UNEQUAL HOURS: THE JEWISH RECEPTION OF TIMEKEEPING TECHNOLOGY FROM THE BIBLE TO THE TWENTIETH CENTURY

David Zvi Kalman

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Supervisor of Dissertation

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Talya Fishman, Associate Professor of Near Eastern Languages and Civilizations

Graduate Group Chairperson

____

Joseph E. Lowry, Associate Professor of Near Eastern Languages and Civilizations

Dissertation Committee:
Joseph E. Lowry, Associate Professor of Near Eastern Languages and Civilizations
David Stern, Harry Starr Professor of Classical and Modern Jewish and Hebrew Literature and Professor of Comparative Literature, Harvard University
Adelheid Voskuhl, Associate Professor of History and Sociology of Science

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שהחיינו וקיימנו והגיענו לזמן הזה

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I first began taking the history of technology seriously as a subject for scholarly debate in the course of a series of classes I taught on behalf of Hadar at Penn Hillel. Thank you to Hadar and to Ethan Tucker in particular for making those classes possible.

Thank you to the doctors who prescribed the medication that allowed me to pursue this degree. Graduate school is a long, lonely experience; if you are a graduate student reading this, be assured that it's not just you: the graduate school system is not good for your mental health, and you should seek out help earlier rather than later. If you haven't already, unionize.

This is a dissertation about technology made possible by technology. The evidence described in this study covers vast geographies and time periods and is buried in unlikely places. Collecting it was a gargantuan effort, but most of that effort was not mine. Instead, this dissertation stands upon many digital databases, including the Bar Ilan Responsa Project, Otzar HaHochma, Hebrewbooks.org, and the Friedberg Genizah Project. These resources are often invisible, as they do not appear in footnotes, but they are giants upon whose shoulders I and others stand. Their contribution to the field of Jewish studies is itself worthy of study. In addition, I am grateful for the support of virtual scholarly communities, especially Facebook's "Ask the Beit Midrash" group.

Finally, thank you to my family. Thank you, in particular, to my chemist grandfather, Bernard, who instilled in me an early interest in science (though not enough, apparently, for me to become an actual scientist). Thank you to my other grandfather, Harry, whose kosher winemaking showed me the importance of material culture. Thank you to my father, Stephen, whose endless fascination with how things work and whose ability to become an instant expert in new subjects allowed me to see this project as a reasonable undertaking. Thank you to my children, Avri, Shula, and Tori, for eventually getting around to reading your father's dissertation—hello from the distant past!

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Abbreviations and Use of Terms

For the sake of clarity, I have tried to minimize abbreviations in this study. There is one important exception with regard to Late Antique rabbinic literature. Here I have followed standard citation practices to refer to the Mishnah (m), Tosefta (t), Babylonian Talmud (b), and Palestinian Talmud (y). The citation bBerakhot2a, for example, means folio 2a of Tractate Berakhot in the Babylonian Talmud.

Manuscript citations have been abbreviated; a key can be found at the beginning of the bibliography, on page 345.

Finally, this study makes heavy use of a few technical timekeeping terms; some of these are commonly used, while others are specific to my work. These are defined at several places within the text but for convenience I am giving them here, as well:

- A *seasonal* hour is always 1/12 of the day (or night) on any given day (or night). Because the length of the day and night change over the course of the year, the seasonal hour's precise length is always in flux.
- An *equinoctial* hour is 1/24 of the day/night cycle. Its length is constant.
- A *clock* hour is an hour as defined by a clock's bells or dial.
- I call the word "hour" *technical* when it refers to a specific interval of time; this interval could be seasonal or equinoctial, but it is usually not further defined. It is to be distinguished from the *non-technical* hour, in which "hour" simply means "a short amount of time."

ABSTRACT

UNEQUAL HOURS: THE JEWISH RECEPTION OF TIMEKEEPING TECHNOLOGY

FROM THE BIBLE TO THE TWENTIETH CENTURY

David Zvi Kalman

Talya Fishman

Many studies of Jewish history are set against a backdrop of political or cultural change; few studies, especially those set before the Industrial Revolution, analyze technological change, in part because such change often took place quite slowly. Timekeeping technology has been in development for more than 3,500 years; by examining the long Jewish relationship to timekeeping, this dissertation is intended to serve as proof-of-concept for how historians of Judaism and historians of technology can learn from one another and is an invitation for them to do so. Beginning in Ancient Egypt, this study surveys the origins of formal timekeeping systems and the earliest timekeeping technologies and tracks their appearance in the Bible and Second-Temple-period Jewish writings. Investigating the adoption of Greco-Roman timekeeping systems by the rabbis of Late Antiquity, the study reassesses what the rabbis did and did not expect from the public with regards to timekeeping precision and what they themselves understood about timekeeping on a theoretical level. The study introduces the concept of a "naïve" hour and highlights the role of latitude in legal deliberations. Following the Islamic conquests, Jews in Islamic lands gained access to sophisticated timekeeping concepts through Islamic astronomy, but these did not become popular in non-scientific writings. Rabbanites continued to use the Greco-Roman timekeeping system, whereas Karaites did not. In medieval Christian Europe, access to timekeeping technology and theoretical knowledge was limited, but settlement at northerly latitudes nonetheless forced rabbis to reckon with timekeeping in new ways. With the invention of the mechanical clock around 1300 (and the sandglass, invented almost simultaneously), the Jewish relationship to timekeeping changed yet again, with different areas of Europe and the Ottoman Empire reacting quite differently according to local usage. Seventeenth-century breakthroughs in clock and watch accuracy led to further changes in the Jewish relationship to the devices. Beginning in the eighteenth century, increased toleration of Jews by Christians led to Jews deploying clocks and depictions of clocks in public settings for the first time. This study concludes with an ex-

amination of Jewish protests to the timekeeping system adopted in Mandatory Palestine and the State of Israel.

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Introduction

This is a study of how Jews kept track of time, both in theory and in practice, as they were exposed to a variety of timekeeping systems and a succession of breakthroughs in timekeeping technology. The scope of this study is narrow, but the timeframe is considerable: it begins in the Ancient Near East and ends in the twentieth century.

Generally speaking, Jewish historians dislike writing on such large time scales, since writing across multiple eras leaves one open to criticism from scholars in multiple sub-specialties. Despite the vulnerabilities the scope creates, I have chosen to study this lengthy time span for two reasons. First, the trends I wish to highlight move very slowly; in order to achieve interesting results, it was necessary to study changes across millennia. Second, this dissertation is intended as a proof-of-concept for conducting research at the intersection of Jewish history and the history of technology, two fields which rarely meet. Because technology's history is separate from both politics and culture—and because pre-industrial technological change happened more slowly—its subdivisions do not match those traditionally employed in Jewish history. This project re-examines Jewish texts through the lens of technological development; as a result, its bounds must be set by that development, as well.

Jewish history and the history of technology

The relationship between Jewish history and the history of technology is long and almost entirely unstudied; at the present moment, the fields overlap very little.

For their part, few historians of technology have shown interest in Jewish history; aside from an article on leather-making techniques in Qumran, in *Technology and Culture*—the flagship journal of the field since its birth in 1959—there have been few examinations of Jewish contributions to or reception of technological development.[1]

Conversely, Jewish historians have engaged little with the history of technology, although this is sometimes overlooked because of the robust and growing literature on the Jewish consumption, transmission, and development of scientific knowledge. There are a few reasons that Jewish studies has neglected this field. First, there is no obvious place to begin: prior to the Industrial Revolution, Jewish texts discussing applied sciences and mechanical arts are relatively rare and almost always appear in passing in the service of some related matter. While Jewish writers have produced numerous scientific works over the centuries (a few of which, such as the astronomy of Gersonides, even advanced their fields), there are virtually no extended treatments of any technology—practical or theoretical—until the seventeenth century works of Joseph Solomon Delmedigo (d. 1655), whose writings were motivated both (in general) by the fact that he was able to achieve a full university education and (in particular) by the rising importance of mechanics at his alma mater, the University of Padua.[2] Moreover, Late Antique rabbinic texts spend little time discussing the history of human invention; when they do discuss it, it is almost always to claim God as the true inventor or to denounce the creation or its creator.[3]

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[1] J.B. Poole and R. Reed, "The Preparation of Leather and Parchment by the Dead Sea Scrolls Community," *Technology and Culture* 3, no. 1 (1962): 1–26.

[2] The most important study of Delmedigo remains Isaac Barzilay, *Yoseph Shlomo Delmedigo, Yashar of Candia: His Life, Works and Times* (Brill, 1974). See, as well, Jacob Adler, "J.S. Delmedigo and the Liquid-in-Glass Thermometer," *Annals of Science* 54 (1997): 293–299.

[3] See, for example, the discussion of the invention of fire and animal husbandry in bPesaḥim56a and the creation of the first tongs in mAvot5:6 and tEruvin8:23. Neutral claims about human invention do not

Second, Jewish economic and political circumstances sometimes hampered technological discourse. In both Islamic lands and in the Roman Empire, books on practical engineering and ingenious devices were usually produced with the patronage of the rich or powerful, not by politically impotent minorities. In medieval Europe, local policies frequently prevented Jews from participating in craft guilds, where many new medieval technologies were first introduced. These major centers for innovation thus remained out of sight of most Jews.[4]

Finally, Jewish, Christian, and Muslim thinkers all followed the same basic ranking of the sciences, in which abstract contemplation was held in high regard and the study of practical matters was perceived as being of lesser value—a ranking which, in turn, negatively affected the quantity of scholarly output devoted to practical topics.[5] Books on technology, already a rarity in Arabic, are nonexistent in He-

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appear until the Islamic period; see, for example, Midrash Tanḥuma Bereishit §11 and RNL Evr. II, A 32, 9r (quoted below, page 116). Greeks and Romans, by contrast, were much more willing to discuss human innovations; for an overview, see Kevin Greene, "Inventors, Invention, and Attitudes toward Technology and Innovation," in *The Oxford Handbook of Engineering and Technology in the Classical World*, ed. John Peter Oleson (Oxford University Press, 2009). The first neutral mention of human invention might be the claim in Midrash Tanḥuma (a late rabbinic text, perhaps edited in the ninth century CE) that Noah invented the plow; see Midrash Tanḥuma Bereishit 11:6; cf. Genesis Rabbah 11:6.

[4] S.R. Epstein and Maarten Prak, *Guilds, Innovation, and the European Economy* (Cambridge University Press, 2008). Though Jews did not personally create artisanal items, they did possess quite a few of them as collateral of the rich and powerful, and this seems to have influenced the medieval European Jewish aesthetic: see, for example, the close stylistic affinity between the German monstrance and several *havdalah* candle holders. The best treatment of this subject is Joseph Shatzmiller, *Cultural Exchange: Jews, Christians, and Art in the Medieval Marketplace* (Princeton: Princeton University Press, 2013).

[5] Much has been written on this topic. In the Christian European sphere see, for example, George Ovitt, Jr., "The Status of the Mechanical Arts in Medieval Classifications of Learning," *Viator* 14 (1983): 89–105. Ovitt sees thirteenth-century monastic attitudes towards labor as a turning point; disputing this, Elspeth Whitney posits that the turning point was instead the rise of the university; see Elspeth Whitney, "Paradise Restored: The Mechanical Arts from Antiquity through the Thirteenth Century," *Transactions of the American Philological Society* 80, no. 1 (1990): 1–169. The hierarchy of knowledge is slightly more complicated for Muslim's *falāsifah*. Some, like al-Kindī (d. ca. 870) wrote on a variety of eclectic and practical subjects, such as sword making. Over time, however, *falāsifah* tended to place greater focus on the "highest" subjects, such as physics and metaphysics; some works, such as *Ḥayy ibn Yaqẓān* of Ibn al-Ṭufayl (d. 1185) argued that exposure to the material world was not necessary and was perhaps even detrimental for the seeker of true knowledge. Ahmed Dallal contrasts these "metaphysical" approaches to reason (*ʿaql*) with what he calls a "procedural" approach, under which rationality is subject-dependent; see

brew. There is, in short, no *locus classicus* from which to begin this study, and so study rarely begins.

But, to quote Galileo (apocryphally), *eppur si muove*—technology *has* been moving, despite the dearth of contemporary descriptions. The fact that textual material relevant to the history of technology is scattered throughout the Jewish legal corpus has not stopped scholars from utilizing this material, but the absence of a concentration of interesting data *has* made contextualizing and synthesizing this material much more difficult. It is worth highlighting two bodies of research, both of which are important precedents for the current project.

The closest Jewish studies has come to a subfield in technology is the study of *realia*, sometimes called *qadmoniyyot* ("antiquities") literature. This subfield, which began as part of the *Wissenschaft des Judentums* movement and took off in the late nineteenth century through the pioneering and voluminous *Die Flora der Juden* of Leopold Löw (d. 1944) and *Talmüdische Archäologie* of Samuel Krauss (d. 1948), has continued to develop through the work of scholars such as Raphael Patai, Meir Ayali, Tziona Grossmark, and most especially Daniel Sperber.[6] From its inception, the study of *realia* in Jewish documents has been focused on Late Antique rabbinic texts and its research has largely been garnered from contemporary linguistic and archaeological investigations of Greek, Latin, and (most recently) Sassanian sources. This linguistic focus explains why a number

Dallal, *Islam, Science, and the Challenge of History*. Still, the subjects themselves did not change much, and so mechanics was not greatly elevated under either approach.

[6] On the history of *realia* literature, see Steven Fine, "Archaeology and the Interpretation of Rabbinic Literature: Some Thoughts," in *How Should Rabbinic Literature Be Read in the Modern World?*, ed. Matthew Krauss (Piscataway, N.J.: Gorgias Press, 2006), 201–219; Yaron Z. Eliav, "Samuel Krauss and the Early Study of the Physical World of the Rabbis in Roman Palestine," *Journal of Jewish Studies* 65, no. 1 (2014): 38–57; Daniel Sperber, "The Use of Archaeology in Understanding Rabbinic Materials: A Talmudic Perspective," in *Talmuda De-Eretz Israel: Archaeology and the Rabbis in Late Antique Palestine*, ed. Steven Fine and Aaron Koller (De Gruyter, 2014), 321–346.

of *realia* works take the form of lexica for Talmudic technical terminology, often with a focus on loanwords. While these studies do investigate technologies, they do not examine technological development *per se*, in part because they restrict themselves to Late Antique texts.[7]

A second body of literature concerns the printing press, the sole pre-industrial technology whose engagement with Jewish culture has been adequately researched.[8] These studies are very important; it is difficult to imagine understanding Jewish intellectual history in the fifteenth and sixteenth centuries without them. At the same time, the printing press is not a good representation of how Jews normally received new technologies, being unusual in two significant ways.

First, the printing press fundamentally and permanently altered the manner in which Jewish ideas were disseminated, in the process shifting the balance of power away from local rabbinic authorities towards books, authors, presses, and censors. Rabbis, as one might imagine, had quite a bit to say about this shift, and as a result there is an identifiable corpus of material that one can study. This corpus is valua-

[7] There have been a few attempts at taking *realia* into the medieval period, mostly produced in the middle of the twentieth century. One such study is Shereshevsky, "Realia as Portrayed By Rashi: A Description of Medieval Household Utensils," an uncritical but resource-rich work. A few studies in the genre have been organized topically, such as Shapira, "Sugar and Sugar Cane in Hebrew Literature"; Brand, *Ceramics in the Talmudic Literature*; Brand, *Glassware in the Talmudic Literature*. Throughout these works, the method is largely philological. The most notable exception lies in Genizah research, especially the portrait of the economy painted by S.D. Goitein and, more recently, scholars like Jessica Goldberg and Phillip Ackerman-Lieberman.

