and in many of his other works, to build his theories out of principles in this way. He too chose two starting assumptions for relativity theory: first, any observer moving at a constant speed would have the same laws of physics; second, the speed of light is always constant no matter how fast or in what direction the light source was moving. In order to reconcile these two ideas, he argued, it was necessary to put basic ideas of space and time on a defensible and nonarbitrary footing. So Einstein's idea of time really begins at the beginning of the theory, and is necessary to get off the ground at all – in the service of simplifying, unifying, and streamlining the theory. Poincaré's theory was differently epistemological, less concerned with "What can we know of an external Nature, and how can we secure that knowledge?" than with his aim of fixing the theory such that it correctly predicted phenomena while maximizing convenience. Poincaré's modernism aimed at an aggressive program of technical repair; Einstein's at a purifying reformulation. Poincaré fastened on simplicity-for-us, assiduously avoiding reference beyond the human. Einstein's modernism aimed for a kind of depth, a matching between representation and the world not just in predictions but deeper in the theory itself. Einstein, after all, in his later years loved to talk about how much choice God had at the beginning of the universe (not a personal God but an underlying order). Poincaré never even grazed that kind of metaphysics. All that said, it would be gross distortion to treat Poincaré as a reactionary or a failed Einstein. The modernism of Picasso is not the modernism of Pollock; and to force the very different breaks with the past into a single line of progression is to lose sight of history.

DGB: The irony here is that, far from being the wild-haired radical, Einstein is revealed to be, if anything, deeply 'classical' in his conception of physics.

PLG: Well, in some ways, Einstein is the *most* classical of classical physicists. He is somebody who saw himself in a way as purifying, simplifying, symmetrizing – bringing out elements of a less baroque physics. There are many moments, famous moments, in his career, when he objects to the way physics has turned – notably in quantum mechanics. By exploring the relationships of classical physics, by deepening them, and by connecting different domains of thought previously held to be disjunct, Einstein, I believe, saw himself as a kind of radical classicist.

DGB: And yet he was, perhaps despite himself, a kind of time bomb in that classical tradition.

PLG: I think here that Einstein's extraordinary apology to Newton – where Einstein writes, in this odd and intimate way, "Newton, verzeih' mir'" – is, in a sense, his coming to terms with the fact that in his pursuit of this purifying classical vision he disrupted it. In a way it is a note to himself – a note about his own life trajectory, a note on the transformation that resulted from an attempt to deepen and streamline a classical vision.

DGB: One reading of your book would be that you think you have discovered

the 'smoking gun' for this very transformation, the smoking gun for nothing less than the theory of relativity itself: Einstein is at his patent desk, looking at diagrams of electromechanical networks for time distribution along railway lines. "Eureka!" he shouts, and he sits down to demolish the idea of absolute time and space. I know that you don't care for this reading, and you don't think this is your story, but it will be tempting for many readers …

PLG: It is absolutely *not* how I think of the problem – not for Poincaré, not for Einstein. Almost all of my work stems from a concern with the strange juxtaposition of the very abstract and the very concrete. This is not a question that is by any means restricted to physics, but physics makes it abruptly clear how suddenly we pass from symbols to materiality. In *Einstein's Clocks, Poincaré's Maps* I want to get away from two widespread ideas: first, a notion that science proceeds by a kind of Platonic ascension, an evaporative or sublimating process that takes the material into the abstract. Material relations do not eject ideas or produce ideas like ripples on the surface of deep-flowing currents. And here coordinated clocks did not *cause* Einstein to introduce the synchronizing procedure. Telegraphic longitude mapping did not force Poincaré to the simultaneity procedure. Conversely, physics does not advance by pure condensation – it would be a terrible distortion to see physics beginning in a realm of pure ideas, and then gradually acquiring the weight of materiality until they stand in corporeal form as the objects of everyday life. So the reason that I find this moment of late-nineteenth- and early-twentieth-century contemplation of time so interesting is that it represents *neither* of these unilateral directions (concrete-to-abstract or abstract-to-concrete). Instead there is an extraordinary oscillation back and forth between abstraction and concreteness. I like this mix – this high-pressure interaction of material technologies, philosophy, and physics. Each was in play, in different ways, and 'simultaneity' was at stake in each domain: in Lorentz's mathematical 'local time,' in the technological exchange of time signals, in the philosophical critique of absolute time. In their own ways, Poincaré and Einstein were reading philosophy, working at technological projects, grappling with electrodynamics. Einstein certainly knew pieces of what Poincaré had done (how much and exactly when is a longer story). Then came Poincaré's moment in December 1900 (and Einstein's in May 1905) when a statement about what simultaneity *is* suddenly participated in all three arcs – the crossing point.

DGB: Technology, metaphysics, physics.

PLG: What interests me about this story is precisely that you can't start to tell it if you think that it's all on one scale, or all is really grounded in only one of these domains. Or rather you see very limited pieces of it while vast blocks of the story become unmotivated, even incomprehensible. So if you tell the story of time coordination as a pure history of ideas then Poincaré's references to telegraphy and telegraphic longitude remain …

DGB: incoherent …

PLG: Incoherent, or, more precisely, they appear as fully abstract thought experiments, with the subject (the ground of the metaphor) chosen arbitrarily. But what is interesting to me about it is that as you start to tell the story, no matter where you start – and in some ways you have a choice about where to begin – you

need the other levels. Otherwise the story contains arbitrary elements: Why, for example, is Poincaré publishing about the same procedure for coordinating time in a journal of philosophy of metaphysics and morals, in the Annals of the Bureau of Longitude, and in the physics publications? I think that the very quick back and forth between scales actually points to a dimensionality of history that simply is wiped out if you try to narrate it from a single line. This is a theme of my work, that the metaphorical and the literal are inextricable: that the literal is always referring outwards metaphorically and the metaphorical flickers back into the literal. Asking about the history of physics leads at some key moments both to very material circumstances and to the ethereal layers of metaphysics as well. In the book, I am constantly trying to avoid the historiography of both sublimation and condensation. Instead, I find a peculiar state of vapor and water known as 'critical opalescence' to be a better metaphor for the relationship between the abstract and the concrete. For under particular pressure and temperature, vapor flashes back into liquid and liquid into vapor at every scale, from a few molecules to the whole system. The light that we shine on the opalescent mixture reflects back in every color, at every scale. In the late nineteenth century, synchronized time was more like that: debates over synchronizing time – debates over the conventionality of time itself – took place at the scale of buildings, blocks, cities, countries, and the planet, while at the same time arguments came fast and furious about the philosophical and physical basis of time. What I wanted to know – very specifically – was how a simple proposition, "time – simultaneity – is nothing other than the coordination of clocks, taking into account the electrical signal-time between them," could function jointly in this multiplicity of trajectories: physics, metaphysics, technology.

DGB: Where somebody was actually *making that notion real* by creating synchronized zones, by creating coordinated clocks, even as the same proposition was transforming our understanding of the physical world, and, perhaps, our place in it.

PLG: Exactly. In 1899, Poincaré was arguing with Greenwich astronomers about how to get their astronomical clocks synchronized, giving a lecture in which he reinterpreted Lorentz's time concept, and presenting to the philosophers his arguments against absolute space and time. All of this occurred essentially at once – no one domain *drove* the others. Precisely the simultaneity of all this presents the historian with two great challenges. One is to show how the domains come together. But the other is to exhibit the quasi-stability of each of these discourses, games, or traditions.

DGB: And to do this we must, as you say, "look up to see down, and down to see up."

PLG: The juxtapositions, the links – all this is *historical*. It is now a commonplace for string theorists to think of physics and algebraic geometry 'going together'; twenty-five years ago that wasn't obvious at all. For those turn-of-the-century decades it made perfect sense to mingle machines and metaphysics. For us, perhaps, the nearness of things and thoughts seems to have vanished, at least where time is concerned. When Poincaré and Einstein looked into the details of electrical engineering, when they stared at generators, radios, and cables, they saw in them critical prob-

lems of physics and philosophy. Conversely, they could hardly consider philosophical questions of time and space without asking about central features of physics – or technology.

DGB: With hindsight, we will surely discover that we now have our own "philosophical machines." It is tempting to say that the computer is for us what the clock was for much of the history of science: a machine to think with.

PLG: Moments of critical opalescence in the history of science – moments when a huge variety of scales are implicated – are not frequent. But the development of the modern computer is such a moment – as was the late-nineteenth-century deployment of synchronized clocks. It simply isn't possible to tell the story of information theory, for example, without invoking the history of computation. Conversely, there can be no coherent history of electronic computation without showing in detail how the hardware story crossed with the development of theories of information – or theories of brain function.

DGB: But let's pull back for a moment. How does the story you tell in this book fit with larger narratives in the history of clocks and timekeeping? Is Einstein's relativistic time 'just' time? Is it the apotheosis of the classic history of technology story about time, that wonderful story of progressive human efforts to push time up out of the dirt and the grass, the pulse of the blood and the organic cycles of days and seasons, and to create instead an abstract, disembodied, 'pure' time – a flowing that would be monitored with fantastically precise devices, devices so precise that they would become critical tools of investigation of nature, and reveal and measure, through time, the myriad quirks and wobbles of the cosmos? With Einstein's time, perhaps, that abstraction outreaches itself, in a way, and collapses back onto us, onto the earth, onto the contingencies of here and there. Does that make sense?

PLG: You can tell that story of the earlier physics of time, as you suggest: Time passed from a world in which the sublunary sphere was thought of as corrupt and material to another realm, beyond the superlunary, to the inaccessible reaches of Newton's pure, mathematical time. The story of the late nineteenth century, though, is one in which the abstraction and concreteness of time are both present. Conventionalizing time through the exchange of signals forced the made-ness of time into the domain of the visible: time zones imprinted the technical fabrication of simultaneity in everyday life. Physicists, philosophers, psychologists, astronomers – all were debating how to *make* time, how to measure it precisely and ship it from place to place. As Poincaré and Einstein inserted technical, engineered time into the physics of electrodynamics, they very deliberately set aside reference to Newtonian absolutes. They brought the abstract into the concrete – not by jettisoning the realm of the ideas for the sun and seasons, but by joining the material to the abstract. We could say that the modernity of time is made visible by the absence of time-in-itself, by the absence of time-as-absolute.

DGB: In a way, that traditional history of time and timekeeping, particularly as cultivated by historians of science and technology, has been a story of the 'demythologizing' of time. Sure, people went on using time imagery for didactic or symbolic functions – from *vanitas*

paintings of skulls to devotional hourglasses. But the history of time in science and technology has been the story of *abstracting* that pure and precisely metered flow from such accretions of 'meaning.' And yet, the products of such progressive purifications are always themselves reintegrated into the realm of human meaning-making. For instance, the emerging concept of 'geological time' in the eighteenth and nineteenth centuries rapidly came to be entangled with systematic theology and deist notions of natural law – were rocks a particular lesson in eternity? This sort of endless 'folding' between science and signification makes me wonder: Was there – is there – a didactic or symbolic significance in Einstein's time?

PLG: You might approach this in two ways. One would be to look at the specificity of the way Einstein and his physicist interlocutors treated time, and the other would be to explore how time was taken up in the wider cultural sphere. For example, Einstein was very amused by the 'twin paradox' in which one twin travels out and back at relativistic speeds and ends up much younger than his stay-at-home sibling (he called this "the thing at its funniest"). But Einstein's heart was always elsewhere – his real investment was in the *in*variants he found (for example, the absolute speed of light, or the identity of the laws of physics for all inertial reference frame observers). He was consistently more interested in these aspects of the theory than he was in the differing perspectives of each observer on space and time. But clearly the wider public was, and has remained, fascinated precisely with the relativity of time. From jokes to art and ethics, Einstein has been invoked to justify the tenet that the most basic of concepts were 'just relative.'

DGB: And yet – and this is so easy for the lay reader to overlook – 'relativity' is predicated on a cosmic and universal *absolute*.

PLG: Indeed – there is a great irony here, since Einstein preferred to see his work as 'Invariant Theory' but knew he could not buck the worldwide trend to label it 'Relativity Theory.'

DGB: So while the public seized on the relativity of time, what did physicists take from Einstein's intervention?

PLG: The critical gaze that Einstein cast on the notion of time promptly put other concepts under the microscope. Einstein had made time and simultaneity stand with, not behind, experience and procedure. Now physicists wanted to know how this rebuilding of a concept could be extended into quantum theory: What was causality? What did it mean for a particle to have a momentum and a position? Over the decades that followed, physical concepts fell one after another from a priori metaphysical heights to the ground where they (coupled to other concepts) met experimental inquiry. Time invariance – that a movie of the physical world should be playable backwards and forwards – was not, it seemed, the rule of a priori law. Nor was parity invariance (that the mirror reflection of phenomena should always be physically possible). Now from a distant philosophical perspective one might say that the criticism of causality, for example, was even more dramatic than Einstein's and Poincaré's critique of Newtonian absolute time. But the critique of time came first, and in a deep and abiding sense it guided the rebuilding of physical knowledge for generations after 1905. This, I believe, is because the reformation of time was not

just a change in a particular doctrine ("time is better measured this way than that way"). At stake was what it meant to have a physical concept *at all*.

DGB: And at stake too was how one gains access to such a concept, no? Since 'abstraction' – or, as you call it, 'sublimation' – is not merely a way to tell historical stories; it is also a way to think about nature, it is a way to think about what science itself is and how it should be done. And yet Einstein's pursuit of time leads to a simultaneous apotheosis and inversion in the larger history of time in science and technology. His is an exercise in abstraction that is also, improbably, a kind of reification.

PLG: Understanding the history of time always involves examining exactly that relationship between the abstract and the concrete, and, for Einstein, understanding time itself demanded this as well. What I find so remarkable about the fin de siècle is that not just in relativity theory, but in the whole cultural surround, the categories of time and space exhibit a kind of abstract concreteness (or concrete abstraction). When the French finally persuaded the international community to 'sanction' the meter in 1889, they held an elaborate ceremony, and a ritualized 'burial' of the standard. At the moment the assembled dignitaries and scientists sealed the iridium-platinum rod in its triple-locked chamber (and shared out the keys), this precisely engineered rod rose to become 'M' – the object that could measure but not be measured. Practical? Of course; industrialists desperately needed a reference meter. But symbolic? How could one say no?

DGB: When people start playing with absolutes, when they start to conjure them – they do, we do, the strangest things. It takes strange activity to bring absolutes into the contingencies and localities of human life. You can be sure that people are going to start making some very unusual gestures, and bring out keys and locks and boxes and bury things in the ground and make funny noises…

PLG: And particularly in the Third Republic, where religious iconology morphed into scientific-technical procedure. Time, too, was similarly concrete-abstract. In the 1890s, for example, Poincaré joined a commission on the decimalization of time. On one reading, this was entirely a practical affair – railroad administrators argued passionately for the simplicity that 9.56 or 22.34 o'clock would afford by allowing travelers to calculate time differences by simple subtraction. On another, though, it was entirely symbolic: a reanimation of the dream of rationality so passionately advocated during the French Revolution and brought to international prominence through the Convention of the Meter in the 1880s. Reflections on time are so often like this – practical and more than practical, utterly utilitarian and highly symbolic.

DGB: Hence, the practical utility, for Newton, of a 'physics time' that lived in, of all places, the *Sensorium of God*. Talk about practical and more than practical! But I still wonder: Did Einstein and Poincaré bring time back to earth? Remove it from the realm of first and final things?

PLG: Yes and no. True, they grasp time from the domain of the pure absolute. True, they rope it into procedure of electro-chronological coordination. But they surely do *not* sever time from its wide

and deep bonds with modernity. Both scientists' writings on the 'new mechanics' (with its non-absolute time) were widely read by artists, philosophers, and writers. Both – though in different ways – saw the relativity of time as a fundamental piece of the new physics.

DGB: The meaning of the clock would never be the same.

PLG: And yet, of course, clocks have never been just gears and pointers. Some were mounted in late-medieval towers, establishing dominion of property and faith. In paintings they stood as harbingers of death. By the late nineteenth century, mounted in factories, observatories, and trading rooms, they stood for the modern ambitions of regulated life, precision-mapped territory, and the instantaneity of contemporary life. It is against this seven-hundred-year clock history that relativity entered, and when it did, there were certain to be no small effects.

DGB: 'Grand narrative' historians have long talked about the conflict between 'church time' and 'merchant time' in the late-medieval period: the steeple clock versus the factory clock. On the one hand the time of God, on the other the time of labor and money. Your story of Einstein and Poincaré, of clocks and maps in the fin de siècle, could be read – playfully, I admit – as the final confrontation of these two chronometries of European civilization: in 1905 the Sensorium of God gets tied to the tracks of railway time . . .

PLG: But modernity is not – or perhaps should I say 'not just' – a train wreck! Instead, what we see in this story is that the great metaphors of time – trains and maps – chosen by Einstein and Poincaré are both the most imaginative of all thought experiments, and, at the same time, the most everyday technologies of the modern world.

Jennifer M. Groh & Michael S. Gazzaniga

How the brain keeps time

One of the keys to playing the piano – or at least to playing it well – is the ability of the pianist to time appropriately a sequence of movements of the fingers. How does the brain coordinate and synchronize such complex movements? Obviously, it is not simple – as anyone who has watched a baby struggling to walk can attest.

As it happens, the timing of complex tasks poses a dilemma not just for brains, but also for computers. Neither brains nor computers are clocks – yet both must somehow 'keep' time in order to operate properly in the face of various forms of delay in processing information.

Computer scientists and electrical engineers have developed several different algorithms to allow computing devices and networks of computing devices to coordinate complex tasks. By exploring how these man-made systems manage to synchronize their operations, and then comparing how computers and brains solve analogous problems, we may gain insight into some of the solutions that evolution has conceived to enable babies to crawl – and pianists to play the most devilishly difficult of Chopin's *Études*.

The microprocessors at the heart of computers employ sets of tiny transistors in silicon chips to represent information. These transistors are wired up in pairs to convey values of either 0 or 1; other quantities are encoded by grouping together multiple sets of transistors or bits, and by representing numbers by their base-two decomposition into 1's and 0's.

In contrast, neurons represent information not in sets of 1's and 0's but in trains of electrical pulses known as action potentials. Each action potential is roughly the same size and shape, so the action potential itself contains little information. Rather, the *rate* at which

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these action potentials occur is thought to be the medium for carrying information through the nervous system. Discharge rates can vary continuously, with information being conveyed by the length of the intervals between identical action potentials, rather than by discrete 'on' and 'off' states. In short, the brain's internal language differs from that of computers in two key respects: the code is analog, not digital, and the vocabulary of that code is time, rather than voltage.

Generally speaking, this neural code seems to operate on a timescale in the 1 – 100 millisecond range. Action potentials last about 1 millisecond each, so the fastest rate for a train of action potentials is limited to about a thousand action potentials per second. In practice, neurons rarely 'fire' at such high rates for more than a few action potentials in a row; more commonly, discharge rates range up to the low hundreds of action potentials per second.

Both computers and brains routinely experience transmission delays, although at wildly different orders of magnitude. Electricity travels along wires at roughly the speed of light (300,000 km/s). Thus the delays to travel the full length of, say, a standard computer card are on the order of nanoseconds.

Although neural action potentials are also electrical in nature, they do not propagate along neural tissue at anything close to the speed that electricity travels along copper wire. Neural 'wires' are axons, which are essentially long, leaky tubes of fluid attached at one end to the main part of the neuron – the cell body. At the other end, axons form connections, known as synapses, with recipient neurons. Because axons are much worse at conducting electricity than copper wires, action potentials decay in size as they move down the axon. They would generally die out completely before reaching the next neuron in the chain were it not for a special active process that boosts the action potential back up to its original size periodically at a series of relay stations along the axon. This regeneration process introduces a brief delay at each node. How far the action potentials can travel before they need to be regenerated depends on the diameter of the axon (thicker is better) and whether the axon is insulated with myelin. Resulting conduction speeds range from about 0.5 – 100 meters per second – fast, but not as fast as copper wire.

An additional factor contributing to transmission delays in computers and brains involves how fast the computing elements can respond to their inputs. The transistors in today's computers can switch between on and off within about 5 nanoseconds of receiving an input signal pulse. How long it takes a neuron to generate an action potential varies, depending on how strong the input signal is and how this input signal is being generated and transmitted. In the retina, the generation of neural activity in response to light takes on the order of tens of milliseconds, in part because the precipitating event – the absorption of a photon by a molecule of photopigment in a light-sensitive neuron – is so small that a process of biochemical amplification is needed to convert this event into an electrical signal. In contrast, the air pressure waves of a sound physically jostle the neurons of the inner ear, causing pores in the cell membrane to stretch open or be squashed shut. The alteration in the flow of charged ions through these pores then creates an electrical signal. The resulting response latency of the auditory nerve can be on the order of a few milliseconds or less.

Additional delays can be introduced at the synaptic connections between neu-

rons. The brain's synapses come in two basic flavors – electrical and chemical. At electrical synapses known as gap junctions, the pre- and post-synaptic neurons are physically fused with one another, and the electrical current can pass directly between them very quickly. At chemical synapses, the arrival of an action potential triggers the release of chemicals known as neurotransmitters into a small space between the axon and the next neuron in the chain. The neurotransmitters diffuse across and bind to specialized receptors on the other side of the gap. These receptors then cause an electrical response in the recipient neuron. At excitatory synapses, the post-synaptic electrical response can help trigger a full-blown action potential, whereas at inhibitory synapses the post-synaptic electrical response serves to impede the production of any action potentials that might otherwise be triggered from one of the neuron's other synapses. The whole process can take between 1 – 5 milliseconds.

In short, brains appear to lumber along when compared with contemporary computers. Yet even computers cannot solve the problem of synchronizing operations simply by being fast.

To ensure that operations proceed in the desired sequence, most modern microprocessors employ a central clock that distributes a timing pulse to ensure that each circuit is marching to the same beat. This allows the output of any one circuit to provide the input to any other circuit in the next time step.[1] This clock rate must be slow enough to allow the slowest operations to be completed before the next set of operations begins.

1 I. E. Sutherland and J. Ebergen, "Computers without clocks: asynchronous chips improve computer performance by letting each circuit run as fast as it can," *Scientific American* (August 2002).

The solution works because modern microprocessors have a comfortable margin of speed, and waiting for computational stragglers does not pose a major problem.

Given the brain's comparative sluggishness, it seems unlikely that a synchronizing clock signal could work for it in the same fashion. Simply conveying this signal from a common source to distant regions of the brain could take many tens of milliseconds, and the size of this delay would vary substantially depending on how far the signal had to travel, with neurons located near the clock center receiving the timing pulse much sooner than more distant neurons. This would be a bit like trying to run a conference call via Pony Express, so it's hard to see how synchronized computations could result. What, then, might be the solution?

The answer may be more analogous to an alternative method of coordinating operations known as asynchronous computing. This method has long been used by networks of computers, and recent research in computer science has focused on applying the technique at the level of chip design for the next generation of microprocessors.[2] When the elements of an asynchronous computer system exchange information, they use feedback to ensure that the message has been received, much like a conversation in which the listener acknowledges the speaker by nodding his head. If the sender fails to obtain confirmation that a particular message has been received, that message is resent. This method is flexible, allowing for messages to be exchanged either quickly or slowly in any given instance, and it works well in contexts like the Internet in which the speed of the operations can vary over a large range of time delays – exactly the situation faced by the brain.

2 Ibid.

What features would be needed for a biological computer consisting of neurons to implement asynchronous coordination? Several critical features come to mind. First, the neural 'hardware' for delivering feedback should exist, and second, neural signals should show temporal profiles that are appropriate for asynchronous coordination.

The neural wires that could serve to provide the feedback necessary for asynchronous coordination exist in abundance. A neuroanatomical rule of thumb holds that every connection between brain areas is bidirectional, meaning that some neurons will send information from area A to area B and that others will send information from area B to area A. There are exceptions to this rule of course, but it provides a good general sense of the extensive interconnectedness of the brain.

Connections that proceed from the sensory periphery to the higher-order areas of the brain that are implicated in more complex processing are known as ascending or feedforward projections. Connections directed in the opposite direction are known as descending or feedback projections. Even within a brain area, neurons are heavily interconnected with one another, potentially forming feedback loops at the local level. Identifying the specific roles of these connections has proved tricky, because the activity of individual neurons is the complicated product of all of its inputs, and dissociating some sources of inputs from others is difficult. But it is certainly possible that part of the role of these reciprocal connections is to acknowledge receipt of incoming messages.

To transmit information 'return receipt requested' implies that if the message is not received, it ought to be resent. This in turn means that the message must be either continually broadcast or stored for later retransmission until the acknowledgement is received, at which point the message must be deleted.

Asynchronous coordination, then, calls for a kind of working memory operating at the neural level. Specifically, it requires an ability to sustain a pattern of neural activity for an arbitrary period of time, following the cessation of a sensory input signal. As it happens, this pattern of neural activity – known as delay period activity – has been identified in a variety of areas of the brain thought to be involved in remembering things for short periods of time.

Consider, for example, the simple behavior of looking at fireflies on a dark summer evening. The firefly's light is only visible for an instant. In the fraction of a second that it takes to plan and execute an eye movement to that spot, the light is often gone. But neurons in the brain have been found to maintain the signal of where the light was located even after the light has disappeared.[3] This sustained activity lasts until an eye movement is made to the remembered location, and then it ceases, as if the signal has served its purpose and can be discarded when it is no longer needed.

One of the fascinating things about delay period activity in neurons is that no one knows how it arises. Computer

3 L. E. Mays and D. L. Sparks, "Dissociation of visual and saccade-related responses in superior colliculus neurons," *Journal of Neurophysiology* 43 (1980): 207 – 232; J. W. Gnadt and R. A. Andersen, "Memory related motor planning activity in posterior parietal cortex of macaque," *Experimental Brain Research* 70 (1988): 216 – 220; C. J. Bruce and M. E. Goldberg, "Primate frontal eye fields. III. Maintenance of a spatially accurate saccade signal," *Journal of Neurophysiology* 64 (1990): 489 – 508; R. Levy and P. Goldman-Rakic, "Segregation of working memory functions within the dorsolateral prefrontal cortex," *Experimental Brain Research* 133 (2000): 23 – 32.

transistor pairs are specifically designed to have 'state': they maintain their value of 0 or 1 until instructed otherwise. However, if you dissected a typical neuron out of the brain, put it in a petri dish, and activated it using a stimulating electrode you would find that its firing pattern generally tracked that of the input pulses you delivered – it would not keep firing for very long after the input train ceased. Thus, delay period activity appears to reflect a specialization of some neurons or circuits of neurons. In fact, the feedback pathways described above could well play a role in creating and controlling this delay period activity – a volley of pulses will reverberate around a positive feedback loop, causing a sustained activity pattern in response to a transient input.

Saving a message until its delivery has been assured is vital to asynchronous coordination, but it is not the only thing that is crucial. Deletion of delivered messages is also critical. Possible fingerprints of message deletion are observable in another ubiquitous property of neural response profiles, namely, the tendency to respond to a sustained input with a transient change in discharge rate. Neurons in the visual, auditory, and somatosensory pathways frequently respond most vigorously to a sensory event right at the beginning of that event, and then the response rapidly decays. The resulting brevity of the neural response may help keep one message from stepping on other messages as it is sent up to higher brain areas. Many mechanisms might account for this pattern, including the possibility that inhibitory feedback from these higher areas serves to indicate that the message has been received.

