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THE MATERIAL CULTURE OF ASTRONOMY IN DAILY LIFE: SUNDIALS, SCIENCE, AND SOCIAL CHANGE

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Sundials are among the most ancient of astronomical instruments. The earliest surviving examples date from 1500 B.C. By tracing the length and angles of shadows and by employing mathematical projections of the celestial sphere, early dials marked the passage of time, the recurring seasons, and the apparent motion of the sun in the sky. They reflected time consciousness. Sundials have also been time discipliners. Since Hellenistic times, they have been used to coordinate activities such as meals, prayers, and business. With the rise of commercial society in the late Middle Ages, a new sense of time pressure led to increased production and further development of sundials. Personal timepieces kept busy people on schedule. One goal of this paper is to show how the material culture reflected changes in people's experience of time consciousness, time discipline, and time pressure.

A second goal is to explore the place of sundials in consumer culture. People acquired sundials, like other consumer goods, for many reasons: because they needed or desired them; or because the goods had symbolic value or projected a particular image of their owners (*cf.* Figure 1). As material goods, sundials offer instances of social hegemony, class structure, and regional taste. Their diverse mathematical forms and designs reveal how people spent their time and the degree to which religion and politics were valued.

Historiographically, this is a new way of looking at old sundials. Often curators and sundial enthusiasts focus their attention on the mathematics of the different types of dials, the panoply of shapes and designs, or the craftsmanship of particular instrument makers. These are worthwhile projects and require considerable connoisseurship. I aim to go beyond these studies in order to explore not only the supply side, but also the demand side of the sundial trade. Mathematicians designed and instrument makers produced sundials to serve and please their customers. The three groups — mathematicians, makers, and consumers — were not in mutual isolation. Material culture was the link between theory, production, and consumption, and it sheds light on all.

I take as my foundation a careful study of over two thousand historic sundials preserved in museums worldwide. Although literary evidence is useful, it is only by the close inspection and comparison of many dials from different places and periods that one can build a picture of astronomy and mathematics in daily life. Two great sundial collections are at the Adler Planetarium and Astronomy Museum in Chicago and the Harvard Collection of Historical Scientific Instruments. This paper will be illustrated by instruments in both museums.[1]

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FIG. 1. Man using an astronomical compendium with an equatorial sundial. Drawing by Urs Graf (1485–1528). Öffentliche Kunstsammlung Basel, Kupferstichkabinett, 1978.91.

1. TIME CONSCIOUSNESS AND TIME DISCIPLINE

Even though the oldest surviving sundials are Egyptian and date from about 1500 B.C., it is possible that sundials were invented as early as the third millennium when Egyptian priests began to divide the night and day each into twelve equal parts.[2] In this system of time reckoning — known as temporal, seasonal, or unequal — the daylight and nighttime hours expanded and contracted in length with the seasons. The sixth hour was by definition at midday; the eighteenth hour (i.e, the sixth hour of the night) was at midnight.

The twenty-four-hour day and the art of making sundials reached ancient Greece via the Babylonians.[3] Anaximander of Miletus is credited with setting up a gnomon in Sparta in the sixth century B.C.[4] Literary references to these early sundials indicate that their functions were primarily astronomical and calendrical, and that they were used to mark solstices and equinoxes.

Hour-recording sundials did not become common in Greece and Rome until the third century B.C. But then they became very common indeed. As literary sources, extant dials (Figure 2), and excavations at Pompeii confirm, sundials were placed in private courtyards, in public squares, near temples, and in public baths.[5] Used to coordinate meal times and other activities, they became social tools for structuring the day.

How did a common person, who was neither priest nor astronomer, come to use a sundial? What was his or her sense of time? The answers depend in part on whether that person lived in a rural or urban setting.

People living in rural communities had little use for sundials. The daily sequence was defined less by social conventions than by the rhythms of agriculture, circadian periods, the cycle of the seasons, and the rising and setting of the sun. Recurring patterns of shadows that swept across fields were part of the natural cycle too. By keeping track of mowing and sowing, of eating and sleeping, or of the lengths and positions of shadows (cast by the body, a stick, or other object), the rural person entered into a world of time consciousness.

Time consciousness itself has varied with time and place. In traditional agricultural societies, the sense of time was cyclical. According to this view, time was divided into recurring units — days, seasons, cycles of birth and death, and regular bodily urges. In ancient Greece and Rome, for instance, the common people partitioned the day into three or four segments. These were given names like *gallicantus* (time of the cock's crow) or names derived from routine activities or meals.[6] "The most accurate clock in the world is the peasant's stomach", wrote Tommaso Garzoni in 1586, expressing a long-cherished opinion.[7]

But a peasant's belly was not a timepiece on which everyone could depend. Sundials were introduced. Not everyone was pleased by the new technology. A

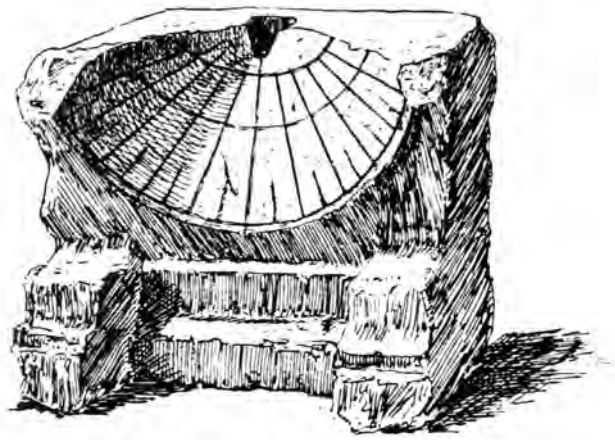

FIG. 2. Greek sundial. From Eden and Lloyd, *op. cit*. (ref. 17).

Roman comic writer of the late third century B.C. complained:

> The gods confound the man who first found out
> How to distinguish hours. Confound him, too,
> Who in this place set up a sundial,
> To cut and hack my days so wretchedly
> Into small pieces! When I was a boy,
> My belly was my sundial — one surer,
> Truer, and more exact than any of them.
> This dial told me when 'twas proper time
> To go to dinner, when I ought to eat;
> But nowadays, why even when I have [plenty],
> I can't fall to [i.e., dig in] unless the sun gives leave.
> The town's so full of these confounded dials.[8]

As this hungry author noted, the introduction of sundials not only reinforced time consciousness, but also encouraged time discipline. This was a new urban experience.

City dwellers of the ancient world were more prone to scheduling than their rural counterparts, since natural chores did not punctuate their days. Sundials were a tool for scheduling. The new time discipline was seen variously as unnatural, humorous, or praiseworthy.[9] But time discipline was not confined to busy city folk. Perhaps the most disciplined time-finder was the Christian church.

FIG. 3. Mass dial on church in Kirkdale, Yorkshire, c. 1063–65, during the reign of Edward the Confessor. From Eden and Lloyd, *op. cit*. (ref. 17).

FIG. 4. Sixteenth-century dial held by an older angel on Chartres cathedral.

2. CHURCH TIME

Church time — like agrarian time — was essentially cyclical. It was built on the recurrence of holy days and the rhythms of prayer. Early Christians continued to use the familiar system of temporal hours employed throughout the Roman empire, and their liturgy was structured around it. Tertullian (A.D. 160–220) recommended daily prayers to be scheduled at the third, sixth, or ninth hours of the day, as well as in the morning and evening.[10] The times for prayers were chosen as reminders

of the Passion of Jesus. With the rise of monasticism, prayer times became strictly regulated in each monastic house. Best known and most influential was the Rule of Saint Benedict (established around A.D. 530). According to the Benedictine Rule, there were to be seven daytime services and one at night.[11] These were known as offices, or collectively as the Divine Office. The offices and the times for reciting them were:

Lauds	daybreak
Prime	sunrise
Terce	third hour
Sext	sixth hour
None	ninth hour
Vespers	sunset
Compline	nightfall
Vigils	after midnight

Vigils later merged with and was called Matins, which was recited before daybreak. The offices of Prime, Terce, Sext, and None took their names from the temporal hours with which they were originally associated.