[8] One of the earliest studies is David Werner Amram, *The Makers of Hebrew Books in Italy* (Philadelphia: J.H. Greenstone, 1909). Important contributions include: Yitshak Ze'ev Kahana, *Ha-Defus Ba-Halakhah* (Jerusalem: Mossad HaRav Kook, 1945); Michael Pollak, "The Invention of Printing in Hebrew Lore," *Gutenberg-Jahrburch*, 1977, 22–28; Mark Hurvitz, "The Rabbinic Perception of Printing as Depicted in Haskamot and Responsa" (Hebrew Union College-Jewish Institute of Religion, 1978); Stephen G. Burnett, *Christian Hebrew Printing in the Sixteenth Century: Printers, Humanism and the Impact of the Reformation* (Universidad Pontificia de Salamanca, 2000); Joseph Davis, "The Reception of the Shulḥan ʿArukh and the Formation of Ashkenazic Jewish Identity," *AJS Review* 26, no. 2 (2002): 251–276; Vivian B Mann and Daniel D Chazin, "Printing, Patronage and Prayer: Art Historical Issues in Three Responsa," *Images*, 2007, 91–98. In addition, there have been extensive studies of book circulation, censorship, and libraries.

ble, but it is also exceptional; most pre-industrial inventions are not discussed directly in the same manner.

Second, the printing press stands out among pre-industrial technologies in that development was quite fast, had a single point of origin, and the device was hailed almost immediately as a world-shaking invention. This invention narrative became quite common beginning in the late nineteenth century—the telephone and electricity both have such stories told about them—but at the time it was highly unusual, and the rabbinic response was highly unusual, as well. As opposed to the printing press, most pre-industrial technologies developed over a very long period of time, often improved anonymously by the craftspeople who built them, but because of this pace it was sometimes not clear that they were changing at all.

In choosing timekeeping technology as the focus of my study, I have attempted to examine the Jewish response to what I believe is a more typical example of technological change. Timekeeping technology developed slowly; though sophisticated sundials and clepsydra already existed in Late Antiquity, the public normally did not have access to the best timepieces, if they had access to any at all. Developments were numerous, but usually minor; the invention of the mechanical clock, which Lewis Mumford hailed as the beginning of the path to the Industrial Revolution, was so seamless with what had come before that the new devices and the old devices continued to share the name *horologium* for most of a century.[9] Development again moved slowly while the devices became increasingly ubiquitous; in the seventeenth century, a series of incremental breakthroughs again led to significant improvements in accuracy, and subsequent breakthroughs led to the devices becoming not just more accurate, but smaller and

[9] Lewis Mumford, *Technics and Civilization* (New York: Harcourt, Brace and Co., 1934), 14–15.

more portable, as well.

In one way or another, Jewish culture bore witness to all of these changes—but it did so in small ways, through subtle changes in expectations around timekeeping, in changing uses of the word "hour," in descriptions of short intervals, in new and renewed legal discussions, and in references to timekeeping devices themselves. Attitudes towards timekeeping changed over and over again, all without anyone noting it; in fact, none of the sources cited in the first five chapters of this study acknowledged that timekeeping technology was changing or had changed in the past. This lack of acknowledgment of technological change, I wish to argue, is far more typical than that which took place following the invention of the printing press.

If the history of timekeeping technology is unusual, it is only in its sheer length. Few technologies can boast a 3,500-year history; those that can—like the wheel—are usually less eventful.[10] Clocks, however, have long been complex devices; as a result, there has always been room for improvement and variation. This long history has allowed me to showcase what a study like this can accomplish when constructed across most of Jewish history.

Finally, I have chosen to examine the history of timekeeping because—while its Jewish dimensions are largely unexplored—it has been a subject of intense study by both scholars and amateur clock and watch collectors for more than a century. Despite the vastness of this literature, it has almost entirely skipped over Jewish texts and artifacts. Just as I hope that this study ignites interest in the history of technol-

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[10] On the wheel's invention and development, see Richard W. Bulliet, *The Wheel: Inventions and Reinventions* (Columbia University Press, 2016).

ogy among historians of Jewish studies, I hope that it will invite historians of technology to engage with Jewish studies in future explorations.

Calendrical studies vs. timekeeping studies

When we speak about "timekeeping," we may be speaking about two separate activities. On the one hand, there are timekeeping activities for which the day is the *smallest* unit and the basic building block; from this building block one creates weeks, months, years, and so on. Historically, timekeeping on this scale involved coordinating the movements of the sun, moon, and stars in order to establish months, seasons, years, and various astrological cycles—in other words, the components of the calendar. Making calendars requires mathematics, as well as some astronomical knowledge, but it does not require constant, direct observation of celestial bodies. Many calendrical systems, like the now-defunct Julian calendar, have been built on inaccurate empirical data, and some, including the Jewish calendar, no longer rely on direct observation at all. In Jewish law, the necessity of determining the dates of holidays, fast days, and the beginning of new months resulted in a long, sophisticated calendrical discourse; it also sparked battles between Jewish leaders vying for political power.[11] In Jewish studies, calendrical treatises and calendrical debates have both received scholarly attention. I devote very little attention to calendrical studies in this work.[12]

The second kind of timekeeping treats the day as the *largest* unit; here the task is to

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[11] See, for example, mRoshHashanah2:8–9. The most well-known calendrical debate is the tenth-century Ben Meir controversy; on this, see the recent research by Sacha Stern and Marina Rustow, "The Jewish Calendar Controversy of 921–922: Reconstructing the Manuscripts and Their Transmission History," in *Time, Astronomy and Calendars in the Jewish Tradition*, ed. Sacha Stern and Charles Burnett (Leiden: Brill, 2014), 79–95.
[12] On the calendar in Jewish history, see, most recently, Elisheva Carlebach, *Palaces of Time* (Cambridge, Massachusetts: Harvard University Press, 2011).

subdivide the day into portions of various sizes for the purpose of determining how much time has elapsed from the beginning of the day (to answer "What time is it?") or from some arbitrary point (to answer "How much time has passed?"). Historically, this small-scale timekeeping has been a much more difficult task, because it relies heavily on empirical observation and as a result is highly dependent on the quality of one's instruments. Many such instruments have been invented over the last 3,500 years, with the most significant improvements occurring after the invention of the mechanical clock in the late thirteenth or early fourteenth century.

It is this second form of timekeeping which I cover in this study. Unlike Jewish calendrical studies, this form of timekeeping has no central text from which to begin; references to the day or portions thereof can be found throughout Jewish literature, but they are scattered and little space is spent for reflections on timekeeping as a practice or the terminology used to describe various portions of the day. As a result of this problem, Jewish timekeeping has received far less scholarly attention than the Jewish calendar; when it is discussed, it is normally as an extension of calendrical studies, the subjective experience of time, or the concept of time itself.

Previous research

In the last few years, a number of Jewish historians have applied themselves to the Jewish relationship to time in the Second Temple period and among rabbis in Late Antique Palestine and Babylonia. In his work on the rabbinic conception of time, Sacha Stern has investigated the inexactitude of rabbinic timekeeping; he has also noted that rabbinic timekeeping is frequently tied to events within the day, rather than to some notion of time which exists independently of those events.[13] Stern does spend some time in medieval literature, but his major interest is in Late Antique rabbinic texts. His interest in technology is peripheral; his analysis of rabbinic timekeeping is in service of a philosophical point about the primitive nature of the Jewish conception of time.

Three more studies are also relevant. Sarit Kattan Gribetz's 2013 dissertation discusses the bi-directional relationship between Roman and rabbinic timekeeping on the daily, weekly, and monthly levels; importantly, she has attributed to the Romans the rabbis' increased interest in tracking time as part of ritual.[14] Gribetz's study is mostly focused on larger time scales, and is interested in the effects of Roman culture generally, rather than the sundial and water-clock in particular. Lynn Kaye's study of time and temporality in the Babylonian Talmud devotes a chapter to the rabbis' understanding of human imprecision and divine precision, tying this to material evidence about sundials and clepsydras from the region. There is overlap between her work and the final section of chapter 2; her work contains additional sources and ideas beyond what I have covered here.[15] Most recently, Eshbal Ratzon has investigated how Babylonian clocks and timekeeping systems might have influenced calendars and timekeeping systems in Qumranic and apocryphal texts.[16]

Within the realm of Jewish studies, the best treatment of timekeeping's technologi-

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[13] Sacha Stern, *Time and Process in Ancient Judaism* (Littman Library of Jewish Civilization, 2007), chap. 2.
[14] Sarit Kattan Gribetz, "Conceptions of Time and Rhythms of Daily Life in Rabbinic Literature, 200–600 C.E." (Princeton University, 2013).
[15] Lynn Kaye, *Time in the Babylonian Talmud: Natural and Imaginative Times in Jewish Law and Narrative* (Cambridge University Press, 2018), chap. 2.
[16] Eshbal Ratzon, "Jewish Time: First Stages of Seasonal Hours in Judea," *Studies in History and Philosophy of Science Part A*, November 2018.

cal development is in an article by Israel Ta-Shma on early reactions to the mechanical clock and sandglass.[17] Ta-Shma's work highlights many of the earliest Jewish witnesses to these objects, mostly in Ashkenaz; he also notes that the arrival of these timepieces led to changes in the way that rabbis discussed seasonal and equinoctial hours, and that it enabled the use of more precise descriptions of small time intervals. Much of the material described in this article is covered in chapter 5, Part V. I have not found reason to argue with Ta-Shma's conclusions; instead, I believe I have been able to fill them out with additional examples, place them in context with parallel developments in Italy, and bring the highlighted shifts into focus by understanding them in a wider historical context.

Major themes

The results of this study are many and varied, but a few major themes emerge. First, there is the changing Jewish exposure to timekeeping technology. At one extreme, such devices were almost entirely out of the hands of Jews; at another, they were widespread and Jews were involved in their manufacture. Jewish access to timekeeping technology did not increase linearly, and the technology itself often did not improve for long periods of time. Access to the technology affected not only the rabbis' ability to describe the devices, but expectations about punctuality and the associations of the technology with the divine, as well.

The changing meaning of the term "hour" is another major theme. In contemporary usage, "hour" always refers to 1/24 of a day/night cycle, and this does not

[17] Israel M. Ta-Shma, "The Measurement of Time as Reflected in Medieval Rabbinic Literature [Hebrew]," *Tarbits* 72, no. 1/2 (2003): 245–57.

vary according to the season. Historically, this “equinoctial” hour is frequently contrasted with the “seasonal” hour, which is always 1/12 of the day (or night), and which therefore varies in length over the course of the year. Both awareness and ignorance of this distinction are recurring elements of this study.

Another theme is changing rabbinic expectations about how well the public should be expected to track the time. These expectations varied widely across cultures; importantly, these expectations are sometimes lower than what one might surmise based on the terminology in use.

Finally, this study affirms that Jews had a tendency to absorb elements of every timekeeping system which they encountered: many of the attitudes expressed in rabbinic sources have corollaries in Christian or Muslims sources. At the same time, new timekeeping systems and expectations did not wipe away what had come before; instead, the Jewish attitude towards timekeeping has been a slow accumulation of ideas imported from a wide variety of cultures across millennia.

Structure of this study

Because it is intended to be of use to historians of Judaism, I begin each chapter with a survey of the existing literature on the history of timekeeping. Because it is intended for historians of technology, as well, I have attempted to explain key concepts in Jewish history and thought to a greater degree than would be necessary for an audience solely composed of Jewish historians. In attempting to make this project more accessible, I fear that I have also added to its length.

This study is arranged in chronological order. Chapter 1 aims to show how Jewish culture first developed a relationship with timekeeping and timekeeping technologies. Here I cover the origins of formal timekeeping in Ancient Egypt and Mesopotamia, as well as its adoption into Hellenistic culture and the settings in which sundials and clepsydras were typically used. I survey the evolving meaning of the term "hour" in different languages, the development of the twelve- and 24-hour day, and popular usage of both. Against this backdrop, I analyze the few Biblical passages which may display an awareness of a formal timekeeping system or timekeeping devices. Though the Bible itself does not provide much useful material, it serves as a foil for timekeeping in Second Temple literature. Towards the end of this chapter I contrast the Biblical perspective with those found in Qumranic and apocryphal literature, as well as Jewish literature written in Greek.

In chapter 2, I explore in detail how the rabbis of Late Antiquity thought about timekeeping in relation to the Hellenistic society in which they participated. Here I analyze the words that the rabbis used to talk about time, the symbolism with which they endowed timekeeping devices, their expectations for how well the average person would be able to keep track of time, and their understanding of the difference between divine and human timekeeping ability. In this chapter I also critique the way in which seasonal and equinoctial hours have been read into Late Antique rabbinic texts, arguing that a third type of hour—what I call a "naïve" hour—better represents the available data, and that it represents the beginning of a conceptual progression that led to the emergence of seasonal and equinoctial hours in Jewish texts. Finally, this chapter also explores rabbinic timekeeping in relation to Persian timekeeping, but on this front, there is simply less information available at the moment.

In chapter 3, I examine how the concept of timekeeping developed under medieval Islamic rule, as Jewish specialists gained access to the new Islamic astronomy and instrument-making, while the Roman timekeeping system fell into disuse in most settings. This chapter highlights a new divide between the way in which specialists and non-specialists speak about timekeeping. This divide persisted as astronomical knowledge was transferred to Jews in Europe, and ultimately was not resolved until the mechanical clock became a respectable scientific instrument. This chapter also pinpoints the origins of the concept of "seasonal hours" in rabbinic Judaism. Finally, I provide an analysis of Karaite timekeeping, arguing that the Karaites provide rare insight into how timekeeping in rabbinic law might have developed differently had it not so thoroughly absorbed the Hellenistic timekeeping system.

Chapter 4 examines Christian Europe prior to the invention of the mechanical clock, covering roughly 1000 to 1350 CE. This chapter describes timekeeping awareness at its lowest ebb, with the old Roman timekeeping system falling out of use in secular contexts and familiarity with even basic timekeeping devices relatively rare. Nonetheless, both weather and latitude forced Jews and Christians into a new relationship with timekeeping, even absent sophisticated theoretical knowledge. Towards the end of this period, exposure to astronomical knowledge caused this relationship to shift somewhat.

The culmination of my study is chapter 5, which describes the invention and reception of the mechanical clock and sandglass beginning at the end of the fourteenth century, as well as the various systems by which clocks were made to ring out the hours.

After briefly considering evidence of mechanical clocks and sandglasses in Avignon, Spain, and Portugal. I describe three quite different receptions of the clock in Ashkenaz, Italy, and the Ottoman Empire. This chapter relies both upon evidence from Jewish legal sources and new manuscript research, with a particular focus on book colophons, and also argues that the time between the clock's appearance and the first Jewish reactions was no more than a few decades. Here I also claim that, for Jews, the public clock retained its status as a Christian symbol, despite the ostensible secularization that the mechanical clock provided. Finally, I note that the European shift to clock time led, ironically, to a Gentile concept of "Jewish hours."