Sustaining a brief input signal and truncating a prolonged one are flip sides of the same coin. Both are necessary to give the brain control over the duration of its activity patterns. Truncation can help keep separate signals from coinciding when they converge on higher brain areas. Sustaining brief signals gives neurons 'state,' so that they can hold a bit of information until recipient circuits are ready to act on it. Saving a bit of information until it can be responded to, and then deleting it so that it is not responded to twice, are both critical aspects of asynchronous coordination.

What happens if the temporal coordination of neural activity goes awry?

Let us return to the example of making eye movements to the remembered location of a visual stimulus. Suppose that the memory trace of the visual stimulus is not discarded after the eye movement has been made. Scientists can artificially create this scenario using a technique known as microstimulation. This technique, pioneered in the 1950s by Wilder Penfield in patients undergoing surgery for intractable epilepsy, involves activating a population of neurons *in vivo* using a stimulating electrode. A sustained pattern of neural activity, potentially mimicking a memory trace for the location of a visual stimulus, can be evoked by delivering a sustained train of microstimulation pulses to one of the areas of the brain in which neurons normally show sustained activity pending an eye movement to the remembrance of the location of a real visual stimulus. This stimulation typically triggers an eye movement. But if the train of microstimulation is turned off too soon, the eye movement either doesn't occur at all, or it falls short of the intended target.[4] If

4 T. R. Stanford, E. G. Freedman, and D. L. Sparks, "Site and parameters of microstimulation: evidence for independent effects on the properties of saccades evoked from the primate superior colliculus," *Journal of Neurophysiology* 76 (1996): 3360 – 3381.

the train of pulses is left on too long, a second, then a third eye movement is made. In other words, continuing to broadcast the eye movement command signal even after the movement has been executed once produces repeated iterations of the same movement.[5]

Disorders of timing may underlie or at least contribute to the symptoms of a variety of naturally occurring neurological syndromes, such as those diseases that manifest themselves as some kind of motor impairment. For example, multiple sclerosis involves the progressive destruction of the myelin that insulates neural axons. This loss of insulation results in slower conduction of action potentials along axons. Early signs of MS include clumsiness, as it becomes difficult to coordinate movements when transmission delays get out of whack.

Disorders of movement provide the most obvious window into the critical role of timing in producing properly ordered computations, because failures of coordination are readily apparent when physical actions are involved. Disorders of timing on the sensory end may be equally disruptive. Indeed, impairments in processing the temporal sequence of sensory information are currently thought to contribute to dyslexia. To conceive of these disorders as relating to deficits in the brain's ability to synchronize its computations does not necessarily shed light on what went wrong to trigger a particular disease or condition, but it may help illuminate the constellation of symptoms that can result.

Perhaps both the synchronizing-clock and asynchronous-computing algorithms described here are used in the brain in different contexts, as is the case for man-made computing systems. Or perhaps the brain uses a wholly different method that we have yet to imagine.

Whatever the mechanism that the brain employs to synchronize its operations, when it all works swimmingly, the results are astounding. The product is the effortless integration of a myriad of sensory information to produce coherent thought and graceful physical action. And while most of us do not achieve the level of manual dexterity needed to play piano in Carnegie Hall, we do think, walk, and talk – although not necessarily in that order and not always at the same time. And this, given the tools that the brain has to work with, is nothing short of a miracle.[6]

5 D. A. Robinson, "Eye movements evoked by collicular stimulation in the alert monkey," *Vision Research* 12 (1972): 1795 – 1807; P. H. Schiller and M. Stryker, "Single-unit recording and stimulation in superior colliculus of the alert rhesus monkey," *Journal of Neurophysiology* 35 (1972): 915 – 924.

6 We are indebted to B. R. Donald, K. N. Dunbar, H. Farid, C. R. Gallistel, S. T. Grafton, A. M. Groh, and M. N. Shadlen for their helpful comments on an earlier version of this manuscript. We are grateful to the following sources for providing financial support: the Alfred P. Sloan Foundation (JMG), the McKnight Endowment Fund for Neuroscience (JMG), the Whitehall Foundation (JMG), the John Merck Scholars Program (JMG), the Office of Naval Research Young Investigator Program (JMG), the EJLB Foundation (JMG), The Nelson A. Rockefeller Center at Dartmouth (JMG), and NIH NS 17778-19 (MSG and JMG).

Danielle S. Allen

The flux of time in ancient Greece

> Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration: relative, apparent, and common time is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time....
>
> – Isaac Newton, *Principia* (1687), scholium

In childhood, I visited the Jet Propulsion Labs in Pasadena, California, home to space programs, and there, among many other wonders, saw a short cartoon about Einstein and relativity. A Jetsons-like family is embracing before some of its members depart on a space vacation at the speed of light. The travelers look out their spaceship's windows at the starry night; the family members at home go about their daily chores. A reunion is prepared. The voyagers return, and stunningly, find themselves now younger than the people whom they had left home, who arrive at the reunion wrinkled and gray. Time had slowed for the space travelers. Presumably it will pick up its pace again, now that they are home.

This film assumes that its audience thinks of time as something that flows as predictably as its cartoon frames, passing by everyone's eyes at the same uniform rate. And its animators expect to upend this expectation by dramatizing Einstein's key claim: that time is elastic, and that it may accelerate or slow down, according to the frame of reference of the people experiencing it.

Yet to my mind, it is the belief in the uniformity of time, the idea that it is the same everywhere and always, that merits explanation. Einstein's view of time, by contrast, has archaic antecedents: for much of human history, people have experienced the flow of time as potentially irregular, rather than uniform.

The ancient Greeks, for instance, worried about gray-haired infants and rivers that ran backwards. They knew that the sun could disappear. Above all, they knew that human passions, especially anger, could vary the flow of time for each individual, making time always relative to personal experience. It was this very knowledge, I believe, that helps to

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explain why the Athenians made clocks a central tool of civic life. By imposing a more reliable external measure for the passage of time, they were trying to moderate the passions, and bring a due measure of order to their city.[1]

Before there were sundials or water clocks – and long before there were mechanical watches – people measured the time of day by their shadows, months by the waxing and waning of the moon, and seasons by the appearance and disappearance of constellations and by the migrations of animals.

Modern scholars have long maintained that nothing is more regular than this sort of 'natural' time. In support of this claim, they invoke the archaic Greeks, often citing Hesiod's *Works and Days,* among other classical sources. However, a closer look at the evidence suggests that Hesiod, like a number of other early Greek writers, had a far subtler sense of how deeply irregular and unreliable the passage of time in nature really is.

A stern older brother is the speaker of Hesiod's eighth-century didactic poem of approximately eight hundred lines. In the poem, he prescribes farming routines to his lazy younger sibling, the foolish Perses, insisting above all that Perses act 'seasonably':

> But when Orion and Sirius come into midheaven, and rosy-fingered Dawn sees Arcturus, then cut off all the grape-clusters, Perses, and bring them home. Show them to the sun for ten days and ten nights: then cover them over for five, and on the sixth day draw off into vessels the gifts of joyful Dionysus. But when the Pleiades and Hyades and strong Orion begin to set, then remember to plough in season: and so the completed year will fitly pass beneath the earth.[2]

But superficial appearances to the contrary, Hesiod's text is not simply a farmer's almanac. Stephanie Nelson, who is a farmer as well as a classicist, has pointed out that learning to farm from Hesiod's poem is about as feasible as learning to sail from Homer's *Odyssey*.[3]

As in most poetry, the temporality represented in Hesiod's verse is not so simple as it first seems. Here the defining feature of the human condition is a mutual dependence that forces human beings into patterns of reciprocal exchange, which unfold only through time. But Perses has recently taken more than his fair share of a joint inheritance, disequilibrating this system of reciprocity. Insofar as the moral order requires securing this system, people must make sure always to do things both in the right measure and at the right time. As Laura Slatkin puts it, "Life can be regulated according to calculable elements, says the Hesiodic tradition, and if you measure your actions and exchanges appropriately you can recapitulate that order."[4] So the speaker gives Perses a lec-

1 My thanks especially to Laura Slatkin. This essay originated in response to her very rich "Measuring Authority, Authoritative Measures: Hesiod's *Works and Days*," in L. Daston and F. Vidal, eds., *The Moral Authority of Nature* (Chicago: University of Chicago Press, 2003). The reading of Hesiod I present here is largely derivative from that essay. Cf. Stephanie A. Nelson, *God and the Land: the Metaphysics of Farming in Hesiod and Vergil* (New York: Oxford University Press, 1998). Also, I owe my methods of reading Greek poetry in particular to Anne Carson, *Economy of the Unlost* (Princeton, N.J.: Princeton University Press, 1999), and to Robert von Hallberg.

2 Hesiod, *Works and Days,* lines 609 – 617, in Hesiod, *Homeric Hymns, Epic Cycle, Homerica,* trans. by Hugh G. Evelyn-White (Cambridge: Harvard University Press, 2000 [1914]).

3 Nelson, *God and the Land,* 48 – 58, 165 – 169.

4 Slatkin, "Measuring Authority," 14.

ture on time, invoking the natural order and its seasonability, in order to give his brother a figure for thinking through his ethical obligation.

Significantly, the idea of seasonability upon which Hesiod's poem depends describes a very unstable temporal order; after all, the speaker badgers his brother always to act seasonably precisely because Perses has failed to do so. As in the mortal world of ethics, so too in the natural world. Violations of seasonability are possible even there – as both Anaximander and Heraclitus agreed in the centuries after Hesiod.

In the early sixth century B.C., Anaximander made the Hesiodic idea of seasonable action the basis of his cosmology. He argued that the basic principle of existence is that opposites pass into each other.[5] Just as the heat and drought of summer give way before the wet and cold of winter, day gives way to night, then again night to day. This pattern of one element giving way to another was, in his view, best understood as a pattern of judicial reciprocity. He wrote: "And the source of coming-to-be for existing things is that into which destruction, too, happens 'according to necessity'; for they pay penalty and reciprocal retribution to each other for their injustice according to the assessment of time (*tên tou chronou taxin*)."[6]

The idea behind Anaximander's passage must be that any given state of the world (of dry heat, for instance) would endure eternally but for countervailing forces. "The prevalence of one substance at the expense of its contrary is 'injustice,' and a reaction takes place through the infliction of punishment by the restoration of equality – of more than equality, since the wrongdoer is deprived of part of his original substance too. This is given to the victim in addition to what was his own, and in turn leads (it might be inferred) to . . . surfeit, on the part of the former victim, who now commits injustice on the former aggressor."[7] The seasons do not establish a secure order on which human beings should model their own behavior, but themselves constitute the raw material of a cosmos that must be secured through exchanges. Time is responsible for negotiating transactions of cosmic reciprocity – just as, in Hesiod, Perses is responsible for negotiating mortal exchange. But this makes time as unreliable a figure as the foolish Perses.

Anaximander was not the only natural philosopher to adopt the view that temporal orders are immensely unstable. The following Heraclitan aphorism has a similar force: "The sun will not transgress his measures. If he does, the Furies, ministers of Justice, will find him out."[8] As with so many of Heraclitus's remarks, the statement is constructed as a riddle or paradox. It opens with an assertion of the absolute regularity of time – but a description of the measures that will follow if any irregularity should occur abuts this confident claim. The second sentence transforms the first from an indicative statement of fact into something more like an optative expression of desire: not merely, "the sun will not transgress," but "the sun will not transgress [I hope]." The idea that even the sun will be punished for transgressions shores up the hope of the first sentence, and relies on the logic of deterrence to transform a wish into a fact.

5 G. S. Kirk and J. E. Raven, *The PreSocratic Philosophers* (Cambridge: Cambridge University Press, 1962), 104 – 138.

6 Ibid., fragment 103, 105 – 108.

7 Ibid., 119.

8 Fragment 44 in Charles H. Kahn, *The Art and Thought of Heraclitus* (Cambridge: Cambridge University Press, [1979] 1999), 48 – 49.

The aphorism is in fact an only minimally inflected statement of what we can presume to have been the psychological stance out of which the Hesiodic speaker fashioned his lines to Perses: "My brother will not do me wrong. If he does, the Furies will find him out." But Perses did do him wrong, and so now the Furies, cast in the form of the poet's regular measures, must find him out. Just as Hesiod wishes to set the ministers of justice on a transgressive second son, so Heraclitus would set them on the sun itself.

Anaximander and Heraclitus, then, are as explicit as Hesiod about their worry that time may be as insecure and irregular as human systems of reciprocity. And *Works and Days* does not merely worry, allusively, about the parallel instabilities of moral and temporal orders. Hesiod poses the problem bluntly when he gives an account of the history of humankind as divided into five ages. His own age is the age of iron:

> For now truly is a race of iron, and men never rest from labor and sorrow by day, and from perishing by night; and the gods will give them sore cares .... And Zeus will destroy this race of mortal men also when they come to have grey hair on their temples at birth.[9]

If the people of the iron age, like Perses, fail at their obligation to act in the right time and with right measure, the moral and temporal orders will both collapse. "The sign of the last stage of corruption among mortals, when they have become so degenerate that Zeus will destroy them, is a stunning one: the mark of their corruption is that their *timing* is *out of synch* .... When newborns look like old men, the seasons of our lives are truly out of joint."[10]

The Athenian playwright Euripides (c. 484 – 406 B.C.) alludes to the same alarming possibility – that the direction of time can be reversed – in the *Medea*. There the chorus considers Jason's violation of his oath to his wife to be fundamentally disruptive of a moral order based on promise-keeping. They lament: "Backward to their sources flow the streams of holy rivers, and the order of all things is reversed: Men's thoughts have become deceitful and their oaths by the gods do not hold fast."[11]

The moral is clear. In Slatkin's summary of Hesiod: "[T]o observe the due sequence of things – to pay attention to the calendar – is not only to bring temporality, that inescapable fact of our lives, in some small way under control, but it is also to resist such moral chaos as is envisaged for the end of the Fifth age, the age of iron – our own."[12]

The inverse is also true. To resist such moral chaos as seems to characterize our own iron age is to bring temporality under control, ensuring that rivers will not run backwards, that babes will not be born gray, that the sun will not transgress its bounds.

The sun will not transgress his measures, Heraclitus wrote. But of course the sun regularly does. Eclipses occur, and every so often the sun disappears from view. Pre-Socratic philosophers made various attempts to explain its disappearance: the sun had, perhaps, stepped accidentally into a hole while making its

9 Hesiod, *Works and Days*, lines 174 – 181, in Hesiod, *Homeric Hymns, Epic Cycle, Homerica*, trans. by Evelyn-White.

10 Slatkin, "Measuring Authority," 15.

11 *Medea* 410 – 414, *Euripides*, ed. and trans. by D. Kovacs (Cambridge: Harvard University Press, 1994).

12 Slatkin, "Measuring Authority," 15 – 16.

circuit? The bowl he was riding in had been turned away from earth?[13]

If one counts time by days, what's to be done when the sun is suddenly gone? Precisely because the natural world was the basis of their temporal measures, the early Greeks were hypersensitive to the very real possibility of ruptures and disturbances in this order. They could not simply plot moral ideals off of some fixed natural grid, for no such grid exists. Instead, early Greek thinkers identified points of instability in both the natural and the political order and believed that collapses in either could destabilize the other.

One of the earliest and most revealing Greek texts about the uncertainty of temporal orders and the close relationship of that uncertainty to moral difficulty is a fragment from the archaic poet Archilochus. Paros, where Archilochus was born, experienced a total eclipse in 648 B.C.[14] This poem turns on the figure of the eclipse. Here is all we have of it:

Take all the world's crud; in it there's
  nothing beyond belief
or consternation or oath now that the
  Olympian father, Zeus,
has from day worked night, pickpocketing
  the light
of a burning sun. Terror pools in mortals.

From here on out husbands and fathers
  should believe
the unbelievable. Let none of you
ever again marvel at what he walks in on,

not even if four-footed beasts are
  swapping with dolphins
for salty homes and the crashing breakers
  of the deep sea
have grown more beloved to those beasts
  than earth
and upon those waves the wooded hills [15]

In Hesiod, moral degeneracy led to temporal implosion. Here the opposite occurs. An eclipse of the sun leads to the complete collapse of all the boundaries that had kept things in their appropriate places.

If the poet had been a natural philosopher, the fragment might count as a whole thought, paraphrasable as: "There was an eclipse; therefore all orders, moral and natural, came undone." But we are listening not to an astronomer, not to a didactic older brother preaching to a greedy sibling, not even simply to the persona of the poet. The voice instead, as Aristotle tells us – and this is all he tells us of the matter (*Rhetoric* 14418b28) – belongs to a father aggrieved at his daughter's behavior with a suitor. The paraphrasable theme of the poem – that eclipse brings about the end of order – does not in fact exhaust its commentary on time; the basic function of the poem is rather to draw a tight link between human psychology and temporal experience.

The poem of Archilochus begins from an emotion motivated by a moment of betrayal. Its dramatic chronology moves from that betrayal to the emotional response and only then to the eclipse, the implosion of natural orders, and the implicit castigation of a disintegrating moral order, figured through despair about a natural world where animals and plants are expected to keep to their prop-

13 Kirk and Raven, *The PreSocratic Philosophers,* 174 – 175, 203. Also Anaxagoras and Empedocles knew the right answer, Ibid., 334 – 335.

14 David A. Campbell, *Greek Lyric Poetry* (Bristol: Bristol Classical Press, [1967] 1982), 155.

15 The translation is my own. The poem does not have a title in the Greek. I have also taken a liberty with the phrase "what he walks in on"; the Greek would more literally be "what he sees, looking on."

er places but no longer do. In this, the poem does not record the real eclipse through which Archilochus lived, but the effect of strong emotions on our experience of time – whether it seems to rush or stand still.

Because this little poem is a dramatic monologue that originates in an emotional response to a personal crisis, one would expect the piece as a whole to convey the full run of the motivating emotion. The trochaic meter of the poem, which regularizes time, takes a real measure of the experience of time's standing still, giving the audience access, in precise temporal terms, to the feelings the speaker has had.

But since the end of the poem no longer exists, the reader is caught in the momentary psychological experience of time standing still, figured by the eclipse: we are not able to experience the precise span of time allotted by Archilochus to its stoppage. If one takes this fragment as part of a dramatic moment, rather than as a statement of natural philosophy, the reader feels its incompletion, and in so doing, feels out of sync with time. In putting a precise measure on the stoppage of time, the complete poem would, I presume, have worked to reintegrate speaker and audience into time's more ordinary flow.

As in the Archilochus fragment, Greek poetry often took upon itself the job of rendering the variety of temporal experiences that, because of the topsy-turvy nature of our emotional lives, characterizes human life.

Homeric epic provides the most powerful example of the Greek interest in the instability and elasticity of time. As Aristotle noted (*Poetics* 1459a30ff), a crucial formal feature that binds the *Iliad* and the *Odyssey* as examples of the same genre is that each converts a very small amount of real time within a story of extended historical sweep into a very lengthy chunk of narrative and poetic time. Even professional classicists are apt to refer to the *Iliad* as a book about the Trojan War, the Greeks' famous decade-long attempt to ruin Troy in retaliation for Paris's abduction/seduction of Helen. And yet the poem, which requires roughly twenty-five hours of performance time, covers only fifty-three days of that ten-year war.[16] What's more, of those fifty-three days, only fourteen are actually narrated in detail. The others pass in a line: "Nine days the arrows of god swept through the army" (devastating the Greeks with plague); "but now as the twelfth dawn after this shone clear the gods who live forever marched home to Olympus," (after their vacation in Ethiopia).

How do we know that the action narrated in the *Iliad* takes fifty-three days (and only fourteen of real action), and that the action of the *Odyssey* takes forty days (eighteen of real action)? It is no accident that the phrase "rosy-fingered dawn" comes quick to the tongue when someone mentions Homer; the bards of each poem are remarkably precise in giving us temporal markers. Rosy-fingered dawn and her sisters – for instance, "dawn who sits on her golden throne" – constitute the poems' major organizational device. The epithets seem retrospectively, to the casual reader, like the tick of a metronome, setting a regular pace through the course of the epic narrative: sunrise, sunset, sunrise, sunset. What could be more regular than that?

But in fact the repeated tick of the epithets is not at all regular, in terms of real time. In the epics, no day is equal in

16 These figures and the rest of those that follow for the *Iliad* derive from Oliver Taplin, *Homeric Soundings* (New York: Oxford University Press, 1992), 11 – 31.

length to any other; dawn comes sometimes quickly and sometimes only after a very long stretch of text. Her rose-colored fingers do touch the earth repeatedly – there are no eclipses in either poem – but one cannot predict the length of any given day when the dawn rises. Let me concentrate on the *Iliad* to provide examples of this.

In the *Iliad,* the first four days of real action (plus nineteen days of action that pass in a line) take 611 lines, or, roughly, an hour and a half of performance time. The fifth day, in contrast, takes almost six hours of performance time, or five and three-quarters books of the epic. This is the first day of fighting after Achilles has withdrawn from the war, and during it Hector, whom Achilles will eventually kill, fights Ajax instead. In other words, this day will feel to an audience almost sixteen times as long as any of the first days.

From the sixth through the eighth day, the pace quickens again – both sides pick up their dead; the Greeks swiftly build a defensive wall and ditch; there is another short battle. These events take roughly two hours of performance time.

And then we hit the longest day of all in the *Iliad*: the day of Hector's triumph on the battlefield that ends also in Patroclus's death. This single day of Achilles' greatest loss stretches out for seven and a half books, or almost nine performance hours, so listeners and readers experience it as about twenty-five times as long as any one of the first four days passed in the tale.

The longest day is followed by a night in which arms are fashioned for Achilles, and then by one more lengthy day of fighting – this time resulting in Achilles' slaughter and mutilation of Hector. This day takes just over four books, or five hours of performance time.

And then time speeds up again. The remaining twenty-four days of the tale, of which only four are narrated in detail, pass in about an hour and a half of performance time, at roughly the same rate as the first four days of the tale.

The longest day is the moment of the greatest crisis, when Achilles still will not fight and the battle is at its fiercest. The day, like the warring, goes on and on. Agamemnon is wounded; the Trojans press near the ships; Achilles watches it all, occasionally making a comment to his friend Patroclus.

At last Patroclus can stand the expansion of time no longer. He begs Achilles to send him to battle *quickly* (*ôka*); he cannot bear Achilles' intractable patience. He must join the temporal order of the men fighting on the plains.

He comes to Achilles in tears and lays out the situation: Diomedes is brought down, Odysseus and Agamemnon are wounded, Eurypylus is wounded too. "But *you* are intractable, Achilles! Pray god such anger never seizes *me,* such rage you nurse . . . . at least send me into battle, *quickly*."[17] Patroclus insists that the moment is right for a quick response; his entrance to the fighting is, he is sure, seasonable. So Achilles sends Patroclus, and this long day continues until Patroclus is dead.

Any number of commentators talk about time's seeming to stop during this epic day. Here it is important to remember that Greek meter was quantitative: any given epic line, written in dactylic hexameter, ought to have taken essentially the same amount of real time to perform as any other, and so the poem in fact establishes a fixed grid of reference against which to convey the total variability of individual temporal experience. Greek poetry regularized time,

17 *Iliad* 16.29 – 30, 38, trans. R. Fagles (New York: Penguin Books, 1990), 413.

precisely as it was underscoring how widely individual's subjective experiences of time diverge.

The central poetic effect of the *Iliad* is to render time's elasticity. It speeds up and slows down, in our experience of it. And in the *Iliad*, the causes of all these changes are one man's emotions: "Sing, muse, of the wrath of Achilles." So begins the *Iliad*, and then we get, for twenty-five performance hours, a remarkably precise calibration of the different speeds at which time can flow when inflected through the experience of fury.

Achilles' anger lasts forty-one days (the remaining twelve of the poem are given over to the burial of Hector), or for about twenty-three hours of narrative time. And within that twenty-three-hour span, time sometimes speeds up – during the arguments with Agamemnon and the reconciliation with Priam – and slows down – during the period that he most strenuously resists the plea that he return to battle.

Just as Archilochus's small poem is meant to figure, in poetic meters, the experience of time's stopping, the *Iliad* measures the temporal contours of wrath. Importantly, it also depicts the degree to which human conflicts arise out of characters' competing sense of what's appropriate when. "Isn't it time to go back to war, Achilles?" says Patroclus. "No, not yet," says the angry fighter.

The problem of doing things in the right season, which Hesiod put to us in *Works and Days*, is not pressed on us by nature nearly so much as by our passions, and by the degree to which emotions put people out of joint with each other. Heraclitus had assigned the job of regulating the sun's progress to the Furies, whom he called ministers of justice. But how can they be, when they do the opposite of regularizing time?

The sensitivity of archaic Greek poets to the elasticity of lived temporal experience leads to a neat formulation of a basic problem of human interaction and of politics. Anger, and other emotions, puts people out of sync with each other, in part because when time flows differently for particular people within any community, their actions will, to each other, seem unseasonable, out of joint.

The difficult project of justice is not merely to settle conflicts, but also to equilibrate people's sense of temporal propriety. If the Furies are indeed left with the task of restoring temporal order, we should despair of the assignment, for anger does the opposite of calibrating and harmonizing time. As long as the Furies are the masters of time, there will be no regularity in it. Heraclitus's claim that the Furies will correct the sun's transgressions, like his famous remark that one never steps into the same river twice, describes the all-pervasiveness of change. Nothing can calibrate time such that it is the same everywhere for everyone. The sun will not transgress his measures, but everyone else will, and they will make time seem infinitely various to each other, with each person's anger being directed at restoring the temporal order that seems natural to him. Thus we get also Heraclitus's statement about time's arbitrariness: "Time (*aiôn*) is youth playing, moving pieces in a board game, and he holds the king piece."[18]

Several of the loveliest extant Greek vases depict Achilles playing a board

18 Fragment 94 in Kahn, *The Art and Thought of Heraclitus*, 70 – 71. I offer my own translation and interpretation here, drawing conceptually on Leslie Kurke, *Coins, Bodies, Games, and Gold: The Politics of Meaning in Archaic Greece* (Princeton, N.J.: Princeton University Press, 1999), 254 – 274. My translation also depends on my own conviction that men could be called *pais* in Greece, up until the time of their marriage. This is a controversial position. On the ambi-

game with Ajax during his 'long' absence from the war.

Archaic Greek poets and philosophers located the source of time's elasticity in the human psyche, and in anger in particular. How, then, did the Greeks nevertheless manage to forge a sense of time that was regular and uniform?

Take the case of Athens. By the end of the fourth century B.C., the city had, right in the middle of the agora, a big public clock that divided every stretch of daylight into twelve hours. Time was still elastic – the twelve hours of a winter day would be shorter than the twelve hours of a summer's day. But nonetheless something important had happened.

The word for hour by the end of the fourth century was *hora*; earlier this same word had meant 'season' and, derivatively, 'fitting or appointed time.' Over the course of their democracy, the Athenians' conception of time had evolved from an orientation toward seasonability, and so toward the infinite variability of judgment inflected by emotion, to a focus on hours as abstract measures of time itself. How did this change from the idea of the seasonable to that of the hour come about?[19]

Like characters in epic and Hesiodic poetry, the Athenians measured time according to changes in the natural world. They gauged the time of day according to their shadows and, well into the fourth century, used expressions like "when the agora is full" and "before the agora is emptied." Their interest in clocks first arose around the 430s, as far as the evidence goes. Meton, an astronomer working with time measurement, is reported to have erected a sundial on the Pnyx, the hill where the Athenian assembly met.[20] And from this same period we have our first extant references to the use of a water clock, or *klepsydra*, in the courts to time speeches (in Aristophanes' *Acharnians* of 426/5).