The monks believed that the power of prayer was strengthened when the whole religious community raised their voices collectively. To this end, the Church was more concerned with the daily cycles and rhythms of prayer than it was with the precise moments during the day when the prayers were collectively said. As a result, the prayer services drifted in time and moved forward during the day. For instance, the ninth hour service of None moved to the sixth or midday hour, giving us the English name of "noon" for midday. The times of the offices became known as the "canonical hours" in order to distinguish them from the civil temporal hours.[12] Eventually, each office became synonymous with its corresponding canonical hour. It was in this sense that the monks were said to "recite the hours".[13]

Beyond the Monastery

In A.D. 606, Pope Sabinian allegedly issued a decree that sundials be placed on churches in order to regulate the times for prayer.[14] Simple scratch dials — sometimes called mass dials — are still to be found on hundreds of churches in England and continental Europe dating from the seventh century onward. The dials were usually placed on the south wall or alongside the priest's door. Often the canonical hours on these dials were marked by crosses.[15] On later examples, after the canonical hours had shifted forward in the day, the crosses were replaced with the initials T, S, N, V, C, standing for the names of the divine offices.[16] A well-preserved and high-quality Saxon example is at Kirkdale, Yorkshire (Figure 3). On the great cathedrals of Europe, sundials were also placed in the hands of angels who watched over the hours (Figure 4).[17] Such fixed sundials did more than help the clergy to determine the times for mass. They were inscribed in prominent positions above the doorways of churches in order to remind passers-by to stop and pray. To

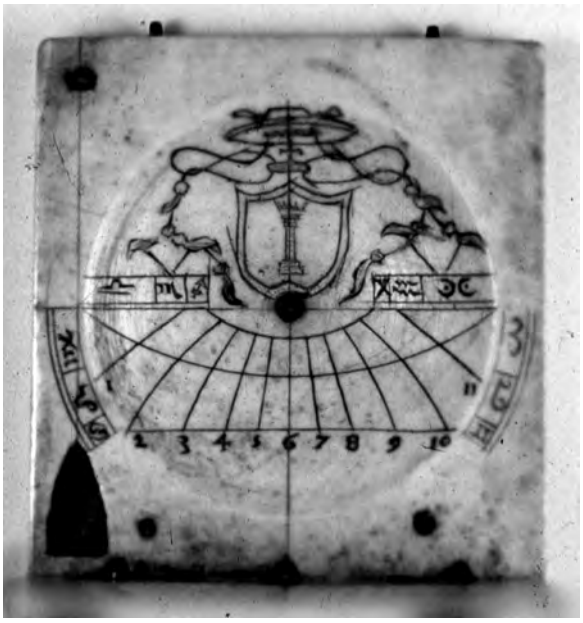

FIG. 5. Prelate's hat and temporal hours on an ivory pocket sundial likely made for Cardinal Pompeo Colonna (1479–1532) or Cardinal Ascanio Colonna (1560–1608). Adler Planetarium & Astronomy Museum, DPW-49.

FIG. 6. Flagellation of Jesus on an ivory diptych, c. 1475–99. Adler Planetarium & Astronomy Museum, M-249.

this end, they give us a glimpse of a community's relationship to time finding and religion. These were public sundials.

Sundials could also be private property and serve the personal needs of the devout. In Chaucer's *Canterbury tales*, a gentle monk consults his portable, cylinder dial before inviting the wife of his host to mass and breakfast.

> "Goth now youre wey", quod he, "al stille and softe,
> And lat us dyne as soone as that ye may;
> For by my chilyndre it is pryme of day."[18]

Admittedly, the two were up before Prime planning a tryst, so this incident does not show the most reverent use of a sundial. But it does tell us about private ownership. Perhaps the famous Saxon sundial unearthed in recent times in the cloister courtyard at Canterbury Cathedral had a more God-fearing owner. This tenth century, bejewelled, altitude sundial indicated the liturgical times for Terce, Sext, and None.[19] We are on even more certain ground in the case of an ivory diptych sundial preserved at the Adler Planetarium. Adorned with a prelate's hat and the arms of the Colonna family, this pocket dial was undoubtedly made for Cardinal Pompeo Colonna (1479–1532) or Cardinal Ascanio Colonna (1560–1608) (Figure 5).[20]

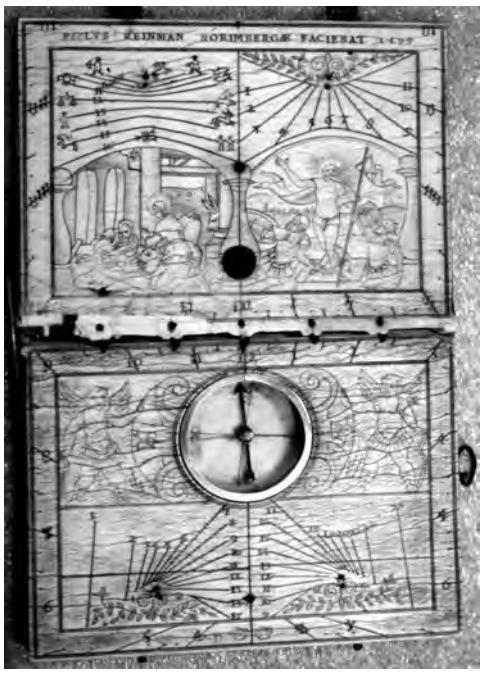

FIG. 7. Nativity and resurrection of Jesus combined with sundials for temporal, common, Nuremberg, and Italian hours on an ivory diptych by Paul Reinmann, Nuremberg, 1599. Adler Planetarium & Astronomy Museum, M-246.

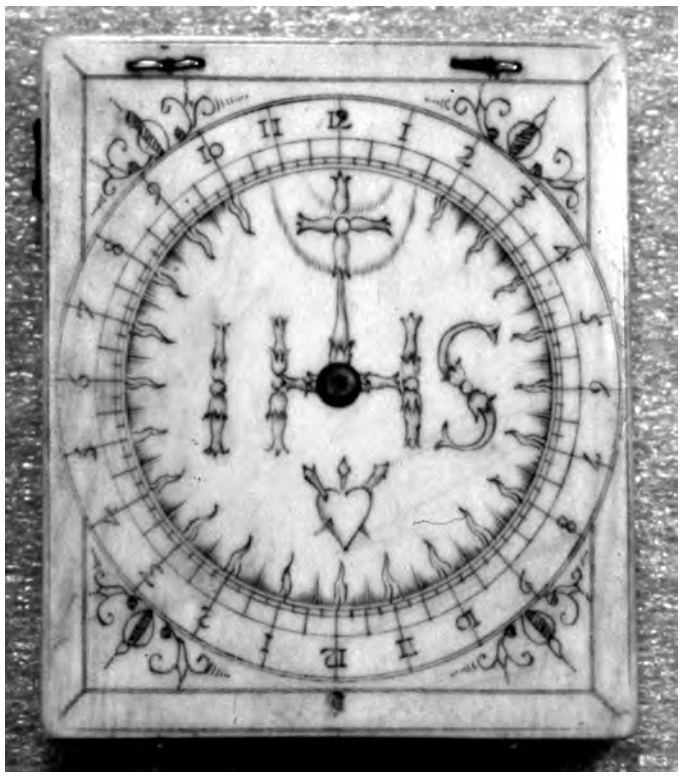

FIG. 8. Religious symbols on an ivory diptych and Oughtred-type dial made by Charles Bloud, Dieppe, *c.* 1650. Adler Planetarium & Astronomy Museum, DPW-19.

Iconography and Piety

There were many ways that sundials served the devout in addition to helping them find the times for prayer. In the fifteenth, sixteenth and seventeenth centuries, dials were ornamented with scenes from the life of Jesus (e.g., the nativity, flagellation, crucifixion, and resurrection), portraits of the Virgin, saints, and Church dignitaries, and images from the Bible. Religious symbols — such as the monogram of Jesus (IHS), a pierced heart, a cross, or a dove — adorned others (Figures 6–8).[21] Sometimes the gnomons were fashioned in the shape of these symbols.[22] Yet others had pious phrases such as "Maria help us" serving as mottos.[23] Iconography reinforced piety.

Contour was another means to give voice to one's faith. Christoph Clavius (1538–1612), the esteemed astronomer of the Society of Jesus, and mathematicians in other religious orders advised the faithful to erect sundials shaped as crosses (Figure 9).[24] The arms of the cross were inscribed with hour lines and their edges served as the sundial's gnomons.[25] Large stone crosses sometimes marked parish

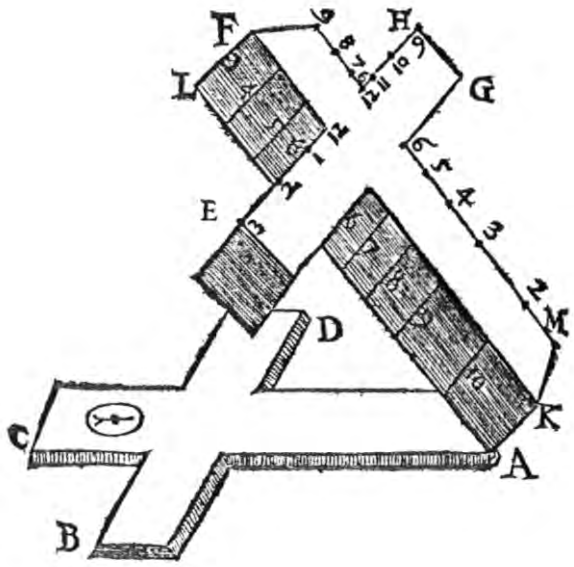

FIG. 9. Cruciform sundial described in Christoph Clavius, *Gnomonices libri octo* (Rome, 1581). Dibner Library of the History of Science and Technology, Smithsonian Institution.

boundaries or were set in church graveyards.[26] What better symbol to remind wayfarers to take time to live righteously? Small brass or ivory crosses were hung on cords around the neck, suspended from a belt or rosary, or carried in the pocket. They were used as amulets to ward off evil spirits as well as tell the time for the divine offices.[27] The finest cruciform sundials also served as reliquaries. An example from Ulrich Schniep's workshop in Munich *circa* 1560 holds the bones of four saints and has a little crucifix formed by wood allegedly from the Cross bound in gold (Figure 10).[28] To serve religion, sundials were also inserted inside the covers of breviaries and psalters (Figure 11).[29] Small, book-shaped sundials made in Nuremberg and Italy in the sixteenth century called these prayer books to mind. These could also be worn on cords around the neck.[30] In cruciform and book-shaped dials, form and function were well married.