Chapter 6 begins around 1657, when mechanical clocks and watches began to see significant improvements in accuracy. Unlike the previous chapters, this one does not attempt to be exhaustive; nonetheless, it sketches the most important developments in Jewish timekeeping between the seventeenth and early twentieth centuries. First, it outlines how increased accuracy opened up new legal controversies that had previously been ignored or seen as moot. Second, it describes how the Jewish relationship to clocks in the public square changed along with greater toleration of Jews and eventual emancipation. Here I outline the ways in which clocks feature in synagogue architecture, portraiture, religious artifacts, and other aspects of Jewish life and literature.

Chapter 1: Timekeeping in the Bible and Second Temple Period Literature

> "May the gods destroy that man who first discovered hours and who first set up a sundial here; who cut up my day piecemeal, wretched me. For when I was a boy, my only sundial was my stomach, by far the best and truest of all clocks. When it advised you, you ate, unless there was no food; now even when there is food it isn't eaten unless the sun allows it. Indeed, now the town is so filled with sundials that the majority of its people crawl about all shriveled up with hunger."
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> —*Plautus (d. 184 BCE)*, The Boeotian Woman[1]

Formal timekeeping—that is, the imposition of artificial structures on the progression of the night and day—is very old, but it is not eternal. An individual employing a water-clock or sundial in the twelfth century CE would have been employing a technology which had not substantially changed in more than 2,500 years. Timekeeping metrics have proved to have even greater longevity; both the twelve hour (and twenty-four hour) division of the day, as well as the sexagesimal division of both the hour and the minute, have origins more than three millennia old.[2] Jewish history, like Ancient Greek and Ancient Egyptian history, is old enough to bear witness to the initial adoption of timekeeping systems and timekeeping technologies. In this chapter, I examine what

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[1] Translated in *Greek and Roman Technology: A Sourcebook* (Routledge, 1998), 517. A more poetic translation appears in Sara Schechner, "The Material Culture of Astronomy in Daily Life: Sundials, Science, and Social Change," *Journal for the History of Astronomy* 32 (2001): 192.

[2] The sixty-minute hour and sixty-second minute are inheritances of Babylonia's base-60 mathematics, but Babylonians did not themselves use the sixty-minute hour or sixty-second minute. Instead, texts describe the *bēru* (30°, i.e. 1/12 of a day/night cycle, i.e. the equivalent of two equinoctial hours) and the *uš* (1°, i.e. four minutes). The *uš* is divided into 60 units; these are the equivalent of four modern seconds. See Alexander Jones, "Introduction," in *Time and Cosmos in Greco-Roman Antiquity*, ed. Alexander Jones (Princeton University Press, 2016), 28; Robert Hannah, *Time in Antiquity* (Routledge, 2009), 71; Wayne Horowitz, *Mesopotamian Cosmic Geography* (Winona Lake, Indiana: Eisenbrauns, 1998), 182.

biblical and Second Temple writings can tell us about the early history of Jewish timekeeping by mapping these texts onto the early history of timekeeping in the Near East.

I. Background

The first formal timekeeping systems

The history of formal timekeeping spans more than four millennia; the history of timekeeping technology is only slightly shorter. The first known attempt to divide up the day or night is the "rising star chart," which appears on an Egyptian coffin dated to 2150 BCE. Unlike the sun during daylight, the night sky itself—filled with a catalog of identifiable, shifting celestial objects—could be viewed as a timekeeping device by identifying the relationship between the rising and setting of various stars. Egyptian star charts attempted to accomplish this by tracking 36 groups of stars, called decans.[3] After examining the eastern horizon for the most recently risen decan, an observer could consult the table, identify the day and month, and learn in which division of the night he was currently located. A component of this system was the need to divide the night into twelve equal parts; only later was the twelve-part division applied to the day, as well.[4] It is in this nocturnal context that the term "hour" (Egyp. *wnwt*) first appears.[5]

The Egyptian divisions did not represent a full-fledged system for keeping track of time. The charts delineated the night, but the twilight period—whatever its length—

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[3] R.A. Parker, "Ancient Egyptian Astronomy," in *The Place of Astronomy in the Ancient World* (London: Oxford University Press, 1974), 53.

[4] Neugebauer suggests that the day was initially divided into ten hours, with two hours reserved for twilight; later, the twilight hours were folded into the day. See O. Neugebauer, *The Exact Sciences in Antiquity* (Providence: Brown University Press, 1957), 86. On the correlation between these constellations and the Egyptian week, see O. Neugebauer, "The Egyptian 'Decans,'" *Vistas in Astronomy* 1 (1955): 47–51.; Parker, "Ancient Egyptian Astronomy," 56. For a more recent study, see Jones, "Introduction," 19.

[5] Marshall Clagett, *Ancient Egyptian Science: A Sourcebook. Volume II: Calendars, Clocks, and Astronomy* (Philadelphia: American Philosophical Society, 1995), 49.

was excluded, as was daytime itself. Furthermore, it does not appear that the twelve hours on any given day or night were identical to one another in length.[6]

The first *systematic* attempts to track time emerged around 1500 BCE; it is then that we find the shadow clock, the first known object to be constructed for the sole purpose of tracking the passage of time.[7] While the relationship between the sun's position and the length of shadows had surely been noted before, the shadow clock is distinguished by its standardized nature and by acknowledgement of its purpose in contemporaneous documents.[8]

The shadow clock proved to be a transitional solar-based timekeeping device; while scholars have assumed that these devices were intended to read out seasonal hours, a recent study has argued that these clocks were not yet even this sophisticated.[9] Shadow clocks were portable, but they could not be used year-round. They often contained just five markings to cover the entire day, and tended to be less accurate around noon. The clocks attest to a desire to quantify time, but only crudely. In fact, it is possible that their early usage was purely ornamental, a trend in clock design which we shall encounter again below.[10]

The appearance of the first sundials, not long after the first shadow clocks, marks the emergence of a set of devices which would remain one of the two primary timekeeping tools well into the medieval period. Sundials first emerged in Egypt, found their way to Babylonia by 1000 BCE at the latest, and may have appeared in Greece as

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[6] Jones, "Introduction," 25.
[7] Parker, "Ancient Egyptian Astronomy," 56–57.
[8] Sarah Symons, "Ancient Egyptian Astronomy: Timekeeping and Cosmography in the New Kingdom" (University of Leicester, 1999), 128. See also footnote 130 there, where Symons rebuts the claim that obelisks, which bear a superficial resemblance to giant gnomons and long predated the earliest star charts, were ever used to tell time.
[9] Symons, 147.
[10] Clagett, *Ancient Egyptian Science: A Sourcebook. Volume II: Calendars, Clocks, and Astronomy*, 56.

early as the sixth century BCE.[11] There are more than a dozen types of sundial, many of which seem to have been developed simultaneously, but all share a gnomon (Gk. "pointer"), whose shadow is cast upon a surface marked to indicate the time of day (and, depending on the phase of the moon, night).[12] Lines radiating from Egyptian gnomons suggest that a division of the day into twelve equal parts was in place quite early.[13]

Sundials varied significantly in design from one another both in their precise mode of action and in their size and accuracy. In the first century we even see evidence of portable dials, although "portability" was still a relative term, as a portable dial might still need to be hung from a wall.[14] These dials could actually be more difficult to operate, since stationary sundials were pre-calibrated for specific latitudes, while portable sundials needed to be calibrated by the user.[15]

Regardless of design, all sundials suffered from two major shortcomings. First, they were useless on moonless nights or in cloudy weather; second, they were not useful in measuring intervals, since the time that passed between marks fluctuated with the seasons. Both of these problems were addressed in the water-clock, whose first known description dates to the sixteenth century BCE and whose first known exemplar dates to the reign of Amenhotep III (early fourteenth century BCE).[16]

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[11] Robert Hannah, "Sundials," *The Encyclopedia of Ancient History*, no. 1976 (2012): 6455–56.
[12] Hannah, *Time in Antiquity*, 95.
[13] For a complete analysis of known Egyptian sundials, see Sarah Symons and Himanshi Khurana, "A Catalogue of Ancient Egyptian Sundials," *Journal for the History of Astronomy* 47, no. 4 (2016): 375–85. Data from this study, including pictures of many of the devices, are available online at Hannah, *Time in Antiquity*, 96.
[14] See Pattenden, "Sundials in Cetius Faventius," especially the tablet on page 108.
[15] See Richard J.A. Talbert, *Roman Portable Sundials: The Empire in Your Hand* (London: Oxford University Press, 2017), 14ff.
[16] Karlheinz Schaldach, "Measuring the Hours: Sundials, Water Clocks, and Portable Sundials," in *Time and Cosmos in Greco-Roman Antiquity*, ed. Alexander Jones (Princeton University Press, 2016), 65. On Egyptian

The invention of the water-clock, or clepsydra (Gk. "water stealer"), marks the first attempt to track time without reference to a celestial body. In the original outflow variety, a receptacle with a small spout at the bottom is demarcated on the inside; as water spills out, the water level on the outflowing receptacle indicates elapsed time. Inflow clepsydras—in which time is demarcated on the sides of a vessel into which water is flowing—was somewhat more sophisticated; both are already in evidence in Egypt.[17] The clepsydra was well suited for measuring fractions or multiples of equinoctial hours, although popular interest in seasonal hours sometimes led to attached charts which could translate the water level into different values for different times of the year.[18]

Despite the concept's simplicity, accurate clepsydras were difficult to construct, especially when they were intended to measure longer intervals.[19] Because the rate of flow slowed as the water level decreased, the outflow vessels needed to be tapered to compensate.[20] Debris could build up in the valve, causing the flow rate to slow over time; as a result, the devices needed to be inspected regularly.[21] Water is also quite dense, so a long-interval clepsydra might need to contain several hundred pounds of water.[22] Finally, the properties of water change with temperature, so the devices did

water-clocks, see Clagett, *Ancient Egyptian Science: A Sourcebook. Volume II: Calendars, Clocks, and Astronomy*, 59ff.

[17] Clagett, *Ancient Egyptian Science: A Sourcebook. Volume II: Calendars, Clocks, and Astronomy*, 77.

[18] John G. Landels, "Water-Clocks and Time Measurement in Classical Antiquity," *Endeavour* 3, no. 1 (1979): 33.

[19] For a detailed study, see John H. Fermor, Arthur E. Burgess, and Victor Przybylinski, "The Timekeeping of Egyptian Outflow Clocks," *Endeavour* 7, no. 3 (1983): 133–36.

[20] The relevant mathematical function is given in Donald R. Hill, *A History of Engineering in Classical and Medieval Times* (Routledge, 1996), 5.

[21] Schaldach, "Measuring the Hours: Sundials, Water Clocks, and Portable Sundials," 65. Pliny informs his readers that a six-minute clepsydra contained 6.4 liters of water. Assuming a valve of the same size, a 24-hour clepsydra would need to contain more than 1.5 tons of water—roughly the weight of a small car.

[22] The largest of these is the Tower of the Winds (ca. 40 BCE); see Robert Hannah, "Tower of the Winds, Athens," *The Encyclopedia of Ancient History*, 2012, 6789–90.

not fare well in areas with sudden temperature changes: in hot weather a clepsydra will empty more quickly, while in cold weather it might simply freeze.[23]

By the sixth century BCE, Antiquity's two major timekeeping devices had been invented, and the twelve-part division of the day and night had been established. These concepts and devices seem to have been transmitted to the Greeks, although later Roman and Byzantine sources suggest that the Greeks had developed the devices themselves.[24] The Greco-Roman period did see incremental developments, most notably the invention of an inflow clepsydra attributed to Ctesibius (d. 222 BCE), which solved many of the rate-flow problems of the outflow clepsydra.[25] Pliny (d. 79 CE) also records the first known instance of a candle clock, whose regular burn rate allowed the candle's steadily decreasing height to indicate the time. The candle clock was supposedly used in a silver mine, where both sundials and clepsydras would have been impractical.[26]

Greco-Roman popular reception

Egyptian and Babylonian timekeeping technology theoretically allowed anyone to track time to a high degree of accuracy, and a sophisticated vocabulary developed around this ability; indeed, all the key timekeeping terminology had come into use by the second century BCE.[27] Still, tracking subdivisions of the day was not terribly convenient and could not be accomplished without the aid of sophisticated mathematics.

[23] B. Cotterell, F. P. Dickson, and J. Kamminga, "Ancient Egyptian Water-Clocks: A Reappraisal," *Journal of Archaeological Science* 13 (1986): 46.
[24] See Hannah, *Time in Antiquity*, 68.
[25] Cotterell, Dickson, and Kamminga, "Ancient Egyptian Water-Clocks: A Reappraisal," 39. See also Landels, "Water-Clocks and Time Measurement in Classical Antiquity," 34. Two early references are in Aristotle, *On the Heavens* 294b.14–30 and Pseudo-Aristotle, *Problem* 914b.
[26] Pliny, *Natural History*, 33.96–7; see also Hannah, *Time in Antiquity*, 96.
[27] Alan C. Bowen and Bernard R. Goldstein, "Hipparchus' Treatment of Early Greek Astronomy: The Case of Eudoxus and the Length of Daytime," *Proceedings of the American Philosophical Society* 135, no. 2 (1991): 233–254.

As a result, there was a significant disparity between actual practice and theoretical capability.

Although Greco-Roman society did not make any major technological break-throughs in the realm of timekeeping, the devices themselves proliferated; more than 500 sundials have been discovered.[28] Greek and Latin texts provide a useful window onto the slow adoption of the new technologies and of “the hour” as a central organizing concept. The sources reveal that timekeeping devices began as—and largely remained—the purview of a few specific applications but did not become essential for most people. While the twelve-part division of the day was eventually adopted in Antiquity, it never fully displaced terminology linked to the appearance of the sun in the sky, descriptions of the early morning horizon, qualitative evaluations of light levels, the rhythms of human activity, or the behavior of animals.

The terminology used in Greek and Roman historiographies is somewhat ambiguous; as a result, it is difficult to determine precisely which devices are intended. Robert Hannah suggested that the earliest sundials may not have been used for timekeeping at all. Instead, they may have been calendrical devices, used to mark the dates of the solstices and equinoxes; in Hesiod (d. ca. 650 BCE), for example, only knowledge of the solstices is assumed.[29] Still, by the fourth century BCE, hour-marking devices seem to have become quite widespread,[30] and by the third century significant advances in precision had been made.[31]

[28] Jones, “Introduction,” 28. Very few water-clocks have survived.
[29] Hannah, *Time in Antiquity*, 71.
[30] Schaldach, “Measuring the Hours: Sundials, Water Clocks, and Portable Sundials,” 65.
[31] Schaldach, 70.

Despite the presence of these hour-marking devices, the hour itself (Gk. *hōra*) took substantially longer to become popular. In his account of the advent of various time-keeping devices, Herodotus (d. ca. 425 BCE) describes the day being divided up into twelve "parts" (Gk. *merea*); indeed, until the second half of the fourth century the term "hour" had no technical meaning, having previously signified only "season" or "appointed time."[32] The first non-scientific use of the term to mean 1/12 of the day does not come until the third century BCE.[33] Even after this point the term only rarely appears outside of technical treatises; one important exception is the phrase, "The ninth hour has caught up," to mean that it is dinnertime.[34]

Instead of hours, Greek and Latin sources continued to refer to short intervals using more practical means. Even when sundials were not used, it was still possible to tell time by looking at the length of one's own shadow; from around 200 BCE we have "shadow tables," where one could look up the time based on the time of year and the length of one's shadow.[35] This ad hoc tool appears in dialogue; Aristophanes (d. ca. 386 BCE) has a character say that the time is "ten feet."[36] For public speeches, discussed below, time was commonly quantified in terms of the clepsydra, without direct reference to the hour at all.