It is not known whether the sundial on the Pnyx would have measured the sun's progress during a given day, or only its course over a year, but it must have been a largely ornamental device. It would have been of use only on the forty assembly days per year, and then only to those six thousand residents of the city-state, out of roughly two hundred thousand who attended the assembly. Also, all assembly meetings ran from sunup to sundown, so no clock was necessary for starting or concluding business. The water clock was the timepiece that counted, and this seems to be confirmed by the fact that when the city did decide to install a clock in a prominent location in an agora, where it would be available to everyone, male and female, free and slave, it built a giant stone water clock with a one-thousand-liter capacity out-

guity of the line between *pais* (youth) and *aner* (man), see Gloria Ferrari, *Figures of Speech: Men and Maidens in Ancient Greece* (Chicago: University of Chicago Press, 2002), 127 – 138. For a beardless Achilles, there is "Sosias cup": Attic red-figure kylix interior. Berlin, Bildarchiv Preussicher Kulturbesitz, Antikensammlung, Staatliche Museen zu Berlin F 2278 (Ferrari, *Figures of Speech*, fig. 130).

19 The rest of the argument in this essay draws heavily on arguments I have made in "A Schedule of Boundaries: An Exploration, Launched from the Water-Clock, of Athenian Time," *Greece and Rome* (43) (1996): 157 – 168; in "Punishment in Ancient Athens," Center for Hellenic Studies website, <http://www.chs.harvard.edu> (2002); and in *The World of Prometheus: The Politics of Punishing in Democratic Athens* (Princeton, N.J.: Princeton University Press, 2000).

20 Robert Flacelière, *La Vie Quotidienne en Grèce au Siècle de Périclès* (Paris: Hachette, 1959), 205.

side one of the most important courts in the city.[21]

Though philosophers had long been working on the problem of time in Greece, it was not a scientific effort to measure natural time that led, finally, to the production of a public machine for measuring and making 'hours' – but rather a political need. And it was not the philosophers' study of the heavens but the availability of water to ordinary folk that enabled this cultural transformation.[22]

According to the pseudo-Aristotelian *Constitution of Athens*, in every courtroom three jurors were appointed by lot to take charge of the water clock.[23] A special tool would be used to fill the clock every time, and the water was apportioned according to the types of speeches to be given, so that equal jars of time were distributed to the citizens involved in a judicial case. Certain types of cases were assigned a full day, and that day was then divided into the different portions of the trial, with water clocks for each. The divisions from the shortest day of the year set the standard for all days – so that a daylong trial in summer would not in fact consume all the daylight hours – and this standard-length judicial day came to be known as the 'measured-out' or 'divided' day (*hemera diamemetrêmenê*).[24]

It is tempting to see this measured-out day as an early effort to measure time abstractly. But what was measured by this idea was not so much time, as the opportunity for different parties to a dispute to vent their anger. "Sing, muse," the bard had said, "of the wrath of Achilles," and the muse sang for twenty-five hours. Orators, too, wanted to sing of their anger when they arrived in court. The divided day and the water clocks set limits on the ability of any particular politician to play out events according to the pace set by his anger.

The Athenians punished because someone was angry at a wrong and wanted that anger dealt with. Anger was so central to the Athenian experience of wrongdoing and redressing that courtroom litigants could describe laws as establishing levels of anger appropriate to the offense: "Observe," writes Demosthenes, "that the laws treat the wrongdoer who acts intentionally and with hubris as deserving greater anger and punishment; this is reasonable because while the injured party everywhere deserves support, the law does not ordain that the anger against the wrongdoer should always be the same."[25]

The centrality of anger to wrongdoing and punishment ensured that when all the parties to a case – prosecutor, defendant, jurors, and presiding magistrate – gathered, each would already have settled into a very different and particular temporal rhythm; each would have a different sense of how much time was necessary for what in the courtroom, and of

21 The clock is still extant in the ancient agora in Athens. See John Camp, *The Athenian Agora* (London: Thames and Hudson, 1986), 112, 113, 157–159.

22 Water clocks and sundials seem to have come into existence simultaneously in Egpyt, around 1450 B.C. See E. R. Leach, "Primitive Time-Reckoning," in Charles Singer, E. J. Holmyard, and A. R. Hall, eds., *A History of Technology* (Oxford: Clarendon Press, 1955), 112ff.

23 [Aristotle], *Constitution of Athens*, 67.

24 Ibid.

25 Demosthenes, *Against Meidias*, paragraphs 42, 43; trans. my own. (The citation method I use here, with speech title and paragraph number, is standard across editions of the orator's speeches. All the Demosthenes texts referred to in this note and in notes 17 and 18 are available in both Greek and English in the Loeb Classical Library Collection, currently published by Harvard University Press.)

what sorts of actions would be seasonable when. In Aristophanes' *Wasps,* a chorus of recalcitrant jurors describes itself as headed to court already bearing three days' worth of troublesome anger (242 – 244). Does it mean that they have stored up their anger for three days? Or that they are angry enough to try to stretch the matter out over a three-day period? Either way, at the level of syntax, duration expresses the magnitude of anger these comic jurors feel.

When the water clock in the courtroom puts everyone on the same schedule, requiring everyone to accept the same rhythms to structure their claims, the aim in fact is to restrain the very thing that has made time relative: anger. Aeschines describes the moment when litigants must debate the penalty to be imposed on a convict as being when "the third water is poured in [to the water clock to time the speeches to be made] about the penalty and the extent of your anger (to megethos tês orgês)" (Aes. 3.197). To measure time by limiting the duration of courtroom speeches was to regulate anger; and to measure and thereby restrain anger was to regulate time, by smoothing idiosyncrasies in the citizens' experience of it. The water clock put limits on how dramatically human passions could set time, and so human relations, out of joint.

The imperative, "Sing muse, of the wrath of Achilles," gave the Homeric bard license to control the flow of time. Orators also wanted such license, but the water clock aimed to strip them of it. Plato wrote: "the man of the law-courts is always in a hurry when he is talking: he has to speak with one eye on the clock. Besides, he can't make his speeches on any subject he likes, he has his adversary standing over him."[26] The rhetorician Demosthenes several times complained, in fact, that the water clock had brought the force of necessity to bear on his arguments. He may have had to leave something out, he tells one jury, "because I have been forced [*anagkazomai*] to speak with but little water."[27] And elsewhere he complains that it is impossible to tell the whole story "within the time allotted by the present water; it is necessary to discuss each question separately."[28] The temporal license of epic and of the pursuit of seasonability was not an option in the courts. There, the necessity of the hour of which Demosthenes complains replaced time's elasticity.

Much later, in the fifth century C.E., lexicographer Hesychius would gloss the Greek word for necessity, *anangke,* with the phrase 'a judicial water clock.'[29] In the standard interpretation of his gloss, Hesychius is simply noting the inexorability of time. But why then did he not simply gloss the word 'necessity' with 'chronos'? His gloss is in fact unusually sensitive to the representation of time in Greek literature. There time was not inexorable, regular, or fully predictable.

26 Plato, *Theaetetus* 172c – d, trans. M. J. Levett in M. Burnyeat, *The Theaetetus of Plato*; with a translation of Plato's *Theaetetus* by M. J. Levett, revised by Myles Burnyeat (Indianapolis: Hackett, 1990).

27 Demosthenes, *Against Boeotus II,* paragraph 38.

28 Demosthenes, *Against Aphobus,* 1.2. See also Demosthenes, *Against Spudias,* 30; *Against Nicostratus,* 33; *Against Macartatus,* 8; *Against Stephanus I,* 48, 86; *Against Aphobus,* 4, 9; *Against Meidias,* 129; *Against Neaera,* 20; *Against Leochares,* 45; *Against Evergus,* 82; and Lysias, *Against Eratosthenes,* 1.

29 Lexicon, alphabetic letter *alpha*, entry 4234, line 1.

One could worry about gray haired infants and backwards running rivers. One knew the sun could disappear. Human passions could vary the flow of time for each individual, making time always relative to experience and frame of reference.

Finally, it was not the sun, not Zeus, and not the Furies that established necessity, but the judicial water clock. Not time as such, but "time's assessment" (as Anaximander had put it), the measuring out of time, established regularity.[30] In short, Hesychius's gloss tidily notes that the uniformity of time, which is expressed by the idea of necessity, is not a fact of nature but a human invention.

We explain time to ourselves with cartoons, but the Greeks used myths. Let me offer you one, based on an important story in Hesiod, and extended to include the history of the water clock:

A teenage Zeus and a twenty-something Prometheus are quarreling over who is going to have the most authority in the cosmos. They are both invited to a handsome feast. Prometheus plays a trick on Zeus: he carves the meat and sets out servings, putting a tempting piece of meat on top of a pile of bones, and a nasty looking piece of skin on top of a pile of good meat. Zeus picks the tempting piece and gets the pile of bones. In his anger, he hides fire from mortals, plucking the sun from the sky. (This is a novel interpretation of the story in which Zeus hides fire, but it seems justified, given that in line fifty of *Works and Days* Hesiod describes the event with the very verb that Archilochus, having added a prefix, will later use for Zeus's eclipse, and that Aeschylus, in *Prometheus Bound*, will also use to denote the disappearance of day into night – *kruptein*, *apokruptein*, and *apokruptein*.) Just as angry as Zeus, Prometheus steals fire back. But, pulled between the two great gods, time splits.

Zeus and Prometheus square off in a furious battle that lasts some ten thousand years. Time is gone; natural orders can't be counted on. Mortals are the losers. But they come up with their own solution: Zeus and Prometheus had stolen fire? They will steal water.

They build themselves a water clock, liberating themselves from the divine fire-thieves who do not care to make time uniform. The *klepsydra* is their invention; its name means water-thief. Time flows, as people have said for centuries: originally this was not a metaphor for abstract time, but a metonym.

The gods might now and then pocket the sun, but the waters always flow.

30 The Greek here, *tên tou chronou taxin*, can be translated either as a subjective genitive where "time's assessment" means the assessment that time carries out, or as an objective genitive, where "time's assessment" means that time is the object being assessed or measured. Here I choose the second translation.

Anthony Grafton

Dating history: the Renaissance & the reformation of chronology

In 1485, the Portuguese explorer Diogo Cão erected the Cape Cross monument in what is now Namibia. He and his men had long since passed the boundaries of the space that Europeans had traditionally navigated. They did not and could not know exactly where they were. Still, they were confident that they knew one thing: when they had arrived. They inscribed the cross with a commemorative message, which dated their coming, with a precision that boggles the modern mind, to the year of the world 6685.

To obtain this date they used a method as traditional as their exploits in navigation were radical. The Greek text of the Old Testament, the Septuagint, and most Western world chronicles held that fifty-two hundred years had passed between the Creation and the Incarnation. To locate their particular doings in the longest imaginable term, that of world history, Cão and his men simply added the number of years that had passed since the birth of Christ to this biblical total – which they evidently saw as fixed, governed by an authoritative text, the sort of knowledge that could be set in stone.

In the fifteenth and sixteenth centuries, as everyone knows, European explorers ranged the world and revolutionized – among many other things – the study of geography. They found that the Atlantic and the Indian Ocean, which the world map in the great ancient atlas, Ptolemy's *Geography*, represented as closed, really opened to the south. They discovered unknown continents to the west and made contact with a vast range of societies in Africa and Asia as well as the Americas. Gradually even the scholars who stayed home in Europe realized that – as Gerard Mercator put it in 1572 – Ptolemy's work was now of merely historical interest, and they replaced it with more modern charts.

Explorers and scholars alike understood that their new knowledge of the earth's surface called many established beliefs into question. When Europeans had known only three continents – Asia, Europe, and Africa – they could easily

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trace the population of each of them back to one of the three sons of Noah. But from whom did the inhabitants of the Americas descend? Why had the Bible and the ancients not mentioned them? Or did they? Could the newly discovered land of Peru, with its gold mines, be the biblical Ophir that had supplied Solomon with his riches? Was it a Chinese settlement, reached by daring expeditions across the Pacific? Or were the Incas and the other American peoples the children of a separate creation?

The new geography called much in doubt – as the Jesuit José de Acosta famously noticed when he shivered while crossing the equator. Acosta found himself laughing aloud at the Aristotelian doctrine of the torrid zone that was still taught, along with Ptolemy's more accurate views, in colleges back home in Europe.

Yet most of those who made this revolution in Europe's mental spaces – explorers like Cão and innovative intellectuals like Mercator – for many years continued to accept a traditional account of historical time. According to this account, history began with the Creation of the world, as narrated in the Bible and pictured in endless sequences of images of the Six Days of God's work. But this was not the end of the matter, since uncertainty remained about the exact duration of the time between the Creation and the coming of the Messiah. If one accepted the Greek text of the Old Testament as authoritative, the total number of years was fifty-two hundred; on the other hand, if one accepted the Hebrew text of the Old Testament, the biblical total came to around four thousand years. (Thus, in the 1640s, Archbishop James Ussher of England, treating the Hebrew text as authoritative, argued that the world was created in precisely 4004 B.C.)

Whichever version of biblical chronology they accepted, scholars and sailors normally thought that the Old Testament offered a detailed narrative of the early stages of history – especially those that took place before the universal Flood. Where the biblical text thinned out, as it seemed to in the first millennium B.C., the ancient poets and historians chimed in, telling their tales of Troy, Athens, and Rome. These in turn set the stage for the birth of the Savior and the beginnings of a new, Christian age. This age too would end at a determinate time – an eschatological date that radicals set in the immediate future, while more conservative thinkers, who insisted that only God knew when time would have an end, generally placed it within a few hundred years.

While the Western understanding of geography expanded during the Renaissance, then, the traditional dating of the past and future remained curiously narrow-minded. So, at least, one might think, when one stands by Cão's monument, now in a museum in Berlin – or when one sits in any rare book room and turns the leaves of most of the dozens of chronicles and chronological textbooks produced between 1450 and 1700. These range in size and splendor from Hartmann Schedel's massive, magnificently illustrated *Nuremberg Chronicle* of 1493, with its hundreds of woodcuts, some of them the work of the young Dürer, to the Jesuit Denys Petau's tiny, tight-packed, text-only *On the Reckoning of Time*, which went through dozens of editions and introduced thousands of schoolboys and scholars to the basic concepts and problems of chronology.

With what now looks like inexplicable patience, the authors of these books built and rebuilt the same basic armature of names and dates. On illuminated scrolls and in heavy printed folios, on wall charts and in textbooks, they pack-

aged history as a single genealogical tree. Rooted in the family dramas of the Old Testament and the Trojan War, the trunk gradually branched out into the ancient Persian, Macedonian, and Roman Empires. Still later, it flowered into the variegated cities and states of the Middle Ages. Again and again, chronologers applied the same techniques to the materials they assembled along the tree's trunk and branches.

In order to cope with the awkward discrepancy between the Hebrew and Greek texts of the Old Testament, chronologers from the thirteenth century on dated the events of ancient history *backward* from the birth of Christ, as well as forward from the Creation. By dating backward, chronologers could use both computations, showing how they differed. They assured their readers that they could resolve whatever discrepancies they encountered. Pocket almanacs and wall charts, modest textbooks and stately folios all taught, long before the unfairly notorious Archbishop Ussher came on the scene, that the world began at a particular time on a particular day around 5200 or 4000 B.C., and that scholarly examination of the evidence could securely identify the exact date.

Why all this interest in what Voltaire condemned as "the sterile science of facts and dates, that confines itself to determining the year in which some totally insignificant man was born or died"? We all know that space mattered, in this age of exploration. But time mattered too, in early modern Europe. New devices for measuring the passage of time more exactly than ever before appeared throughout the continent. Immense, spectacular escapement clocks rang the hours in every city square, indicating the phases of the moon and the movements of the planets. Their mechanisms did more than tell time. They mobilized squads of automata, designed to teach moral and theological lessons. Clockwork cocks crowed and clockwork skeletons swung their sickles, all to remind passersby that time moved quickly, so they must hurry to their places of work and worship. Smaller but equally magnificent clocks glittered and rang on every affluent family's mantelpiece.

Splendid as they were, moreover, these timekeeping devices were only the material embodiment of a new consciousness of time that would, eventually, transform the traditional forms of dating the past. This new consciousness first appeared in the advanced mercantile cities of Italy and Flanders and in the wealthy monasteries of England, France, and the Holy Roman Empire. Old men schooled their sons in the principle that business and politics alike depended on promptness. Long before Protestants appeared on the scene, creating the new ethics of the secular vocation, the Florentine writer Leon Battista Alberti made a character in his dialogues *On the Family* tell the younger members of his family that "you must always watch the time." He explained that he kept a diary of engagements, followed it to the letter, and never went to bed with business undone. Clock time drove workers in Europe's most sophisticated manufacturing enterprises, from Brunelleschi's workshop to the Venetian arsenal. It also drove the religious to their prayers. Old monks instructed novices just as rigorously as old merchants instructed their apprentices about the vital importance of their daily routine. Monasteries built massive, expensive clocks and bells to teach astronomy and ensure that everyone woke in time to pray. A new sense of time, as something uniform, determined by the stars, and accessible to human industry, pervaded Western culture. It found expression in every imaginable medium: from the paintings that represented Op-

portunity with the back of her head bald, to the Shakespearian play in which a deposed king cried out, "I wasted time, and now doth time waste me."

All Europeans, northern and southern, Protestant and Catholic, agreed: societies that measured time accurately were superior to those that did not. The imperial ambassador to Turkey, Ogier Ghislain de Busbecq, mocked his hosts because "they have no chronology," and thought that Job was King Solomon's chamberlain, and Alexander the Great the master of his cavalry. By contrast, when Michel de Montaigne read Lopez de Gomara's account of New Spain, he appreciated the sophisticated calendrics of the Aztecs. The people of the kingdom of Mexico, he concluded, "were clearly more civilized and skillful in the arts" than the other inhabitants of the Americas.

This newfound mania for precision made Christian experts on the calendar rage and mourn, every year, as the Church celebrated Easter on the wrong Sunday. Mother Church was in the wrong. Worse still, in every synagogue in Europe the Jews, who used a more accurate nineteen-year luni-solar cycle, ridiculed the Christians while they themselves celebrated Passover on the correct days. Even a Christian who did not understand the importance of time could hardly claim to be cultured. When an acquaintance asked the mild-mannered Protestant scholar and teacher Philip Melanchthon why he should bother studying chronology, since the peasants on his estate knew when to sow and when to reap without doing so, the Reformer flew into a rage. "That is unworthy of a doctor," Melanchthon railed: "someone should shit a turd into his doctor's beret and stick it back on his head."

If time and the disciplines that opened up its mysteries inspired fear, respect, and fascination, historical time seemed especially alluring. Ancient books – so learned men agreed – contained the keys to the kingdom of knowledge. Only a mastery of historical time could make it possible to set the events they described, the inventions they commemorated, and the philosophical systems they preserved on a single, coherent time line. No wonder, then, that chronology, the scholarly study of time past, attracted ambitious, hard-driving thinkers. Every year at the Frankfurt book fair, the publishers laid out new chronologies for sale. These thick volumes, stuffed with tables and larded with long quotations in Greek and Hebrew, offered their readers long analyses of the dates of world history and the development of every imaginable calendar. Influential scholars wrote them: Luther and Melanchthon, Mercator and Ussher, Newton and Vico.

One chronologer in particular, the Huguenot scholar Joseph Justus Scaliger (1540 – 1609), won renown for his reformation of the traditional approach to chronology. Working in the decades around 1600, Scaliger relaid the technical foundations of the field.

As Scaliger practiced it, chronology looks startlingly remarkably modern. He treated biblical and classical texts as equally important, and read both with historical insight and imagination. He used dateable eclipses and conjunctions to fix great dates from the fall of Troy to that of Constantinople. And he not only detected gaps in the historical record, but also managed to fill them by astonishing feats of historical detective work. In many cases, the works of ancient historians who offered vital testimony had been lost. Ransacking ancient glossaries and polemical treatises by the fathers of the Church, Scaliger collected and evaluated their fragments. He performed bibliographical and philological miracles,

and used their results to create a coherent, solid structure – basically, the one that scholars still use. His achievement inspired widespread excitement. It won him eager, expert readers like Johannes Kepler. It provoked bitter attacks from his Catholic rivals in the Jesuit order. Eventually it gained him a full-time research appointment – the first in modern European history – at the innovative Leiden University.

If time mattered to everyone, chronology mattered to all scholars. In an age of polymaths who mastered all the disciplines, knew many languages, and wrote more than any modern can read, chronology, with its varied contents and technical difficulties, seemed the essence of scholarship. That explains why Scaliger, the most arrogant as well as the most learned of men – he believed he was a descendant of the della Scala of Verona, and wore the purple robes of a prince when carrying out official duties as a professor – chose to cultivate this rocky field.

Formal rhetoric, it has been said, is one of the great obstacles that prevent us from understanding our ancestors. We have forgotten the technical canons that they followed religiously every time they spoke in public, and we fail to see why what now seem empty words once gripped audiences. Technical chronology, in its own way, also stands between us and our scholarly forebears. This densely difficult body of scholarship had, for its sixteenth- and seventeenth-century devotees, something of the all-consuming excitement that structuralism generated in the 1960s. But what they knew as a scene of lively activity, of construction and reconstruction, has become a sunken city. We look up the dates of events in biblical or classical history, the moment at which an eclipse took place or the sequence of Egyptian pharaohs, online or in reference books – and rarely worry how this knowledge was obtained. Experts in chronology – like Bonnie Blackburn and Leofranc Holford-Strevens, the authors of the magnificent *Oxford Companion to the Year* – still consult Scaliger and his ilk. But they also consult primary sources unknown in the Renaissance, like the masses of dated papyri discovered in Egypt in the nineteenth and twentieth centuries that have transformed our knowledge of how the calendars of Roman Egypt functioned. The waters of oblivion cover the ruined towers of Renaissance chronology.

A few historians have duly celebrated Scaliger's achievement. A hundred and fifty years ago the brilliant, bitter Jewish classicist Jacob Bernays wrote his biography and hymned his "universal erudition" in phosphorescent terms. So, some years later, did Bernays's eloquent British friend Mark Pattison – who not coincidentally became the model for George Eliot's Mr. Casaubon. Yet even Bernays and Pattison, who knew the learned world that Scaliger inhabited at first-hand, did not find it easy to explain what made his work excite his contemporaries so much – much less why an ambitious and brilliant scholar would have chosen the field of chronology as the one in which to exercise his great mental powers. Both of them described chronology, before Scaliger transformed it, as a coherent, unchallenging, elementary discipline – one whose questions and answers were cut and dried, and whose purpose was merely to produce simple tables of the Jewish kings and Roman consuls. "Hitherto," wrote Pattison, "the utmost extent of chronological skill which historians had possessed or dreamed of had been to arrange past facts in a tabular series as an aid to memory." He and others have evoked an almost pastoral picture of chronology: herds of contented scholars browse, placidly, over the same stubble of biblical and historical data, con-

structing baby books for students. Pattison thought that it took a Scaliger – someone whose name had the proverbial power of Einstein's name, in the mid-twentieth century – to charge it with excitement, to make the pasture a city inhabited by active, irritable crowds.

Early modern readers, however, saw chronology in very different terms. For all its appearance of coherence and simplicity, the field swarmed with challenging, unsolved problems – as becomes apparent when one looks away from the decorative scrolls and wall charts and into the more technical literature of the field. Jean Bodin, a French jurist who brought out in 1566 a pioneering manual on the method for studying history critically, was only one of many Renaissance thinkers who compared chronology to geography. He treated them as twin disciplines: "the two eyes of history," as he and many others put it. Bodin insisted that no one could practice either of them except by mastering a wide range of disciplines. Like the geographer, the chronologer had to wield not just the philological and hermeneutical keys that could unlock biblical texts and ancient histories, but also the mathematical discipline of astronomy. Only dated astronomical eras and eclipses, in the end, could establish a firm framework for historical time. Yet even astronomical data could not solve every problem. The date of Creation itself, for which scholars had proposed dozens of differing solutions, remained uncertain, as Bodin pointed out. His first readers went through his chapter on chronology pen in hand, eager for enlightenment on what they saw as a difficult and important topic.

When Bodin came to England in the 1580s on a diplomatic mission, the learned Cambridge scholar Gabriel Harvey put him through an interview on chronology. Harvey noted down not a scheme of dates but a bibliography of the best ancient and modern sources for the field – clear evidence that chronology seemed to both men to offer better questions than answers. When Scaliger wrote his first major work in the field, *On the Emendation of Chronology*, in the early 1580s, he not only made many discoveries and innovations of his own, but also synthesized arguments already made by Bodin and Mercator and by now-forgotten chronologers like Johann Funck and Paulus Crusius. Chronology had already attracted the attention of some of the most innovative thinkers and writers in Europe. Bodin's Italian Jewish contemporary Azariah de' Rossi – whose work, in Hebrew, Christian scholars like Scaliger encountered relatively late – labored with equal energy, and quite independently, to reconcile the evidence of the skies with that of the classical and biblical texts, as Joanna Weinberg has shown in her magisterial edition of Azariah's *The Light of the Eyes*.

In the middle of the sixteenth century, in other words, informed readers saw chronology not as a fixed textbook discipline but as a challenging interdisciplinary study, one that swarmed with unsolved problems. They had regarded it in the same light a hundred years before, when the brilliant German astronomer Johannes Regiomontanus corresponded with a Ferrarese colleague, Giovanni Bianchini, about the dates of the Savior's life. And they would find it even more difficult a hundred years after Bodin – when Catholic scholars like Martino Martini and Protestant scholars like Isaac Vossius, who agreed on very little, found common ground in arguing, from the best available historical and astronomical evidence, that Chinese and Egyptian history apparently began before the usual dates for the universal Flood. The textbooks existed. Sailors

might think that chronology was simple and uniform. But in the musty libraries where scholars rooted in the past, the study of time seemed just as complex, just as difficult, just as provocative and scary as the study of space.

From the late sixteenth century onward, in fact, religious dissidents regularly cited chronological evidence when they challenged the authority of the Bible. The impious poet Christopher Marlowe, who blasphemed against the Bible in London taverns, had little in common with the pious "Christian without a Church" Isaac La Peyrère, who argued in a scandalous, anonymous book that there had been *Men Before Adam*. Yet both believed in the deep time of Aztec, Chinese, and Egyptian history, as revealed by modern travelers' accounts and ancient texts. And both saw it as sufficient reason to reject as absurd the idea that the world could have come into existence a mere fifty-six hundred or sixty-eight hundred years before their own day. Baruch Spinoza seems not to have taken a great deal of interest in chronology. Yet this purportedly mainstream form of scholarship troubled the orthodox and supplied ammunition to Spinoza's radical allies.