Easter Time

In addition to setting the times for prayer, the Church was concerned to set the date of Easter each year and the cycle of movable feast days that was coupled to it. In A.D. 325 the Council of Nicaea mandated that Easter be celebrated on the first Sunday after the first full moon on or after the vernal equinox. Consequently, the movable holidays were tied to both the solar and lunar cycles in a complex way. Help was sought in methods of time reckoning, which included medieval computus,

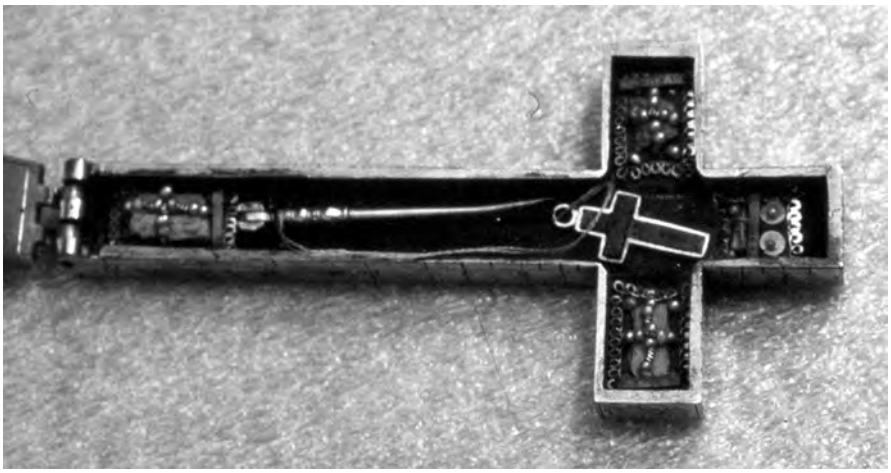

FIG. 10. Details of reliquary with bones of four saints and wood from the Cross found inside a cruciform sundial from the Ulrich Schniep workshop, Munich, *c.* 1560. Adler Planetarium & Astronomy Museum, M-253.

FIG. 11. Sundial inside a breviary. Valentino Pini, *Fabrica de gl'horologi solari* (Venice, 1598). Dibner Library of the History of Science and Technology, Smithsonian Institution.

systems of golden numbers correlating calendar years with the nineteen-year lunar cycle and the twenty-eight-year solar cycle, dominical letters and perpetual calendars predicting which civil dates would fall on a Sunday, and epacts indicating the moon's age at the beginning of a given calendar year. The Julian calendar, however, was based on a year that was slightly too large and had too many leap years, leading to the calendar being ten days behind the seasons by the sixteenth century. To bring the calendar back in alignment with the seasons, to develop a new leap rule, and to create a new algorithm for calculating the date of Easter, Pope Gregory XIII appointed a commission of astronomers, canon lawyers, and theologians. The ranking astronomer was Clavius, who published a major mathematical treatise on time finding instruments while serving on the committee. The Gregorian calendar was inaugurated in 1582, but adopted initially along religious lines. In Western Europe, Catholics embraced it much earlier than Protestants, who were suspicious of the Catholic invention but ultimately accepted it (in some cases centuries later) for economic and political reasons.[31]

Debates over time-reckoning methods and calendar reform brought the theologian and astronomer together. The material culture reflected the controversy and gave people access to local conventions. Complex sundials included tables or volvelles with the cycle of the sun, golden numbers, dominical letters, perpetual

FIG. 12. Julian and Gregorian epact tables on an ivory diptych, Joseph Ducher, Nuremberg, *c*. 1642. Collection of Historical Scientific Instruments, Harvard University, 7899.

calendars, epacts, and dates of festivals.[32] In the seventeenth century, in regions like Germany, it was common to find side-by-side on a single instrument both Julian and Gregorian epact tables for computing the date of Easter (Figure 12). Consumers could take their pick.[33]

Serving Pilgrims

Many sundials were not only portable but also designed to work at multiple latitudes. Known as universal sundials, these instruments were intended for merchants, pilgrims, and other long-distance travellers. To determine the right time, the traveller first had to consult a gazetteer inscribed on the instrument or pasted inside its case. The gazetteer listed cities with their latitudes (Figure 13). The traveller would use the information to incline the sundial at the proper angle

and read the correct hour scale.

Portable sundials often included special pin-gnomon dials that found the length of the current day and night so that hours for travel could be planned. Lunar volvelles not only indicated the amount of moonlight to be expected on a clear night, but also converted the sundial into a moon dial. It was also common for sixteenth- and seventeenth-century universal sundials to find the time simultaneously in terms of Nuremberg hours, Italian hours, and common hours so that the traveller would not be caught off guard when crossing a border.[34] Magnetic azimuth sundials made by Charles Bloud and Jacques Senecal in Dieppe, France in the mid-seventeenth century went to greater lengths to accommodate travellers' needs. Some (see Figure 14) had a handy *guide Michelin* built right in! A table offered the traveller information about the services in each town, including perhaps the highest ranking ecclesiastical authority or noble, schools, courts, inns, stables for post horses, public baths, and so forth.[35]

FIG. 13. Length of the day by season, gazetteer, string-gnomon horizontal dial for six latitudes, and scaphe for Nuremberg and Italian hours. Ivory diptych by Leonhart Miller, Nuremberg, 1613. Collection of Historical Scientific Instruments, Harvard University, 7459.

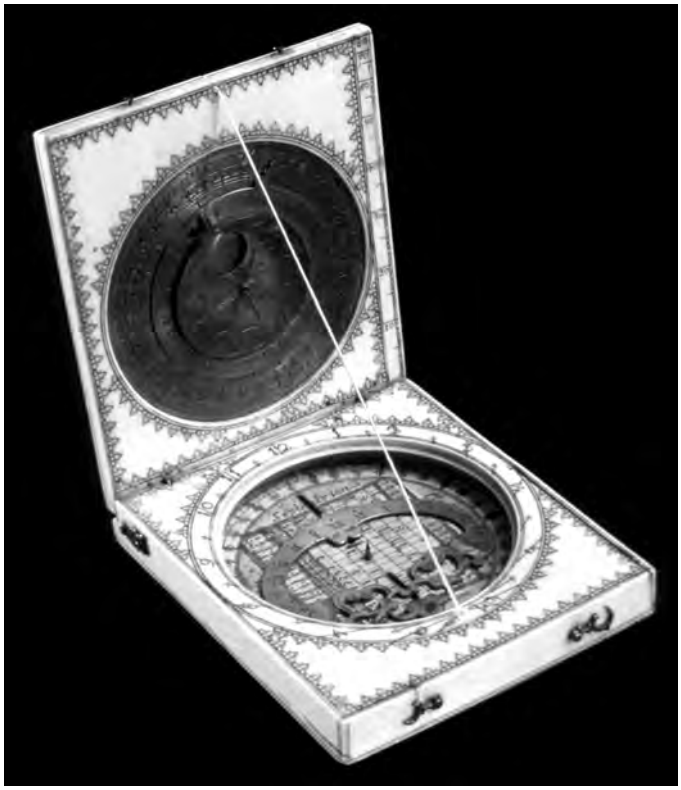

FIG. 14. Travel guide inside the compass bowl of a magnetic azimuth ivory diptych dial by Jacques Senecal, Dieppe, *c*. 1650–60. Collection of Historical Scientific Instruments, Harvard University, 7510.

Exceptional instruments had maps, quadrants, and nocturnals to serve travellers further (Figures 15 and 16).[36] For instance, in 1513 Erhard Etzlaub of Nuremberg provided a map of Europe and North Africa instead of the usual gazetteer on the top leaf of his wooden diptych. The map showed pilgrims the way to Rome, Jerusalem, and Sinai.[37] If the pilgrim were unsure of his location, he could find his latitude from the sun or stars by means of a quadrant provided on the lower leaf. With this information in hand, the pilgrim opened up the instrument and found the time by means of the hour scale that corresponded with his latitude. Etzlaub even provided a rare scale for use in Sinai or Egypt.