Though shadow tables might appear to have been far less accurate than sundials, this was not necessarily the case. Sundials were not understood to be precision instruments; in *The Pumpkinification of Claudius*, Seneca (d. 65 CE) remarks that sundials were

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[32] Danielle Allen, "A Schedule of Boundaries: An Exploration, Launched from the Water-Clock, of Athenian Time," *Greece & Rome* 43, no. 2 (1996): 163.
[33] Hannah, *Time in Antiquity*, 75.
[34] Jones, "Introduction," 19.
[35] Stephen Quirke, *The Cult of Ra: Sun-Worship in Ancient Egypt* (New York: Thames & Hudson, 2001), 47. Because a person's foot is roughly proportional to their height, it should be possible to always use one's *own* feet to measure the length of one's shadow.
[36] Aristophanes, *Assemblywomen*, l. 652.

less likely to agree with one another than philosophers, the latter being a group notorious for argumentation and indecision.[37] Of the hundreds of surviving sundials, only a very few have markings for the half-hour, regardless of size or ornateness.[38] Indeed, Marcus Cetius Faventinus (fl. third–fourth centuries CE) instructs sundial makers that it is not worth placing such half-hour markings, since people are "in too much of a hurry to want to know more than what hour it is."[39] Greater accuracy was not generally sought out; indeed, Athenaeus of Naucratis (d. early third century CE) tells the story of a prostitute whose practice of timing her sessions with a water-clock was so unusual that she earned the nickname Clepsydra.[40] Many households created makeshift time-keeping devices simply by noting the correspondence between a shadow hitting a scratch in some wall and some significant daily event, e.g. dinner.

While indifference characterizes popular Greco-Roman reaction to the sundial and the twelve-part day for the most part, there is some early evidence that people chafed at the suggestion that one's time—and, in particular, one's meals—should be governed by numbers instead of by natural desire. One such source has already been cited in the epigraph to this chapter; another, from the sophist Alkiphron (fl. ca. 200 CE), makes similar complaints and suggests that the sundial should be destroyed or manipulated to bring mealtime about more quickly.[41]

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[37] Symons and Khurana, "A Catalogue of Ancient Egyptian Sundials."
[38] Hannah, *Time in Antiquity*, 96.
[39] Pattenden, "Sundials in Cetius Faventius." This is perhaps similar to modern analog clocks, many of which are only marked at five-minute intervals. Unfortunately, most of the literature on sundials from Late Antiquity has been lost; see Anthony J. Turner, "A Use for the Sun in the Early Middle Ages, The Sun-Dial as Symbol and Instrument," *Micrologus*, 2004, 28.
[40] Hannah, *Time in Antiquity*, 101. Cf. the discussion of bSotah4a below.
[41] Alkiphron, Letter 3.1, cited in Hannah, 82. Eventually, Hannah notes, this disconnect from the body's natural rhythms is taken to be a marker of humanity's distinctive nature.

In short, Greco-Roman popular culture appears to have both embraced the sundial and simultaneously marginalized it. While the concept of seasonal hours and the twelve-part day did penetrate popular culture, they continued to compete with other ways of speaking about the passage of time.

Pre-Islamic Iranian timekeeping

As is the case regarding many matters concerning pre-Islamic Iran, we lack adequate source material to paint the full picture of timekeeping devices, terminology, and popular usage comparable to that which is available to us for Greco-Roman culture. Babylonian astronomy appears to have been imported to Iran only in the Parthian period (247 BCE–224 CE); this knowledge was subsequently passed to India, which developed it into a distinct astronomical tradition that ultimately made its way back to Iran. Astronomy of the Sasanid period (224 CE–651 CE) represents a synthesis of Greco-Roman and Indian knowledge.[42]

As in Greco-Roman culture, there was probably a gap between theoretical and practical timekeeping abilities. On one hand, Islamic-era descriptions of the throne of Khosrow II (r. 590–628 CE) has the ruler's seat adorned with some sort of timekeeping device, although it is unclear what kind; it is possible that this depiction was influenced by tales of similarly mechanized thrones found in Greek, Hebrew, and Arabic sources.[43] On the other hand, *Šāyast nē šāyast* ("Proper and Improper"), a late-Sasanian book of

[42] For a useful overview, see D. Pingree and C.J. Brunner, "Astrology and Astronomy in Iran," in *Encyclopaedia Iranica*, 1987.
[43] See Ra'anan Boustan, "Israelite Kingshop, Christian Rome, and the Jewish Imperial Imagination: Midrashic Precursors to the Medieval 'Throne of Solomon,'" in *Jews, Christians, and the Roman Empire: The Poetics of Power in Late Antiquity*, ed. Natalie B Dohrmann and Annette Yoshiko Reed (Philadelphia: University of Pennsylvania Press, 2013), 167–182.

religious practices, describes how one might determine the time for a given latitude based on the length of one's shadow at a particular time of year. Rather than being able to determine the hour, the text is only concerned with specifying the length of one's shadow at noon; such "noon marks" will be discussed in greater detail below. As with many other cultures, the practitioner is expected to measure her shadow with her own feet.[44]

Time-critical applications in Antiquity

Despite popular indifference, timekeeping technology continued to improve. Driving these developments was a small set of important but specialized applications, most of which were governmental, scholarly, or religious in nature. This may not be coincidental; Robert Hannah has suggested that the turn towards sundials had little to do with technological advances and was instead driven by development in city infrastructure.[45] The following represents my attempt to create an exhaustive list of applications for which there is evidence of timekeeping devices being employed.

Timing speeches

Of all the clepsydra's uses, its function in Greco-Roman courtrooms was most closely associated with the device itself. The clepsydra's use as a timer to regulate speech in a public forums is described by Plato, who writes of men who "always speak in haste, for the flowing of the water [of the clock] urges them on."[46] In other texts "water" is

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[44] E.M. West, *Pahlavi Texts* (Oxford Clarendon Press, 1880), 397.
[45] Hannah, *Time in Antiquity*, 83.
[46] Plato, *Theaetetus*, 172d.

employed to mean "time."[47] Aristophanes uses the term metonymically to refer to the courts.[48] In these contexts, the clepsydra was a standard time unit unto itself; references in Pliny allow us to infer that each clepsydra would run for a third of an hour,[49] although the type used in courtrooms seems to have lasted just six minutes, an interval too short to measure by any other means.[50]

The standardization of the courtroom clepsydra allowed room to regulate the length of each side's arguments. Aristotle notes that the number of clepsydras allotted in monetary cases varies based on how much money is at stake, whereas cases involving "imprisonment, death, exile, loss of civil rights, or confiscation of goods" were allowed the equivalent of a full winter's day.[51] Roman legislation makes reference to the number of clepsydras allotted to each side in a court case; eventually, the defendant was formally allotted 50% more time than the accuser.[52]

Prayer times

Egyptian sources attest to a relationship between ritual and timekeeping, rising out of the divine significance of the movement of the stars.[53] The records of several Egyptian sects, including the Osiris cult, feature litanies of hours; these rituals were under-

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[47] Landels, "Water-Clocks and Time Measurement in Classical Antiquity," 32.
[48] Aristophanes, *Acharnians* 694 and *Wasps* 93.
[49] Pliny, *Epistles* II.11.14
[50] Robert Hannah, "Clocks," in *The Encyclopedia of Ancient History* (Blackwell Publishing, 2013), 1583–85. See also Landels, "Water-Clocks and Time Measurement in Classical Antiquity."
[51] Aristotle, *Constitution of Athens*, 67.2–5; translation found in Tony Roark, *Aristotle on Time: A Study of the Physics* (Cambridge University Press, 2011), 21. It has been suggested that the choice of a winter day perhaps reflects the need to ensure that the trial would never drag on into the night (Ibid.).
[52] "The Roman Bar," *The North American Review* 96 (1863): 306–307. Hill (*Arabic Water-Clocks*, 6) claims that capital cases would be given more water. In support of this, he cited H. Diels, *Antike Technik* (Leipzig and Berlin, 1914), 194. However, this source simply refers to important cases and does not cite a source in support of this position.
[53] Quirke, *The Cult of Ra: Sun-Worship in Ancient Egypt*, 47. See also Cotterell, Dickson, and Kamminga, "Ancient Egyptian Water-Clocks: A Reappraisal," 32.

stood to effect cosmic change.[54] Still, these sects were not public; the need to mark each and every hour was restricted to a small group of devotees.

Astronomy

Closely tied up with religious concerns was an interest in understanding the movement of celestial bodies. Babylonians are known to have used timekeeping devices for this purpose from at least the eighth century BCE, and the first Greek sundials were probably also used exclusively for this purpose.[55] Some of the smallest subdivisions of the hour occur in the context of astronomy; *P. Hibeh 27*, the oldest surviving Greek sundial, can measure as little as 1/45 of an equinoctial hour. Ptolemy (d. ca. 170 CE) gives intervals as precise as 1/6 of an hour in his texts on astronomy.

Magic

Magical undertakings sometimes involved keeping track of specific durations, as well. Some Greco-Roman practices involved lighting candles of a specific size in order to indicate the window of opportunity for a specific spell.[56]

Funerary inscriptions

A frequent feature of Roman tombstones is a careful indication of the precise time of death, indicated down to the hour or even the very minute. This practice developed

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[54] Quirke, *The Cult of Ra: Sun-Worship in Ancient Egypt*, 41ff. For a full investigation of the Hour Ritual, see Jan Assmann, *Egyptian Solar Religion in the New Kingdom: Re, Amun and the Crisis of Polytheism* (Kegan Paul International, 1995), 16–37. The idea of night as a time of divine rebirth emerges again in Christian Europe; see Mary W. Helms, "Before the Dawn: Monks and the Night in Late Antiquity and Early Medieval Europe," *Anthropos* 99, no. 1 (2004): 185.

[55] See John Fermor, "Timing the Sun in Egypt and Mesopotamia," *Vistas in Astronomy* 41, no. I (1997): 157–67. See also David Brown, John Fermor, and Christopher Walker, "The Water Clock in Mesopotamia," *Archiv Für Orientforschung* 46/47 (2000): 130–48. On Greek sundials, see the authoritative Sharon L. Gibbs, *Greek and Roman Sundials* (Yale University Press, 1976).

[56] Hannah, *Time in Antiquity*, 97.

with the Roman Republic's exposure to Greek knowledge, though Greek tombstones do not share this specific feature. In a comprehensive study, Simeon Ehrlich has shown these inscriptions to serve a primarily astrological purpose: just as the hour of birth indicated one's fate in this world, the hour of death indicated one's fate in the next. Finer divisions, however, are probably a kind of *memento mori* or a way of expressing affection for the departed, especially for children.[57]

Athletics

Unlike modern sporting competitions, the Ancient Olympics and other competitions did not carefully track athletes' finishing times for racing events. It is possible, however, that there was a clepsydra at the Circus Maximus in Rome for the purpose of setting a time limit on various events during the Great Games.[58]

Military

Water-clocks would sometimes be used in the army for administrative purposes. One of the first Greek military writers, Aeneas Tacticus (fl. fourth century BCE), suggests the use of water-clocks to determine the time until the next guard shift-change.[59] These shift changes are the likely source of the four Roman "watches" of the night (as opposed to the biblical three), which were subsequently adopted in rabbinic literature.

To Aeneas is also ascribed an emergency signaling system reliant on clepsydras, although to call it "timekeeping" would be something of a stretch. Two outposts would

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[57] See Simeon D Ehrlich, "Horae in Roman Funerary Inscriptions" (University of Western Ontario, 2012).
[58] C.W. King, "Notice of a Remarkable Intaglio Representing the Clepsydra Used At Races in the Circus Maximus," *Archeological Journal* 21, no. 1 (1864): 136–42. I have found no recent discussion of this artifact.
[59] Aeneas Tacticus 22.24–25; discussed in Schaldach, "Measuring the Hours: Sundials, Water Clocks, and Portable Sundials," 64. See also Allen, "A Schedule of Boundaries: An Exploration, Launched from the Water-Clock, of Athenian Time," 163.

each be equipped with a clepsydra, identically marked not with temporal intervals but with a number of predetermined urgent messages that one might want to transmit quickly. The vessels would then be filled to the same level. When one party wished to signal the other, it would get the other's attention by lighting a flare.[60] With the link established, the sending party would light another flare, signaling that both clepsydras should be unplugged simultaneously. When the water level had reached the desired message, the transmitting party would extinguish its flare and both parties would stop up their clepsydras again. The receiving party would then have been able to read the marking of their clepsydra.[61] It is unclear if this system was ever actually employed.

Mining

As in military applications, the unusual and difficult working conditions associated with mining meant that some device other than the sun was necessary in order to regulate work shifts. Pliny notes that men in a Spanish silver mine used oil lamps—which burn quite steadily—to keep track of the duration of their tasks.[62]

Medical Use

While the pulmonary system would not be discovered until the medieval period, the physician Herophilus (d. 280 BCE) appears to have carried a clepsydra with him when examining patients. Under the theory that different age groups had different pulse rates, he would adjust his clepsydra to the "expected" rate for any given patient and would then measure the patient's pulse to determine if it was too fast or too slow.

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[60] This is not dissimilar to the method for quickly sending messages described in mRoshHashanah2:2–4. Until the early nineteenth century, these chains of flares or flags continued to represent the fastest way of transmitting information. See David Hochfelder, *The Telegraph in America* (Johns Hopkins Press, 2012).
[61] Polybius, *Histories* 10.44.
[62] Hannah, *Time in Antiquity*, 96; see notes there.

This was presumably accomplished not by determining the number of beats per minute, but by counting beats until a specified number had been reached.[63] This technique is also mentioned in a work on pulses by one Marcellinus (second century CE?).[64]

Prestige Use

Beyond the applications described above, there is strong evidence that many timekeeping devices were constructed solely for aesthetic purposes. This was particularly true for sundials, which are often quite intricate and beautiful, but not in ways which would benefit someone who wanted to know the time. Sharon L. Gibbs' comprehensive survey of Greco-Roman sundials shows only four upon which all of the hour-lines are marked with letters.[65] The expense of creating a beautiful specimen served as signal of the creator's wealth, knowledge, or technical ability;[66] how else to explain the presence of a sundial on a headstone?[67] Even portable sundials seem to have been constructed with prestige in mind; they were designed to be conspicuous.[68] Because of their mathematical sophistication, sundials became symbols of knowledge in artwork, as well.

Derek de Solla Price, one of the most important twentieth-century historians of science, summed it up thus: "It would be a mistake to suppose that water-clocks, or the sundials to which they are closely related, had the primary utilitarian purpose of telling the time. Doubtless they were on occasion made to serve this practical end, but on the whole their design and intention seems to have been the aesthetic or religious satisfac-

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[63] Heinrich von Staden, *Herophilus: The Art of Medicine in Early Alexandria* (Cambridge University Press, 1989), 282.
[64] Marcellinus, *De Pulsibus* 11; see Orly Lewis, "Marcellinus' De Pulsibus: A Neglected Treatise on the Ancient 'Art of the Pulse,'" *Scripta Classica Israelica*, 2015, 181–194. See also Schaldach, "Measuring the Hours: Sundials, Water Clocks, and Portable Sundials," 64.
[65] Gibbs, *Greek and Roman Sundials*, 86.
[66] Schaldach, "Measuring the Hours: Sundials, Water Clocks, and Portable Sundials," 87–9.
[67] Albert E. Waugh, *Sundials: Their Theory and Construction* (New York: Dover, 1973), 181–2.
[68] Talbert, *Roman Portable Sundials: The Empire in Your Hand*, 157.

tion derived from making a device to simulate the heavens."[69] The movement of the sun across the sky was understood to follow an elegant (and divine) order, and expressing mathematical knowledge of that order was praiseworthy. Ultimately, however, many sundials were simply demonstrations of prowess. In the real world, they were not all that useful.