It is not surprising that the study of historical time proved so complex, and even contradictory, in pre-modern Europe. The anthropologist Bernard Cohn showed, in a classic article, that the twentieth-century Indian villagers of Senapur, not far from Benares, found meaning in multiple pasts, ancient and recent, legendary and historical, as their caste memberships and political situations dictated. Learned Europeans, similarly, used chronology to sort out a wide range of problems, from the origins and fate of the universe to the privileges of particular towns, convents, and universities (one of the great chronological controversies of the sixteenth century had to do with the ages of Oxford and Cambridge – a scholarly anticipation of the Boat Race, in which both sides claimed Trojan ancestry). Like the Indians of Senapur, the Europeans of Leiden and London approached the past from many different standpoints. Religious and national, disciplinary and personal attachments shaped their views.

The raw materials that chronologers deployed, moreover, came from an immense variety of sources. Any given scholar attacking a single problem might find himself ransacking the Bible and the Greek and Roman historians, thumbing through modern commentaries on all of these, consulting Islamic astronomical tables, and examining patristic and medieval chronicles – not to mention Renaissance forgeries crafted to show that Pope Alexander VI or the Holy Roman Emperor Maximilian I could trace his ancestry back to the rulers of ancient Egypt. Every library's reference shelves for history and chronology bent under materials that could explode when combined, and chronology regularly brought these into contact.

Suppose, for example, that a scholar tried, as many did, to fix the exact date of Noah's Flood. Simple reckoning of the ages at which each of the biblical patriarchs produced his son would not suffice. As we have seen, the Hebrew and Greek texts of the Old Testament differed – in this case by several hundred years. Another source of information had to be found.

Everyone knew that the sun, moon, and planets moved uniformly, that God had set the sun and moon in the skies to rule the seasons and the years. Astronomers could predict their future positions or compute their past ones with certainty. So the scholar might hopefully

consult the standard astronomical tables of the time, the *Alfonsine Tables*, compiled in Christian Spain from Islamic sources. And there he would find what looked like an astronomical date for the Flood. This served as one of the *Tables'* epochs, the firm dates from which their authors and readers reckoned later dates and the positions of the planets.

Only one fly disfigured the ointment – but it was a big one, and buzzed loudly. The *Alfonsine Tables* set the Flood in 3102 B.C. – a date that agreed with neither the Hebrew nor the Greek text of the Bible. Indian astronomers had taken 3102 B.C. as the epoch date of the Kaliyuga, the current celestial cycle. Muslim astronomers took over this usefully early astronomical era, but they also transformed its meaning, as translators so often do. Christian scholars, totally ignorant of Indian astronomy and religion, could not possibly know the date's origin. Yet some saw the date as the best one they had, since it appeared in an authoritative work on astronomy. As a result, they struggled to explain why the evidence of the book of the heavens departed so radically from Holy Writ.

In this intellectual situation – one in which books theoretically contained all-powerful knowledge, but standard handbooks rested in practice on historically diverse and even contradictory foundations – chronologers naturally came to different conclusions. In fact, they argued so vociferously, over everything from the dates of the kingdoms of Israel and Judah to those of the consuls of ancient Rome, that their quarrels became proverbial. Everyone knew, one seventeenth-century expert wrote to a colleague, that chronologers, like clocks, never agreed.

Scaliger did not invent modern chronology. Rather, he reconfigured the elements of what had long been a fashionable field of study. And his version of it, though powerful and provocative, lasted no more than a generation, since his Jesuit rival, Denys Petau, replaced his work with a more user-friendly, less idiosyncratic synthesis.

To appreciate the explosive impact of this reformation of historical chronology, we need to look backward. For like geography, chronology was an ancient scholarly discipline – one that took shape long before the Renaissance, and that had always drawn methods and materials from widely different traditions.

As early as the fifth century B.C., Greek scholars compiled lists of Olympic victors and priestesses of Hera, to whose years they could affix major historical events. They also tried to use astronomy to date earlier events. A scholar named Damastes noted that according to one text, the moon rose at midnight on the night when the Greeks sacked Troy. He dated the city's fall, accordingly, to the third quarter of the lunar month in question, when the moon rises late, and this in turn to seventeen days before the summer solstice. His effort and others like it, now obscure and preserved only in scraps of lost texts, were widely known in antiquity. When Virgil wrote in the *Aeneid* that the Greeks sailed back to Troy "tacitae per amica silentia lunae," through the friendly silence of the moon, he made clear that he knew exactly when Troy fell. Poets – who in antiquity were often scholars in their own right – studied chronology.

Once Alexander the Great conquered Mesopotamia and Egypt at the end of the fourth century B.C., moreover, new kinds of chronology burgeoned as societies came into close contact for the first time. Scholars from the conquered nations – the Chaldean Berossus and the Egyptian Manetho – drew up chronicles

of their kingdoms in Greek, designed to show that their nations and cultures were far older than those of their masters, and thus to avenge their military and political downfall in the realm of the archive. A little later, Greek-speaking Jews did the same.

Meanwhile the Greek scholars who inhabited the new city of Alexandria in Egypt did their best to collate everything they could learn about historical time. Eratosthenes – the Alexandrian scholar now best remembered for his ingenious method of measuring the earth – also drew up chronological tables. These were widely read in a verse reworking by Apollodorus. Already in the ancient world, geography and chronology went together, as demanding technical disciplines designed to put order into the apparent chaos of world history. The rise of empires not only gave rise to a more cosmopolitan view of history, but promoted the technical study of eras and dates.

The Romans of the late Republic and early Empire were as obsessed with time, in their own way, as the Europeans of the sixteenth and seventeenth centuries. Their calendar malfunctioned regularly until Julius Caesar and Augustus reformed it. Their future worried them as well. Throughout the seismic political shifts that brought the Empire into being, prophets and astrologers tried to fix the duration of Rome's past in order to predict the moment at which the city would fall. The Gauls' sack of Rome, in which all early records had perished, made the city's early history obscure. Sorting out the divergent traditions posed endless problems. Some Roman scholars tried to fix their city's past on massive stone structures, which they inscribed with lists of magistrates and triumphs, year by year. Others, like Varro, who mastered the technical disciplines of Greek scholarship and applied them to the Roman historical tradition, practiced chronology as a technical discipline in the Greek mode. Unable to find historical records that established the date of Rome's founding beyond doubt, Varro asked an astrologer, Nigidius Figulus, to infer from Romulus's character the dates of his birth and life. Nigidius did so, using what he thought were the dates of eclipses to gain a fix on Rome's early past.

In the third and fourth century C.E., finally, Christian scholars set out to fuse all of these materials into a single structure that would encompass Greek Olympic victors, Egyptian pharaohs, and Roman consuls. In late antiquity, both pagans and Christians regularly undertook enterprises like this one, which aimed at the creation of vast taxonomic systems encompassing, in effect, the whole world. As the Oxford classicist Oswyn Murray has pointed out, Ptolemy's *Geography*, his astrology, and the later codification of Roman law all represent parallel efforts to impose an intellectual order on the world. But chronology had a special task in addition. It had to show that all of the local histories it encompassed fit a single divine plan, one that led up to the unification of the world by Rome and the appearance of the Messiah. Its internal structure and contents, accordingly, were pulled and torn by contradictions that did not affect the mapping of the earth or the codification of the laws.

Julius Africanus, a third-century scholar based in Rome, did pioneer work. He tried not only to trace the contours of time past, but also to reveal the patterns of time to come, and even to fix the date of the apocalypse. But a slightly later writer, Eusebius of Caesarea, used the materials that Africanus had collected and other sources to establish the basic structures of Christian chronology. Paradoxically, he also laid down the dynamite that would, some centuries later,

destroy his creation. Aided by the biblical scholarship of Origen, who had laid out the text of the Old Testament in Hebrew and Greek in parallel columns, Eusebius saw that the Hebrew and Greek texts of the Bible disagreed on chronology. Accordingly, he made no effort to draw up a dated list of events from the Creation. He divided his *Chronicle*, instead, into two books. In the first he compiled a vast amount of information, some of it quite worrying to a Christian reader – for example, the deep-time chronologies of Egypt and Babylon by Manetho and Berossus. And he frankly admitted that he could not impose order on this troublesome, teeming body of data.

In the second book, by contrast, Eusebius provided something that seems to have been new: a comparative table of world history from the birth of Abraham onward. He laid out dynasties and lists of magistrates in parallel columns that showed when states and dynasties were born, flourished, and died. At times, six or seven nations flanked one another. In the end, however, all of them dwindled down into the single empire of the Romans, which unified the world in time for the appearance of the Savior – and finally, thanks to Eusebius's patron Constantine, supported Christianity (though Eusebius could not make this point in the early versions of his work, which he completed before Constantine's victory at the Milvian Bridge). Eusebius, in effect, drew up a highly legible chart of world history, one that adumbrates in its form Charles Minard's famous diagram of the Napoleonic army's sufferings in Russia.

Jerome, the biblical scholar who was Augustine's contemporary, translated Eusebius's work into Latin. Concerned with practical needs, always worried that too much interest in pagan learning could tempt a Christian scholar to fall away from his true religion, Jerome omitted Eusebius's troubling first book, and translated only the second, which he also corrected and brought up to date. He thus created what became the chronological tradition in Western Europe: one that taught simple Christian lessons, and used a single, coherent diagram to capture all of world history. It seems natural that later readers and users of Jerome's work extended it backward to the Creation, as Eusebius had refused to. They were only doing to Jerome what he had done to Eusebius. Latin chronology, accordingly, seemed safe, coherent, simple – except to the few highly perceptive readers who bothered to ask, for example, why Egyptian history, in Jerome's version of Eusebius, began with the seventeenth, rather than the first, dynasty of pharaohs. The textbooks and wall charts of the Renaissance, like the inscription on Diogo Cão's cross, derived from Jerome's work.

In the Greek world, however, scholars continued to read Eusebius's entire *Chronicle*. Many found his inclusion of strange material from Egypt and Mesopotamia upsetting. Some – like the Alexandrian scholars Panodorus and Annianus – tried to use astronomical information to impose order on the sprawling mass of Eusebius's material. Others simply copied it, adding critical remarks. But it was not until the summer of 1602, when Scaliger discovered the remains of Eusebius in Greek, that the explosive potential of his work became clear. Scaliger realized at once that the kingdom of Egypt had begun not only before the Flood, but before the Creation itself. He felt strongly tempted – as he said in marginal notes – to dismiss the new materials Eusebius had collected as obviously false. But he also saw that they were gen-

uinely old and strange. He concluded that they were more likely the work of Egyptian and Mesopotamian scholars who had learned Greek late in life than that of Greek forgers. So he published them, in 1606, to the dismay of many of his Protestant friends and the delight of many of his Catholic critics. Disquieting information had already reached Europe, from both the New World and China. Learned pagan priests, it seemed, claimed that history began long before Europeans thought it had. And now Europe's greatest scholar had fished up, from an ancient and impeccable source, evidence that posed a radical challenge to biblical chronology.

In other words, Scaliger not only devised what became the modern discipline of chronology; he also opened its ancient Pandora's box of intractable data about the early history of the world. In geography, knowledge obtained in the great world smashed the walls of the scholars' *hortus conclusus*. In chronology, the explosion took place in the garden, when Scaliger dug up and touched off an ancient bomb.

Strong-minded dissenters, as we have seen, seized on all this new information and used it to raise doubts about the inerrancy of the Bible. So, more surprisingly, did highly respectable members of the Jesuit order. In the 1650s, Martino Martini drew up, in Latin, the first history of China based on a wide range of Chinese sources, which he had read in the original. Though Martini hesitated, in the end he argued that recorded Chinese history had begun before the Flood. He felt able to do so, he made clear, because his own teacher, Athanasius Kircher, had shown that the Egyptian kingdom also preceded the Flood. And Kircher, in turn, had learned as much from Scaliger, even though as a good Jesuit he pretended to rely on a different set of sources, one not discovered by a Calvinist. Through the later seventeenth and eighteenth centuries, scholars argued relentlessly about the details of Egyptian and Chinese chronology. Their intricate, sometimes violent debates dragged on for decades, and no solution any of them could propose compelled assent. Edward Gibbon, who avidly read chronology as a boy, recalled in later life that after he steeped himself in that literature, the dynasties of Egypt became his "top and cricket-ball" – toys used in combative play. Eventually, the chronologers' argument without end brought their whole field – and the authority of the Bible – into widespread disrepute. Giambattista Vico's *New Science* represented only one of many efforts to show that all detailed chronologies of ancient times rested on a misconception of the nature of ancient record keeping. Voltaire and other philosophes, less committed than Vico to the tradition of learning, turned chronology into a synonym for sterile pedantry, a noun that almost demanded the adjective 'mere.'

Chronology, in short, is more than a once-fashionable discipline that has lost its apparent urgency and interest in an age when few professional scholars see the Bible as inerrant and encyclopedias provide all the dates that most of us need. Once upon a time, it was both an ancient and deeply curious tradition and a cutting-edge interdisciplinary field of study. In Europe's great age of unrestrained, exuberant learning, it attracted the most learned writers of them all. As these giants sorted the rubble of biblical and classical, ancient and medieval, Western and Eastern traditions, they built strange, fascinating new structures from the debris. It's worth the dive to their sunken city to gain the chance of examining what remains of these.

It seems safe to assume that chronology will never again become fashionable. But the history of this once compelling field is a complex, all too human story that does not quite resemble any other. The ancient geographical system of Ptolemy fell apart when Diogo Cão and others found new lands and seas. The ancient chronological system of Eusebius, by contrast, fell apart when Renaissance scholars did their best to reconstruct it. Sometimes, even scholarship can be renewed from within.

J. Hillis Miller

Time in literature

> But, Holy Saltmartin, why can't you beat time?
>
> – James Joyce, *Finnegan's Wake*

It's about time. All literature is about time. Yet concern with time in literature today is untimely. It comes at the wrong time.

These two contradictory propositions should govern all contemporary reflection about time in literature.

On the one hand, an enormous and continually augmenting secondary literature exists on the subject of time in literature. A search of the Modern Language Association of America's International Bibliography from 1963 to April of 2002 produces twenty-one pages of items for "time and literature." Some of these items are trivial or irrelevant, but many are on the mark. One example of the latter, of so many, is William Weitzel's "Memory, Stillness, and the Temporal Imagination in Yeats's 'The Wild Swans at Coole'" in the *Yeats Eliot Review*.[1]

On the other hand, the topic seems these days somewhat outmoded, old hat, vieux jeu. The most salient works in this area were published quite some time ago – among them Wyndham Lewis's *Time and Western Man* (1927), Georges Poulet's magisterial series of four critical books called *Études sur le temps humain* (1950 – 1968), A. A. Mendilow's *Time and the Novel* (1952), and, more recently, Paul Ricoeur's authoritative three-volume *Temps et récit* (*Time and Narrative*, 1983 – 1985). Indeed, explicit concern with time seems today a feature of a somewhat faded modernism, as in Proust's *À la recherche du temps perdu* (1913 – 1927), Thomas Mann's *Der Zauberberg* (1924), Jorge Luis Borges's *Nueva refutación del tiempo* (1947), and Samuel Beckett's *That Time* (1976).

In these days of focus on class, race, and gender, the subject would seem to many literary scholars far too abstract, artificial, philosophical, and formalistic to be worth pursuing. Time may nevertheless make a backdoor entry through the now ubiquitous topic of 'history' (epitomized in Fredric Jameson's slogan "Always historicize"). But for many literary historians, history is construed as a

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1 *Yeats Eliot Review* 16 (4) 2000 : 20 – 30.

sequence of materially and socially imposed epochs (as in the notion of 'the time of late capitalism'), and not in terms of an exigent conception of the temporal 'event.' Such a temporal event is something irruptive and unpredictable, both in its causes and effects. An example is the inaugural event of the composing and signing of the American Declaration of Independence – or, for that matter, the publication of Kant's Third Critique. It is not fortuitous that my two examples are both textual. I shall return to this.

Literary works, no one can doubt, may reflect the philosophical, theological, or scientific concepts of time prevalent when they were written. Much secondary work has been devoted to demonstrating, whether persuasively or not, these connections – for example, the influence of Bergson on Virginia Woolf. Nevertheless, by 'the study of time in literature' one presumably primarily means the investigation of the way literary works present in one way or another the human experience of lived time. This is not easy to do; doing it is not the same thing as just mentioning time or attempting an abstract analysis of temporality, human or otherwise. One would not go to literature for scientific information about time. And vice versa: the essays in the September 2002 issue of *Scientific American* devoted to time make, as one might expect, hardly any references to its place in literature – aside from a few illustrative thematic citations from Herrick, Marvell, and Shakespeare.

Though scientists and philosophers disagree about time, their goal is by scientific or logical methods to reach universal and universally accepted definitions of it. By contrast, representations of human time in literary works are singular, sui generis, different from all the others. They do not build on one another in a progressive clarification, as scientific theories of time at least aspire to do; Shakespeare's time is not Faulkner's, nor are either like Yeats's. Each literary work has a different time sense – even those by the same author – though a short essay like this one will not be able to prove that hypothesis convincingly.

The basic issue for me now is the question of how words can be used to represent the subjective experience of lived time, in a different way for each work. Literature, after all, is made of words. The basic object of literary study is therefore linguistic in nature. The problem, as Heidegger long ago recognized in *Sein und Zeit* (1927), is that the words and figures for temporality in Western languages are primarily spatial. They transform time into space. Time thereby escapes direct representation. It is turned back into an abstraction.

The most salient everyday example of the spatialization of time is the movement of the clock's hands through space. Lots of clockwatching is represented in literature, for example in all those mystery stories that turn on the exact time, as registered by some clock, at which the murder or something ancillary to it occurred; or as in Quentin Compson's attempt to destroy clock time by tearing the hands off his watch, in William Faulkner's *The Sound and the Fury* (1929).

Heidegger's own formulation of the 'ecstasies' of time, and his definition of Dasein's temporality as a moving forward into the future in order to come back to the past are no exception to the rule of spatializing time. Indeed, Heidegger's idea of 'ecstasy' (in the etymological sense of standing outside) and his figure of moving forward to come back are both spatial.

No literal words as such exist for lived time. All terms for it in literature are

therefore in one way or another figurative. The strongest figures, it turns out, use language itself as a form for temporality.

Expressions of the inscrutability of time have punctuated the history of thinking about temporality in the West. I shall cite four of these.

Book Nine of St. Augustine's *The Confessions* is one of the earliest great reflections on the mystery of human temporality. There Augustine asks, "What then is time?" and goes on to answer, "If no one asks me, I know: if I wish to explain it to one that asketh, I know not."[2]

Augustine's meditation on time culminates in a reflection on what happens as he repeats a psalm he knows by heart – at first expecting the whole, then gradually, as he repeats more and more of its words, moving them one by one back into the past, into his memory of having said them. For Augustine, human time is experienced and measured through the sequential syllables of a sacred poem, the psalm that he already knows before he begins reciting it.

Shakespeare uses a similar figure in Macbeth's great speech about lived time. For Macbeth, time is a sequence of days that stretches out in a line leading to its cessation at death, figured as a series of syllables making a sentence or strings of sentences, for example a speech by an actor on the stage. Time, for Macbeth, exists only as it is recorded. It is a mad, nonsensical tale, an incoherent narrative. Such a narrative is made of pieces that do not hang together, a series of syllables that do not cohere into words and sentences:

> Tomorrow, and tomorrow, and tomorrow
> Creeps in this petty pace from day to day,
> To the last syllable of recorded time;
> And all our yesterdays have lighted fools
> The way to dusty death. Out, out, brief candle!
> Life's but a walking shadow, a poor player
> That struts and frets his hour upon the stage
> And then is heard no more. It is a tale
> Told by an idiot, full of sound and fury,
> Signifying nothing. (V.v.19 – 28)

A few years later Blaise Pascal was, in *Réflexions sur la géométrie en général* (1657 or 1658), to define 'time' as one of the "primitive words." 'Time' has neither a nominal definition nor a real definition according to the distinction Pascal makes between words that are used within an arbitrary code like mathematics and words whose validity depends on their reference to extraverbal things. The problem with such words as 'time' is that they do not ensure knowledge of the entities they name. "It is not the case," says Pascal,

> that all men have the same idea of the essence of the things which I showed to be impossible and useless to define . . . (such as, for example, time). It is not the nature of these things which I declare to be known by all, but simply *the relationship between the name and the thing*, so that on hearing the expression *time*, all turn (or direct) the mind toward the same entity [tous portent la pensée vers le même objet].[3]

Pascal here has a touching faith that we all turn our minds toward the same entity when we hear the word 'time.' How would one go about verifying that? As Paul de Man observes, Pascal is describing a tropological turning.

2 Saint Augustine, *The Confessions*, translated by Edward B. Pusey (New York: Pocket Books, 1951), 224.

3 Blaise Pascal, *Oeuvres complète*, ed. Louis Lafuma (Paris: Seuil, 1963), 350; and translated by Paul de Man, "Pascal's Allegory of Persuasion," in *Aesthetic Ideology*, ed. Andrzej Warminski (Minneapolis: University of Minnesota Press, 1996), 56.

The word 'trope' means, etymologically, 'turn.' The word 'time' is a trope. To be more exact, it is a catachresis, or "abusive transfer," for something that remains unknown and therefore has no literal name. The word 'time' is posited, without authority or possibility of verification, as a figurative expression for something unknowable. De Man's formulation of the way this 'turn' works is succinct and precise. "Here," he says,

> the word does not function as a sign or a name, as was the case in the nominal definition, but as a vector, a directional motion that is manifest only as a turn, since the target toward which it turns remains unknown. In other words, the sign has become a trope, a substitutive relationship that has to posit a meaning whose existence cannot be verified, but that confers upon the sign an unavoidable signifying function.[4]

The final literary assertion of time's inscrutability that I will discuss is from the twentieth-century French poet and essayist Paul Valéry. The word 'time,' says Valéry in "Poetry and Abstract Thought," is no problem when you just use it in any number of everyday expressions – for example in asking "What time is it?" – without thinking much about it. The word becomes a problem, he says, when you detach it from any context, look at it in isolation, and ask yourself, as St. Augustine did, "What is time?" The word then becomes an unfathomable enigma.

It seems to have far more meaning than the sum of its uses in ordinary language. One might compare the word to a plank over an abyss that holds your weight without difficulty if you step briskly across it, but that breaks, plunging you into the chasm, if you stop halfway across. As Valéry writes:

> It is almost comical to ask oneself exactly what is the meaning of a term that one uses all the time with full satisfaction. For example: I catch the word Time as it flies by. This word was absolutely limpid, precise, honest, and faithful in its service, as long as it played its part in a proposition, and as long as it was spoken by someone who wanted to say something. But here it is, all by itself, seized by its wings. It takes revenge. It makes us believe that it has more meaning than it has functions. It was only a *means*, and now it has become an end. It has become the object of a frightful philosophical desire. It changes itself into enigma, into abyss, into torment of thought ....[5]

If time is such an enigma, and if the word 'time' – even after the most stringent philosophical analysis – does not give us any sense of what lived human time is really like, if all words for time are doomed to be catachreses, how then can literature find ways of expressing and conveying to a reader this or that of the innumerable diversified experiences of human time?

Here I must make some important distinctions. Critical analyses of temporality in literature tend to fall into three categories. These correspond, more or less, to the three categories of the medieval trivium, the basis of language instruction in the Middle Ages: grammar, logic, and rhetoric. Grammatical investigations – such as Gérard Genette's three-volume *Figures* (1966 – 1972), or Harald Weinrich's *Tempus* (1964) – tend to concentrate on tense structures and on the use in literature of terms that refer di-

4 De Man, "Pascal's Allegory of Persuasion," 56.

5 Paul Valéry, "Poésie et pensée abstraite," in *Oeuvres* (1), ed. Jean Hytier (Paris: Gallimard, 1968), 1317; my translation.

rectly to temporal dimensions: before, after, then, now, etc. Logical investigations, such as Ricoeur's *Time and Narrative*, or even Poulet's *Studies in Human Time*, focus primarily on thematic representations of temporal experience in literature, taking the language of these representations more or less at face value. What I call rhetorical interpretations of temporality in literature – my focus in what follows – tend to concern themselves with the means whereby figurative language of certain extreme and problematic sorts is used in literature to represent that unknowable thing, human temporality.

The classic critical essay in this third region of investigation is Paul de Man's "The Rhetoric of Temporality" (1969). In that essay, de Man identifies irony and allegory as the tropological devices of language that can be used to convey to the reader a vivid sense of the enigma of time. Allegory is a sign to sign relation, as opposed to the sign to thing relation of symbol. In modern secular allegory, says de Man, the meaning of the allegorical signs is "not decreed by dogma":

> We have, instead, a relationship between signs in which the reference to their respective meanings has become of secondary importance. But this relationship between signs necessarily contains a constitutive temporal element; it remains necessary, if there is to be allegory, that the allegorical sign refer to another sign that precedes it. The meaning constituted by the allegorical sign can then consist only in the *repetition* (in the Kierkegaardian sense of the term) of a previous sign with which it can never coincide, since it is of the essence of this previous sign to be pure anteriority.[6]

6 Paul de Man, "The Rhetoric of Temporality," in *Blindness and Insight: Essays in the Rhetoric of Contemporary Criticism*, 2d ed. (Minneapolis: University of Minnesota Press, 1983), 207.

Irony is defined by de Man, following Friedrich Schlegel, as "permanent parabasis," that is, as the suspension, all along the narrative line, of narrative coherence and sense. Allegory is the spreading out along a temporal axis, in a narrative, of the disjunctions that are expressed punctually, in an instant, by irony.

De Man's essay ends by claiming that Stendhal's *The Charterhouse of Parma* (1839) is an "allegory of irony." De Man clarifies what this means in a much later essay, "Pascal's Allegory of Persuasion" (1981). After having said that "*irony*, like *zero*, is a term that is not susceptible to nominal or real definition" – just as Pascal had claimed was the case with 'time' – de Man remarks that:

> To say then, as we are actually saying, that allegory (as sequential narration) is the trope of irony (as the one is the trope of zero) is to say something that is true enough but not intelligible, which also implies that it cannot be put to work as a device of textual analysis.[7]

De Man's sentence is itself unintelligible – because ultimately, or perhaps from the start, neither irony, nor zero, nor time, is intelligible, though they may be *figured*. Irony and time can be figured in literature by allegory in the de Manian sense, just as zero in mathematics is represented by the one – that is, by saying that zero is one something, for example the empty set.

Is all this, pace de Man, of any conceivable use in the reading of actual representations of temporal experience in works of literature?

I move now to give some examples of my own approach to what I would call in one way or another 'rhetorical,' as opposed to grammatical or logical, repre-

7 De Man, "Pascal's Allegory of Persuasion," 61.

sentations of lived human time in literature. Any literary narrative, it might be argued, is a spatially arrayed allegory of temporality. I mean by this that the words in sequence, as you read them, follow one another across the page, one by one, from the beginning to the end, in a literally spatial display. The words must be read one after the other if sense is to be made of the narration, just as, for human or literary temporality, moments in time follow one another until they add up to make a story – the story, for example, of someone's life, from beginning to end, though that story may be like a tale told by an idiot.

This figuration of temporality by the spatial sequence of the words on the page is often, in turn, emblematized in narratives by the actual journeys upon which their characters embark. An example is Odysseus's journey that forms the narrative armature of the *Odyssey*. Odysseus moves through time and space experiencing virtually endless adventures that keep putting off the moment when he will reach home and Penelope's arms, just as the reader makes his or her way through book after book of the narration – just as Homer's hearers followed it from moment to moment as he recited it.