Religion Serving Time Finding

Not only did time finding serve religion, but religion served time finding. Astronomers were permitted to transform great cathedrals into monumental sundials and astronomical instruments. In 1475 Paolo Toscanelli made a hole in the cupola of

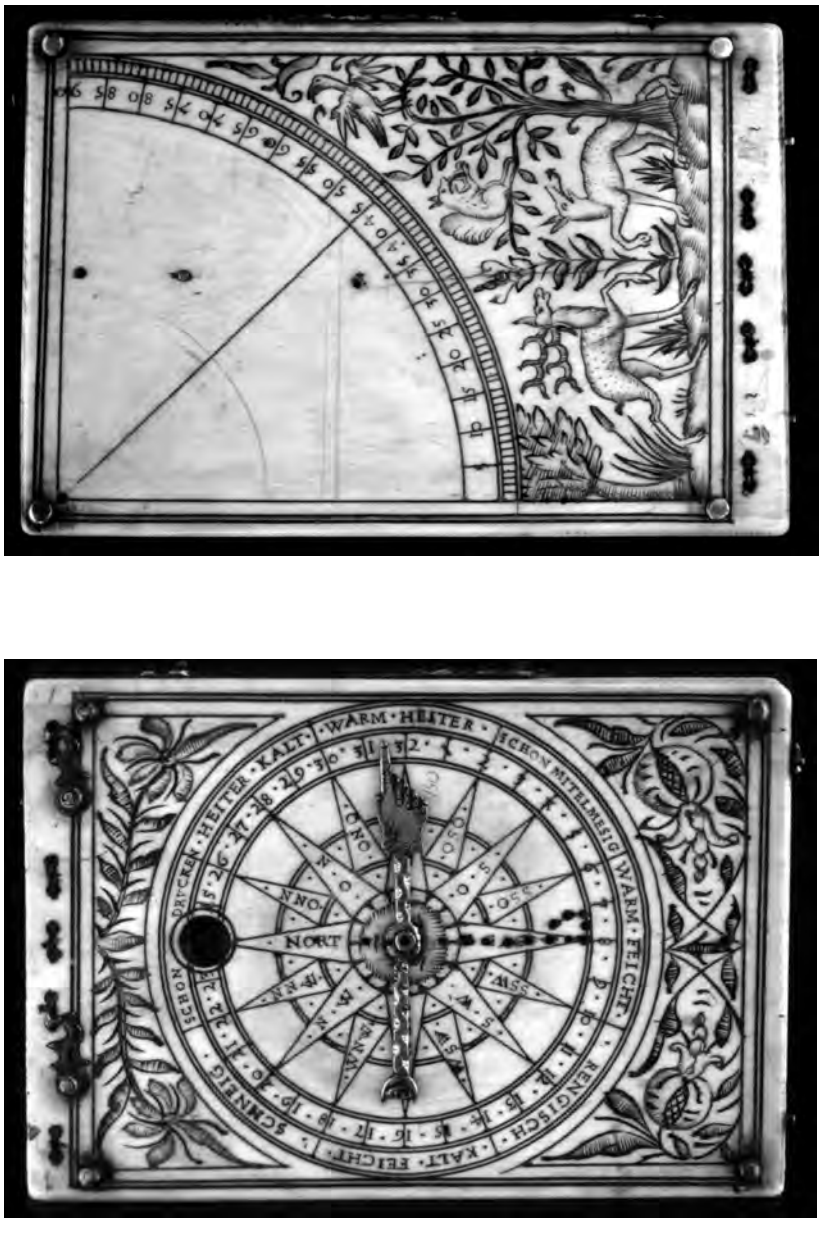

FIG. 15. Tools for the traveller: weather vane and quadrant on an ivory diptych by Leonhart Miller, Nuremberg, 1613. Collection of Historical Scientific Instruments, Harvard University, 7459.

FIG. 16. Pilgrimage map on a wooden compendium by Erhard Etzlaub, Nuremberg, 1513. Adler Planetarium & Astronomy Museum, DPW-22.

Santa Maria del Fiore in Florence to serve as a gnomon. A shaft of light entered the church through the hole and descended 90-plus metres to the pavement, where the light fell on a calibrated meridian line (Figure 17). In 1574, Egnazio Danti began construction of a meridian line in Santa Maria Novella in Florence before relocating to Bologna where in 1575 he laid out a meridian in the basilica of San Petronio. In 1579, he traced another in the Vatican's Torre dei Venti. In 1665, Gian Domenico Cassini, while professor of astronomy at the University of Bologna, reconstructed the San Petronio meridian with much greater dimensions. The primary function of these instruments was to determine the exact dates of the solstices and equinoxes, in the tradition of the ancient Greek monumental gnomons. Cassini moreover hoped to find the apparent diameter of the sun during the course of the year and from this the eccentricity of the earth's orbit.[38]

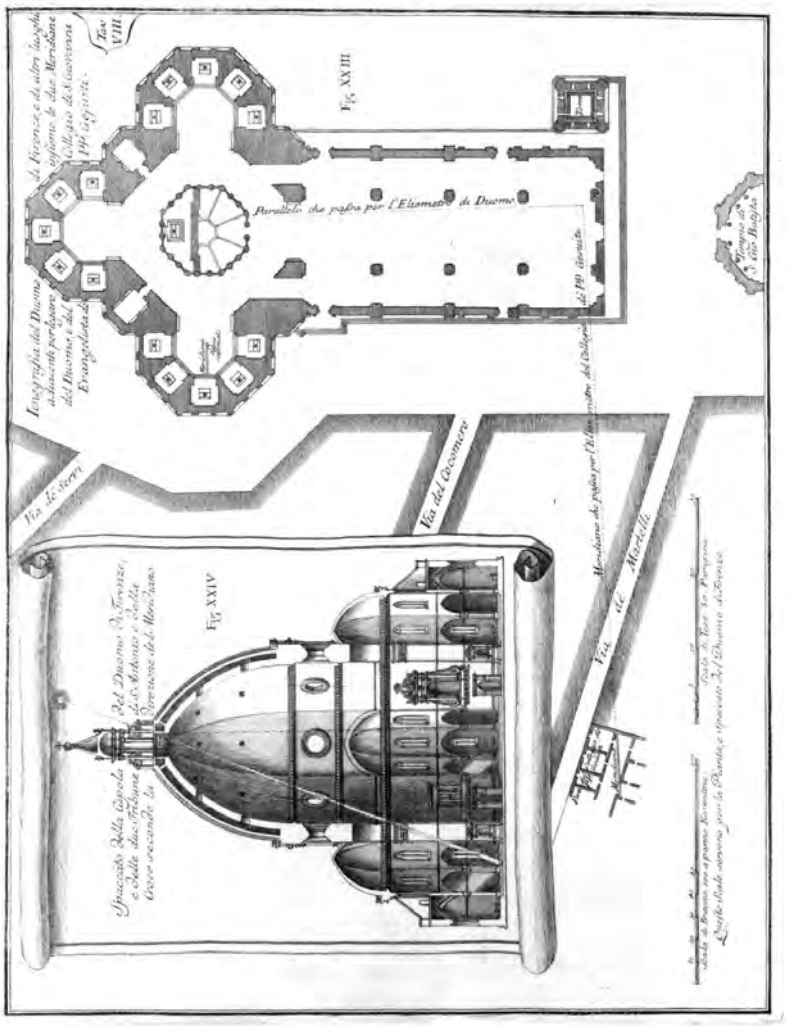

FIG. 17. Duomo in Florence showing a shaft of light coming from Toscanelli's gnomon down to the pavement. From Leonardo Ximenes, *Del vecchio e nuovo gnomone fiorentino* (Florence, 1757). Houghton Library, Harvard University.

These towering church sundials came to the aid of astronomy just as astronomy through the science of gnomonics helped the Church to maintain its time discipline. And so, like the pastoral rhythms of church life, this part of the story comes full circle — from dials mounted outside churches to churches that were themselves great dials. The material culture of astronomy — carried in pilgrims' pockets, scratched over church doorways, or embracing congregants within the cathedral — was part of people's religious experience.

3. MERCHANT TIME

From the fourteenth to the seventeenth century, as feudal society built on the rhythms of the countryside gave way to more urban, commercial society, time became a precious commodity to be budgeted and spent wisely. Merchant time was not the cyclical flow familiar to farmers and friars, but money slipping through the fingers. Time wasted meant missed opportunities and lost profits.