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As is clear from these applications, the Greco-Roman adoption and development of timekeeping devices were powerfully felt in a few specific sectors but were largely irrelevant for most individuals in most situations. This does not mean that the average person was unaffected by Greco-Roman developments; indeed, the metrics of the sundial and clepsydra did infiltrate both Greek and Latin texts, although such terminology continued to be used alongside more subjective terminology. While a Roman farmer may not have been any more fastidious in his timekeeping than his Ancient Egyptian counterpart, the former's interest in describing the day's passage numerically distinguishes him from the latter. A similar shift is evident in the transition from biblical to rabbinic texts, which I will examine presently.

II. Timekeeping in the Hebrew Bible

Archaeological investigations of First Temple Judea have yielded no sundials or other timekeeping devices; as a result, our knowledge of timekeeping during this period stems entirely from texts.[70] The Hebrew Bible's most important contribution to the history of timekeeping resides in two passages describing a device known as *maʿalot*

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[69] Derek J. de Solla Price, "Automata and the Origins of Mechanism and Mechanistic Philosophy," *Technology and Culture* 5, no. 1 (1964): 9–23.
[70] Ratzon, "Jewish Time: First Stages of Seasonal Hours in Judea," 4.

aḥaz—literally "the steps of Aḥaz," but normally translated as "the Dial of Aḥaz." In Isaiah 38:4–8, the device is described as follows:

> Then the word of the Lord came to Isaiah: "Go and tell Hezekiah: Thus said the Lord, the God of your father David: I have heard your prayer, I have seen your tears. I hereby add fifteen years to your life. I will also rescue you and this city from the hands of the king of Assyria. I will protect this city. And this is the sign for you from the Lord that the Lord will do the thing that He has promised: I am going to make the shadow on the steps, which has descended on the Dial of Aḥaz because of the sun, recede ten steps." And the sun['s shadow] receded ten steps, the same steps that it had descended.

This narrative also appears in 2 Kings 20:9–11:

> Isaiah replied, "This is the sign for you from the Lord that the Lord will do the thing that He has promised: Shall the shadow advance ten steps or recede ten steps?" Hezekiah said, "It is easy for the shadow to lengthen ten steps, but not for the shadow to recede ten steps." So the prophet Isaiah called to the Lord, and He made the shadow which had descended on the Dial of Aḥaz recede ten steps. (2 Kings 20:9–11)[71]

The meaning of these passages has been of great fascination to scholars ancient, medieval, and modern.[72] It has long been accepted that *maʿalot aḥaz* was some sort of timekeeping device; Greek translation attributed to Symmachus (second century CE) renders *en hōrologiō̧ Akhaz* and the Vulgate (late fourth century CE) translates the term as *horologium*; neither translation refers to a specific timekeeping instrument. The Aramaic translation known as Targum Jonathan (second century CE) is more specific, rendering *even sheʿaya*, which is similar to the Hebrew *even shaʿot* that the rabbis would

[71] For a slightly different version from the Qumran corpus, see 1QIsa-a 31, 7–8.
[72] For additional references, see René R.J. Rohr, *Sundials: History, Theory, and Practice* (University of Toronto Press, 1970), 8–9.

soon use to describe sundials.[73] Modern research has agreed with this assessment, although it is unclear whether the device represented was a normal radial sundial or some more exotic shadow-measuring device.[74] It is also unclear whether the phenomenon displayed was merely an unusual occurrence or, as the Babylonian Talmud maintains, it in fact involved the miraculous backwards movement of the sun.[75] Finally, assuming that this object was a sundial, we do not know what kind of formal timekeeping system it employed.

Whatever the case may be, neither of these biblical passages nor any other exhibit an interest in formal divisions of the day. Despite the Bible's interest in tracking units larger than the day, it neglects smaller divisions.[76] Indeed, nowhere in the Bible is the day divided into anything smaller than a quarter.[77] The word "hour" (*shaʿah*, pl. *shaʿot*) is not contained in the Hebrew portion of the Hebrew Bible at all; it is, however, used

[73] See Targum Jonathan on Isaiah 38:8. Rashi (d. 1105) provides the similarly ambiguous *orlogin* in his commentary on Isaiah.

[74] The key study of *maʿalot aḥaz* was done by Yigal Yadin; see Yigal Yadin, "The Dial of Ahaz," *Eretz-Israel: Archaeological, Historical and Geographical Studies*, 1958, 91–96. Yadin argues that the device was a kind of portable sundial in the shape of a house; similar devices have been found in Egypt. Yadin's position was attacked by Samuel Iwry; see Samuel Iwry, "The Qumran Isaiah and the End of the Dial of Ahaz," *Bulletin of the American Schools of Oriental Research*, no. 147 (October 1957): 27. Iwry argued, in part on the basis of an alternate reading in the Qumran Isaiah scroll, that these passages simply refer to a shadow on the steps of Hezekiah's palace. Both of these positions were recently challenged by van Dorp, who posits a normal, radial sundial. Van Dorp notes that *maʿalot* was understood to be a technical astronomical term by the Septuagint; it could in fact be the equivalent of the Babylonian *uš*, described in the next section (see below, page 50). See Jaap van Dorp, "The Prayer of Isaiah and the Sundial of Ahaz (2 Kgs 20:11)," in *Psalms and Prayers: Papers Read at the Joint Meeting of the Society of Old Testament Study and Het Oudtestamentische Werkgezelschap in Nederland En België, Apeldoorn August 2006*, ed. Bob Becking and Eric Peels (Leiden: Brill, 2007), 253–266.

[75] See bSanhedrin96a. For further deliberation on this topic, see van Dorp, "The Prayer of Isaiah and the Sundial of Ahaz (2 Kgs 20:11)," 265. Van Dorp understands the sign to be an astronomical phenomenon known as "retrogradation." On the miraculous interpretation of the passage, see also Pirkei de-Rabbi Eliezer §52:9.

[76] Eshbal Ratzon has pointed out that it is particularly striking that authors of the Bible's priestly sections ("P")—who were otherwise quite concerned with precise measures—were not concerned with precision in the realm of timekeeping. See Ratzon, "Jewish Time: First Stages of Seasonal Hours in Judea," 4. For a similar conspicuous absence in rabbinic literature, cf. bRoshHashanah13a, discussed on page 101, note 161, below.

[77] Nehemiah 9:3. Two exhaustive studies of time-related words in the Bible exist. See Levana Tsfania, ed., *The Stone Vessel Industry in the Second Temple Period* (Jerusalem: Israel Antiquities Authority, 2002), 114–115 and Gershon Brin, *The Concept of Time in The Bible and the Dead Sea Scrolls* (Brill, 2001).

three times in the Aramaic portion of Daniel, likely composed only in the mid-second century BCE, making it one of the last texts to be included in the Hebrew Bible.[78] Even here, *shaʿah/shaʿata* is not used in a technical sense. In two instances, "the same hour" (*bah shaʿata*) refers to events happening simultaneously or in close proximity (Daniel 3:6, 4:30).

In the remaining instance, the context suggests that the phrase is being used *both* imprecisely *and* in reference to an amount of time substantially shorter than the modern hour:

> "I, King Nebuchadnezzar, had this dream; now you, Belteshazzar, tell me its meaning, since all the wise men of my kingdom are not able to make its meaning known to me, but you are able, for the spirit of the holy gods is in you." Then Daniel, called Belteshazzar, was perplexed *for a moment* (*ke-shaʿah ḥadah*, lit. "for an hour"), and alarmed by his thoughts. The king addressed him, "Let the dream and its meaning not alarm you." Belteshazzar replied, "My lord, would that the dream was for your enemy and its meaning for your foe!"[79]

It seems highly unlikely that Daniel stood perplexed before Nebuchadnezzar for a full twelfth of the day. Instead, despite the fact that *one* hour is specified, the phrase *ke-shaʿah ḥadah* was likely not intended to refer to units of any kind, and the phrase is best translated as "for a time," or "for a short while."[80] This valence of the phrase *shaʿah ḥadah* is not unique to the Aramaic of the Book of Daniel; the Babylonian Talmud, which uses a later form of Aramaic, employs it several times to describe a rabbi who had been

[78] This composition is so late that, as we shall see below, its division of the day may have been preceded by apocryphal works.
[79] Daniel 4:15–16; emphasis mine.
[80] Many others have come to this conclusion, as well. See Louis F. Hartman and Alexander A. Dilella, *The Book of Daniel (The Anchor Bible)* (New York: Doubleday, 1978), 178.

momentarily shocked into silence by a colleague.[81] Nor is the usage unique to Aramaic; below, we shall see the Hebrew equivalent carrying a similar valence in rabbinic sources.[82]

If a precise apportionment of the daylight is to be found, it is in the Book of Neḥemiah, another late addition to the canon. In Neḥemiah 9:3, the Israelites are described as "reciting from the scroll of the Teaching of God for one fourth of the day (*riviʿit ha-yom*), and for a fourth they confessed and prostrated themselves before the Lord their God." While this narrative imagines a more precise division of the day than any other found in the Hebrew Bible, it is still quite crude. We shall speak about the quadripartite division of the day at greater length in the next chapter.

Whereas there is an almost complete lack of technical terminology to demarcate portions of the day, the Bible does contain one term consistently applied to divide up the night—but only in military contexts. *Ashmoret*, "watch," appears three times, in each case to describe portions of the night. That there are exactly three such divisions is implied in Judges 7:19, which describes a night raid by Gideon "at the beginning of the middle watch (*rosh ha-ashmoret ha-tikhonah*)." The other two instances (Exodus 14:24 and 1 Samuel 11:11) appear in the phrase *ashmoret ha-boqer*, "morning watch," the third of the night which abuts the morning; the former describes the Egyptian army, the latter the Israelite army of King Saul.[83] As highlighted in the previous section, the military was notable for demanding greater-than-average time awareness, especially at night.

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[81] See bKiddushin39a, bMoedKatan3b, bShabbat47a, and bSukkah44a.
[82] The Bible does employ several non-technical, poetic terms when the purpose is to emphasize the shortness of a time period. See Brin, *The Concept of Time in The Bible and the Dead Sea Scrolls*, 141f.
[83] The related term *ashmurah* appears four times. In Psalms 90:4 ("For in Your eyes a thousand years are like a passing day, like a watch of the night."), *ashmurah* indicates brevity, much as *shaʿah* does in Daniel. The remaining instances (Psalms 63:7, 119:148; Lamentations 2:19) all refer to multiple watches in order to indicate behavior that takes place throughout the night; this is equivalent to "every hour."

In short, the Hebrew Bible accords perfectly with what we know about contemporaneous cultures of timekeeping. On the one hand, sophisticated timekeeping devices are almost definitely known and available to the ruling class, and divisions of the night are demarcated for specialized military purposes. On the other hand, any terminology associated with those devices seems not to have made much of an impression on either the Bible's Hebrew or Aramaic passages.

III. Timekeeping during the Second Temple period

The Bible's discussion of timekeeping is very limited and can be easily described. By contrast, Jewish texts from the Second Temple Period suggest considerable variety in the knowledge and use of timekeeping terminology and concepts, stemming both from the various scientific contexts in which they were written and the various purposes for which they were deployed.

Within this period, it is possible to pick out three distinct approaches to timekeeping. The texts of Qumran largely maintain the Bible's indifference towards or ignorance of timekeeping and its technologies. This was not an inevitability; by the third century, Jews had already come into serious contact with the Babylonian astronomical tradition, as evidenced by the *Astronomical Book*, to be discussed below. For Greek-speaking Jews, however, this tradition was ultimately displaced by the Hellenistic tradition, as may be seen, early on, in the works of Philo and Josephus. It was the latter tradition which, through the medium of rabbinic law, would ultimately become permanently embedded in Jewish literature.

Qumran

Beginning with the second century BCE, evidence for a Jewish concern with time-keeping and its artifacts begins to solidify. In the past two decades, an enigmatic stone device at Qumran has drawn particular attention.[84] Because it is unlike contemporaneous sundials, theories about its nature have varied substantially, although most scholars agree that its purpose had something to do with tracking the sun.[85]

This artifact notwithstanding, the only clear Qumranic statement concerning time-keeping is an instruction in the Community Rule scroll, which instructs the community to stay awake in study and prayer for "[the first] third of all nights of the year."[86] (Note that *ashmoret* is not used here, although the tripartite division of the night remains.) Emanuel Tov has posited a mention of the fifth hour of the night in 4Q535 Frg. 2, but this seems problematic, as most of the reconstructed phrase is missing (only ש בליליא is present). In short, the Qumranic corpus contains no unambiguous use of the "hour" in a technical sense.[87]

Astronomical Book

Apart from the enigmatic sundial, a few intriguing Aramaic fragments seem to at-

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[84] Tsfania, *The Stone Vessel Industry in the Second Temple Period*, 114–5.
[85] Initial research posited the device as a Babylonian-influenced sundial; see Uwe Glessmer and Matthias Albani, "An Astronomical Measuring Instrument from Qumran," in *The Provo International Conference on the Dead Sea Scrolls*, ed. D.W. Parry and E. Ulrich (Brill, 1998), 407–442. For an argument that the device is in fact an odometer, see Barbara Thiering, "The Qumran Sundial as an Odometer Using Fixed Lengths of Hours," *Dead Sea Discoveries* 9, no. 3 (2002): 347–363. Hollenback has suggested that it is in fact a rare equinoctial dial; see G.M. Hollenback, "The Qumran Roundel: An Equatorial Sundial?," *Dead Sea Discoveries* 7 (2000): 347–363. A more recent theory understands the device to be a conical sundial; see Paul Tavardon, *Le Disque de Qumrân* (Paris: Gabalda, 2010). Ben-Dov has provided critiques for each of these approaches; see "The Qumran Dial: Artifact, Text, and Context," in *Qumran Und Die Archäologie: Texte Und Kontexte*, ed. J. Frey, C. Claußen, and N. Kessler (Tübingen: Mohr Siebeck, 2011), 211–237.
[86] 1QS VI, 6–7.
[87] Emanuel Tov, "4Q535," Dead Sea Scrolls Electronic Library Non-Biblical Texts.

test to the remnants of advanced astronomical knowledge in the community that lived around Qumran. These fragments, together with their Ethiopic translation, comprise the *Astronomical Book.*

Like the Bible, very few of the Jewish apocryphal texts develop any concepts related to timekeeping or the divisions of the day. This is perhaps unsurprising, given that the Bible lacks (or even rejects) interest in cosmography; in the ancient world, an interest in the movement of the celestial spheres frequently went hand in hand with better timekeeping awareness.[88] Nonetheless, as Annette Reed has noted, the scribes of the Second Temple Period were not monolithic in their ideas; just as this was a time of great literary fertility, it was also a time of scholarly experimentation, and it was during this period that some scribes seemed to have begun to engage with Jewish cosmography in earnest. It is in this context that *Astronomical Book* (1 Enoch 72–82) came into being.[89]

Unlike virtually every other Jewish astronomical treatise, the scientific information contained in *Astronomical Book* derives not from the Hellenistic astronomical tradition, but rather from its older Mesopotamian counterpart. The work, originally composed in Aramaic, is likely the oldest element of 1 Enoch and one of the very first extra-biblical Jewish books. Though dozens of fragments of the work were found at Qumran, the full

[88] One possible exception is Jubilees 25, which appears to contain both a non-technical usage (verse 14: "And at that *moment*, when the spirit of righteousness descended into her mouth…") as well as a technical usage (verse 3: "I bless you every *hour* of the day and *watch* of the night."). These verses only appear in the Ge'ez manuscript; in both verses, the Ge'ez term used is not *saʿāt* (cognate of Hebrew *shaʿah* and carrying the same range of meanings) but *gize*, a term likely of Ethiopic origin (connections to Arabic *ghāza* and *juz'* have been raised, but ultimately rejected; see Wolf Leslau, *Comparitive Dictionary of Geʿez* (Otto Harrassowitz, 2006), 210). Both words can mean "hour," but only the former is used to refer to seasonal hours. It is therefore difficult to make the case for *shaʿah* as the reconstructed original term. The term for "watch," *ʿuqābe*, seems to carry the same valence as Hebrew *ashmurah/ashmoret*, but is also not linguistically related. My thanks to Michael Segal for his assistance with these passages.
[89] Annette Yoshiko Reed, "Enoch, Eden, and the Beginnings of Jewish Cosmography," in *The Cosmography of Paradise: The Other World from Ancient Mesopotamia to Medieval Europe*, ed. Alessandro Scafi (Warburg Institute, 2016), 88ff.

work is only known through an Ethiopic version.[90] This Ethiopic *Astronomical Book* (EAB) is understood to be a translation from the Aramaic *Astronomical Book* (AAB) by way of a Greek intermediary; nonetheless, the two differ so significantly and AAB is so fragmentary that, for our purposes, they must be treated as separate works.