Let me exemplify this spatial allegorizing of temporality by way of William Faulkner's novels. Trying to convey through narration the experience of temporality was clearly one of Faulkner's most abiding concerns. As Jean-Paul Sartre put this, "Faulkner's metaphysics is a metaphysics of time."[8]

8 Jean-Paul Sartre, "On *The Sound and the Fury*: Time in the Work of William Faulkner," in *Literary Essays* (New York: Philosophical Library, 1957), 79. This essay was originally published in French in 1939.

Faulkner was extraordinarily adept at using spatial figures to express human temporality. Vivid, circumstantial descriptions of 'realistic' events are in his works used as allegories, in the de Manian sense, of time. The realistic circumstantiality of the vehicle of the allegory is no bar to the allegorical function of the description – it is necessary to it. As de Man says in "Pascal's Allegory of Persuasion":

> The "realism" that appeals to us in the details of medieval art is a calligraphy rather than a mimesis, a technical device to ensure that the emblems will be correctly identified and decoded, not an appeal to the pagan pleasures of imitation . . . . The difficulty of allegory is rather that this emphatic clarity of representation does not stand in the service of something that can be represented.[9]

In the case of Faulkner, I am claiming, the something that cannot be represented but that is nevertheless allegorically 'stood for,' alluded to, catachrestically named, is human time.

The primary vehicle of Faulkner's allegorical expression of time is the movement of human bodies through space. Such movements organize whole novels by Faulkner, such as the antithetical movements of Lena Grove and Joe Christmas that structure the double plot of *Light in August* (1932), or the journey to bring the coffin containing Addie Bundren's body to the cemetery and bury it that her family makes in *As I Lay Dying* (1930). In both cases, death is the endpoint of human time, though in different ways in the two novels.

The representation of human time in Faulkner's *The Sound and the Fury* (1929) is too complex for adequate treatment in this short essay, but one aspect of it is

9 De Man, "Pascal's Allegory of Persuasion," 51.

admirably encapsulated in a figure Jean-Paul Sartre uses in what is the best essay on Faulknerian time. As Sartre rightly put it, for Faulkner "Man's misfortune lies in his being time-bound."[10] Faulkner's "vision of the world," he goes on to say,

> can be compared to that of a man sitting in an open car and looking backward. At every moment, formless shadows, flickerings, faint tremblings and patches of light rise up on either side of him, and only afterwards, when he has a little perspective, do they become trees and men and cars.[11]

Sartre's spatial figure is an admirable emblem of the time lag between the event and the awareness of the event that defines Quentin Compson's sense of his doom, in his part of *The Sound and the Fury*. He can never quite catch up with his present.

Light in August balances two antithetical ways to be related to time. The novel opens with Lena Grove thinking to herself, "I have come from Alabama: a fur piece. All the way from Alabama a-walking. A fur piece."[12] She is traveling in search of Lucas Burch (or Brown), who has made her pregnant and then run away. The novel ends with Lena still traveling, but now having made it through Mississippi all the way up to Tennessee. She gives birth along the way, and replaces, along the way, Lucas Burch (alias Joe Brown) with Byron Bunch. The latter will now accept the responsibilities of being husband to Lena and father to the child he has not fathered. Lena exchanges Bunch for Burch – a replacement of just one letter, n for r, as if to suggest that for her one man is just about as good as any other.

Lena represents an inexhaustible human vitality that can move forward through time as through space and that constantly renews itself by change. She travels by a kind of metaphorical or at least tropological – since it is as much metonymic as metaphorical – displacement, while still remaining the same. "My, my," says Lena in the novel's concluding lines. "A body does get around. Here we ain't been coming from Alabama but two months, and now it's already Tennessee."

Lena's story, treated with affectionate and admiring irony by the narrator, surrounds the deathbound story of Joe Christmas. Christmas is caught in the impossibility of being either black or white. He is unable to break out of the sterile circular repetition of the impasse he is in, which keeps bringing him back to the same place:

> he is entering it again, the street which ran for thirty years. It had been a paved street, where going should be fast. It had made a circle and he is still inside of it. Though during the last seven days he has had no paved street, yet he has traveled further than in all the thirty years before. And yet he is still inside the circle. "And yet I have been further in these seven days [while he is fleeing after killing Joanna Burden] than in all the thirty years," he thinks. "But I have never got outside that circle. I have never broken out of the ring of what I have already done and cannot ever undo."[13]

Clearly it is better to be Lena Grove than Joe Christmas, but the novel shows why it is not all that easy to choose to be one or the other.

10 Sartre, "On *The Sound and the Fury*," 79.

11 Ibid., 81 – 82.

12 William Faulkner, *Light in August* (New York: Vintage International, 1990), 3.

13 Ibid., 339.

Addie Bundren says in her only soliloquy in *As I Lay Dying*, "I could just remember how my father used to say that the reason for living was to get ready to stay dead a long time."[14] Living is moving, in *As I Lay Dying* and *Light in August*, even though the movement is, as for all of us, toward death as endpoint and underlying motivation. At the conceptual center of Addie's soliloquy is a radical disjunction between words and doing:

> . . . I would think how words go straight up in a thin line, quick and harmless, and how terribly doing goes along the earth, clinging to it, so that after a while the two lines are too far apart for the same person to straddle from one to the other; and that sin and love and fear are just sounds that people who never sinned nor loved nor feared have for what they never had and cannot have until they forget the words.[15]

Though Addie allows for a condition of "dark voicelessness in which the words are the deeds," as opposed to "the other words that are not deeds, that are just the gaps in peoples' lacks,"[16] among the latter she includes the word 'time': "I knew that that word ['love'] was like the others: just a shape to fill a lack . . . . time, Anse [her husband], love, what you will, outside the circle."[17] If this is the case, to name time directly is to falsify it. Time can only be spoken of indirectly, in those performative figures for time, words that are deeds, that Faulkner tirelessly invents.

As I Lay Dying, with the exception of Addie's one soliloquy, consists of relatively brief segments of internal monologue ascribed to one or another of her family or neighbors, although the title suggests that the whole novel takes place within Addie's consciousness, as she lies dying. 'Internal monologue' is not quite the right term for these strange pieces of language; they are rather fragments or wedges of first-person narration presented by one or another of the characters, and represent the perpetual present of consciousness to itself as it registers the stream of its experience, what it sees and hears and also what it thinks and feels.

Human temporality, this mode of narration suggests, consists of blocks of language that register what is 'out there' from different temporal and spatial points. These articulations always exist in the present, even when consciousness/language is devoted to the act of remembering, even, as is sometimes the case in this novel, when they are enacted in the past rather than present tense and out of chronological order. Flashbacks and retracings of particular events from different perspectives produce a jagged, cubist rendering that suggests that any human event consists of the linguistic perspectives on it. These perspectives are in turn discontinuous, fragmented, as the events move forward in time. It seems as if the reports of those events must exist in an atemporal database to which only the invisible narrator has access; and the events of the story as turned into language seem to hover somewhere in perpetual simultaneity, going on being repeated over and over, waiting to be partially recited in one or another of the blocks of narrative.

Taken all together, they add up ultimately to a story, as the reader reads them, one by one. The reader moves forward through the time of reading, skipping over the blank spaces between one narrative block and the next. Each block

14 William Faulkner, *As I Lay Dying* (New York: Vintage, 1964), 161.

15 Ibid., 165 – 166.

16 Ibid., 166.

17 Ibid., 164.

is labeled with the name of one or another of the characters. These are given in the running heads, oddly enough, in parentheses, as though the name were no more than a nominal tag attached to a given block of language: "(Darl)," "(Vardaman)," "(Anse)," "(Addie)." These chunks of narration do not, however, add up to a shapely organic whole. There are gaps and hiatuses between them. Each moment of suspended temporality exists as a potentially limitless multitude of linguistic perspectives on it.

It is wrong to think of these blocks of narrative as registering in a completely straightforward way the linguistic consciousness of this or that character, as Joyce at least purports to be doing in Molly Bloom's soliloquy at the end of *Ulysses*. The characters in *As I Lay Dying* have a prescient knowledge of events they have not seen or heard with their own eyes and ears – as though they could be where they are not. The absent Darl, for example, narrates the episode in which Cash and Vernon finish Addie's coffin in the pouring rain. Though often the dialect of the characters is mimed, it is extremely unlikely that these country folk would find language for the lyric Faulknerian representations of what consciousness is conscious of.

One example, of so many, is what goes on in Dewey Dell's mind when she goes down to the barn to milk the cow just after her mother has died. Dewey is pregnant by Lafe, a town boy. She is more than a little worried about that, worried beyond worrying. The word 'dead' echoes through her musing:

> The sky lies flat down the slope, upon the secret clumps. The dead air shapes the dead earth in the dead darkness, further away than seeing shapes the dead earth. It lies dead and warm upon me, touching me naked through my clothes. I said You dont know what worry is. I dont know what it is. I dont know whether I am worrying or not. Whether I can or not. I dont know whether I can cry or not. I dont know whether I have tried to or not. I feel like a wet seed wild in the hot blind earth.[18]

In a strange anomalous kind of indirect discourse – strange because it is in the first, not the third person – the ubiquitous, anonymous, effaced, omniscient narrator has given to the characters his (or its) power of language. This is a distinctively Faulknerian, inimitable lingo (one remembers that Faulkner is supposed to have written *As I Lay Dying* on a wheelbarrow used as a desk while he was working for a coalfired power plant in Mississippi). The whole novel is enclosed within the grave, compassionate, perpetual present tense of the narrative voice. This is a kind of collective consciousness/language, within which the individual voices of the characters are embedded. This narrative voice, it could be argued, coincides, or at least overlaps, with the distinctive consciousness/language of Addie Bundren, the protagonist who lies dying.

If the narrative voice, an anonymous 'it,' encompasses the whole narration in an embrace like that of some god or goddess who has taken the form of a ubiquitous cloud, it is just as true to say that the whole novel is enclosed within Addie Bundren's mind. *As I Lay Dying* is surrounded as a strange kind of proleptic anticipation by the consciousness of the 'I' of the title, that is, of Addie, as she lies dying. In the opening narrative segments she is still alive, listening to her son Cash as he saws and nails her coffin, but by the sixth segment, spoken by the neighbor Cora, she is dead. Cora's soliloquy is in the past tense, spoken at some inde-

18 Ibid., 61.

terminate time after Addie's death. If Addie's consciousness as she lies dying is thought of, on the strength of the title, as encompassing the whole novel – including all the events that happen after she is dead and laid in the coffin her son has fashioned with hand tools – then the novel would, with a vengeance, express a moment of Heideggerean 'ecstasy' – a moving forward into the future, a movement even beyond the moment of one's death, to come back to the past. That past is articulated in Addie's sole section, inserted long after her death has been narrated. The dead-alive Addie soliloquizes about her past life with her husband and the infidelity to him with a local preacher that produced her son Jewel.

If the relation of a human body's movement through space – that is, the movement of Addie's corpse toward its burial – provides the large-scale temporal framework for *As I Lay Dying*, certain linguistic moments encapsulate Faulknerian lived temporality more exactly, in a single emblematic representation.

The novel opens with an odd narration, by Darl, of the way he and his half-brother Jewel walk in single file across a cotton field, with Jewel at first behind by fifteen feet and then ahead by fifteen feet after Darl follows the path around the cottonhouse in the middle of the field, while Jewel steps through the cottonhouse, in one window and out another.[19] Spatial movement here allegorizes temporal progress. The scene suggests that time develops according to different rhythms for different people. It would follow that temporal progress is relative, not synchronized.

Another passage, quite characteristic of Faulkner, describes the dreamlike motion – a motion so slow as to seem movement in place – of the Bundren wagon toward a goal called, opaquely, "it" – presumably the grave in which Addie will be buried. Here movement through space seems to be a crossing through time that is everywhere at once: "We go on, with a motion so soporific, so dreamlike as to be uninferant of progress, as though time and not space were decreasing between us and it."[20]

Dewey Dell's lovemaking with Rafe happens in the woods beyond the rows where they have been picking cotton. If her cotton bag is full by the end of the row, she thinks, she will join him in the woods; he fills her bag for her, and she succumbs: "I said if it dont mean for me to do it the sack will not be full and I will turn up the next row but if the sack is full, I cannot help it . . . . And so it was full when we came to the end of the row and I could not help it."[21]

This is one of the many places where Faulkner dramatizes his sense that human time, as he understands it, eliminates human freedom and any moment of decision. For Dewey Dell 'not yet' has proleptically turned into an 'always already,' as if every deed is done before it is done – a view of time that eliminates the very possibility of an irruptive, unpredictable and inaugural event.

The most explicit identification of spatial movement with time in *As I Lay Dying* comes when the family is trying to pull, futilely, with rope, the wagon containing the coffin that holds Addie's fast-rotting corpse across the flooded river. Part of the family (Darl, Cash, and Jewel) is on this side of the river with the wagon, the coffin, the corpse, the mules, Cash's tools, and Jewel's horse. Part is on the other side ("Vernon and pa and

19 Ibid., 3 – 4.

20 Ibid., 101.

21 Ibid., 26.

Vardaman and Dewey Dell").[22] The looping rope across the river, the "terrific" flowing of the flooded river itself, express the sagging of time. This is perhaps a reference to the bending of time in Einsteinian relativistic physics, borrowed by Faulkner to express in a spatial figure the disjunction or timelag between one person's experience of time and another's. By Darl's account:

> The river itself is not a hundred yards across, and pa and Vernon and Dewey Dell are the only things in sight not of that single monotony of desolation leaning with that terrific quality a little from right to left, as though we had reached the place where the motion of the wasted world accelerates just before the final precipice. Yet they appear dwarfed. It is as though the space between us were time: an irrevocable quality. It is as though time, no longer running straight before us in a diminishing line, now runs parallel between us like a looping string, the distance being the doubling accretion of the thread and not the interval between.[23]

This passage explicitly thematizes the way human temporality is experienced as some form of spatial movement – how space transforms into time.

Time, for Faulkner, exists not as a continuity between future, present, and past, but as a simultaneity, an all-at-once viewed from multiple perspectives. To die, for Faulkner, is to enter time as the co-presence of everything happening at once. Darl, closest perhaps to Faulkner of all the characters in *As I Lay Dying* (though, ironically, he ends up in an insane asylum), best expresses this distinctively Faulknerian temporality in one of his soliloquies: "If you could just ravel out into time. That would be nice. It would be nice if you could just ravel out into time."[24]

For Faulkner, one does not ravel out of sequential time into eternity. One ravels out, or wishes to ravel out, *into* time. To ravel out into time would be to escape the false time in which one thing seems to happen after another, in a line, by dissolving or fraying out into the all-at-onceness or always-already that is time for Faulkner.

To conclude, I would like briefly to indicate how W. B. Yeats's "Leda and the Swan" expresses a quite different conception of human time from Faulkner's. For Yeats, time is neither a simultaneity (as it is for Faulkner) nor a seamless continuum between past, present, and future. It is, rather, a flow punctuated rhythmically by violent instantaneous interruptions, as well as by innumerable smaller events, such as those his poems often register. These larger irruptions come in two-thousand-year intervals as 'annunciations' from on high, and are radically inaugural. They precipitate the series of historical events that fatefully flow from them, just as the smaller events are in one way or another determinative for individual lives.

Zeus's rape of Leda is signaled by Yeats's use of the word 'sudden,' as important and recurrent a word for Yeats as the word 'terrific' is for Faulkner. "Leda and the Swan" begins: "A sudden blow: the great wings beating still/Above the staggering girl . . . ." Then: "A shudder in the loins engenders there/The broken wall, the burning roof and tower/And Agamemnon dead" [25] – this event, since it engenders Helen and Clytemnestra,

22 Ibid., 137.

23 Ibid., 139.

24 Ibid., 198.

25 William Butler Yeats, *The Variorum Edition of the Poems*, ed. Peter Allt and Russell K. Alspach (New York: Macmillan, 1957), 441.

'causes' the Trojan War and Clytemnestra's murder of her husband, two central stories in Greek historical mythology. However, as the note of explanation Yeats wrote to accompany the first publication of the poem (in *The Dial*, June 1924) indicates, the poem grew out of concern not for the distant past but for the political present. The Enlightenment, initiated by Hobbes, Yeats says, has left "a soil so exhausted that it cannot grow that crop again for centuries .... Nothing is now possible but some movement from above preceded by some violent annunciation."[26]

That new annunciation, I claim, is the poem itself. The poem is a performative linguistic event that exceeds its circumstances. In this, it is, in its own small way, an irruptive, unpredictable, and inaugural event, just like the Declaration of Independence or the publication of Kant's Third Critique. "The editor of a political review [George Russell, editor of *The Irish Statesman*]," says Yeats, "asked me for a poem . . . but as I wrote, bird and lady took such possession of the scene that all politics went out of it."[27] The poem, like all felicitous speech acts, brings about the thing it talks about. It is an ironic, punctual allegory, in the prolonged instant of the poem, of the contemporary politics that have vanished from any explicit mention in the poem.

It would take a longer argument to make my claims about the distinctive temporality of Yeats's "Leda and the Swan" fully intelligible and persuasive. But I hear the bartender in Eliot's "The Waste Land" calling out "HURRY UP PLEASE IT'S TIME."

So a fuller discussion of time in literature must await a timelier occasion.

26 Ibid., 828.

27 Ibid.

Mary Douglas, Michael Thompson
& Marco Verweij

Is time running out? The case of global warming

Most climatologists agree that by burning fossil fuels and engaging in other forms of consumption and production we are increasing the amount of greenhouse gases that float around in the atmosphere. These gases, in trapping some of the sun's heat, warm the earth and enable life. The trouble is, some predict, that if we continue to accumulate those gases, over the course of the new century the average temperature on earth will rise and local climates will change, with possibly catastrophic consequences.

Will this indeed happen? If so, should we do something about it? And if yes, when? Does global warming put the future of the world at risk? Is time running out? Or should we take our time in order to investigate and evaluate soberly the possible risks of greenhouse gases?

In our view, how an individual answers these questions and understands a phenomenon like global warming will largely depend on what kind of social setting he or she is a component of. Different social settings produce in their adherents different perceptions of reality, including the perception of time.

In order to understand current conflicts over the prospect of global warming, we find it helpful to sort out these 'social settings' in terms of the different forms of social solidarity. Each of these forms, in our view, produces characteristically different modes of anticipating the future.

The current landscape of the social sciences can for our present purposes be divided roughly into two camps. One camp is built on the assumption that human beings are fundamentally the same.

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Rational choice theory – or the economic approach to social analysis – is a major contender from this camp. Via its 'homogeneity assumption,' this approach posits that all individuals are similarly rational, or self-interested. The second camp harbors a contrary position: the only goal to which social scientists can truly aspire is to document how every person, community, and epoch is incomparably different from other people, communities, and epochs. Post-structuralism, for instance, explicitly rejects making generalizations about social life on the grounds that such an exercise would always do injustice to the uniqueness of people and cultures. But also many of those who have not embraced post-structuralist tenets have ended up arguing that social scientists can only uncover causal relationships that are entirely local and temporary.[1]

We feel that both of these edifices sit on shaky foundations. In view of the cultural and social variety across time and space, it seems odd to insist that all individuals merely follow a single rationality. It is not possible to explain social differences – for instance, why war or poverty reigns here and now but not there and then – on the basis of human universals. If everybody were similarly rational or self-interested, then this factor could not explain any differences between cases; ironically, by assuming that everyone is similarly rational or self-interested, rationality and self-interest are automatically ruled out as explanatory factors in any comparative analysis. Yet if it were true that individuals were wholly different from each other, how could we ever manage to communicate across cultures, understand history, cooperate, and interpret new events?[2]

Fortunately, we don't have to choose between these two extreme positions. It is possible – at least in principle – to distinguish simultaneously between a limited number of social and cultural forms, and still recognize wide social and cultural variety. Present-day physics maintains that all the material objects that we can observe on earth and beyond consist of endlessly varying combinations of only six basic particles. Analogously, it might be possible to discern a limited number of fundamental forms of social organization from which a large variety of ultimate forms of social and cultural life can be derived. This is the starting point of what we have come to call cultural theory.[3]

The original aim of this theory was to devise a typology of social forms that fit – to the extent possible – the classificatory schemes developed by the grand old social theorists (Durkheim, Tönnies, Maine, Weber, etc.), as well as the evidence collected in subsequent ethnographic studies.[4]

According to our cultural theory, there are four primary ways of organizing,

1 For example, Donald P. Green and Ian Shapiro, *Pathologies of Rational Choice Theory: A Critique of Applications in Political Science* (New Haven, Conn.: Yale University Press, 1994), 188; Bent Flyvbjerg, *Making Social Science Matter*, trans. Steven Sampson (Cambridge: Cambridge University Press, 2001), 167.

2 Aaron B. Wildavsky, "Choosing Preferences by Constructing Institutions," *American Political Science Review* 81 (1987): 3 – 21.

3 Mary Douglas, ed., *Essays in the Sociology of Perception* (London: Routledge, 1982); Mary Douglas, *How Institutions Think* (London: Routledge, 1987); Michael Thompson, Richard Ellis, and Aaron Wildavsky, *Cultural Theory* (Boulder, Col.: Westview Press, 1990). This approach has also sailed under the flags of 'theory of sociocultural viability,' 'grid-group analysis,' and 'theory of plural rationality.'

4 Mary Douglas, "Cultural Bias," in *Occasional Paper* No. 35 (London: Royal Anthropological Institute, 1978); Alan Page Fiske, *Structures of Social Life: The Four Elementary Forms of Human Relations* (New York: The Free Press, 1991).

perceiving, and justifying social relations (usually called 'ways of life,' or 'social solidarities'):

- fatalism
- egalitarianism
- hierarchy
- individualism.

We postulate that these four ways of life are at issue in every conceivable domain of social life. Most such domains (say the way in which a school operates, or the way in which an international regime functions) will consist of some mixture of these pure forms. As many social domains can be distinguished within and between societies (and as many societies can be distinguished around the world), the theory allows one to perceive a wide and ever-changing cultural and social variety – while still enabling one to formulate general propositions about social and political life. These propositions include possible ways in which people perceive and structure their time. In order to explain and illustrate this, we will have to set out our cultural theory in some detail.

Each of the four ways of life consists of a specific way of structuring social relations and a supporting cast of particular beliefs, values, emotions, perceptions, and interests. Our fourfold typology is strictly derived from two dimensions: what we will call 'grid' and 'group.'[5] Grid measures the extent to which role differentiation constrains the behavior of individuals: where roles are primarily ascribed, grid constraints are high; where roles are primarily a matter of choice, grid constraints are low. Group, by contrast, measures the extent to which an overriding commitment to a social unit constrains the thought and action of individuals.

High-group strength results when people devote a lot of their available time to interacting with other members of their unit. In general, the more things they do together, and the longer they spend doing them, the higher the group strength. Where admission to the social unit is hard to obtain, making the unit more exclusive and conscious of its boundary, the group strength also tends to be high. An extreme case of high-group strength is the monastic community whose members renounce their private property upon entering and depend on the corporate body for all their material and social needs. High-group strength of this sort requires a long-term commitment and a tight identification of members with one another as a corporate identity. Individuals are expected to act on behalf of the collective whole, and the corporate body is expected to act in the normative interests of its members.

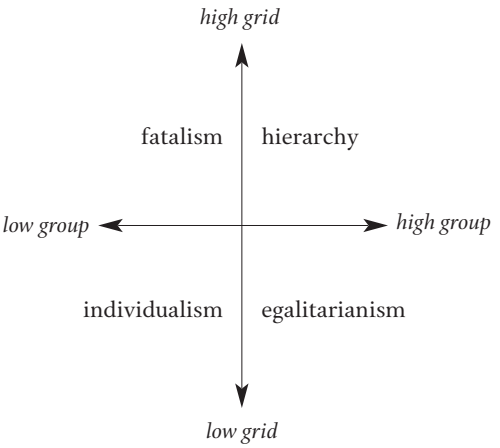
Group strength is low when people negotiate their way through life on their own behalf as individuals, neither constrained by, nor reliant upon, a single group of others. Instead, low-group people interact as individuals with other individuals, picking and choosing with whom they will associate, as their present preoccupations and perceived interests demand. The low-group experience is a competitive, entrepreneurial way of life where the individual is not strongly constrained by duty to other persons. Attractive though this freedom from constraint might first appear to some, there is a serious disadvantage: in a low-group context, you cannot count on the support of your fellows should your personal fortune wane. In the high-group context, the safety net of social support compensates for the loss of personal autonomy.

5 Jonathan L. Gross and Steve Rayner, *Measuring Culture: A Paradigm for the Analysis of Social Organization* (New York: Columbia University Press, 1985).

Grid stands for the complementary bundle of constraints on social interaction. Grid is high whenever roles are distributed on the basis of explicit public social classifications, such as gender, color, position in a hierarchy, holding a bureaucratic office, descent in a senior clan or lineage, or point of progression through an age-grade system. It is low when classificatory distinctions only weakly limit the range of social choices and activities open to people. A low-grid social environment is one in which access to roles depends on personal abilities to compete or negotiate for them, or even on formal regulations that ensure equal access and opportunity to compete. In either case, access to roles is not dependent on any ascribed characteristics of rank or birth.

Assigning two values (high and low) to the grid and group dimensions gives the four ways of life: the four social solidarities. The combination of a high score on the grid dimension (many rules prescribing people's roles) with a high score on the group dimension (strong group boundaries) gives the *hierarchical* way. A high-grid score with a low-group score characterizes *fatalism*. The third way of organizing and justifying social relations, *individualism*, is associated with low scores on both the grid and group scales. Last, *egalitarianism* is associated with a low-grid score and a high-group score (see figure 1).

Figure 1
Four Forms of Social Solidarity



Group measures the extent to which an overriding commitment to a social unit constrains the thought and action of individuals. Grid stands for the complementary bundle of constraints on social interaction.

We are now in a position to describe how these four different forms of association tend to produce different ways of perceiving the natural world and also different approaches to a phenomenon like global warming.

In an individualist social setting, actors view nature as benign and resilient – able to recover from any exploitation – and man as inherently self-seeking and atomistic. Trial and error, in self-organizing ego-focused networks (markets), is the way to go, with Adam Smith's invisible hand ensuring that people only do well when others also benefit. The upholders of individualist solidarity, in consequence, trust others until they give them reason not to and then retaliate in kind (the winning 'tit for tat' strategy in the iterated prisoner's dilemma game), and see it as only fair that (as in the joint stock company) those who put the most in get the most out. They think institutions that work with the grain of the market (that get rid of environmentally harmful subsidies, for instance) are what are needed.

In an egalitarian social setting, actors see nature as fragile, intricately interconnected and ephemeral, and man as essentially caring (until corrupted by coercive institutions such as markets and hierarchies). We must all tread lightly on

the earth, and it is not enough that people start off equal; they must end up equal as well – equality of result. Trust and leveling go hand-in-hand, and institutions that distribute unequally are distrusted. Voluntary simplicity is the only solution to our environmental problems, with the Precautionary Principle being strictly enforced on those who are tempted not to share the simple life.

In a hierarchical social setting, actors see the world as controllable. Nature is stable until pushed beyond discoverable limits, and man is malleable: deeply flawed but redeemable by firm, long-lasting, and trustworthy institutions. Fair distribution is by rank and station or, in the modern context, by need (with the level of need being determined by expert and dispassionate authority). Environmental management requires certified experts to determine the precise locations of nature's limits, and statutory regulation to ensure that all economic activity is kept within those limits.