Scholars also felt the strain. Educational reformers urged them to organize or double-up studies methodically in order to maximize learning in limited hours. Otherwise, they would run the risk of leaving nothing to their credit when they died. Petrarch spoke for many when he noted, "Everything consists in the ordered disposition of time".[39]

Although the reasons for these changes have been much debated within recent years, the fact that change took place is undisputed.[40] With the new time pressures came new images of Chronos or Time. Classically portrayed as a joyful, winged youth holding a sundial, Time came to be seen in the Renaissance as a ruthless old man, an inescapable force causing ruin and decay. Illustrators and poets depicted Time as a decrepit elder with wings to symbolize his fleeting nature, sandglass to measure time, and scythe to cut down anything in his path. Time and Death gloated over their partnership in laying waste to youth, human arts, technology, learning, and power. Time acquired lethal instruments. People saw themselves in a battle against him.[41]

Sundials reflected the new attitude toward time. Father Time and other *mementi mori* appeared on sundials in order to caution people to use time wisely (Figure 18).[42] For instance, some ivory diptych sundials by Hans Troschel, Paul Reinmann, and Michael Lesel, all working in Nuremberg in the late sixteenth century, show a reclining putto with an arm resting on a skull. In the Troschel example, the putto also holds a sand glass, and a motto reads, "HORA FVGIT MORS VENIT" ("the hour flies; death comes").[43] On a French paper sundial from the late seventeenth century, a spooky skull scowls beneath an altitude dial that drips blood.[44] The message was still compelling fifty years later, when an artist painted a stained-glass window sundial, currently in the Basel Historical Museum. On it, Chronos supports the fabric of time — a cloth marked with the hours — as a skeleton peaks around the edge.[45] And in the late eighteenth and early nineteenth centuries, Father Time was shown on the western side of cube sundials by E. C. Stockert and followers. The

western side was the afternoon side, so as the day drew to a close, the user would be reminded of the limits of life and the final reckoning.[46]

Time is Money

The science of gnomonics and art of sundials not only saved souls but preserved the market economy and society. As the English mathematician William Leybourn declared in 1659:

> What is more necessary in a well ordered *Common-wealth* [than dialing]? what action can be performed in due season without it? or what man can appoint any business with another, and not prefix a time, without the losse of that which cannot be re-gained, and ought therefore to most be prized?[47]

Merchant time was not just linear, but money-conscious. In 1748, Benjamin Franklin counselled:

> Remember that TIME is money. He that can earn Ten Shillings a Day by his Labour, and goes abroad, or sits idle one half of that Day, tho' he spends but Sixpence during his Diversion or Idleness, ought not to reckon *That* the only Expense; he has really spent, or rather thrown away, Five Shillings besides.[48]

During the Continental Congress, Franklin whiled away some slow hours designing money for the United States. In 1787, the first currency authorized by the new country was a one-cent coin, the penny. Franklin's design showed the sun in splendour above a horizontal sundial with the motto "FUGIO" ("I fly"). Below the dial, the coin read, "MIND YOUR BUSINESS". The so-called Fugio motif also appeared on dollar coins and some paper notes.[49] In the currency of the day, time *literally* was money!

Clocks and Sundials

It is often said that the new linear sense of time was clock-driven, but the development of clocks was more consequence than cause for the urgent sense of time that arose in the late Middle Ages and Renaissance.

Introduced in the thirteenth century — most likely as alarms in monasteries — mechanical clocks were soon installed in the residences and cities of territorial rulers in order to enhance their prestige. Public tower clocks were set up first in Italy and then throughout Europe in the fourteenth century.[50] The diffusion of clocks introduced the public to a new system of time measurement — that of equal hours. Traditional hours found by the sun were temporal and unequal; their lengths varied by the season. Thus the invention of the clock led people away from "natural" time to "artificial" time. The town clock with its regular beat and tolling bells brought new rhythms and organization to communal life. In 1410, an English friar observed, "In cities and towns, men rule themselves by the clock".[51]

Clocks were seen as tools for the good administration of civic life, and their bells

FIG. 18. Altitude dial with an hour scale dripping blood and a skull. Paper, French, late seventeenth century. Collection of Historical Scientific Instruments, Harvard University, 7173.

were used to synchronize work schedules.[52] Nevertheless, the same roles were given to sundials, sand glasses, and calendars. Indeed, parallel improvements in these time finding and time keeping instruments arguably were symptomatic of time pressures people had begun to feel. The underlying causes of the new preoccupation with keeping time deserve further exploration than can be given here.

Clocks did not put sundials out of business. In the fifteenth century, sundials calibrated for equal hours first appeared so that clocks and sundials were using the same system. These sundials divided the hours into half and quarter intervals. Most contemporary clocks were equipped with only an hour hand and dial. It was another century before they recorded half-hour intervals. Clocks were notoriously inaccurate as well. They required their owners to use a sundial to set them to the correct time. Sundials regulated clocks.[53]

The rise of the clockmaking profession was driven by demands from royal houses and very wealthy merchants for personal time pieces.[54] These domestic clocks were beyond the means of individuals and institutions with modest finances. Sundials filled the gaps. For instance, the Ecclesiastical Constitutions of Saxony and Lower Saxony, passed in 1580 and 1585, called for sundials in all parishes that had no clock:

> §39. And in villages without a clock, the pastor should admonish the church, and in particular the people who can afford it, to buy one, so that the church-offices can be carried out at the appropriate time in accord with the clock, and the people

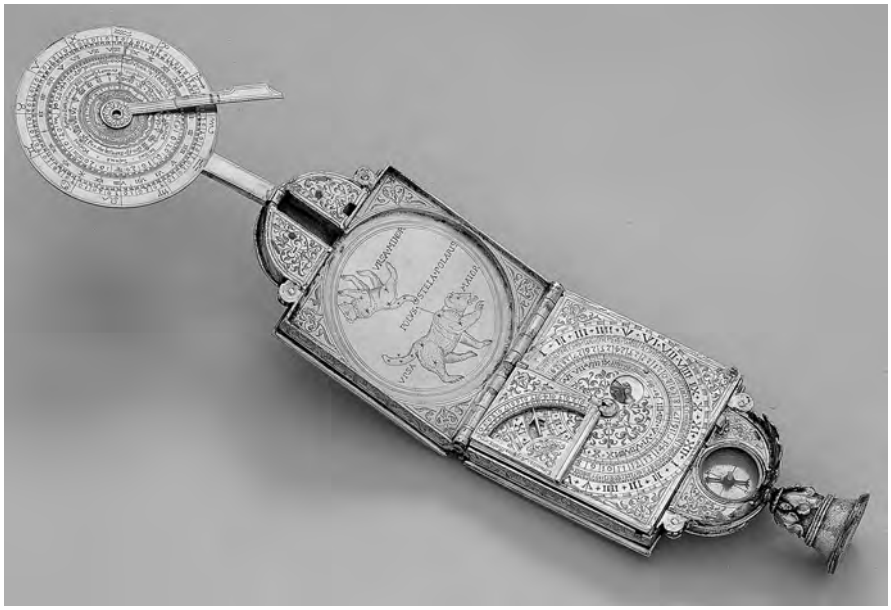

FIG. 19. Astronomical compendium, V.C., [London], 1557. Adler Planetarium & Astronomy Museum, M-363.

> in other respects, too, should be guided by it in their housekeeping.
>
> But if the parishioners are so poor that they cannot buy a striking clock, the pastor shall give thought to a sundial, which can be obtained at little cost. And until it is installed, the sextons shall learn from the pastor who has a compass [sundial], or purchase it themselves, and the sexton shall use it to determine the ringing.[55]

Clocks and sundials were developed in parallel and became more diffused throughout society. From the time of Petrarch, improvements in both were manifestations of the need people felt to use time wisely or impress their associates.

Sundials and Consumer Culture

The pressure to schedule life's events encouraged a dramatic increase in the production of sundials, in their importance to all levels of society, and in their precision.[56] The necessity of sundials was perceived by early modern authors as so obvious that it hardly needed comment. "Here would be the place to report all the uses of sundials", Philippe de la Hire wrote in 1698, "but I believe it suffices to say that there is no state in life in which exact knowledge of the time is unwarranted, be it for regulating matters of religion and the Divine Office, or for apportioning work and rest fairly".[57]

But missed appointments and worries about wasting time do not fully explain the increased demand for sundials, the types bought, or their meaning in people's lives. The art of dialing was part of polite culture. Many authors commended it as a "rational and instructive Amusement to the young Student ... and to Ladies and Gentlemen in general". A competent understanding of its first principles and the relationship of gnomonics to astronomy, geometry, and optics was declared "requisite for forming the *Scholar* and the *Gentleman*" and essential for "making a man compleat and excellent".[58] Under such circumstances, the possession of a sundial was a sign of good breeding and a marker of some status. No doubt, many owners did not understand the mathematical projections that underlay their pocket sundials, but they could pretend they did or declare that they had the means to learn the mathematics if they ever deigned to do so. The more complex their instruments were, the greater the prestige they bestowed on their owners.