Between the two versions, EAB has been much more widely studied, as this version is both complete and well known through its inclusion in the Enochic corpus. The EAB treatise describes the solar year, the sun's position on the horizon over the course of the year, as well as the period and position of the moon.[91] It is in the context of describing the sun's position that 1 Enoch 72 makes a point which had not previously been stated explicitly in any Jewish text: the length of the day varies over the course of the year.

The way in which EAB describes these variations is unusual. While the treatise indicates that variations in the length of the day can be quantified, its quantification system does not make reference to hours, to a 24-part division of the day, or even to the twelve-part division of the full day/night cycle common in Babylonian sources. Instead, every day/night cycle is divided into eighteen "parts." In the equinoctial months, the day and night each have nine "parts."[92] With each passing month, there is a shift of one "part" from the day to the night (or vice versa) until a solstice month, at which point the ratio between the day and night is twelve parts to six parts.[93] From then until the following equinox the parts again shift until the number of parts for each is again at parity and the cycle repeats.

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[90] Reed, 74.
[91] For a short overview, see Jonathan Ben-Dov, "Astronomy in the Book of Enoch," *Handbook of Archaeoastronomy and Ethnoastronomy*, 2015, 1889–1893.
[92] 1 Enoch 72:20.
[93] 1 Enoch 72:14.

Parts of this system are easier to understand than others. Long ago, Otto Neugebauer suggested that the eighteen-fold division of the day was purely a matter of mathematical convenience: if we assume that the day and night exchange one "part" each month, an eighteen-part day allows the ratio between day and night to shift from 2:1 to 1:1 over the course of exactly six months. Noting that the use of 2:1 as the solstitial ratio seems obviously too great a fluctuation for the relatively moderate latitudes in which EAB was written, Neugebauer explained that the Enochic "parts" are not parts of the day, but rather parts of water in a clepsydra.[94] Unfortunately, Neugebauer's interpretation of the Babylonian and Enochic texts has not stood up to scrutiny.[95] Instead, his critics have argued, the 2:1 ratio was never intended to correspond to reality; rather, it was used by the Babylonians (as well as EAB) because of its apparent elegance. This also explains why the Babylonians had a 360-day solar year, when this clearly does not correspond with reality.[96]

Regardless of whose interpretation is correct, the Ethiopic *Astronomical Book* breaks important ground in the history of Jewish timekeeping. It is the first Jewish text to ex-

[94] The reason for this relates to a principle in fluid dynamics called Torricelli's Theorem. Inasmuch as the time it takes for water to drain from a cylinder is proportional to the *square root* of the height of the water in the cylinder (and because the height of the water is directly proportional to the weight of the water), a 3:2 ratio of the longest day to the shortest day (or night) in fact translates to a 9:4 ratio of largest to smallest quantity of water needed for a clepsydra to track the entirety of the day (or night). Because 9:4 is quite close to 8:4, Neugebauer argued, Babylonian astronomical texts came to use 2:1 as a rule of thumb for the variation in water weight over the course of the year; supporting this, the Babylonian texts which use this ratio do so in reference to "*manas*," (i.e. units of weight), rather than hours. (See O. Neugebauer, "The Water Clock in Babylonian Astronomy," *Isis* 37, no. 1/2 (1947): 38–39.) While Neugebauer presents this interpretation of 1 Enoch 72 in his commentary on *Astronomical Book*, he ultimately concludes that the connection to water weight is only conjecture, since the term "parts" is ambiguous. See Otto Neugebauer and Matthew Black, *The Astronomical Chapters of the Ethiopic Book of Enoch (72 to 82)*, vol. 40, 1981, 11–12.

[95] In a 2000 paper, three British researchers argued that Babylonian texts are quite explicit that the 2:1 ratio refers to time, and that "*mana*" is here simply a metonym for time. Furthermore, Neugebauer's interpretation does not fit the empirical evidence. An experimental recreation of Neugebauer's outflow water-clock revealed that 2:1 would not in fact have been the correct ratio. See Brown, Fermor, and Walker, "The Water Clock in Mesopotamia," 135ff.

[96] Brown, Fermor, and Walker, 141.

plicitly acknowledge that the length of the day oscillates over the course of the year. It is also the first to quantify that oscillation, if imperfectly. According to Neugebauer's interpretation, EAB is also the first Jewish text to explicitly acknowledge the existence of the water-clock. Even if he is not correct, however, the *Astronomical Book*'s significance for the history of Jewish timekeeping is clear: this is the first extant Jewish text to have adopted a clear and coherent timekeeping system from an outside culture.[97]

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If we turn to the Aramaic *Astronomical Book* (AAB), a final, intriguing idea emerges. AAB was discovered at Qumran in a highly fragmented state, and these fragments contain none of 1 Enoch 72, the chapter which describes shifts in the length of the day. Nonetheless, AAB remains interesting for its curious and repeated use of the number seven, often transformed into fourteen by being broken into half-units. Thus, for example, the duration of the moon's light can have fourteen possible values, calibrated according to halves, from one to seven.[98] Similarly, AAB divides the night into fourteen parts.[99] Jonathan Ben-Dov, who has argued that AAB is itself a Jewish adaptation of an even older Akkadian text, sees the repeated use of the number 14 as a specifically *Jewish* adaptation of the Babylonian *Enūma Anu Enlil* (EAE), a work which employs a fifteen-part division instead.[100] The shift from fifteen to fourteen, Ben-Dov argues, was moti-

[97] A second interesting text is 1 Enoch 89:72, which makes a reference to "twelve hours." The Ethiopic term here is *saʿāt*. Like the passage in Jubilees, discussed above in note 88, the term need not carry a technical meaning. Furthermore, it has already been pointed out that these twelve *saʿāt* are a portion of a 70-part period. See Matthew Black and James C. VanderKam, *The Book of Enoch or 1 Enoch: A New English Edition with Commentary and Textual Notes* (Brill, 1985), 273.
[98] Jonathan Ben-Dov, *Head of All Years: Astronomy and Calendars at Qumran in Their Ancient Context* (Brill, 2008), 87.
[99] Ben-Dov, 284.
[100] Ben-Dov, 265. This cosmological interest in using the number seven had already been noted in Matthias Albani, "Zur Rekonstruktion eines verdrängten Konzepts," in *Studies in the Book of Jubilees* (Mohr Siebeck, 1997), 79–125.

vated by the significance of the number seven with the Jewish tradition (seven days per week, counting seven weeks until the holiday of Shavuot,[101] a *shemitah* year every seven years, seven cycles to the Jubilee, etc.).[102]

If Ben-Dov is correct, AAB's seven/fourteen-part scheme is the first known uniquely Jewish system for keeping track of time. AAB thus represents both the first and last attempt to construct a wholly different Jewish timekeeping system. The degree to which it caught on is hard to know; had Jews developed an independent school of astronomical knowledge perhaps it would have been longer-lived.[103] By the time of Philo and Josephus in the first century CE, however, a different culture's astronomical knowledge had firmly taken hold.[104] It is likely as a result of this system's widespread success of this system that this modified Babylonian scheme dies out. Still, its presence is a useful reminder that the twelve-hour day (and night), which the rabbis would wholeheartedly adopt, was hardly inevitable.

Greek writings

Babylonian timekeeping may have been first to penetrate into Jewish texts, but it was the timekeeping language and devices of Hellenistic culture which ultimately won over the Jews of Palestine. At least one Jewish tomb indicates the hour of death in its

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[101] On this counting ritual, see note on page 285, below.
[102] Ben-Dov, *Head of All Years: Astronomy and Calendars at Qumran in Their Ancient Context*, 51ff. On whether this system could have accorded with reality, see Dennis Duke and Matthew Goff, *The Astronomy of the Qumran Fragments 4Q208 and 4Q209*, *Dead Sea Discoveries*, vol. 21, 2014. Their model has been critiqued in Eshbal Ratzon, "Methodological Issues Concerning the Astronomy of Qumran," *Dead Sea Discoveries* 22, no. 2 (2015): 202–9. My thanks to Ratzon for her assistance in understanding this debate.
[103] Ratzon, "Jewish Time: First Stages of Seasonal Hours in Judea," 13.
[104] Babylonian influence on Jewish timekeeping is also present in other ways, most notably in the fact that the day begins at night. See Yosef Green, "When Does the Day Begin?," *Jewish Bible Quarterly* 36, no. 2 (2008): 81–87.

funerary inscription.[105] As well, sundials have been found in Egypt, Delos, and Judea; they have been found both on the Temple Mount and elsewhere in Jerusalem.[106] In Egypt and Delos, sundials seem to have been associated with synagogues in particular.[107] While it has been posited that this had something to do with the need to reckon prayer times, we shall see below that such devices were probably ornamental, as they were in the design of Roman temples.

The sundial's growing availability among the public is not registered in Hebrew texts of the period. Jews writing in Greek, on the other hand, fully embraced the technical valences. With the possible exception of Enoch, apocryphal literature written in Hebrew and Aramaic does not describe the hour; Greek apocryphal texts, on the other hand, mention both specific hours of the day[108] and refer to the hour as a well-defined interval on several occasions;[109] these documents represent the first unambiguous Jewish adoption of the hour as a technical concept. The Jewish philosopher Philo of Alexandria (d. ca. 50 CE) was the first Jewish author to state explicitly that the day is composed of twelve hours (although he only wrote this in passing).[110] The first Jewish writer to regularly employ seasonal hours is the historian Josephus (d. 100 CE), who uses this terminology regularly in two specific contexts, both recognizable from other Greek sources, as noted above. One of these areas is ritual; thus, for example, Josephus specifies that the Temple priests offered up the Passover sacrifices from the ninth to the

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[105] David Noy, *Jewish Inscriptions of Western Europe, Volume 1: Italy (Excluding the City of Rome), Spain and Gaul* (Cambridge University Press, 1993), 20–21. The Greek inscription itself is apparently undatable.
[106] For further references, see the notes in Ben-Dov, "The Qumran Dial: Artifact, Text, and Context," 222. For an early Egyptian example, see William Horbury and David Noy, *Jewish Inscriptions of Graeco-Roman Egypt* (Cambridge University Press, 1992), 196–200.
[107] See John W. Humphrey, John P. Oleson, *Greek and Roman Technology: A Sourcebook*, 515, which in turn cites Horbury and Noy, *Jewish Inscriptions of Graeco-Roman Egypt*, 196–199.
[108] *Letter of Aristeas* §303; 3 Maccabees 5:14; *Testament of Joseph* 8:1.
[109] *Testament of Judah* 3:4–5; *Testament of Benjamin* 3:7.
[110] Philo, *On Dreams*, Book II, §39, l. 225.

eleventh hours.[111] More enigmatically, Josephus notes a miraculous yearly occurrence during which, at the ninth hour of the night on the eight day of the month of Nissan, a bright light would shine from the Temple "for half an hour."[112] Indeed, Josephus' description of the Essenes' daily practice—his claim that members of the community worked "until the fifth hour"—offers a more precise measurement of time than any found in the Dead Sea Scrolls themselves.[113]

In military matters, Josephus is even more exact. His depiction of the Temple's destruction describes the length of particular battles (e.g. "the fight had lasted from the ninth hour of the night till the seventh hour of the day")[114] and the exact time at which campaigns commenced.[115] Josephus' timekeeping is also noteworthy because of his insistence on using seasonal hours for the nighttime, rather than resorting to the standard tripartite division of watches."[116] Josephus' precision here appears to be in line with Roman sources, which are similarly exact in describing the timing of battles.

Despite his substantial use of seasonal hours, Josephus is adamant that the sundial is a foreign influence on Judaism. In *Against Apion*, Josephus rejected the idea that a boat-shaped sundial had been set up in the Tabernacle and added that Solomon's Temple had no use for such "needless decorations."[117] This negative characterization further supports the notion that many sundials—perhaps especially those in religious

[111] Josephus, *The Wars of the Jews*, Book VI, 9:3; cf. *Antiquities*, XIV, 4:3.
[112] Josephus, *The Wars of the Jews*, Book VI, 5:3.
[113] Josephus, *The Wars of the Jews*, Book II, 8:5.
[114] Josephus, *The Wars of the Jews*, Book VI, 1:7.
[115] Relevant military sources include: Josephus, *Wars of the Jews*, Book VI, 1:6, 2:5, 2:7, 2:8, 4:4. Cf. Book I, 3:5.
[116] In at least one instance, Josephus appears to use "watch" (Gk. *phulakē*) to mean "hour;" this explains why Josephus' rendition of Judges 7:19 describes the night raid as having taken place not, "at the beginning of the middle watch," as the Bible has it, but instead, "about the fourth watch of the night." (Josephus, *Antiquities*, Book V, chapter 6, line 223.)
[117] Josephus, *Against Apion*, Book II, §11.

buildings—had a purely ornamental purpose.

* * *

Notwithstanding the proliferation of sundials, Jewish discussions of timekeeping during the Second Temple period did not undergo a radical transformation relative to earlier sources. Furthermore, I have found no Jewish text from this period which makes mention of water-clocks, despite the evidence of their presence in contemporaneous cultures. While references in Josephus suggest that timekeeping conventions were changing, seasonal hours are still only used in the context of describing rituals and military operations. Both of these contexts are historiographical in nature; as a result, Josephus was free to be as precise as he wished, since he was not bounded by any practical limitations on the timekeeping ability of the public.[118] Given the rabbinic developments that follow, Jewish texts of the Second Temple period should be viewed as belonging to a transitional phase, one in which Jewish forays into Greek composition paved the way for the infusion of Greek and Latin terminology into Hebrew.