In a fatalistic social setting, finally, actors find neither rhyme nor reason in nature, and suppose that man is fickle and untrustworthy. Fairness is not to be found in this life, and there is no possibility of effecting change for the better. 'Defect first' – the winning strategy in the one-off prisoner's dilemma – makes sense here, given the unreliability of communication and the permanent absence of prior acts of good faith. Without the possibility of ever getting in sync with nature, or of building trust with others, the fatalistic world unlike the three others is one in which learning is impossible. "Why bother?" therefore is the rational management response.

Since it was formulated, this classification of the four different ways of life has helped illuminate the paradoxical and sometimes contradictory ways in which individuals in different social settings approach contemporary public policy issues. As Barry Schwartz has acutely remarked:

> Each way of life undermines itself. Individualism would mean chaos without hierarchical authority to enforce contracts and repel enemies. To get work done and settle disputes the egalitarian order needs hierarchy, too. Hierarchies, in turn, would be stagnant without the creative energy of individualism, uncohesive without the binding force of equality, unstable without the passivity and acquiescence of fatalism. Dominant and subordinate ways of life thus exist in alliance yet this relationship is fragile, constantly shifting, constantly generating a societal environment conducive to change.[6]

In the context of complex modern societies characterized by competing ways of life, cultural theory thus has several normative implications.[7] First, there is the realization that people are arguing from different premises and that, since these premises are anchored in different forms of solidarity, they will never agree. Second, in line with the 'argumentative turn' in policy analysis, this contention, as well as being unavoidable, is all to the good: something to be harnessed through constructive communication. Third, though each solidarity has its own distinctive model of democracy,[8] no one of them has the 'right' model; the essence of democracy, rather, is in its contestation.

6 Barry Schwartz, "A Pluralistic Model of Culture," *Contemporary Sociology* 20 (1991): 765.

7 Steven Ney and Michael Thompson, "Consulting the Frogs: The Normative Implications of Cultural Theory" in *Cultural Theory as Political Science*, ed. Michael Thompson, Gunnar Grendstad, and Per Selle (London: Routledge, 1999).

8 Hierarchy calls for a guardian model of democracy; egalitarianism instills a preference

Since nature is perceived differently within these different ways of life, we should not be surprised to find that time, too, is perceived variously within these settings. Indeed, this variation in the social constructions of time – simply in terms of how the long- and short-terms are distinguished from and related to one another – is among the longest established of the seventy or so sets of predictions from cultural theory. Long before climate change became a hotly debated political issue, these predictions were set out in Douglas (1978), Rayner (1982), and Thompson (1984)[9]:

- Individualistic actors will tend to see the long-term as the continuation of the short-term. Myopically, they insist that doing well in the here-and-now is the best guarantee for doing well later on. 'Business as usual' is how complex systems-modelers characterize this individualistic line of action.
- Hierarchical actors – regulators, planners, public-health inspectors, and the like – will tend to be unhappy about all this short-termism (as they call it). While individualists like Henry Ford consider history bunk, hierarchical actors are at pains to anchor their collectivity in it. Hierarchical actors, therefore, can see both the short-term and the long-term, and do not see the latter as merely the continuation of the former. Development in the here-and-now, they reason, may not be sustainable a decade or two down the road. Their aim, therefore, is to provide a clear description of long-term sustainability and then to intervene in the short-term activities of the market actors to ensure that we all arrive safely at that desirable future: 'wise guidance,' as modelers call it.
- Egalitarian actors will tend to be as distrustful of hierarchies as they are of unfettered markets. The short-term, for egalitarians, is severely truncated, and the long-term – disastrous if we do not learn the error of our inequitable ways; wonderful if we do – is almost upon us. Radical change now – not business-as-usual and not wise guidance – is what is needed if we are to have a future at all.
- Those fatalistic actors who find themselves marginal to all three active solidarities – individualistic ego-focused networks, bounded and hierarchically ranked organizations, and bounded but unranked groups – will see no point in sorting out long-terms and short-terms this way or that. "If your number's on it," they assure one another, "that's it." Why put yourself to a whole lot of bother over something you can do nothing about?

These four ways of being time-bound – distinguishable in terms of how the long- and short-terms in each correspond to one another – are mutually incompatible. "It would be a dull world," barroom philosophers are fond of declaring, "if everyone were the same" – and we agree with them. We would also add that, since this fourfold contestation is essential, that dull world is unattainable. But that, of course, does not stop people from trying to ignore crucial dif-

for a participatory model of democracy; individualism extols a protective model of democracy, which should enable individuals to carry out their own plans; and fatalism breeds a belief that democracy may be a good thing, but will not be established in this life.

9 Douglas, "Cultural Bias"; Steve Rayner, "The Perception of Time and Space in Egalitarian Sects: A Millenarian Cosmology," in *Essays in the Sociology of Perception*, ed. Mary Douglas (London: Routledge, 1982); Michael Thompson, "Among the Energy Tribes: A Cultural Framework for the Analysis and Design of Energy Policy," *Policy Sciences* 17 (1984): 321–339.

ferences, as the case of climate change demonstrates.

We can now return to the issue of global warming. Will this indeed happen? If so, should we do something about it? And if yes, what and when?

Adherents of the different solidarities will tend to answer these questions differently.

Those who bind themselves into egalitarian settings – often radical environmental groups such as Earth First! – are convinced that corporate greed and power lust are already unleashing catastrophic climate change, and that we must drastically alter our behavior now, before it is too late. Compromise, for these 'deep ecologists,' is therefore out of the question:

> To avoid co-option, we feel it is necessary to avoid the corporate organizational structure so readily embraced by many environmental groups. Earth First! is a movement, not an organization. Our structure is non-hierarchical. We have no highly-paid "professional staff" or formal leadership.[10]

The conviction that the problem is serious, imminent, and – if not dealt with quickly – irreversible, supports this egalitarian mode of organization:

> …our activities are now beginning to have fundamental, systemic effects upon the entire life-support system of the planet – upsetting the world's climate, poisoning the oceans, destroying the ozone layer which protects us from excessive ultraviolet radiation, changing the CO_2 ratio in the atmosphere, and spreading acid rain, radioactive fallout, pesticides and industrial contamination throughout the biosphere.
>
> We – this generation of humans – are at our most important juncture since we came out of the trees six million years ago. It is our decision, ours today, whether Earth continues to be a marvelously living, diverse oasis in the blackness of space, or whether the charismatic megafauna of the future will consist of Norway rats and cockroaches. [11]

Here (as in Steve Rayner's classic 1982 study of the Workers' Institute of Marxism-Leninism Mao Xedong Thought, in London's Brixton) past, present, and future are compressed in a way that is typical of the egalitarian form of solidarity. All of the past – in this case, six million years of it – has been but a buildup to our present situation; never before have our actions so threatened the viability of the planet on which we depend. Our current choices, moreover, are decisive for all time to come. Make the right decision today – at this "our most important juncture" – and eternal bliss – "a marvelously living, diverse oasis in the blackness of space" – will be our reward. Fail to make that decision and there will be no eternity, save for the "Norway rats and cockroaches."

Those who belong to organizations of a more individualistic bent – the United States's Cato Institute, for instance, and Britain's Institute of Economic Affairs – see it all very differently. They are skeptical of the diagnosis itself and they are convinced that, even if it is correct, the consequences will be neither catastrophic nor uniformly negative. Far from being at a six-million-year juncture, we are, they assert, where we have always been: faced with uncertainties and challenges that, if tackled boldly by a diversity of competing agents, can be transformed into opportunities from which

10 All Earth First! quotes are from <http://www.earthfirstjournal.org/efj/primer/index.html> (26 July 2002).

11 Ibid.

all can benefit. The long-term holds no fears for them, because this optimistic short-term bubble, as it moves along, will take care of it all. For that to happen and go on happening, of course, there must be no junctures; at the very least, they must be far enough out into the future for us to not need to worry about them.

Given this social construction of time, individualistically organized outfits prefer a two-pronged approach: the dismantling of junctures within the short-term bubble, and adaptation to any that may exist beyond that bubble. They therefore focus on the *lacunae* in current climate-change science:

- Clouds, whose formation is poorly understood but which are expected to be more prevalent in a warmer world, would likely reflect more sunlight back into space before it reached the earth's surface.
- Human sources of greenhouse gases are dwarfed by natural sources (volcanoes, for instance, and termites and other wood-digesting creatures) – which means that it is impossible in the short-run to say whether any warming (if it is happening) is man-made.
- The climate models that are being used to predict future changes cannot even accurately chart changes that have already occurred.

Looking beyond the short-term bubble, they point out that a carbon-richer climate would increase agricultural productivity, and that, even if the negative impacts did outweigh the positive ones, we would still need to compare the costs of preventing global warming now to the costs of adapting to higher temperatures a few decades hence. Money not spent on preventing climate change, they point out, could be used to tackle other, more pressing environmental and social ills.

On top of all that, individualistic organizations, thanks to their myopic construction of time, are open to the view that technological progress and the unpredictable forces of 'creative destruction' may soon render today's fuss over climate change irrelevant. The production costs of renewable energy, they point out, have fallen dramatically over the last few decades, and these new technologies – wind, hydro, geothermal, and solar – are rapidly becoming (indeed, in some instances, have already become) competitive with the old technologies of fossil fuels. Their prescriptions, in consequence, dramatically differ from those of the deep ecologists. As Roger Bate, director of the Environment Unit of the Institute of Economic Affairs, concludes:

> On the whole, society's problems and challenges are best dealt with by people and companies interacting with each other freely without interference from politicians and the state.
>
> We do not know whether the world is definitively warming, given recent satellite data. If the world is warming, we do not know what is causing the change – man or nature. We do not know whether a warmer world would be a good thing or a bad thing.
>
> [The scientific evidence] does not suggest that immediate action for significant limitation on energy consumption is urgently required . . . . Until the science of climate change is better understood, no government action should be undertaken beyond the elimination of subsidies and other distortions of the market.[12]

This business-as-usual strategy is anathema to the members of the numer-

12 Roger Bate, "The Political Economy of Climate Change Science," in *Environmental Unit Briefing Paper* No. 1 (London: Institute of Economic Affairs, 2001), available at <http://www.iea. org.uk/files/48.pdf> (27 July 2002).

ous hierarchical organizations that have dominated the global warming debate. They are appalled by its short-termism and its accompanying assumption that the myriad and uncoordinated actions of firms and consumers will inevitably be beneficial for the totality. Worse still when this assumption is made across time as well as space – because, hierarchical actors insist, the long-term is never simply the continuation of the short-term. And they are also dismissive of the egalitarian claim that, if only we make the right (and radical) choice today – at this "our most important juncture" – all will be fine for evermore.

In the hierarchical view, each single contribution that households, companies, and even whole countries make to the buildup of greenhouse gases is so small as to be insignificant to these undiscerning actors. Moreover, the consequences lie far into the future and spread across the entire globe: way beyond their temporal and spatial kens. It therefore makes no sense for any household or firm or country to unilaterally reduce its emissions. What we are faced with, therefore, is a 'tragedy of the global commons' – and the only conceivable remedy is for all the governments and parliaments of the world to formally agree on the extent to which future emissions should be cut, which countries should do so, how, and when. States should then impose these intergovernmental agreements on the multitude of consumers and producers within their borders.

This is the logic behind the 1997 Kyoto Protocol to the UN Framework Convention on Climate Change. It is espoused by almost all the governments of the world, by UN agencies and the World Bank, as well as by the large mainstream environmental organizations (the ones of which Earth First! is so disparaging). Implicit in their shared commitment is the belief that we can, and should, steer ourselves, in a planned and orderly way, to a rather precisely defined and timed future. The computer models built by the Intergovernmental Panel on Climate Change (and by other proponents of 'wise guidance'/'global stewardship') have been churning out scenarios that supposedly show a variety of future global emissions of greenhouse gases, along with their worldwide ecological and economic impacts, and the costs of attaining these future states. Their business-as-usual scenarios, however, typically account for little rapid technological change (and certainly for no out-of-the-blue, Schumpeterian gales of creative destruction). Other projections that are free of imminent discontinuities – ocean currents changing direction, for instance, or ice caps collapsing catastrophically – reveal that the radical and immediate action advocated by the deep ecologists would be extremely costly and disruptive.

The scenarios, as a result, reproduce the models' hierarchical temporal assumptions as their conclusions[13]: only a gradual and orderly phasing out of greenhouse gas emissions, undertaken by governments and spread out over the next fifty or so years, will see us through. And, as the language in which these conclusions are couched makes clear, these things should be left to the experts:

> Studies show that the costs of stabilizing carbon dioxide concentrations in the atmosphere [carbon dioxide being the main greenhouse gas] increase as the concentration stabilization level declines. While there is a moderate increase in the costs when passing from a 750 to a 550 ppm concentration stabilization level, there is a

13 Michael Thompson, "Among the Energy Tribes."

larger increase in costs passing from a 550 to a 440 ppm unless the emissions in the baseline scenario are very low.[14]

In other words, global climate change policy should go neither too fast (as the deep ecologists would have it) nor too slow (as the individualistic actors would have it). Instead, only those bureaucratic organizations that are both long-lived and farsighted can determine what that pace should be, and then get all the world's nations to march in step to it.

Does global warming put the future of the world at risk? Is time running out? Or should we take our time in order to investigate and evaluate soberly the possible risks presented by greenhouse gases?

We don't have the answer to these questions. But our cultural theory teaches us that vigorous debate among rival perspectives is the best way to address them. That is because the issue of global warming will never be resolved simply by making a rational choice on strictly scientific grounds. It is a battle, as well, between groups of actors with different perceptions of time that derive from conflicting ways of organizing and justifying social relations.

Is time running out?

Unlike the rational choice theorists, we do not assume that one group's predictions are inherently more rational or accurate than another's. Unlike the poststructuralists, we do not shy away from concluding with a normative generalization: If this sort of institutional turmoil intensifies as we approach various environmental limits, then one policy challenge will be to maintain and nurture a dynamic plurality of contending points of view. Wisdom will lie in remaining open to, and appropriately critical of, each one.[15]

14 Intergovernmental Panel on Climate Change, *Climate Change 2001: Synthesis Report* (2001), 28.

15 Steve Rayner and Elizabeth L. Malone, "Zen and the Art of Climate Maintenance," *Nature* 390 (1997): 332–334; Marco Verweij, "Curbing Global Warming the Easy Way: An Alternative to the Kyoto Protocol," *Government & Opposition* 38 (2003).

Richard Fenn

Apocalypse & the end of time

Religious traditions seek to turn the mere sequence of moments and events into a significant past, present, and future. Christianity, like Judaism and Islam, has created a sacred history – an account that binds together the moments of life into a continuous narrative with a beginning, middle, and end – of which those who are included in the authorized version of such a myth may see their own time on earth as a part. If individuals live according to the prevailing myth, they may pass the test of time – and enjoy life eternal.

On the other hand, those who fail the test must suffer the passage of time – a world that is forever disappearing. Only those who live in accordance with the transcendent pattern revealed by the larger story, who conform to its plan and welcome the end, are fit to be relieved of time and its burdens. All others will be eliminated in cosmic battle, or consigned to eternal punishment in the next life, or relegated to the eternally recurring wheel of moments and events.

Biblical prophets speak of a day that comes like a thief in the night, or with the blast of a trumpet, suddenly and with fateful consequences for all except the superbly well prepared. Such visions of the end conjure up some of the disadvantages that inhere in the passage of time: the surprise of the unprecedented, the bewilderment that accompanies the discovery of the unique. But they also promise a partial immunity to the passage of time: There will be a new Jerusalem to replace the old.

There is a price to be paid, however, for the apocalyptic triumph over time. The self must be subdued, the soul fitted into an authorized version of the sacred story. In some versions of Christian apocalypse, the individual is absorbed on the final day into a collectivity engaged in continual adoration of the only One who has any remaining claim to uniqueness, authority, and finality. That One alone has a claim to being unprecedented, having been from the beginning: the only One whose Word is final and whose acts are irreversible. There is no higher sovereignty.

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Indeed, some Christian apocalyptic scenarios view the end as a time in which there will be no surviving rivals to one's own faith: no non-Christians, no infidels. Pat Robertson foresees a cosmic battle pitting "the people of the Babylonian humanistic and occultic traditions" against "the people of the Abrahamic, monotheistic tradition."[1] When the battle is over, the only people left standing will be those whose thoughts, words, and deeds conform to what Robertson has in mind when he speaks of the 'Abrahamic' tradition. But even those Jews who do survive Armageddon will have to become Christians. Robertson's God will be all in all.

Because an apocalyptic vision like this seeks to exorcise the complexities of the social order, the prospect of a soul freed from oppressive spirits becomes a warrant for Robertson's co-religionists to impose their will on each individual's psyche. Some religious traditions indeed predicate apocalyptic hope on a lifetime of self-abnegation and the renunciation of all individual markers of significance and distinction.

Even ostensibly secular societies have exploited the promise of such an apocalyptic purification. Certainly the millennial rhetoric of the Third Reich was informed by the legacy of the conquistadors in creating a Christian 'new world' based on ethnic cleansing. In Hitler's Germany, there were wholesale attempts to remove those who might signify difference, whether they were Jewish, Gypsy, or otherwise marked with the signs of uniqueness. In the end, there would have been no Jew or Gentile, no Christian or non-Christian, but only the Aryan.

Not surprisingly, the most narcissistic elements in apocalyptic belief require of the individual the most radical forms of self-loss. Thus Sikh and Islamic terrorists immolate themselves in suicide attacks while imagining themselves as about to be transported into a world beyond time, as the unfaithful are left to behold their own time running out.

It is no wonder that Muslims should hate the Christian West, exemplified in the power of the United States. No culture appreciates having its own claims to uniqueness and superiority challenged by a rival culture that makes similar claims. Thus Rome and Jerusalem hated each other, and the Nazi advocates of a millennial Reich could stand no rival claim either from Jews or, in the end, Christians.

On the last day, however, all these rivalries will be settled – such is the apocalyptic promise. There will be no more hatred, no more suffering; no more failure, defeat, rejection – only vindication. But in their moment of triumph, caught up in awe, wonder, and praise, those saved must cast down their crowns around the glassy sea. There is no room in the end time for individual distinction and self-assertion, but merely for adoration of someone far beyond the self.

Under the auspices of the apocalyptic imagination, a plague in Egypt becomes the beginning of redemption for a people, as their sacrifices ensure that the angel of death will pass over them and slay their Egyptian overlords. The murder of an Egyptian taskmaster becomes the event that triggers the exodus of the same people from Egypt across the Red Sea, into the wilderness on their way to a better future. The death of a Jewish prophet on a cross becomes the beginning of a new exodus from the slavery that is imposed by law.

To depict such stories of restoration, reversal, and redemption is one function

1 Pat Robertson, *The New World Order* (Dallas, Tex.: Word Publishing, 1991), 258.

of the apocalyptic imagination: it ensures that no event, no matter how unique and devastating, is felt to be irreversible (in contravention of the common-sense expectation that time flows in one direction only – from past to future).

Societies also have sacralized their histories in order to create the illusion that they, too, can transcend the passage of time. The young represent the irreversibility of time; they pose a standing threat of innovation and change. Therefore most, perhaps all, social systems try to initiate the young into a story that spans the generations and incorporates the living and the dead into a spiritual community that transcends time.

In patriarchal societies, the authorized version of sacred history typically regards women, the young, and those who think for themselves as having energies and commitments that flow outside the authorized channels. In such societies, danger to the social order is thought to come from somewhere outside the system – from the bush or neighboring villages, from distant city-states and foreign empires, from infidels and alien religious movements. Such societies may therefore employ spies or a priesthood to purify themselves of corrupting influences. They keep a lookout for external threats, for superhuman and subhuman beings, and also for alien ideas, diseases, foods, and suspicious strangers who are diabolically difficult to distinguish from the pure of heart.

At a time when churches in the United States are having difficulty distinguishing good from bad priests, and the government is on the lookout for 'sleeper cells' of foreign terrorists, it is no accident that the apocalyptic imagination informs public entertainments and popular books. Especially when sacrifices fail to avert danger and death, or when rituals fail to create faith and obedience in the young or to domesticate women, the apocalyptic imagination reveals that all of these dangers, internal and external, threaten the very survival of the society.

At times of crisis, when a way of life seems threatened with extinction, the apocalyptic imagination is liable to flare up with special force. In these circumstances, predictions of an imminent end take on new plausibility, and people may prepare for a war to end all wars. The crisis may be abrupt and spectacularly destructive, like the one that occurred in the United States on September 11, 2001. Or the crisis may be more protracted and hidden from view, as in the case of spiritual communities that feel themselves besieged by outside influences.

For instance, the children of many Christian fundamentalists in America are exposed to the images, songs, and symbols of an insidiously corrupting popular culture – which leads some parents to long for the kind of Armageddon foreseen by evangelical preachers like Pat Robertson. The subjection of Sunni Muslims in his native Saudi Arabia to similar sorts of secular temptations has provoked Osama bin Laden into attacking the West. Pundits who argue that the cure for Islamic radicalism is more exposure in Islamic schools to the secular and democratic ideals of the West are suggesting as a remedy what has in fact been the source of Islamic despair that their own communities are running out of time.

In liturgy and spectacle, in epics and entertainment, prophets and scribes make the flow of time seem more continuous, especially when it has been seriously broken by disaster. As with the construction of a fictional narrative, writers fit the pieces of time slowly back

together.[2] Thus the scribes of the first century C.E. took the anomalous and unfinished life of Jesus and gave it precedents in Moses and Elijah, David and Solomon, while projecting it into a glorious future of return, restoration, and revenge. The scribal community similarly took the destruction of Jerusalem and fit it into the apocalyptic narrative of the destruction and return of once and future cities.

At the same time, once a society begins to live in the shadow of apocalyptic expectation, prophets and scribes, commentators and pundits, begin to search for latent or disguised signs that time is running out. Some search for signs of internal defection and subversion, others for the intrusion of alien ideas and people, in order to issue warnings about what is becoming imminent. They inquire of ancient apocalyptic books and oracles, of sibyls and divines, who remembered the future and predicted it in the past: an exercise in retroactive foresight.

Such defenses against the sheer force of time allow a society to draw a line between those in their midst who are following the authorized version of the sacred story, and those who are following alien sources of inspiration. It is these latter, the apostates and the faithless, or – in the lexicon of the Christian Right – the secular humanists and the Christians in liberal churches, who are a sinister fifth column undermining the foundations of society and preventing the people of God from opposing the work of Satan.

In the weeks after September 11, a variety of Christian commentators fulfilled the traditional function of the scribal community by searching the past for precedent and prediction: for the meaning of signals and messages, of clues and signs, that many had noticed but which relatively few had explicitly understood or announced. For some, America's war against terrorism became part of the ancient struggle between East and West, Greece and Persia, the people of Babylon and the people of Israel. There is no place in such a story for the United States to sacrifice its sovereignty to a collective body such as the UN: no reason to consult with allies, to avoid the use of nuclear arms, or to restrain from preemptive strikes. Here again is Pat Robertson: "An independent America could point out Satan's lies . . . if America goes down, all hope is lost to the rest of the world."[3]

With the end in sight, the old rules are of little use, and it makes little difference what Moses or any other traditional authority may have said. Even religious observance offers no guarantee of final perfection. Aliens may be friendly but dangerous, and evil mimics the good. When it is hard to distinguish allies from foes, a charismatic leader may well emerge, for whom no customary title is sufficient, and who calls on his or her followers to undertake new duties, take on new risks, and to make sacrifices without the guarantee of immediate success or reward. Charismatic leaders – like Robertson, like bin Laden – offer their followers new opportunities for self-denial and self-immolation, while promising commensurate rewards at the end of time.

To live in the expectation that time will end permits the expression of chronic, anticipatory mourning for a world about to be lost, and supports a keen public interest in the history and archaeology of lost worlds. There is no way to know

2 Frank Kermode, *The Sense of an Ending: Studies in the Theory of Fiction* (Oxford: Oxford University Press, 2000), 17. I am indebted to Michael Wood for this reference.

3 Robertson, *The New World Order*, 256.

who is going to make the final cut in history, and who is going to be left behind once and for all. As Frank Kermode suggests, the apocalyptic notion of a critical period of transition has been changed into a sense of our own day as being "an age of perpetual crisis in morals and politics. And so, changed by our special pressures, subdued by our skepticism, the paradigms of apocalypse continue to lie under our ways of making sense of the world."[4]

As the names of Jonestown, Waco, and Heaven's Gate should remind us, apocalyptic demands for self-immolation have been openly pursued by a not insignificant number of Americans. We need also to consider the increasing popularity of Eastern religious notions of a self eventually to be dissolved into the ocean of the cosmos, finally to be relieved of the burdens of time that accompany a separate existence. For those who find the present world either offering too little in the way of satisfaction or too much in the way of uncertainty, apocalypses satisfy the desire to wipe out the world and, with it, the last vestiges of the singular self.

Thus the apocalyptic imagination not only illustrates Marx's aphorisms about religion being "the sigh of the oppressed creature" and "the heart of a heartless world"; it also legitimates an assault on the psyche. That assault is disguised, however, as a last-ditch attempt to remove an oppressive force that threatens not only the society but the individual.

In this respect the apocalyptic vision follows the inner logic of rites of exorcism, especially those that focus on young women who refuse to be domesticated or on children who claim to have their own sources of inspiration and authority. Like a collective exorcism, the apocalypse is expected finally to liberate people from the spirits that have possessed their souls. But it also removes any basis for personal freedom: only the orthodox and right-minded will survive.

It is not surprising that the radical religious Right in this country continues to beat its apocalyptic drums to mobilize support for conflict in the Middle East. What is surprising is the willingness even of liberal, mainline churches to continue to keep apocalyptic visions in their arsenal of belief. There has hardly been a century in the last two millennia when these beliefs did not hearten the poor and the despairing – but they have also encouraged the vicious and the violent to believe that time is on their side. These beliefs have done enough damage in the last two thousand years to warrant fundamental rethinking on the part of the mainline churches.

What might encourage the mainline churches to divest themselves of these apocalyptic beliefs that have long encouraged ethnic and national hatreds?

It might help to recall that dreams of a pitched battle between East and West were Hellenistic and Mesopotamian before they were biblical. It might also help to recall that they were part of Virgil's imperial myth of the Trojans who left the ashes of their own city and sailed for the shores of Italy: apocalyptic visions of a Roman empire that would never run out of space or time.

There is nothing, in short, inherently Jewish or Christian or Muslim about apocalyptic imagery. And if our religious leaders want to defuse the potential for murderous conflicts between rival cultures, they would do well to uproot the remnants of the apocalyptic imagination in their own traditions – and disavow the fantasy that a final orgy of violence will liberate the faithful, once and for all, from the burdens of time.