Conspicuous Consumption

One trait to be found in modern consumer societies is conspicuous consumption — that is, the acquisition of goods in order to set oneself apart or to compete with others. Many types of early modern sundials provide evidence of conspicuous consumption as they expressed their owners' taste for mathematically sophisticated and complex instrumentation. Very often such instruments were commissioned. Made of rich materials such as silver, gilt brass, and ivory, these sundials were show pieces that proud aristocrats pulled out to impress their companions. One example (Figure 19) is an astronomical compendium dated 1557 and signed "V.C." (most likely a Flemish artisan employed by Thomas Gemini in London). Compendia were the 'Swiss army knives' of the sundial world. They combined numerous time finding instruments into a pocket-sized package. The V.C. compendium consists of thirteen

FIG. 20. Conspicuous consumption: pillar dial with knife and fork, style of Erasmus Habermel, Prague, *c*. 1580. Adler Planetarium & Astronomy Museum, M-306.

leaves hinged together in the form of a book. The leaves contain astronomical and astrological tables, lunar volvelles, an aspectarium, calendrical and horological tables, a horizontal sundial, equatorial sundials, moon dials, a quadrant, a nocturnal, star charts, and a world map.[59]

Compendia were not the only form of showy sundial. Another instrument (figure 20) in the Adler Planetarium collection — a gilt brass and silver pillar dial — gives new meaning to the phrase "conspicuous consumption".[60] Likely made in Prague in the 1580s, the pillar housed a retractable knife and a fork. The user could check his sundial, declare it time for dinner, and then convert his instrument into his eating utensils!

Differences in Social Class and Gender

Not all consumption was conspicuous, especially in the case of sundials that were working tools for daily life. Sundials of a single type often display a range of styles (simple to ornate), materials (cheap to precious), or workmanship (crude to masterful). Such cases suggest that the given type appealed both in function and form to people up and down the social ladder. Both the material culture and the makers' sales catalogues inform us that makers adapted their wares to fit the pocketbooks or special needs of both élite and common consumers. For instance, pillar dials dating from the sixteenth to the nineteenth century span the social order.[61] Instruments at the top end of the market were made of engraved silver, gilt brass, and ivory. At the low end, they were constructed cheaply of printed paper glued to wood. Michael Butterfield, an English instrument maker working in Paris between 1665 and 1724, created a cute and popular style of horizontal, pocket sundial in which the gnomon was shaped as a little bird. Butterfield made his best sundials of silver rather than brass and marked them *premier cadran* (top-of-the-line).[62] Bion, Baradelle, Haye, le Maire, and other makers of Butterfield-type sundials likewise divided consumers by metals. The same story of high and low markets can also be told with the portable, equatorial dials known as Augsburg-type sundials.[63]

Gender differences are also observable. In the Adler Planetarium's collection, two instruments illustrate this point. One is a round Augsburg-type dial constructed of silver and gilt brass by Johann Martin of Augsburg, *circa* 1675–1700. The sundial folds up and fits into a silver box on which there is a perpetual calendar volvelle. The silver box, in turn, is stored in a brass box, and the final package is 2.5 inches in diameter. It is designed to fit in a man's pocket.[64] The second instrument was made by Philip Happacher during this same period. It is similar to the Martin sundial, but is daintier and has a gold case with a perpetual calendar. A mere inch across, this instrument was suitable for a wealthy lady's purse.[65]

Social Hegemony

Social hegemony is the dominance of the élite members of society over the lower orders, and the influence the élite exert (often without physical coercion) on their

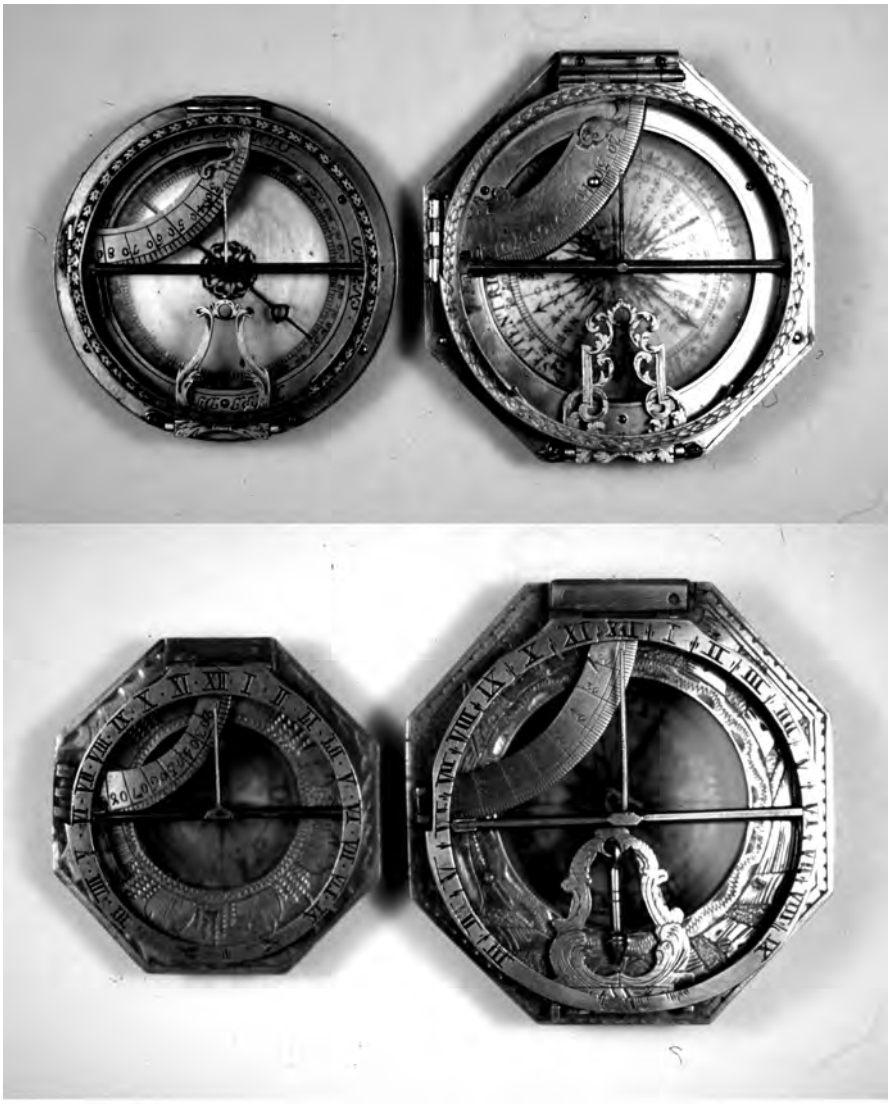

FIG. 21. Evidence of social hegemony: (*above*) Augsberg-type sundials made by Johann Martin and Johann Mathias Willebrand, 1675–1700; (*below*) cruder dials made by Johann Nepomuk Schrettegger, and Lorenz Grassl, 1770–1843. Adler Planetarium & Astronomy Museum, A-98, N-11, T-17, T-18.

subordinates. Social hegemony is seen in the flow of aristocratic tastes and values down the social ladder. Sundials bear witness to this.

One example may be the case where a gentleman's style was scaled-down for use by a lady. Another instance (Figure 21) is found by comparing Augsburg-type dials

crafted over a hundred-year period. Johann Martin and Johann Mathias Willebrand produced Augsburg-type dials in the late 1600s with a high degree of precision and the finest metals. About a century later, the same type of sundial was being mass produced by Johann Nepomuk Schretteger, Lorenz Grassl, and others with more affordable materials and less precision.[66]

Such evidence not only points to members of different social classes using the same form of dial, but also suggests that élite practices trickled down. Lower orders chose to emulate their social superiors as upper-class style and technology became vulgarized over a period of roughly a hundred years. Élite consumers meanwhile often spurned the older styles as they became too common. More research is needed, however, to understand whether lower-class consumers imitated the better sort in order to impress their peers, attempt to rise above their station, or gratify some other need. It may be that they desired the goods for their own sake rather than for any prestige contact with the products might have bestowed.

Forgery

Forgeries also couple production to consumer values. Some early modern instrument makers pirated trendy styles and counterfeited the work of famous makers. Since no

FIG. 22. French possessions in North America listed on the gazetteer of a sundial made by Pierre de Maire 2, Paris, *c*. 1740–85. Adler Planetarium & Astronomy Museum, W-57.

rational crook would have gone to the trouble to forge an undesirable instrument, sundials falsely attributed to Butterfield and others, which survive in museum collections, tell us that their products were in demand.[67] Forgeries relate to conspicuous consumption and social hegemony insofar as they satisfied people's desire to keep up with the Joneses or to enjoy status items at a discount — unless they were taken in by swindlers who sold them knock-offs as the genuine article. The degree of consumer gullibility is underdetermined by the material culture, but the counterfeit objects give us insight into the demands of the consumer marketplace.