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[118] We shall see a similar rabbinic tendency towards greater precision in historiographical contexts in the next chapter.

Chapter 2: Timekeeping in Late Antique Rabbinic Literature

While the influence of Hellenistic timekeeping is already evident in Second Temple era texts, it is with the advent of rabbinic literature that this timekeeping system and its associated technologies became firmly and permanently embedded in Jewish law. Despite being thoroughly entrenched in Hellenistic timekeeping, however, the rabbis did not take full advantage of this new system; instead, there existed a gap between the theoretical capabilities of the timekeeping system, which were significant, and practical rabbinic expectations for how well the public could reckon time, which remained quite low. Furthermore, even the theoretical system may not have been well understood: there is evidence to suggest that the distinction between seasonal and equinoctial hours escaped the rabbis' grasp.

These nuances in the rabbinic adoption of the Hellenistic timekeeping system have long been overlooked. Without understanding them, it is easy to over-read rabbinic statements concerning timekeeping and to ascribe to them a level of precision which the rabbis never intended to condone.

Embracing Hellenistic timekeeping technologies

The twelve-hour day is deeply embedded in rabbinic literature. Many midrashic passages connect the number of hours to the twelve signs of the zodiac, the twelve tribes and the twelve signs on the High Priest's breastplate.[1] These equations suggest that the rabbis understood the twelve-hour day to be as universal and permanent as

[1] See Pesiqta Rabbati §4; Genesis Rabbah 100:9; Pesiqta de-Rav Kahana §16; Midrash Tanḥuma, VaYeshev 8; Midrash Tanḥuma, VaYeḥi 16. See also Deuteronomy Rabbah 2:11. In tNazir1:3, one who declares, "I am a Nazirite like the hours of the day," is understood to have imposed upon himself a twelve-day obligation.

the stars in the sky. Ironically, this attitude contrasts with Greco-Roman sources, which understood the twelve-hour day to be an inheritance from the Babylonians or an invention of King Numa from the earliest days of the Roman Kingdom.[2] While the Talmud is aware that biblical injunctions were never expressed in terms of the hours of the day, the absence of hours was not linked to historical technological development.[3]

Though timekeeping devices are never the focus of rabbinic discussions, the sundial and clepsydra both make their appearance. The Mishnah, a rabbinic text composed in the third century CE, describes a minor dispute about the ritual purity of a sundial's gnomon (*masmer shel even shaʿot*).[4] This dispute does not tell us anything about the usage of sundials, but it does indicate that rabbis were sufficiently aware of them for their ritual status to have been a matter of debate.

More interesting is a passage in Genesis Rabbah which describes a water-clock being used in the context of a courtroom. In this passage, the midrash expands on Abraham's plea that God not destroy the city of Sodom should it contain a small number of righteous people. Initially Abraham asks what would happen if fifty righteous people in the city, slowly reducing this number in repeated questions to God. The midrash explains the reason that Abraham repeated his plea in this manner:

> "*What if the fifty righteous should lack five*?" (Genesis 18:28) — Rabbi Ḥiyya bar Aba [said], "Abraham desired to go from fifty down to five. Said the Holy One Blessed Be He, 'Go backwards [i.e. work your way down to five gradually].'" Rabbi Levi [said], "[this is similar] to a clepsydra [*ḥalaf seridah*][5] full of water: the defense may argue only as long as it is full of water. At times when the judge wishes him

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[2] See Herodotus, *Histories* 2.109 and Livy, *History of Rome* 1.19.6–7. Both are quoted in John W. Humphrey, John P. Oleson, *Greek and Roman Technology: A Sourcebook*, 515.
[3] See bPesaḥim2b.
[4] mEduyot3:8. Cf. mKelim12:4–5.
[5] The spelling is garbled in some manuscripts.

> to argue [more], he says, 'Add water to it.'"[6]

This description of an outflow clock, used to time litigants in a court case, has already been mentioned as one of the most popular uses of this device; indeed, the command "add water" is similar to the Latin command *aquam dare* given in Roman courts.[7] In this passage, Abraham is depicted as a defense attorney, attempting to save the city of Sodom by asking God whether an increasingly small number of righteous residents would be sufficient for the city to be saved. Wanting to hear Abraham prolong his defense, God requests that Abraham bargain his way down slowly.[8]

A powerful but enigmatic text alludes to the use of sundials to determine when each new month should begin:

> "*This month shall be for you.*" (Exodus 12:2) — [The reckoning of the month] is transferred to you. Rabbi Joshua ben Levi said, "[This is like] a king who had a timepiece [*orlogin*]. When his son grew up, he transferred it to him."[9]

This is one of several rabbinic texts which contend that the calendar, which had previously been administered by God, had been transferred to human control.[10] The passage is also interesting for its portrayal of the *orlogin* as a unique, precious instrument, suggesting that its use was mainly restricted to government or to the upper

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[6] Genesis Rabbah 49:12.

[7] See P.W. Wilson, *The Romance of the Calendar* (New York: W.W. Norton & Company, 1937), 226. Conversely would be *aquam perdere*, "to waste time."

[8] Courtrooms in which Biblical figures challenge God become a common theme in later rabbinic literature; this is one of the earlier examples. See Dov Weiss, *Pious Irreverence: Confronting God in Rabbinic Judaism* (University of Pennsylvania Press, 2017).

[9] *Pesiqta* de-Rav *Kahana* 5:13. Cf. the version at yRoshHashanah7b.

[10] See, for example, the debate between Rabbi Gamliel II and Rabbi Yehoshua concerning the date of Yom Kippur (mRoshHashanah 2:8–9). Though *orlogin* (cognate of the Latin *horologium*) does not refer to a specific timekeeping device, a sundial is likely intended here. As we will see below, the hour at which the new moon appears was of great importance for the determination of the new month. Such a calculation could not easily be performed with a water-clock. (The concept of divinely-gifted calendrical agency also appears in medieval manuscripts. As Elisheva Carlebach has noted, many *sifrei ʿevronot*, which contain instructions on how to properly intercalate the Jewish calendar, often *themselves* contain illustrations of angels delivering *sifrei ʿevronot* to humans. See Carlebach, *Palaces of Time*, 79.)

echelons of society. This impression is corroborated by the continuation of the passage, in which other sages describe a king giving his adult son other royal artifacts, such as a signet ring and the keys to many treasuries.

The meaning of the rabbinic "hour"

Rabbinic awareness of timekeeping technology was accompanied by the first extensive Jewish use of the Hellenistic timekeeping system. A passage at the very beginning of the Tosefta, an early rabbinic text roughly parallel to the Mishnah, includes an explicit definition of time terms near its opening.

> Rabbi [Yehudah ha-Nasi] says, "There are four watches (*mishmarot*) to the night. An ʿ*onah* is 1/24 of a *shaʿah* (hour). An ʿ*et* is 1/24 of an ʿ*onah*. A *regaʿ* is 1/24 of an ʿ*et*." Rabbi Nathan says, "The night has three watches, as it says, 'The beginning of the middle watch' (Judges 7:19). There is no 'middle' that does not have something before it and after it."[11]

Rabbi Yehudah's statement is thoroughly aligned with Roman timekeeping metrics.[12] The Bible, as we have seen, divides the night into thirds; Romans, however, divid-

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[11] tBerakhot1:1. The same definitions appear in yBerakhot1:1. They also appears much later in a liturgical poem by Eleazar ha-Qalir (d. ca. 640), who writes: "And the ʿ*onot* of the day are 576 [= 24x24] / And the *rigʿei* are to the ʿ*onah* as the ʿ*onot* are the whole day / And the meticulous divide the *regaʿ* into further *regaʿim*." (Translation quoted from Stern, *Time and Process in Ancient Judaism*, 78–79.) Though it is missing a few units, this description is entirely in line with the definitions located in tBerakhot1:1. While Eleazar acknowledges that some might wish to divide the *regaʿ* further, he names no smaller unit. A second system, which divided each hour into 1080 "parts" (*ḥalaqim*), was used exclusively for astronomical purposes. It will be discussed below.

[12] With the possible exception of a passage in bBerakhot32b (see note 102, next chapter), rabbinic timekeeping does not make use of the Babylonian sexagesimal system. However, sexagesimal systems do appear in other contexts; see, for example, bBerakhot57b: "Five things are 'a sixtieth.' They are: fire, honey, Shabbat, sleep, and dreaming. Fire is one sixtieth of hell. Honey is one sixtieth of manna. Shabbat is one sixtieth of the world to come. Sleep is one sixtieth of death. Dreaming is one sixtieth of prophecy." Other tannaitic and amoraic texts also choose the sixtieth as a significant fraction: see mPeah1:2 (the minimum fraction of the area of one's field that must go to charity), bNedarim39b, bBavaMetzia30b, yBerakhot1:1 (visiting a sick person removes one sixtieth of their suffering), bTaʿanit10a and bPesaḥim94a (the relative size of different land areas). See also tḤullin10:7; tḤallah1:8; tTerumot4:15 and 5:6–7; yBikkurim3:1; *Pesiqta* Zutrata 32:34.

ed it into quarters using the same "watch" terminology (*vigil prima, secunda, tertia,* and *quarta*). The Romans also divided the hour into twelve *unciae*, and each *uncia* could in turn be divided into 24 *scripuli.* While the Tosefta's subdivisions do not correspond exactly here, the unmistakably Roman duodecimal system is preserved; they will be discussed further later in this chapter.[13] Most importantly, however, the Tosefta is clearly using the word *shaʿah* "hour" in a technical sense; as we saw in the last chapter, this had previously only been done by Jews writing in Greek.

As we shall see in later chapters, the Hellenistic timekeeping system became permanently embedded in rabbinic law and continued to be used in Jewish legal discourse even when the surrounding culture was not supporting its use. However, it has frequently been overlooked that the adoption of the technical valence of the term *shaʿah* did not replace overnight its non-technical valences. The rabbis used the term *shaʿah* frequently, and in the vast majority of instances the term has nothing to do with the system of seasonal hours. Thus, for example, the term *b'shaʿah* (literally, "at the hour [of]") and the related *mi-shaʿah* ("from the hour [of]") pertain to the timing of specific events; it is functionally equivalent to "when."[14] In some instances, *shaʿah* refers to events which happen at the same time each day; these events can be natural, as in, "until (*ʿad shaʿah*) it gets dark" (tBerakhot5:1),[15] or conventional, as in, "when (*mi-shaʿah*) the priests enter [their houses] to eat their *terumah*" (mBerakhot1:1).[16] In other instanc-

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[13] The correspondence between Rabbi's position and Roman metrics was first noted in Solomon Gandz, "The Division of the Hour in Hebrew Literature," *Osiris* 10 (1952): 10–34. Gandz suggests that other rabbinic divisions into 24 are similarly influenced; witness the 24 books of the Bible, the division of the *kohanim* into a 24-part rotation (mTaʿanit4:2), and an imagined geography of Jerusalem in which the city is subdivided into seven successive divisions of 24 (Lamentations Rabbah 1:2).
[14] See, for example: mBavaBatra6:5–6; mArakhin2:6.
[15] This is how it appears in the Vienna manuscript *shaʿah*. The Erfurt manuscript omits *shaʿah*.
[16] Though rabbis later attempted to fit both of these phrases into the framework of the Hellenistic timekeeping system, there is nothing to suggest that they are using *shaʿah* in a technical sense.

es, the term *shaʿah* is related to specific activities that have no relation to the cycle of day and night and that do not necessarily recur. Thus, for example, mYoma6:6 discusses the ritual purity of the priest responsible for killing the "goat for Azazel," an act that was a key part of the Temple-era Yom Kippur service: "When did his clothes become impure? From when he would exit (*mi-sheyetze*) the walls of Jerusalem. Rabbi Shimon says, 'From the time (*mi-shʿat*) it [the goat] has been pushed off the cliff.'" Here *shaʿah* serves the same function as the grammatical *shin* prefix used in the previous clause, i.e. in both clauses the "when" is event-based, not time-based.

Similarly non-technical is the phrase *otah shaʿah*, "the same hour," which refers not to events happening within the span of one hour, but simply to events that occur simultaneously or in close proximity to one another.[17] Used in this way a *shaʿah* might be considerably longer than an hour; in mSanhedrin7:2 it is used to refer to the full duration of a given rabbinical court's existence.[18] *Kol shaʿah*, "every hour," follows the same pattern of abstraction; in both mPesaḥim2:1 and tTaʿanit3:11 it simply means "whenever." By itself, the term *shaʿah* can simply mean "a specific time," as in mAvot4:3: "there is no person who does not have a time [*shaʿah*], no word that does not have a place."[19] Both the Mishnah and Tosefta also sometimes use *shaʿah* adjectivally to indicate temporality; thus there is the concept *hora'at shaʿah* (lit. "teaching of the hour") a legal injunction which is not intended to be permanent;[20] and *tzeror shaʿah* (a temporary bundle of water skins), contrasted with *tzeror ʿolam* (a permanent bundle).[21]

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[17] See mBerakhot5:3; mPeah5:4; mNedarim9:10; mSanhedrin3:4; tBerakhot4:18; tMaaserSheni4:12; tShabbat13:3,4; tPesaḥim4:14; tYoma1:4.
[18] For a similar usage, see mArakhin8:1.
[19] See, as well, tBavaMetzia5:9 ("at whatever time he wishes") and tRoshHashanah2:17 ("a fitting time").
[20] See mParah7:6–7.
[21] See mKelim26:4.

The non-technical valence of the term also extends to the phrase *shaʿah aḥat* ("one hour," "a single hour") which, as in Daniel 4:15–6, is consistently used to mean "a brief period of time," or, "an instant," or sometimes simply, "once." Thus, for example, in mEduyot5:6, Rabbi Aqavia b. Mahalalel says, "It is better that I be called a fool all my days and not do evil before God for even *an instant* (*shaʿah aḥat*)."[22] Similarly, tYoma1:4 describes a non-priest who worked under the High Priest "for a short while (*shaʿah aḥat*)." A *baraita* in bGittin28a hypothesizes about a situation in which a husband grants his wife a divorce "one *shaʿah* before my death;" the ensuing discussion understands this to mean the divorce is given immediately before death.[23]

The most dramatic example of this usage appears in the story of rabbinic martyrdom at the hands of the Romans, in bAvodahZarah18a. The Romans had intentionally prolonged the agony of Rabbi Ḥanina ben Teradyon's death-by-fire by wrapping his chest with water-soaked wool, preventing the flames from quickly getting to his vital organs. The executioner, in an act of penance, agrees to pull off the wool and jumps into the fire himself; Rabbi Ḥanina promises him entrance to the World to Come as they both perish. Reflecting on this incident, which could not have taken more than a few seconds, Rabbi Yehudah ha-Nasi says, "There are those who acquire their World [to Come, i.e. the afterlife] in a single *shaʿah*, while others acquire their World [only] after many years."[24]

Understanding the persistent use of the non-technical meaning of "hour" has important consequences for our understanding of mBerakhot5:1, which discusses the

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[22] Cf. mBerakhot5:1, mAvot4:17 for similar sentiments employing the same phrase.
[23] Cf. bYevamot69b.
[24] Other instances of *shaʿah aḥat* to mean "a short period of time" can be found in bShabbat10a; bShabbat83b; bBavaMetzia30a; bYevamot71b; bKetuvot11a; bShabbat141b; and bNiddah30b.

state of mind most appropriate for prayer. It notes, "The first pietists (*ḥasidim rishonim*) would wait for a short time (*shaʿah aḥat*) and [then] pray in order to direct their hearts towards God." The specification that this is a *waiting* period led several commentators (as well as the Babylonian Talmud, discussed below) to argue that a technical hour was intended. Against this reading stands mSotah1:9, which also uses the phrase *shaʿah aḥat* in the context of someone waiting:

> Miriam waited for Moses for a short time (*shaʿah aḥat*) [while monitoring the baby Moses floating down the Nile], as it says, "and his sister stood at a distance" (Exodus 2:4). For this reason, Israel waited for her in the desert for seven days [many years later, after she had been excluded from the Israelite camp upon being struck with leprosy], as it says, "And the people did not travel until Miriam had been gathered" (Numbers 12:15).