4 Kermode, *The Sense of an Ending*, 28.

Poems by Susan Howe

Secrecy let me light you in
In shadow something other
echoed and re-echoed only

The dark who can veneer it
That conjoint abstraction will
come to snow let us go back

Perilous quillwork needlework
Need wheat for an ogee epigram
if old Lille silk one ogival sliver
if miniature bobbin come from
dark underwood again again if
reeling wild silk precede reeler

1775 landscape America
blindstitched to French
edge silk damask cover
Silhouette of Gothic city
soaring bird needlework
Quiet under false scant
lonely ecstatic incessant
white on white coverlet

held once quiet stillicide
at one or two removes no
brought back into touch

Because pain is life we
want you too Disquiet
you've enough about us

Susan Howe, State University of New York Distinguished Professor of English, is the author of several books of poetry, including "The Europe of Trusts" (2002) and "Pierce-Arrow" (1999). A Guggenheim Fellow, she was elected a chancellor of the Academy of American Poets in 2002. These poems are drawn from a series entitled "Bed Hangings II," forthcoming in "The Midnight" from New Directions.

Fiction by Rick Moody

Fish Story

Now the Word of the Lord came unto Jonah Feldman, of the Feldman family of Maspeth, Queens, which regional name in the language of the native population connotes *place of bad waters,* his father being Hyman Feldman, Orthopedist, whose business was at the clinic near the Mt. Zion Cemetery. As *the Word of the Lord* came unto his son, Hyman Feldman was on call setting the broken wrists of a neighborhood kid who'd fallen off his scooter at the storefront clinic of which the prophet spoke, not too far from Rosa's World Famous Pizza. Hyman's father was also Jonah, whose father was Abraham, and so on, Jonahs and Hymans and Abrahams and Zechariahs helixing into the past.

Anyway, *the Word of the Lord* came to this Jonah Feldman, but why this guy, what qualities proved him deserving of such a visitation? What made this kid Jonah Feldman different from say Stanley Rabinowitz, just up the block, much smarter, made his parents happier, went to a fancy Ivy League school, embarked upon medical residency in the Midwest. Almost caused his mother to have an aneurysm she was so happy. *Hard to say why,* but if you pursue honor it will elude you. *The Word of the Lord* had *not* come unto Stanley, bypassed him entirely, nor had *the Word of the Lord* come to Louise Luchese who lived up the street and who wanted to take the vows of a nun in spite of her blasphemous but enthusiastic wantonness, nor to anyone else in Maspeth or in the entire borough of Queens. No, *the Word of the Lord came unto Jonah Feldman,* the only young adult in his neighborhood to have printed business cards for himself on his twenty-fourth birthday that said *Kosher Fag* on the back, by which he intended to disseminate through an elegant but unprepossessing font the fact that he both kept kosher and *liked boys*. Though lately he seemed like he was less often kosher and more often *liking boys*. He ate the occasional cheeseburger, which would have infuriated his grandmother had she known, and he felt in this ritual both a fine disgust and an admiration for him-

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self. He went to the Hispanic butchers in the neighborhood, and he drove on the Sabbath, etc. He was putting more energy into the *fag* part of his five-year plan. For example, the delirious and profound word *cock* was his companion, his spur and staff, the word rather than the thing, its Middle-English origins, *to mete with Cocke they asked how to do*, its blunt Anglo-Saxon simplicity, *what man are thou, when thy cock is up*, its endurance as a slang word, its endurance as an image in his image repertoire, *E'er his small Cock were yet a fortnight old, how with majestick Vigour it should rise*. In boys he saw it, the word, and its syllable rang in his ear, a transgression in want and a transgression in name; it was the name that gave him to wanting, he had come to wanting now, could put it off no longer, and the wanting made the name ring like the church bells of Maspeth in his head. Jonah Feldman was a *Kosher Fag*, his parents could not deny it, for his fealty to *cock* was perfect, his love for *cock*, his nurturance for *cock*. *A hot cock has no conscience*, it is said, but still he worshiped it, though most of the clubs that he frequented with their thundering break beats and handsome but narcissistic regulars would not take kindly to a *Kosher Fag* from Maspeth, Queens, more Maspeth than *queen*, alas, with his kinky dark hair already receding, his soft middle, his proofreading job at Price Waterhouse. His eyebrows met in the middle, despite nervous and painful tweezing. He had no fashion sense at all. He would buy any reasonable clothes at Century 21. He knew nothing about style, he liked sports, even baseball, he couldn't stand Liza Minelli. He would have been happy in sackcloth or polyester, eating locusts and cheeseburgers, as long as he could wear his *yarmulke*. The boys in the clubs with their leather pants, they did not get the *yarmulke*, they did not know that in the neighborhood it was a dignified thing to affix this symbol to the male-pattern baldness of his genetic tribe. They didn't know, for a person does not know what is in his neighbor's heart, that the black accessory bespoke a willingness to lead the community; the *yarmulke* was strong and noble and it could make courageous such a one as Jonah Feldman, *to whom the Word of the Lord came now*. And why not, because he loved by the Word, the Word was with him and in him.

The particular messenger of *the Lord*, that night, it should be admitted, was a young blond fellow by the name of Carolina, or this was the name he gave, though it was clearly an assumed name, for the very air of these nightclubs circulated with assumed identities, with calculated anonymities, with the sorrow of castoff selves, with the shadows of things glimpsed only between songs in the clamp light of the deejay's booth. Here the bartender is dimly perceptible in the black light by the cash register, here couples appear and then vanish into the men's room, here are the men kissing in the cadences of a strobe light. All assumed identities, all assumed masculinities, in leather pants and mesh t-shirts, while afflicted selves like Jonah hovered just out of range. The particular heartache of Jonah Feldman was to come to this place and to see love whirling about him and to know that he was only enough a part of the action to know that he never would participate in full, like a gelding who stands off from the herd.

Thus: one night among the break beats at a certain club, *WestWorld*, very far west in the city of New York, Jonah Feldman of Maspeth, Queens, managed to find himself dancing with a blond from the Bible Belt. *It could not be*, this cavorting, for many months had tran-

spired since last he knew love. And yet it was. Carolina smoked unfiltered cigarettes, was too thin, was possessed of a large, severe nose and a cruel laugh. Yet behold that one incisor that jutted out in the front part of his lowers, behold that cowlick. Carolina said, *Here take some of this,* proffered a certain controlled substance. *Frolic with me, Queens boy.* It was all too good to be true, dancing to the hurtling of the music, dancing to the cascading of machines, all too good to be true, because *untrue,* in a way, for now no other man was in the room, they had all vanished, there was just the music and the boy called Carolina, because when *the Word of the Lord* comes to a room, it is as if none other inhabits it. The somewhat soft and somewhat slovenly Jonah Feldman kissed the pseudonymous Carolina, who had his tongue deep in Jonah Feldman's mouth. It should have been impossible for Carolina to talk. The controlled substance was beginning its navigations in Jonah's organs, the controlled substance which started with the letter *k,* or which had a *k* in it, though maybe it seemed so just because of Jonah's preoccupation with the word *cock,* which also had a *k* as did *kaon,* an unstable meson particle, *kaph,* the eleventh letter of the Hebrew alphabet, *katzenjammer, kestrel, kiddush, kadish, Kislev, kitsch, klutz.* They were kissing, and at some point the controlled substance was collapsing them, and that's when the room began to seem *kaleidoscopic.* For if you have ever wondered at the circumstances which are congenial to *the Word of the Lord,* trust that an unearthly light always *comes from within,* and trust that a voice calls out where none should be. The voice of God should *not* have come from Carolina, as it should *not* come from a West Indian woman who cleans people's apartments in wealthy neighborhoods, and yet it does.

Carolina, in this epiphany, was saying something to Jonah Feldman, the words were becoming clear now, they were becoming audible, they were in the process of revealing themselves in the field of music playing in the room. Here they come now. Empiricists and doubters, take note, the actual *Word of the Lord,* as spoken in a certain nightclub in New York City, in a year of done darkness:

Arise, arise! Neglected servant, arise! Jonah Feldman of Maspeth, Queens, arise! For I have a favor to ask of you, young Jonah, forsaken Jonah, I have a favor! Lend to me your ears! For I am not in the habit of talking to you in this way! I'm asking for you to lay aside your cares, neglected servant, I'm asking for you to draw near to My request. I'm asking if you should consider performing the following task as My representative. I'm asking if you would prepare for a long journey, to a certain village, a village by the name of Lynchburg, where you should search out those with bad reading skills, those who cannot read. And there you should instruct them in the matter of reading, young Jonah. Because in Lynchburg the standardized test scores, to speak in your parlance, are astonishingly low. They are not hearing the different ways I spill My Name on the page, they are not hearing the many poems in which I conceal Myself, they are not hearing the many soaring melodies in which I am so various, My melodies of ecstasy and profligacy and enthusiasm and woe, they are not hearing that I am in all words, that I alike fill the household measuring cup and the mighty ocean, that I adorn all empty places, and that I dwarf all mountains and all skyscrapers. They do not know the many pronunciations of My Unspeakable Name, Jonah, so I ask if you will go to Lynchburg, when you are finished with the oblivion of this particular kiss, there to deal with the splendid wickedness that I have described. I pick you for this task for no reason but that I love you! So remember while you are in Lynchburg, in a whole lot of trouble, as it is already written, that I love you. Travel safe!

His hangover the next morning, for it was now the next morning, was an affliction such as he had rarely suffered in his short life. It was as if he were molting his very skull, his jellied eyes were shish'd on flaming skewers, and he was sorely afraid. He was in Maspeth, Queens, trying to reconstruct the night prior, and his mother was banging on the door, wanting to know if he was going to take the morning repast, his favorite, which she had made especially for him. It wasn't *safe* that he shouldn't eat, etc. With the scrofulous but pragmatic logic of the hungover, Jonah realized, for he was indeed sorely afraid, that he needed *not* to be living at this address any longer, he needed *not* to wake with bite marks on his nipples, pained in certain nether regions, he needed *not* to have his favorite breakfast prepared for him each and every morning by a mother who no longer knew him in his entirety. The plan in which he saved for a down payment on a condominium through the largesse of Price Waterhouse was no longer a valid plan. He could not talk about the half of his life of which his parents did not approve, a portion of his life now growing to be more like two-thirds. Indeed when he got up and put on his terrycloth robe and slippers and went into the kitchen to face his goodly parents – his father with newspaper and bagel, his mother with spatula and coffee – they were looking at him with a noxious disappointment. His mother was going to cry. Why was everyone looking as if they might cry, when all that he had done was kiss a beautiful, elegant boy called Carolina and take a drug with *k* somewhere in its name, after which he'd had a tongue in his mouth, followed by some events he could not remember, including bite marks on his nipples – *wait!* – there was also *the strange monologue* that Carolina had whispered into the ear of Jonah Feldman.

The words were unforgettable, notwithstanding the fact that Jonah had forgotten much of the evening. They came back to him now, and the heart of Jonah Feldman was heavy with dread at these fresh remembrances. These words, perhaps, were the thing that had made him sorely afraid, that made his occluded arteries skitter as with an *SOS*. He tried to eat breakfast as usual, but there was a weakness in him whenever the words returned to his ailing consciousness. Of course, this was evident to his beloved mother, who kept intruding, *Are you feeling well? Honey, will you examine him? There's something wrong, I can see it*. However, his father, the excellent orthopedist, erred on the side of medicinal disbelief where his children were concerned, would not examine his son, as even Abraham himself would not give his son a reflex test, nor perform a throat culture, unto the moment when *the Lord* said that *the sacrifice should now be performed*. On weak legs, Jonah Feldman, in slippers and robe, walked out of his house in search of the copy of *Newsday* on the front step, but transmogrified now, into a *prophet of the Word*.

It would be best if it could be reported that Jonah Feldman of Maspeth, Queens, was such a faithful servant of his recent *hallucination of the Lord* that he immediately, in his bathrobe, embarked on the purchase of plane tickets from the airport called LaGuardia, from which a commercial airliner would then take him to our nation's capitol, where he would board a commuter flight to Lynchburg. There, he would descend into the pit of wickedness called Lynchburg, so as to prophesy variously as to the *thousands of words* hidden in each and every word, the secret languages of *the Lord* hidden in plain sight, etc. Unfortu-

nately, it must be set down here that Jonah Feldman instead walked up the block, halted before Kaplan's Delicatessen, tried to dial Carolina from a scribbled phone number in the pocket of his robe. *Number out of service*. His intention was to ask Carolina, if indeed this was his name, to repeat these numinous things Jonah believed he had heard the night before. *For if he had heard them,* was it not the case that Jonah had been selected for a great and terrifying burden?

Jonah Feldman, in the convexity of uncertainty, made as to flee from Maspeth, Queens. The fleeing came as naturally as breathing or eating, for he was not even observant these days, nor was he old enough to bear *the Word of the Lord,* and he was not a professional success, nor did he have the fire in him which might make him a logical spokesman for the poor or spiritually challenged. *So he fled*. His destination, on this particular morning, was the township of Port Washington, of the island which stretches easterly into the sea, where a certain high-speed boat, the *Ledyard,* owned and operated by the natives of this land, served as a ferry service purposed upon their sovereign tribal nation, which in turn featured an emporium of games of chance and skill. Good business for all involved, boat, casino, taxes, jobs. Since it was the Sabbath, the *Ledyard* would be sparsely occupied, except by the most grizzled of habitual gamblers. They'd be making their way to the casino in an attempt to win back large parcels of gold and real estate they'd lost the week before betting on sports events. Yes, this would perhaps be a place that *the Lord* would not chance to look for Jonah Feldman, formerly of Maspeth, Queens, now a slightly disheveled man wearing terrycloth bathrobe and slippers, clutching a hundred dollars of currency that he had not used the night before to secure the services of a male harlot. So he paid the fare and went down into the boat, so that he might journey to southeastern Connecticut, far from the presence of *the Lord*.

How quickly that tempest was upon them! The high-speed boat, the *Ledyard,* designed to be faster than the clotted federal highway grid in transit to the heavily taxed casino, was equipped with all useful conjuring devices, with a *global positioning system,* with Loran, with depth finders, forward thrusters, etc. It even featured the Weather Channel, on a monitor in the cabin. Yet the spokesmodels broadcasting from the Weather Channel could not explain how this new *weather event,* soon to collide with a northeasterly storm streaking down the eastern seaboard from Newfoundland, had so quickly cohered into an unpredictable *category four hurricane,* name of Katherine, just as the mariners of the craft were steering off of Port Jefferson. The tempest, when it neared the coast, which it did with fearsome alacrity, made all other such storms look like the digital animations from our national dream factory. Waves so high that they disappeared into clouds, gales that betimes lifted the boat from the very sea, rain and hail, all manner of precipitation. The tempest was ancient, mythical, and the mariners despaired, for their high-speed boat was disabled and adrift and they could no longer divine their position. They each shouted to individual gods, which gods had as many names as there are words to describe them, likewise they shouted to their money managers and insurers, their polarity therapists, their yoga instructors, their talk radio hosts, their acupuncturists, their chiropractors, their psychopharmacologists. And then they began throwing things over the side. They threw over-

board the magazine rack from the cabin of the ship, they threw out all the sweetmeats and foodstuffs from the snack bar, they tossed out television monitors, they threw out their baggage, their expensive overnight bags, they threw out the benches, they threw overboard at least one small dog. For the ship was *going down* and, if so, would go in a denuded state, that even one life might be thus saved till the last. The dread of *the Lord* was heavy upon the mariners of the *Ledyard*, likewise the passengers.

Jonah Feldman, who knew finally that there was *no locale to which he might flee,* nonetheless attempted to secret himself in the *men's room* on the boat, *the comfort station,* even if this were unlikely to impede the all-seeing omnipotence of *the Lord*. He drank a flat cherry Coke and muttered that his parents would never forgive him, his neighborhood would never forgive him, his employers would never forgive him, never mind he had done *nothing,* had never asked by way of supplication or through any other means, to become a servant of *the Lord*. In consideration of these requests, he fell fast asleep, because he suffered a little bit with the demon *narcolepsy,* at least where afflictions of the heart were concerned. It was here, asleep on a commode, that he was discovered by the captain of the aforementioned craft. *Wake up, buster!* One of those taciturn mariners with hands like catcher's mitts, with a ruddy, striated face, with a knitted cap, with a scar running perpendicular to his jaw line and down below his chin line to his very breast. Might as well have had a wooden leg. He wore a complete uniform of foul-weather gear. *Wake up! And get your ass above, because we are going to draw lots to see who to throw off the boat first!* The ship once again listed violently to one side. In a timid voice, Jonah inquired if there were not lifeboats or life rings or other flotation devices that might be thrown off the boat with whomever was first to go. The captain chastised him with popular and offensive terms of derision for the unmanly, and then he additionally remarked, *Just get your fat ass topside, if you want to live*.

Above board, where the windows had all been shattered, passengers bled and moaned and gnashed their teeth and huddled in a small maintenance closet. Here the captain laid out his vision for orderly abandonment of the craft: *I have a number of these matchsticks that I use for toothpicks and I have busted one of these very matchsticks down to a nub, and we are going to draw lots from these – one person, one matchstick. I propose that we toss the first poor sonofabitch selects the nub overboard with a lifejacket, since I don't know how much longer we can count on the seaworthiness of this boat.* Of the twelve miserable gamblers in the maintenance closet, all agreed to the plan, naturally, as it had a betting aspect. They cast lots, and the *nub,* as if the captain had fixed the game, fell to Jonah Feldman. Gamblers are *readers* first and foremost, they are readers of the skies, readers of the faces of dealers, readers of auguries, of birds, of dates, of numbers, of names; gamblers are diviners, no flock passes overhead that is not portentous to them. These gamblers had their schemes, they had their racing forms, they had their ideas about the order of the things, they knew prophets and prophecy, and when Jonah Feldman was revealed, through possession of the *nub,* as a man of particularly dark luck, the gamblers fell upon him in a fierce inquiry into his significance. An older man with cracked spectacles and excessive amounts of cologne, offered a brief kind word, before demanding, *Just clue us in here, what's with the instantaneous hurricane, and what's your job, and where do you come from, and where are you going, and*

what is your ethnic and racial self-description and why have you brought us to this dark place?

Jonah Feldman cried out to them all, *I'm a Jew and I'm a homosexual person, I am both, and I won't dissemble here, even if you should throw me over the side. And I fear the Lord, I mean the actual God in actual Heaven, Author of both sea and the dry land, also Author of the results of all games of chance and presidential elections, likewise Author of the stars and equations of physics, including Planck's constant.* The gamblers saw immediately, at least according to their Manichean philosophies, that having a *Kosher Fag* on board their boat was a very bad omen, even if in public settings they professed a certain acceptance of both categories attested to by Feldman's ethnic, political, and religious self-designation. They didn't *want* to throw Jonah to his doom, because they figured it too would be impossibly bad luck, and because it seemed morally dubious, but neither did they want him on the boat. So Jonah said to them, *Take me up and throw me into the sea, since it's for my sake that this tempest is upon you.* By which he meant that there's always a tempest, and always a guilty party, and he was willing to be done with the brief interval of his promising life and proofreading job at Price Waterhouse, he was willing now to be courageous and dead, for tempests are full of revelation. He had done what he ought *not,* he had avoided his duty, and so he must perish. Jonah Feldman asked only for a lifejacket, which at first seemed plausible, but then there was a violent rolling of the craft and a wave of such magnitude that it was as if a sheet was drawn over them, and the twelve gamblers and the crew and the captain knew that their destruction was imminent. They picked up Jonah Feldman, humbled and resigned, and they shoved him through a shattered portal, into the fathomless deep, into the dark draperies of the underworld, and he was gone.

Whereupon the sea ceased from raging.

Immediately, the high-speed ferry, the *Ledyard,* in its grim, senseless course came to a halt, too. Ahead were the splendid cliffs of Block Island. Gulls fluttered above the breakers, sentries at the entrance to this more pacific kingdom. Twenty miles or more the mariners must have come by chance, buffeted by the tempest, soon to have washed up on the rocks here, had not the storm vanished. The sun peeked from behind a riot of clouds. The gamblers were prepared to cash out. There would be no five-card stud today. No craps.

In the meantime, *the Lord had prepared a great fish to swallow up Jonah.* It is possible, of course, that *the Lord* might have beached him on Plum Island, nearby, where the federal government was torturing monkeys and baboons with *bacillus anthracis,* where they refined and aerosolized Dengue Fever and Hantavirus and Ebola and the Plague. This would have been appropriate recompense, but it did not come to pass. *The Lord* did not beach him there, did not let him wonder about grace and mercy while scraping off ulcerated nodules in the twilight of some hemorrhagic swoon. Likewise, *the Lord* might have imprisoned him in a nearby East Hampton restaurant, working without benefits alongside a number of foreign nationals, washing dishes, and bunking with these foreign nationals in a trailer park. There he would have had time to rethink his resistance to *the Lord,* his disinclination to undertake the work that had been given to him to perform. Instead, *the Lord* prepared a great fish.

Into the water Jonah Feldman tumbled, into that tempestuous water according to which there was no up and

down, nor East and West, just expanses of darkness which compassed about him even to his soul, and he felt the last bit of air in him bubbling forth, he saw the jumble of images from his life, his *tuckus* smacked in the Long Island Jewish Hospital; his *bar mitzvah,* and the speech he gave there on the subject of great Jewish baseball players in the early part of the twentieth century; the first older man who, behind a druggist's in Maspeth, Queens, begged to be allowed to part the mysterious folds of Jonah's trousers; likewise the girl his parents nervously found to be his associate, perhaps one day to be his bride; then her contemptuous whispers to him at a temple dance; weeping one night after taunts from high-school friends; awake later, wandering the second floor of their house in Maspeth, Queens, encountering his grandmother, her hair uncoiled about her shoulders, whispering of *the War*; male prostitutes solicited on the avenue down by the subway, some of them gentle and loving; a hundred dates refused; remonstrances from his bosses at Price Waterhouse; and then, again, dancing with Carolina, until the voice came to him, the recollection of it, *Arise! Arise!*

Redactors gifted in the study and interpretation of fishes have long been engaged to comment on the manuscript of Jonah Feldman: seine haulers, surf casters, trawlermen, pearl divers, harpoonists, fly rod specialists, an entire community of anglers. The opinion of these redactors is that the first fish sent for Jonah by *the Lord,* namely a variety of large shark not unknown in those northern waters, absolutely could not have swallowed him, was not physically able. Moreover, a shark is stupider than any large thing in creation. Sharks were made for the sole reason that deadly things are beautiful. Therefore, the fish in question was not that certain kind of shark, that animal which must move or die. It circled around the missile of Jonah Feldman as gravity sucked him down toward the continental shelf. It circled but did not bite. There would have been ribbons of Jonah. The redactors have spoken. A second fish was summoned. The fish was *leviathan,* in particular, it was the blessed Blue Whale, hunted to the edge of its elimination from this world, and it bore down upon Jonah. *The Lord* actually contacted the Blue Whale, preliminarily, asking for indulgence in this matter, *Friend Whale, may I bother you to swallow this particular human being for a brief interval? I know you are an eater of plants and a peaceful being, and I know you fear for your life, as there are anglers in pursuit of you, but this human being needs some three days to reflect and atone, and I would prefer him to spend time where the surroundings provide for both revelation and the great delicacy known as fish cheese.*

Fish cheese! *The Lord's* wonders are mysterious to behold! In the northern countries where it is considered a delicacy, it is called *hákarl,* putrefied fish that is buried for up to a half a year. (It is tolerable only in advanced states of inebriety.) The whale replied, *Happy to serve, as I must,* its melancholy eyes downcast. Taking a mighty breath into its awesome lungs, it dove deep toward the arc of Jonah's fall, and swallowed him up, sweeping in alongside Jonah a healthy portion of plankton and a few automobile tires. Its teeth were not so much knives as brushes, Jonah recognized, or so he felt coming out of the hallucination of his afterlife, a purple corridor populated by dead acquaintances described on television programs. The throat of the fish was not so much gullet as waterfall, in which whole swamps of

vegetal life swirled and mixed in a stew of nutrition. Before he even had a chance, he was swept over these falls and pummeled by the squeezing and dousing of fish peristalsis. It was an hour or so in that esophageal coil, and it reminded him of the time he had the *MRI*, though without sedative. But the entertainment had not even begun, for after the hour of acid-drenched peristaltic massage, he fell end over end into a large unlit room, about the size of a domestic recreational vehicle, spongy floors, about one-third full of liquid as well as marine life and plants and man-made plastics. Among the finds: a short-wave radio, still functioning; a cardboard box, containing red rubber gymnasium balls; a beach cooler, housing a six-pack of a bland domestic beer; and one human skeleton. Before long, he resigned himself to the temperature of the mixture, and to yet another shower of surprises that would rain down upon his head from above, including the occasional muffler, or other injurious missile, as well as live eel or skate or harvest of seaweed.

And there was the smell! The rankness of the *fish cheese*, of death, of eternal decay, where every fishy thing began its decomposition, where living things were scorched and liquidated into a sequence of vitamins and protein chains. It was an awful smell. Jonah Feldman had been in a nightclub in the West Village only the night before, where every man looked like an angel, where the lighting was low and the promises perfect, and now he was in the belly of a whale that ate auto parts and shat them into the North Atlantic when the spirit moved. It was only so long before he was himself excretory. A miracle that he lived thus far, to be sure, that he lived inside the stomach of the whale, but what good is a story of prophecy if it doesn't have a miracle in it? Prophecy is a kind of language, and language is a kind of imagination, and imagination is a kind of desire, and desire knows no containment, wants what it cannot have, and in wanting it *sees*. So Jonah Feldman had three days in the belly of a fish to think, to reflect. Jonah reflected. On the first day, after being bitten by something, some predator that he had to squeeze to death with his bare hands, Jonah reflected, and in the night he likewise reflected, though strictly speaking there were no days or nights there. At first, these reflections had the cast of his own life, and he saw the silhouettes of the Catskills, he saw his parents playing cards, he recalled the night on which he'd been assaulted on 21st St., he saw various academic contests, from elementary school, from Hebrew School. Then the cast of these reflections took on, instead, the rosy tones of desire, the physiques of certain boys and then certain men, the curve just above the hip of a man when he is no longer wearing any clothes, likewise the lips of men, and the tendons in the necks of men busy about their exertions, calves of men, abdominal muscles, and these particular reflections were good and many hours passed according to them. But then, without companion or fellow with whom to commiserate, he thought of *the Lord*, conceived of that thing inconceivable, he worked around the edges of *the Lord*, felt the impossible heft, or at least pointed in the direction of *the Lord*, by enumerating such things as the no-hitter, the paintings of Mark Rothko, the film performances of Judy Davis, all of which seemed to suggest *the Lord*, and amid his reflections he composed a prayer for the forsaken, memorizing it until he could call out its words in his foul-smelling imprisonment:

Thou Celestial Agency,
Who smiles on boys beaten senseless in the gymnasiums of America,
Cleave near;
Cleave near to the contused, both those who in their disgrace *tell tell tell,*
And those who mutter nothing and enfold memories deep in the filing cabinets
Of dark juvenilia, *Thou Celestial Agency,*
Perform not thy vanishing act again;
Shower infinite compassion on those who know polysyllabs
But rarely utter them;
Love all lovers in exile;
Love the impossibly obese, love the leprous, love the homely, love the
Embittered, love transsexuals, love eunuchs and pedophiles,
Love all abdicators and deniers;
Love all those with unusual gaits and bad speech defects,
Love Jews and Armenians,
Palestininians and Tibetans, love Chechens and Albanians;
Let the names of hatred be made into names of
Delight,
Thou Celestial Agency,
Until all degradation is past;
Bear up accretions of words and names of disgust,
And build a new ocean to contain them;
Thou Celestial Agency;
Thy ideas are sometimes bunk,
But you bisected day and night and thus fabricated the dusk and the dawn,
The perfect poise between things;
Love thou the disenfranchised who crowd around your absent shadow, unable to
Finish their business;
For you made *masculine power* and made the football coaches and posturing,
Steroid-addicted simians who are drunk with it,
Bear up those who lie awake at night, pacing the floor in convulsions of
Exile, who weep such torrents that dry fields everywhere are irrigated with the
Floods of their misery – which tears are more numerous?
Give the batterers a *stern talking to, Thou Celestial Agency,*
For they have bilked every shareholder;
For they have *staffed and directed every army,*
For they have directed every dictatorship,
For they have purged every dissenter,
For they have applied the electrodes to every political prisoner,
For they have committed every genocide.
How the hour grows short, *Celestial Agency,* there will soon be only the batterers
And their veiled wives,
Show us your justice and we will lay down our vanities.