Savvy Travellers

Material culture tells us about the geographical interests (if not necessarily the actual destinations) of particular consumers. The gazetteers inscribed on sundials varied from workshop to workshop and sometimes even from one instrument to another within a single establishment. For instance, in the mid-eighteenth century, sundials constructed in London differed from those made in Paris, and some made in Paris exhibited not only a French perspective of Europe, but also an interest in the French possessions in North America. Most pocket dials made by Pierre le Maire 2 between 1740 and 1785 listed principal European cities, but others catalogued towns in French North America from Canada down the Mississippi to New Orleans and into South America (for example, see Figure 22).[68]

How do we interpret this material culture? On one hand, there is documentary and archaeological evidence that the French government supplied dials like these to its officers in North America from 1751 to 1759 in order "to guide them through the forests and wastes of that country".[69] And the French were not alone in catering to foreign markets. Other sources confirm that German, Italian, and British instrument makers also created instruments for sale or use abroad.[70] On the other hand, the fact that these gazetteers listed North American territories does not prove that the dial owners actually ever left Europe. A lot of armchair travelling was done in early modern times, and sundials enabled their owners to fantasize about journeys to far-flung places like Quebec or Calcutta. It is unlikely that the owners of many pocket sundials ever travelled as widely as the gazetteers would suggest.[71] Exotic destinations were also suggested by imagery, such as a Turk and American Indian incised on an ivory sundial from Nuremberg in the early seventeenth century (Figure 23).[72] All we can say for sure about such dials is that the owner thought of himself or wanted others to think of him as the sort of person requiring all the extra information.

Specialized scales and attachments offer more certain information on the location of instrument users. Since it was more labour-intensive to compute and engrave those components, instrument makers would not have undertaken them if they did not have a market lined up. Most Butterfield-type sundials sold by Baradelle of Paris *circa* 1752–94 were inscribed with hour scales for 40, 45, 49, 52 degrees of latitude, which suited European needs. One surviving instrument, though, has

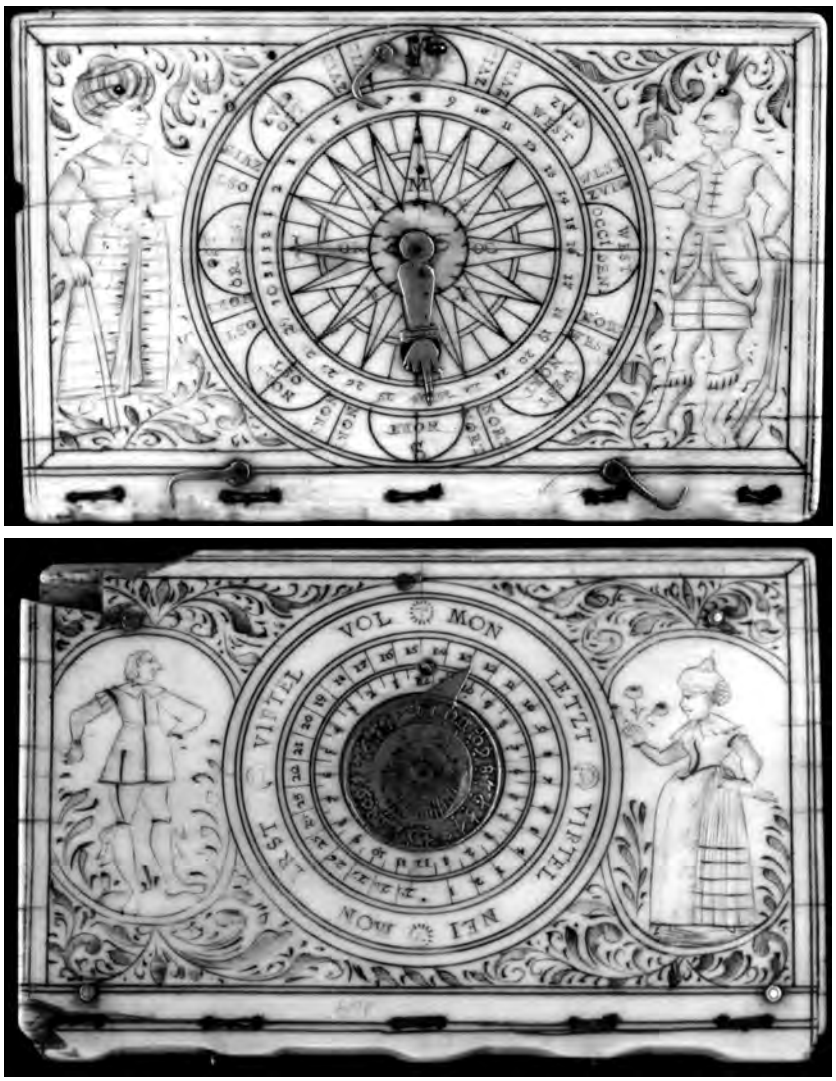

FIG. 23. Individuals from exotic cultures adorn an ivory diptych by Thomas Ducher, Nuremberg, before 1645. Collection of Historical Scientific Instruments, Harvard University, 7579.

hour scales for 18, 20, and 25 degrees of latitude — too low for Europe. Marked for Santo Domingo, that sundial was undoubtedly made for a customer in the Carribean.[73] Early modern sundials made in the coastal town of Dieppe, France frequently included volvelles for determining the times of high and low tides.[74] Tide volvelles were not included on instruments destined for inland users.

Precision

The physical construction of sundials sheds light not only on the dividing skills of their makers, but also on the degree of precision to which consumers aimed in running their lives or businesses. Among the sundials made by Michael Butterfield in Paris around 1700, the Adler Planetarium has a large silver dial marked *premier cadran*, with five hour scales (all graduated to quarter hours), thirty cities on the gazetteer, and a thirty-two-point wind rose on the magnetic compass. Another silver sundial in the collection is much smaller and has only three hour scales (of which two are graduated to half hours), an eighteen-city gazetteer, and a four-point wind rose. This smaller dial was more appropriate for a well-heeled school-boy than a gentleman, and indeed belonged to Brook Taylor, the mathematician, when he was just sixteen years old and entering Cambridge.[75]

Makers of equal skill made different decisions. Butterfield chose to divide the latitude scales of his instruments into one-degree intervals, whereas Edmund Culpeper, his contemporary, felt that two-degree intervals were satisfactory.[76] Culpeper, however, divided his hour scale into five-minute intervals, rather than the fifteen- to thirty-minute segments found on Butterfield's dials. Precision in latitude measurement was apparently less important to Culpeper's clients than the prospect of precision in marking time. Did the impetus for increased precision come from consumers' true needs or from a marketing strategy of the maker? This remains an open question.

4. CONCLUSIONS

Of ancient lineage, wondrous shapes, and mathematical grace, fixed and portable sundials teach us much about people's changing attitudes toward time. Developed first as astronomical instruments, sundials became social tools in Hellenistic times. They were used to coordinate meal times and other activities. In the early Middle Ages, sundials were important in the scheduling of prayers. As pastoral rhythms gave way to more urban, commercial schedules, people experienced new time pressures and the need to coordinate secular activities. Time had become money. In response, sundial production and precision increased during the Renaissance and early modern period.

As material culture, sundials provide clues to who consumers were, how they spent their time, and what they valued. Embodying principles of mathematics, astronomy, cartography, and gnomonics, sundials were used to find the hours of the Divine Office, the dates of Easter and movable feasts, and the way to Rome and Jerusalem. They served pilgrims, held the bones of saints, and encouraged prayerful meditation. On the secular side, sundials satisfied the needs of merchants and soldiers, reflecting travel across political boundaries and the degree of precision required for their affairs. Conspicuous consumption, popular tastes, and social hegemony were also manifest in the material culture of astronomy.

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16. See images of 13th-century sundials on the Minster of Hameln reproduced in Dohrn-van Rossum, *History of the hour* (ref. 5), 31–32; and a sundial in the cloister of the Convent of Saint Dominic at Taggia, described in Arnaldi, "Sundials painted in the cloister" (ref. 12), 23.
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21. In AP, see the ivory diptych by Paul Reinmann, Nuremberg, 1599 (M-246); ivory diptych, unsigned, *c*. 1475–99 (M-249); Oughtred-type dial, C. Bloud, Dieppe, mid-17th century, ivory (DPW-19); Butterfield-type dial, [T?] Haye, Paris, *c*. 1716, brass (A-3). See also the ivory diptych by Paul Reinmann, Nuremberg, 1598/9, illustrated in Penelope Gouk, *The ivory sundials of Nuremberg, 1500–1700* (Cambridge, 1988), Plates 14, 15. In the Harvard Collection of Historical Scientific Instruments [hereafter abbreviated "CHSI"], see the German gilt-brass diptych, 1587 (7455); and Butterfield-type dials by Nicolas Bion, *c*. 1700, silver (7005, 7082).
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25. E.g., cruciform dial, German (Nuremberg?), *c*. 1750–1800, CHSI (7400).
26. Sharp, the Archbishop of St Andrews, had a cruciform sundial placed in the courtyard of his house between 1667 and 1679. See Eden and Lloyd, *Book of sun-dials* (ref. 17), 107–8, for this and other cross dials. Charles Leadbetter, *Mechanick dialling* (London, 1737), pp. vi, 78–82, describes an iron cross dial made by Robert Trevitt and placed at the boundary of the parish of St Stephen, Coleman Street, London in 1706. He thought such dials a "novelty" in England. "I never yet saw or heard there was any other Dial of that Sort in England, besides that which I have mentioned in this Treatise", Leadbetter said. James Ferguson in *A supplement to Mr. Ferguson's Book of Lectures* (London, 1767), 35, also implied that cruciform dials were rare. He described a universal form that would "have a pretty uncommon appearance in a garden". A French example, dated 1632, of gilt bronze is shaped both like a cross and a great key. It may have been a grave marker or church ornament (AP, M-317).
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40. *Cf.* Jacques Le Goff, *Time, work, and culture in the Middle Ages* (Chicago, 1982), and Dohrn-van Rossum, *History of the hour* (ref. 5).
41. Erwin Panofsky, *Studies in iconology: Humanistic themes in the art of the Renaissance* (New York, 1962), chap. 3, "Father Time". See also *Time: The greatest innovator* (ref. 7).
42. Pini, *Fabrica de gl'horologi solari* (ref. 26) has emblematic title page with sundial; François Bedos de Celles, *La gnomonique pratique, ou l'art de tracer les cadrans solaires avec la plus grande précision*, 2nd edn (Paris, 1774), Plate 15 showing a direct east-facing sundial.
43. Gouk, *Ivory sundials of Nuremberg* (ref. 21), cat. 33 and 34. Ivory diptych, Michael Lesel, Nuremberg, early 17th century, CHSI (7559).
44. Altitude sundial with horary quadrant and universal ring dial, French, *c.* 1675, pasteboard and copper, CHSI (7173).
45. René R. J. Rohr, *Sundials: History, theory, and practice* (Toronto, 1970), Plate 8.
46. Inclinable cube sundials, unsigned but attributed to E. C. Stockert, south German, late 18th or early 19th century, wooden, AP (W-215, W-216, G-18); and another unsigned, inclinable, cube sundial, German, early 19th century, silver, AP (M-325).
47. William Leybourn writing in the preface, "To the Reader" of Thomas Stirrup, *Horometria: Or, the compleat diallist*, 2nd edn (London, 1659).
48. Benjamin Franklin, *Advice to a young tradesman, written by an old one*, printed first in George Fisher, *The American instructor: or Young man's best companion*, 9th edn, revised (Philadelphia, 1748), 375–7; reprinted in Leonard W. Labaree *et al*. (eds), *The papers of Benjamin Franklin* (35 vols, New Haven, 1959–), iii, 304–8.
49. The city of New York later issued a six-cent note with the Fugio motif. See Earle, *Sun dials* (ref. 17), 21–23.
50. Dohrn-van Rossum, *History of the hour* (ref. 5), chap. 5.
51. P. Heath Barnum (ed.), *Dives et pauper* (Early English Text Society, 275; Oxford, 1976), 119ff; quoted in Dohrn-van Rossum, *History of the hour* (ref. 5), 1, 150.
52. Dohrn-van Rossum, *History of the hour* (ref. 5), chaps 7–8; Doggett (ed.), *Time: The greatest innovator* (ref. 7), 65.
53. The equation of time appeared on sundials in the 18th century as an aid to set one's clock by the sun. E.g., in AP, see the heliochronometer, J. J. Sauter, Stockholm, *c.* 1785 (M-302); and a mounted universal ring dial, Edward Nairne, London, *c.* 1750–75 (M-314).
54. Silvio Bedini, "The map of time", in *Time: The greatest innovator* (ref. 7), 11–23, esp. pp. 15–17.
55. E. Sehling, *Die reformatorische Kirchenordnungen des XVI. Jahrhunderts* (Tübingen, 1902–), v, col. 423; quoted in Dohrn-van Rossum, *History of the hour* (ref. 5), 155.
56. *Cf.* A. J. Turner, "Dialling in the time of Giovan Battista Benedetti", in *Cultura, scienza e techniche nella Venezia del cinquecento. Atti del convegno internazionale di studio Giovan Battista Benedetti e il suo tempo* (Venice, 1987), 311–20. Turner attributes the dramatic increase in the production of sundials and books about them in the 16th century to the rapid spread of clocks across Europe, the incorporation of magnetic compasses into sundials, which opened up possibilities for new forms of portable dials, and the rise of mathematical interest in sundial projections and the integration of dialing into the mathematics curriculum.
57. Philippe de la Hire, *La gnomonique ou methodes universelles, pour tracer des horloges solaires ou cadrans sur toutes sortes de surfaces* (Paris, 1698), sig. br–bv; my translation.
58. First two quotations are from Benjamin Martin, *The description and use of both the globes, the armillary sphere, and orrery, exemplified in a large and select variety of problems in astronomy, geography, dialling, navigation, spherical trigonometry, chronology, &c.* (London,

[1761?]), pp. 34 and iii respectively. Third quotation is from Leybourn's preface to the reader of Stirrup, *Horometria* (ref. 44).

59. AP (M-363).
60. Pillar dial, style of Erasmus Habermel, Prague, *c.* 1580, gilt brass and silver, AP (M-306).
61. Pillar dials at the Adler Planetarium: style of Erasmus Habermel, Prague, *c.* 1580, gilt brass and silver (M-306); [Erasmus Habermel], Prague, *c.* 1580, gilt copper (M-305); European, 18th–19th century, boxwood (A-160); Savarin, Bordeaux, 18th century, printed paper on wood (W-72).
62. *Cf.* Butterfield-type dial by Michael Butterfield, Paris, *c.* 1665–1724, premier cadran, silver, AP (A-243) with that of Pierre le Maire 2, Paris, *c.* 1740, brass, AP (W-42).
63. *Cf.* Augsburg-type dial by Johann Mathias Willebrand, Augsburg, *c.* 1700, silver and gilt brass, AP (N-11) with that of Lorenz Grassl, Augsburg, *c.* 1770, brass and silvered brass, AP (T-18).
64. Augsburg-type dial in silver volvelle case with brass container, by Johann Martin, Augsburg, *c.* 1675–1700, silver and gilt brass, AP (A-98).
65. Augsburg-type dial with volvelle case, Philip Happacher, Freiburg?, *c.* 1675–1700, gold, silver, gilt brass, AP (A-104).
66. Four Augsburg-type sundials at the Adler Planetarium: Johann Martin, Augsburg, *c.* 1675–1700, silver and gilt brass (A-98); Johann Mathias Willebrand, Augsburg, *c.* 1700, silver and gilt brass (N-11); Johann Nepomuk Schrettegger, Augsburg, *c.* 1797–1843, gilt and silvered brass (T-17); Lorenz Grassl, Augsburg, *c.* 1770, brass and silvered brass (T-18).
67. Example of forgeries: Butterfield-type sundials, Paris, *c.* 1700, AP (M-312, N-5), and CHSI (7009, 7011).
68. *Cf.* Butterfield-type dial by Pierre le Maire 2, Paris, *c.* 1740, brass, AP (W-42), which has the typical European gazetteer, with another Butterfield-type dial by Pierre le Maire 2, Paris, *c.* 1750–1785, brass, AP (T-58), which has fourteen cities in French North America on the gazetteer. *Cf.* also an inclinable brass sundial by the same maker, AP (W-57), which shows the French possessions down the Mississippi to New Orleans and into South America.
69. Quotation appears on a manuscript pasted into the case of a Pierre le Maire 2 Butterfield-type sundial, dated 1743, that belongs to the Musée Stewart in Montreal. This sundial has a gazetteer similar to those discussed in ref. 68. For archaeological records, see Silvio A. Bedini, *Thinkers and tinkers* (New York, 1975), 264, 442 n. 14, and Figs 22–23.
70. Gouk, *Ivory sundials of Nuremberg* (ref. 21), 106–10. In the Adler Planetarium collection, there is an English universal ring dial with French months on its calendar scale (N-32); and a German floating sundial with an English compass rose (N-9). Both are 18th century.
71. See for instance, a Butterfield-type dial by Jean-Gabriel-Augustin Chevallier, Paris, *c.* 1796–1840, copper, brass, silvered brass, AP (A-97), which has ten cities spanning from Paris to Quebec to Warsaw to Rome; an ivory diptych by Hans Ducher 2 or Hans Ducher 3, Nuremberg, *c.* 1570–1621, AP (DPW-30), which covers Africa to Moscow; and a universal ring dial attributed to Johann Sommer, Augsburg, *c.* 1660–1702, AP (A-166), which includes Calcutta, Goa, and Constantinople.
72. Ivory diptych, Thomas Ducher, Nuremberg, *c.* 1620–40, CHSI (7579).
73. *Cf.* Butterfield-type dials by [Jean Louis Jacques?] Baradelle, Paris, *c.* 1752–94, silver, AP (W-41, N-6, and W-67).
74. See the following ivory, Bloud-type sundials at the Adler Planetarium: Gabriel Bloud, Dieppe, *c.* 1666 (N-20); two unsigned instruments, Dieppe, *c.* 1650–70 (A-163, W-30); and Jacques Senecal with Felix Gervaise, Dieppe, *c.* 1660 (DPW-18).
75. Butterfield-type dials by Michael Butterfield, Paris, *c.* 1665–1724, silver, AP (A-243, W-219).
76. Inclinable dial, Edmund Culpeper, London, *c.* 1713–38, silver, AP (W-130).