When Jonah had finished his prayer, there was a sigh in the world, and *the Lord* caucused with the Blue Whale and gave him instructions, and the fish then vomited up Jonah Feldman on the coast of Virginia, next to an expensive and ill-decorated hotel. The whale, now beached, was immediately photographed for the nightly news. However, the man at the site in the fouled terry-cloth robe went unseen into the bush, with no camera nor reporter to demand of him that he tell the story of the miracle of three days in the entrails of a North Atlantic whale.

Fiction by Rick Moody

What is the greatness of a great person? *That person is not ashamed to say I don't know.* For this was the predicament of Jonah Feldman of Maspeth, Queens, who now smelled like the secret life of a bulimic! His slippers were torn! His beard was three days grown out! His thinning hair was matted against his scalp! Jonah Feldman, prophet of *the Lord,* now resembled most a deinstitutionalized schizophrenic, and the citizens of the commonwealth where he had washed up knew not what to think of this, a St. Jerome in the wilderness, a holy man whose martyrdom is to write *the Word of the Lord.* And they therefore feared this new ghostly presence in the countryside. Nevertheless, the fashion stylings of the itinerant psychotic were generally favored by *the Lord,* and if man were indeed made in the image of *the Lord,* might one not conjecture that the raver in the countryside was most what *the Lord* himself looked like, or else why such a prevalence among men?

In the course of his march, Jonah meanwhile chanced upon *the most beautiful place he had ever seen,* for there were not many beautiful places in the borough of Queens, not like this wilderness at the seaside, with its *wild horses.* It seemed scarcely possible that he could have come from the belly of a fish, only to walk but two or three miles away from an ill-decorated hotel to find himself in pristine wilderness, where horses gamboled and galloped and did not take the bit. He saw the pack of them, their manes stirred in the breezes, their haunches as sleek and perfect as anything made by *the Lord,* rearing up onto their hind legs, so that the adolescent stallions could engage in feats of skill and disport with the females. They trampled an open field, and then the males and their mares disappeared into a coniferous wood, thundering across accumulations of soft pine needles. What better emblem of the imperial reign of *the Lord,* the movement of noble beasts upon their last free ramble. Jonah Feldman was sure he was dreaming, by reason of his ordeal. For in a moment, Jonah again heard *the Word of the Lord,* almost as if the voice came from *a talking horse,* although he was pretty sure that talking horses were confined to television situation comedies: *Arise! And go to Lynchburg, Jonah Feldman, for I believe that we had an agreement that you did not honor. Go there and preach to the failed readers and interpreters. Do as I have bid thee.*

Jonah, the prophet of *the Lord,* had not had a decent meal in days, excepting some sea scallops that he had eaten in the Japanese style while inside the fish, and he was hoping to have some Chinese food, or perhaps a curry, anything but seafood. Yet now he understood that ignoring any voice in the wilderness was no longer an option, unless he wished to see earthquake, flood, volcanic eruption, bioterror incident, etc. Through a variety of means of transport, including rowboat, freight train, eighteen-wheel truck, and of course the lowly pedestrian means of transportation, Jonah, in three-days time, traveled directly from the islands of the mighty ocean, across the bay, past crabbing operations, shrimp boats, deep-sea rigs, past the naval mariners in their crafts, inland, across the James River, past hunters and moonshiners, farmers of tobacco, farmers of dairy, truck farmers, agriculturalists of all varieties, through counties with names like Dinwiddle and Amelia and Appomattox, until he was in the interior of the state, in the shadow of the Blue Ridge peaks. Then along a county road strewn with franchises, he came to the city of Lynchburg. He recognized a fiendish cloudbank above him. He felt rain begin to fall. Around Jonah Feldman

there were the portents of the imminent destruction of Lynchburg. *He could see.* For he was a prophet. He made his way directly to a certain chain store that specialized in office supplies, and there he begged for a felt-tip marker and such items as might be fashioned into signage, and then he walked into the town. At the rear entrance to a supermarket, he commandeered a milk crate. Further he walked.

At length, he came to the television broadcasting facility of a televangelist. When he reached this place, he knew that his life's journey had culminated according to the will of *the Lord.* There was a great evil there, and much neglect of the millennia of prophecy that had been organized into the books of *the Lord,* for example the words of lovers, *Come, my beloved, let us go forth into the field; let us lodge in the villages. Let us get up early to the vineyards; let us see if the vine flourish, whether the tender grape appear and the pomegranates bud forth: there I will give thee my loves.* These words had been forgotten, in this spot, and many others besides. And Jonah Feldman took up his signage, and he affixed language to it with the felt-tip marker known in these lands as a Sharpie, as follows: *Free Remedial Reading Lessons! Apply Herewith!* And, beneath: *In forty days, Lynchburg will be consumed by fire.* Then, in a tattered robe, through which his capacious belly was sometimes protuberant, and wearing slippers fashioned from castoff newspapers, smelling like vomit and human soil, unshaven and raving, Jonah Feldman of Maspeth, Queens, preached the glory of reading in front of the security gate of the television station. This went on for many days. At times, the workers of the television station fed Jonah Feldman with fast-food snacks they purchased on their lunch breaks. He thanked them effusively. He said, *I know I look pretty bad, and I'm sorry to be a pest, but I am doing the work of* the Lord. *I will try not to frighten your children.*

Perhaps the arrangement would have persisted, were it not for the sudden arrival of the overlord of this empire, *the King of Blinders,* autocrat of poor reading skills and anti-evolutionist, scheduled to perform that day on his television station for cameras national and global. He was due in makeup, to have his comb-over combed over, to have his pancake applied, to have lipstick faintly smudged across his lips, though he had decried all harlotry and excesses in the matter of appearance. Jonah wondered, as follows: What did it mean to this man to be a lover? Did it mean to care for the indigent with the love that *the Lord* cared for them? Did it mean to awake with worry? Did it mean to attempt perfect compassion? And could this guy read at all? In his cavalcade of limousines, *the King of Blinders* paused for a moment in front of the security gate of the television station, and in that moment, he glimpsed the repulsive freeloader in front of his building, who no doubt, according to *the King of Blinders,* was a product of miscegenation or bastardy. *The King of Blinders* indicated, then, with the faintest of gestures, that an aide in the limousine was to incline an ear to him, and thus the king spake, *Have that guy removed.*

The aide nodded.

The beating, when later administered to Jonah Feldman, was prolonged and merciless. *A soft answer turns away anger,* it is said. Not in this story. He was carried away by men who set records in their high-school football leagues for sacked quarterbacks. They took him to an alley behind a dry cleaners, long after dark, and they knew no sympathy. First these men impugned Jonah's dignity, telling him that he no longer smelled like a

man, but instead smelled like an animal, and then they told him that he was no man, since he would not fight like a man, and many bruises were administered, and there was a cracking and crunching report that issued from Jonah in the region of his nose, and then perhaps also from his jaw, and the men said he was lucky that they didn't *fuck* him, just to show who was boss, but they preferred to *fuck* things that smelled a lot better; lids of trash cans in the alley were used as righteous instruments by these men, until Jonah's head was abundantly swollen, and his eyes shuttered. He had much internal bleeding, and now he was naked and alone. It occurred to Jonah, in his suffering, that it was all madness, that he was a mad person, that the drug that had a *k* in it had *kicked his ass*, that he had been beset by Klansmen, or their confederates, and that *the Lord* had been replaced, in this instance, by the *knavery* of this world, where all was *knockdown-dragout*, where all was *knuckle sandwiches*, where all was *kidney punches*. His madness was clear, it was in his obsession with words to the exclusion of things, his obsession was with sounds that rang in his head, as though the sounds themselves were *the Lord*. This was not enough. He was bereft. Without *the Lord* to intervene, without compassionate soul to tend to his wounds. He was abject in the sight of the world. In this abjection, he composed a second prayer, mumbling it, in his extreme affliction, in the alleys of the city of Lynchburg:

Thou art a gracious *Celestial Agency,*
Merciful and slow to anger, and of great
Kindness,
But why spare
A town full of bigots? Why spare guys who
Hate their wives and belittle them?
Why spare callousness and violence?
And what ever happened to nonviolence,
Celestial Agency?
Was that just a line you favored for a while?
Take, I beseech thee,
My life from me,
For it is better to die than to live.

Might have been the pain; might have been the ordeal; might have been three days in a fish's belly, might have been the drugs; might have been the loneliness of many years; might have been the abuse of older men who loved him and abandoned him; might have been the vilification of generations, the vilification that was like a second heartbeat in his breast; might have been the night; might have been the South; might have been an illness of the soul that had taken root in his fathers and forefathers, *the illness of insight*, how else to explain why for some prophets *it just got worse*. Their families fetched these prophets and carried them to private hospitals where they might rest, where they could be given prescriptions so that they might *forget*. Still, before all this happened, before Jonah's father and his wife came to the city of Lynchburg to bear away their first-born son, the voice of *the Lord* came one more time to that delirious prophet, *Why shouldn't I spare Lynchburg, where there are more than sixscore thousand persons that cannot discern between their right hand and their left?*

Bernard McGinn

on mysticism & art

It may seem strange that in the Christian West, mysticism and art have gone hand-in-hand – strange, because the conjunction is paradoxical. Precisely because it involves a hidden and secret perception of God – the root meaning of *mystikos* – the mystical element of religion ought, by definition, to defy pictorial representation. Mystics have wrestled with language as the necessary, if insufficient, tool of their imperative to invite others to experience an otherwise ineffable God. But why would they need pictures? What is inexpressible in words may seem even further removed from any kind of visualization.

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Still, recent study has shown how often the teaching of Christian mystics found pictorial expression – as images created either by the mystics themselves or their disciples. Since mysticism is a contextual phenomenon embedded in a religious worldview, scholars have also observed that art not only can be a way for mystics to communicate what they are trying to teach, but that images have also helped shape the minds and imaginations of mystics. If the mystic text is an experiment in saying the unsayable, then the mystical image – something far more widespread than once thought – emerges as a fascinating attempt to see the unseeable.

Over fifty years ago, Millard Meiss, in *Painting in Florence and Siena After the Black Death: The Arts, Religion and Society in the Mid-Fourteenth Century* (1951), acutely observed how images influenced mystical accounts, especially in a chapter devoted to Catherine of Siena, the fourteenth-century Italian mystic. It may now strike us as no surprise that mystics' descriptions of encountering God were influenced by the pictorial aspects of their culture. What is surprising is that until the past decade or so there has been so little scholarship on the nature of this influence.

Recently, however, a number of art historians have begun to explore the rich interchanges between art and mysticism. Among these are the late Michael Camille of the University of Chicago, the Italian Chiara Frugoni, and Thomas Lentes of the University of Münster, who helped found the only doctoral program that gives a joint degree in theology and art history.

No one has done more to explore how images are a resource for the study of mysticism than Jeffrey Hamburger of Harvard. From his Yale dissertation published as *The Rothschild Canticles: Art and*

Note by Bernard McGinn

Mysticism in Flanders and the Rhineland circa 1300 (1990), down to his recent *St. John the Divine: The Deified Evangelist in Medieval Art and Theology* (2002), Hamburger's contributions have shown how mystical images are more than just illustrations for texts, but are integral aspects of the presentation of mystical teaching. It is a message that theologians and students of religion have unfortunately been slow to recognize.

Among the most fruitful avenues of research into the relation between art and mysticism has been that of devotion to Christ's Passion, especially forms of literal imitation of the Passion widespread in the late Middle Ages. While not all Passion images are related to mystical *imitatio passionis*, there was a strong link between Passion art and Passion piety between 1200 and 1500 that has opened up new dimensions for the study of how devout Christians sought to identify with Christ on the cross. Pioneering work in this vein was done by James H. Marrow (*Passion Iconography in Northern European Art of the Late Middle Ages and Early Renaissance*, 1979). In the past decade a number of new studies have cast further light on how representations of the crucified Christ help us understand aspects of late medieval mysticism.

Another rich field of investigation centers on the erotic relation between the soul of the mystic as bride, and Christ as the divine Bridegroom. Since the time of Origen (d. 254 C.E.), the Christian mystics read the *Song of Songs* as the premier guide for analyzing the transcendent erotics of the love affair between Christ and the soul. In their commentaries, Ambrose of Milan and Gregory of Nyssa among the early Fathers, and Bernard of Clairvaux and William of Saint Thierry in the Middle Ages mined the tropics of desire found in the *Song of Songs*. From at least the twelfth century, we also find images of the mystical love affair – some based on the descriptions found in the *Song*, and others that create original iconographic forms, such as the heart as a house or dwelling for the Bridegroom. Despite some specialized studies of merit, there are no adequate general works on this important tradition in mystical iconography.

Perhaps the most surprising chapter in the story of mystical art in Christianity concerns the role of the Trinity – belief in the action of the Father, Son, and Holy Spirit in the inner transformative process. According to Christian belief, the Son took on human nature and therefore became visible and capable of being portrayed. The defenders of icons successfully argued this case in the great controversy over the legitimacy of images in the eighth and ninth centuries. Furthermore, the New Testament teaches that the Holy Spirit also became visible, at least in symbolic form, as dove (Mt. 3:16) and fire (Acts 2:3 – 4). But, as John 1:18 put it, "No one has ever seen God [i.e., the invisible Father]." *A fortiori*, the Trinity *qua* Trinity is invisible, and beyond all imagining and thinking.

Although Christian theologians and mystics as early as Augustine and Gregory of Nyssa at the end of the fourth century had already begun to analyze how the Trinity acts in the depths of the soul to bring humans to deeper participation in the divine life, they were suspicious of visual representations of the triune God. Augustine's strong sense of divine ineffability led him to condemn all attempts to portray the Trinity, even with abstract symbols (see *Letter*, 120).

But not all Christians agreed with him. There is a rich tradition of attempts to create images of the Trinity, both in Eastern and Western art, as well as a continuing debate over what kinds of images are acceptable. At least some of

these images can be connected, directly or indirectly, to speculation on the role of the Trinity in mystical transformation.

Attempting to portray the invisible Trinity present in the soul can be described as a limit situation of Christian mystical art: something that is impossible, perhaps even forbidden (as Augustine wished), and yet also imperative for some.

Around the year 1420, the Russian monk Andrei Rublev 'wrote' (as icon painters phrase it) the image of the Trinity. He depicted the three angels that appeared to Abraham at the Oak of Mamre (Gen. 18). This icon, which today hangs in the Tretyakov Gallery in Moscow, is the most famous example of a form that goes back to the fourth century. Early Christian exegesis of the mysterious Genesis account had either interpreted Abraham's vision as Christological, that is, as an appearance of Christ accompanied by two angels, or as a symbol of the Trinity. According to Origen, "that appearance of the angels signified a mystery more than angelic, because the mystery of the Trinity was set forth there" (*Commentarium in Canticum Canticorum*, 2). Exactly how the three angelic figures, whom, according to tradition, Abraham 'adored as one,' portrayed the Trinity was subject to debate, but this unusual iconic form came to be canonized in the Christian East.

While the 'Hospitality of Abraham' (as it was called) originated prior to mystical speculation on the Trinity and cannot be directly tied to a particular mystical system, the icon was used for centuries within a religious world where consideration of the role of Abraham as a biblical model for contemplation was richly developed. Significant mystical authors, like Gregory of Nyssa and the sixth-century monk Maximus Confessor, contributed to this tradition, and quite possibly to mystical interpretations of the image. In the twenty-eighth of his *Questions to Thalassius*, Maximus speaks of Abraham as "the true gnostic [i.e., mystical knower] whose mind had already transcended matter and material types so that God taught him that the immaterial principle of the Trinity inheres in the principle of the Monad. It was for this reason that God appeared to him as three but conversed with him as one." Someone steeped in this thought could make use of the Trinity icon to *become* like Abraham, that is, to gaze with gnostic vision, rather than crude materialistic sight, *through* the image in order to gain deeper union with the invisible Trinity.

In the medieval West there are some fascinating examples of programs of Trinitarian representation that can be more explicitly tied to mystical texts and practices, such as the Trinity images in the *Rothschild Canticles* (c. 1300) and some of the illustrations for the Office of the Holy Trinity found in the *Hours of Catherine of Cleves* (c. 1440). What is particularly intriguing about Western Trinitarian art, though, are the cases where we find mystical authors who became their own iconographers – mystics who created their own images as a necessary way for presenting their message.

For example, Joachim of Fiore (d. 1202) constructed an elaborate Trinitarian theology of history that included hope for an imminent final age of communal contemplation on earth. The Calabrian abbot recognized that his often obscure thought could be best communicated by the intricate diagrams he called *figurae*, a number of which present the relation between the Trinity and humanity's growing mastery of contemplation.

A century and a half later, Henry Suso (d. 1366) was equally fascinated with a

need for using "images to cast out images" in the path to union with God. He commissioned a dozen pictures for the *Exemplar*, the definitive edition of four mystical treatises he produced not long before his death. To illustrate the final chapter of his *Life of the Servant*, Suso created a picture manifesting how the soul comes forth from the hidden divine abyss through the action of the Trinity and finally flows back again through the three persons into the darkness of God. This image not only attempts to visualize invisible mysteries, but also provides a synoptic view of the Dominican's teachings.

The revival of mysticism in recent decades may appear puzzling to those who see religion as an uncomfortable survivor in a scientific world. Whatever one's attitude toward the mystical dimension of religion, the study of mysticism has revealed a rich tradition of artworks that continue to intrigue us by their paradoxical effort to make the invisible somehow accessible to our gaze.

Yi-Fu Tuan

on human geography

As it is practiced today, the academic field of geography spans the entire spectrum of disciplines, from the physical and biological, through the social and economic, to the humanistic. It is weakest today, however, at the humanistic end, and I have often thought that my field might have avoided this fate if we modern geographers had drawn more inspiration from the Humboldt brothers – Wilhelm the humanist (1767 – 1835) and Alexander the explorer and natural scientist (1769 – 1859). Alexander von

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A Fellow of the American Academy since 2002, Yi-Fu Tuan has received honors from the Association of American Geographers, the National Council for Geographic Education, and the American Geographical Society, and was elected a Lauréat d'Honneur of the International Geographical Congress. He is perhaps best known for his landmark study of "Space and Place: The Perspective of Experience" (1977), a work that not only established the discipline of human geography, but also has proved influential in such diverse fields as theatre, literature, anthropology, psychology, and theology.

Humboldt of course made lasting contributions to the fields of physical geography and biogeography, adding to our knowledge of plants, animals, and the earth. He also added significantly to our knowledge of what I call 'human geography' through his histories of landscape painting and nature poetry. All he lacked as a humanist, so his older brother Wilhelm said, was "a quiet contentment in himself and in thinking." A quiet and persistent thinking is certainly one virtue that I have tried to exemplify in my own contributions to the field of human geography.

I have explored a number of different topics in the ten books I have published, but three themes are recurrent: the felt-quality of place, the psychology of power, and culture as imagination.

One way to approach the felt-quality of place is to do a detailed study of a particular place in novelistic detail. I chose not to follow this path, addressing the felt-quality instead from the opposite direction – that is to say, from the universal human endowments of synesthesia and language. Synesthesia is the blending of the senses such that, for example, when one hears a sound one also sees a color. (Language points to its synesthetic grounding when we say, for instance, "What a loud tie you have" or "It's bitterly cold.") To synesthesia many objects owe their particular vividness in our imaginations.

Synesthesia is an advantage to young children because it helps them to locate and fixate on the world's objects; when strongly developed, however, it promotes hallucination. As children grow older and acquire a certain fluency in language, synesthesia weakens, its function to enrich the world being taken over by the metaphorical powers of language. Defined in parallel with synesthesia as the blending of images or concepts, metaphor enables us to make concrete what is diffuse, familiar what is unfamiliar.

Nature is vast, complex, and threatening. It seems less so when we can predicate it on parts of our body, which we know intimately. So we say: headlands, foothills, mouth of a river, spine of a ridge, shoulder of a valley, arm of the sea, and so on.

Even the objects we manufacture ourselves can seem distant and coolly indifferent. To minimize that possibility, we bind artifacts to our anatomy, saying: eye of a needle, spine of a book, hands of a clock, legs of a table, house as body, and body politic. Not just metaphors, but the full resources of language are available to us as poets – and we are all poets to some degree – to firm up the emotional bonds between ourselves and the world.

The world is made up of specific objects (foothills, tables, etc.), but also of more abstract entities such as space and spaciousness. How does language cope with spaciousness, making it more real and vivid to us? One way is to use the specialized vocabulary of numbers. For example, *South English Legendary*, a popular medieval work, conveys the vastness of space by saying, "If a man could travel upwards at the rate of more than 40 miles a day, he still would not have reached highest heaven in 8,000 years."

But more common is to use a geographical vocabulary that can stimulate our imagination, as an anonymous Chinese poet in the second century B.C. and Wordsworth in 1805 do in two poems that bear striking similarities. The Chinese poet writes, "Who knows when we shall meet again? / The Hu horse leans into the north wind; / the Yüeh bird nests in southern branches: / day by day our parting grows more distant." In Wordsworth's poem, just how solitary is the Solitary Reaper? How vast is the

space that envelops her? For answer, Wordsworth evokes, to one side, "…weary bands / Of travellers in some shady haunt, / Among Arabian sands," and, to the other, "…the cuckoo-bird, / Breaking the silence of the seas / Among the farthest Hebrides."

A theme well known to geographers long before it was taken up by the environmental movement of our time is the human transformation of the earth. Ever since Alexander von Humboldt, geographers have studied how forest and scrubland, steppe and swamp, have been turned into arable fields, towns, and cities. This transformation speaks of economic, political, and technological power.

But largely unconsidered by both geographers and environmentalists is the exercising of power for pleasure – the pleasure that is to be had in making gardens and pets. Geographers, like most people, tend to see gardens and pets as belonging to an area of innocence, in sharp contrast to large works of engineering and economic development. Yet, isn't playing with nature and human beings – treating them as aesthetic objects or 'fun' things – even more driven by power, by a power that is not even constrained by economic ends?

Play is not as innocent as we think. I developed that idea in a book called *Dominance and Affection: The Making of Pets* (1984). Water, I say, becomes a pet when we make it dance for us. And we can only make it dance through the exercising of irresistible power – the power of hydraulic engineering and of large labor teams organized along military lines. Fountains, which charm our senses, are blatantly unnatural, and I can just imagine future hydrophiles trying to liberate them from their servile state.

From water, which is alive only in a figurative sense, I move on to plants, animals, and human beings. An outstanding example of violently abusing plants for our entertainment is topiary art. Another is the miniature garden, and bonsai.

Is bonsai a fine art? What kind of fine art is it that regularly uses instruments of torture – knives and scalpels, wires and wire cutters, trowels and tweezers, jacks and weights – to distort plants and prevent their natural growth? Making pets of animals is a familiar story. Somewhat less familiar is the way they are made through techniques of selective breeding into grotesque and dysfunctional shapes, purely for human fancy.

From a psychological viewpoint, power reaches a peak – a peak charged with sadistic-erotic pleasure – when one can turn other people into playthings.

Renaissance potentates kept dwarfs, whom they dressed up, slobbered over, passed around at the dinner table, or presented as gifts to influential friends. Household slaves and servants, if they were comely, enjoyed the status of pets in slave-owning and other strongly hierarchical societies. Women were decorative objects and sexual toys in the Oriental harem. Even in 'enlightened' Western societies, women were legally children – child-wives in dollhouses – until a century or so ago. Today, the temptation to patronize remains and is directed largely at racial minorities and 'our little brown brothers' in the impoverished and developing parts of the world.

A third theme in my work has been culture considered as a product of imagination. By imagination I mean the ability to see what isn't there. A carpenter looks at a wooden plank and sees a bench; Michelangelo looks at a marble block and sees *David*.

Animals migrate when they are pushed. Humans, likewise. But humans also migrate under the lure of a pull –

that is, when they envisage a place 'out there' – say, the New World – that is more attractive. Or they may decide to stay put in the Old World. The pull, then, is an image or plan in their minds that they try to turn into a three-dimensional, material reality. People are never wholly content with what already exists. Having moved to the New World, migrants may in time grow dissatisfied, imagine a better place further west, pick up stakes and move – and do so again and again. Culture as I have characterized it here is potentially progressive.

From this general standpoint, I raise a question that comes naturally to a geographer, namely, What might be the relationship between the quality of environment and the quality of life? As swamps are drained and malaria is conquered, the quality of human life undoubtedly improves. Likewise in a built environment, as peeling walls are repainted, drains are unclogged, and rooms and household amenities are added.

But at what point does adding more rooms and amenities cease to improve, and maybe even detract from, the quality of life – a life that is not only materially but also intellectually and spiritually rewarding? Material things can enslave rather than liberate. But is the same also true of works of art, philosophy, and religion?

Consider an elemental aesthetic experience known to all human beings – that of interior space. The quality of that experience – of what it means to be inside and enclosed – varies enormously, depending on a people's access to great works of architecture. Ancient Egyptians knew the sublimity of exterior space (think of the pyramids under moonlight), but interior space for them was darkness and clutter. Ancient Greeks had the Parthenon on top of the Acropolis to lift their spirit, but its interior was hardly more spacious than the interior of an Egyptian mortuary temple. Europeans had to wait for the construction of Hadrian's Pantheon (118 – 128 A.D.) to acquire, for the first time, the sense of an interior space that was formally elegant, yet sublime – a vast hemisphere illuminated by the rotating sun. Architecture and, with it, the human appreciation of interior space continued to evolve.

This story of architectural/aesthetic progress leads me to ask, What about moral rules and systems? All societies have moral rules, but only a few have elaborated them into systems – into what might be called moral edifices. Are people who live under such edifices – large, complex, subtle, and in some ways beautiful – better off, more able to realize fully their potential as moral beings, than people who live in structures of simpler design – lean-tos, huts, and shelters?

This is the sort of question that deserves quiet and persistent thinking – and makes me hopeful that the humanistic spirit of the Humboldt brothers may yet enrich and expand the field of geography today.

Inside back cover: This small (14.3 x 9.5 cm) and delicately detailed Psalter Map in the collection of the British Library (Add. MS. 28681) accompanies a thirteenth-century copy of the Psalms. A *mappamundi* with the Old Temple at its navel, it is centered on Jerusalem, with Africa to the lower right, Europe to the bottom left, and Asia taking up the top half of the world disk (note the Garden of Eden directly under the figure of Christ). We no longer center ourselves in space. Do we do so in time? See D. Graham Burnett on *Mapping time: chronometry on top of the world,* pages 5–19. Psalter Map reprinted by permission of the British Library.

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roma
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coming up in Dædalus:

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