In this passage, *shaʿah* is intended to both highlight the parallel between Miriam's wait and Israel's weeklong delay and suggest that the latter was recompense for the former. Certainly nothing in Exodus 2:4 specifies the duration of Miriam's wait. For the pietists, then, it is likely that the Mishnah's emphasis is not on the *length* of the delay, but rather on the idea of a mental preparatory period. This interpretation also accords with the subsequent passage, which discusses the correct mindset for prayer and has nothing to do with duration.[25]

Not infrequently, *shaʿot* are contrasted with *yamim* (days) to indicate that some action or status is measured in terms of fractions of the day, with the particular fraction being unimportant. Thus, someone who fasts "for hours" differs from someone who

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[25] On the nature of the *ḥasidim rishonim*, see the comprehensive article by Shmuel Safrai, "Teaching of Pietists in Mishnaic Literature," *Journal of Jewish Studies* 16 (1965): 15–33.

fasts for an entire daylight period.[26] In a different vein, the age of sacrificial animals—which dictates their eligibility for ritual use—was not rounded to the nearest day; instead, it was reckoned by the "hour" at which the animal is born.[27] In both of these instances *shaʿot* could represent any fraction of the day; it need not involve a rounding to the nearest seasonal or equinoctial hour.

Timekeeping expectations and the four-part rabbinic day

Having established that the rabbis persisted in using the word *shaʿah* in a non-technical sense, we can now turn to the many instances in which the term is used in a technical sense to refer to one twelfth of the day (or night). This technical usage is ubiquitous in rabbinic literature, which on its face suggests that people were now capable of reckoning the time to the nearest hour. Evidence from the rabbinic corpus, however, reveals a mismatch between the system's capabilities and real expectations. Not only do the rabbis themselves acknowledge that people will err when reckoning the time, but a statistical analysis of the rabbinic corpus reveals that the rabbis do not treat all twelve daylight hours equally, placing much greater emphasis on those which are easiest to reckon or which correspond to mealtimes. Though the adoption of the Roman system gives the *appearance* of newly heightened expectations, in reality those expectations remained mostly unchanged.

Unsurprisingly, it is in legal discussions that timekeeping expectations are greatest. In certain areas of law, awareness of hours is not only assumed but in fact mandated. Most notable among these is the law of contracts: both the Mishnah and Babylonian

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[26] See bEruvin41a; bYoma82a; bTaʿanit11b–12a; bAvodahZarah34a.
[27] See bAvodahZarah25b; bBekhorot39b.

Talmud specify that contracts signed in Jerusalem would contain not only the date, but the hour at which they had been enacted. This measure was likely introduced for a busy legal environment where connected contracts might be signed on the same day.[28]

Witness testimony is another area in which awareness of the hour appears to be important. Thus, for example, in a discussion in the Mishnah concerning the proper procedure for questioning witnesses, the judges ask, "In which week [did the event occur]? In what year? In what month? On what day of the month? On which day? At what *shaʿah*? In what place?"[29]

Despite this awareness that the time of day *could* be described in hours, rabbinic sources consistently communicate that the average individual was not expected to be able to do this with any amount of precision. This is already apparent in the elaboration of the witness interrogation procedure, at mSanhedrin5:3, which discusses whether slight disagreements about the timing of an event constitute contradictory evidence.

> If one [witness] says [the event occurred] in the second hour and the other says it occurred in the third hour, their testimony stands. If one says [it occurred] in the third hour and the other says in the fifth hour, their testimony is invalidated. Rabbi Yehudah says: it stands. If one says [it occurred] in the fifth hour and one says in the seventh hour, their testimony is invalidated, since the sun is in the east in the fifth hour, and in the seventh hour it is in the west.

An even more direct statement appears in tSanhedrin9:1:

> If one [witness] says [the event occurred] in the second hour and the other says it occurred in the third hour, their testimony stands, for not everyone is an expert in hours (*she-ein ha-kol beqi'in be-shaʿot*).

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[28] See mKetubot10:5 and bKetubot94b.
[29] mSanhedrin5:1.

To be an "expert" in hours, in other words, is simply to know what hour it is at any given moment. Even by a court's rigorous standards, an individual's assessment of the time was permitted to be off by a full hour—or, according to Rabbi Yehudah, perhaps two.

At first glance, these two texts appear to be at odds with the many passages throughout rabbinic literature which mandate that activities take place by a certain hour of the day. Surely it would be unfair to expect someone to perform an activity by a certain time if "not everyone is an expert in hours." However, close inspection of the sources, reveals that, despite the *ability* to cut up the day into twelfths, the rabbis normally declined to do so; instead, it is largely the third, fourth, sixth, and ninth hours which received legislative attention. The rabbinic use of the twelve seasonal hours thus masks a system which is substantially simpler; for most purposes, the day is in fact divided into four roughly equal parts.

1. The early morning work period, which ends in the third hour;
2. The first meal, which begins in the fourth hour but may continue into the sixth hour;
3. The early afternoon work period, which begins after the sixth hour;
4. The late afternoon leisure period, which begins with dinner in the ninth hour and concludes with nightfall.

In order to demonstrate the presence of this latent four-part system, we must demonstrate that (so to speak) not all hours are created equal, with some rarely appearing and others receiving heavy attention. What follows is a study of each of the twelve hours as it appears in the rabbinic corpus. I will begin by presenting each hour, after which I will present my conclusions.

First hour

The first hour is barely ever mentioned in rabbinic literature. When it does appear, it is always as part of a narrative in which one event occurs during each hour of the twelve-hour day. As we have already seen, this literary structure is frequently imbued with religious significance by the rabbis. The most frequent of these narratives concerns God's creation of Adam. One of the earliest versions reads as follows:[30]

> In the first hour [Adam] was conceived. In the second, He consulted the ministering angels. In the third, He gathered his dust. In the fourth, He kneaded him. In the fifth, He arranged him. In the sixth, He stood the formed mass (*golem*) on its feet. In the seventh, He cast a soul into it. In the eight, He inserted him into the Garden of Eden. In the ninth, He commanded him. In the tenth, he [Adam] transgressed what he had been commanded. In the eleventh, he was judged. In the twelfth, he left God's presence, having been pardoned.[31]

The "first hour" also appears in a tannaitic text that describes the mealtimes of different types of peoples:

> Our sages taught: gladiators eat in the first hour, thieves eat in the second hour, heirs (i.e. people who do not have to work) eat in the third hour, workers eat in the fourth hour, sages eat in the fifth hour, and all people eat in the sixth hour. But didn't Rav Pappa say that all people eat in the fourth hour? Rather, reverse it: all people eat in the fourth [hour], workers eat in the fifth, and sages eat in the sixth. From that point [six hours] onward, [eating is] like throwing a stone into a bottle (i.e. it is not beneficial). Abaye said, "We only consider it [not bene-

[30] Note that, by rabbinic standards, God has a "tight schedule," performing a new event each hour, something that humans would not have been expected to do. I discuss differences between divine and human timekeeping abilities below.

[31] Pesiqta de-Rav Kahana §23, Mandelboim ed. Similar versions appear in bSanhedrin38b; Leviticus Rabbah 29:1; Avot de-Rabbi Natan ch. 1 (Version A) and ch. 42 (version B); Midrash Tanḥuma (Buber ed.) Bereishit 25 and Shemini 13; Midrash Tanḥuma (Warsaw ed.) Pequdei 13 and Shemini 8; Pesiqta Rabbati 46; Deuteronomy Rabbah, Devarim §13; and Midrash on Psalms, 92:3. See also Rachel Adelman, "The Poetics of Time and Space in the Midrashic Narrative: The Case of Pirkei DeRabbi Eliezer" (Hebrew University of Jerusalem, 2008), 187 n. 90.

> ficial] if he did not eat [anything] before the afternoon. But even if he did, then we have no [problem] with it (i.e. it is beneficial)."[32]

While the first hour is part of *somebody's* daily rhythm, the literary structure of the text suggests that these staggered eating periods are somewhat artificial, since society is not a high school lunchroom. Furthermore, the text confirms that it is not until the fourth hour that most of society begins eating in earnest; those who eat earlier do so either out of privilege (because they have no work in the morning) or because they are participating in activities frowned upon by the rabbis.[33]

Second hour

The second hour is only slightly less obscure than the first. As with some of the other hours, it sometimes appears for heuristic purposes. Thus, for example, a *baraita* instructs children to be taught how to fast by making them wait a little for their food: "If he is accustomed to eating in the second hour, feed him in the third hour; [if accustomed to eating] in the third, feed him in the fourth hour."[34]

Apart from cases like this, the second hour is mentioned infrequently. Esau is described as having gone to see his father Isaac at the second hour on the fateful day when his brother Jacob takes his birthright (see Genesis 27:1–45), but this is only a single occurrence and is possibly part of a larger attempt to understand the sequence of events on that day.[35]

[32] bPesaḥim12b. Cf. bShabbat10a.
[33] On scorn for gladiators, see bGittin46b–47a. On the erratic hours kept by thieves, see bBavaMetzia83b (cited below). For another example of the first hour being used in sequence with the next few hours, see bPesaḥim13a.
[34] bYoma82a.
[35] Midrash Tanḥuma (Buber ed.), Toldot §17.

A telling final occurrence is in a description of Noah's expertise in maintaining the animals while in the ark. So knowledgeable was Noah that he knew "which animal to feed at two hours of the day or three hours of night."[36] The purpose here is to emphasize Noah's exceeding meticulousness in tending to the needs of the ark's inhabitants; for the purposes of this text, the third hour of the night was just as obscure as the second hour of the day.

Third hour

For the rabbis, the second hour had no particular meaning significance in the day's rhythms. The third hour, by contrast, was widely understood to be the end of the transition from night to day and the hour by which the day was in full swing. The Babylonian Talmud warns against visiting the sick during the first three hours of the day, since during these hours the sick look somewhat better and might not elicit a visitor's prayers, since the healing effects of sleep have not yet worn off.[37]

The third hour is also frequently cited as the hour at which royalty wake up—or, in other words, the time by which the day has fully begun.[38] Indeed, there is some evidence that this was the practice of Roman royalty.[39] Thus, the period of the day ending with the third hour—what we might call the "early morning"—ends when the entire

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[36] See Genesis Rabbah 29:4; Midrash Tanḥuma, Noah §9; Midrash Yelamdeinu, Genesis 37, 25a–b. In Midrash Tanḥuma, Noah §14, the numbers are transposed, with Noah's obligations at two hours of the night and three hours of the day.

[37] bNedarim40a; Cf. Celsus, *De medicina* 2.4, which seems to reach the exact opposite conclusions.

[38] See Mekhilta de-Rabbi Yishmael Bo §13; Mekhilta de-Rabbi Shimon bar Yoḥai 12:30; bBerakhot3b–4a; Lamentations Rabbah §2; Midrash Tanḥuma Beha'alotkha 19 and Bo 7; Midrash Tanḥuma (Warsaw ed.) Beha'alotkha 10; Pesiqta de-Rav Kahana chs. 7 and 17; Numbers Rabbah 15:16; Ruth Rabbah 6:1; and Midrash on Psalms §57.

[39] See Cicero, *Letters to Atticus* 10.13 and Martial, *Epigrams* 12.18. See, however Seneca the Younger, *Epistulae ad Lucilium* 83.14, which describes a certain drunkard named Lucius Piso, who slept until the sixth hour each day.

population is awake. That the third hour is the last reasonable time to be awakened is further confirmed by an early midrashic parable in which a king tells one son to wake him up at sunrise (*netz ha-ḥamah*) and the other to wake him up at the third hour.[40] It is for this reason, as well, that Rabbi Yehoshua sets the third hour as the deadline by which the morning *shemaʿ* must be recited.[41]

Fourth hour

The fourth hour is one of the most frequently mentioned hours. As the sun rises in the sky, the temperature begins to rise, as well. Though the rabbis debate whether the day reaches its hottest point in the fourth or sixth hour, it is in the fourth hour that being in direct sunlight becomes unpleasant; the Talmud suggests that someone trying to discourage animals from resting in the shade of a gravestone should tilt the stone in such a way that it casts as small a shadow as possible in the fourth hour.[42]

The rising heat makes work increasingly difficult, and as a result it is the fourth hour in which the first meal of the day commences.[43] Indeed, no hour is more closely associated with eating than the fourth; according to Rav Pappa, it is "mealtime for all."[44]

According to the rabbis, the fourth hour is also the time at which the first of the

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[40] Mekhilta re-Rabbi Yishmael Bo §17; Mekhilta de-Rabbi Shimon bar Yoḥai 14:22.

[41] mBerakhot1:2. The Babylonian Talmud also states that God is angry for the first three hours of the day, during which the rooster's comb is white (bSanhedrin105b; see also bAvodahZarah4b). Another curious reference to the third hour appears in a late midrash. Here Adam is said to have been tested by God in the third hour and had already been condemned by the ninth hour (Exodus Rabbah 32:1).

[42] bEruvin43b.

[43] Mekhilta de-Rabbi Yishmael, Beshalaḥ 4; Mekhilta de-Rabbi Shimon bar Yoḥai 16:21; and Genesis Rabbah 48:8.

[44] bPesaḥim12b. See also bPesaḥim107b: "Lest you say that nine hours for [King] Agrippas (i.e. he only began eating in the ninth hour) is like four hours for us..." This passage assumes that the reader will understand that the fourth hour is the normal eating time.

two daily sacrifices, known as the *tamid* (daily/constant), was offered at the Temple. The relationship between the *tamid* and the first meal is not clear; the Bible mandates a morning sacrifice, but it is only the rabbis who specify its timing.[45] A fanciful reason provided by several midrashic texts—that King Solomon, who possessed the keys to the Temple, drank too much on the eve of the Temple's dedication and only awoke in the fourth hour—seems quite weak.[46] More likely is a rabbinic notion that God and humans have roughly the same daily schedule, and would thus eat at the same time. I will revisit this idea below.

According to the rabbinic understanding, the timing of the first meal—in the fourth hour at earliest and in the sixth hour at latest—is well fixed and universal. In one Talmudic passage, Rabbi Eleazar ben Rabbi Shimon tells a Roman officer that anyone in a tavern who is sleeping (i.e. not eating) at the fourth hour of the day can only be a Torah scholar, a worker with unusually early hours, a night worker—or a thief.[47] Later rabbinic sources actually mandate that a person should neither eat nor wash before the fourth hour.[48]

Furthermore, the rabbis understood this hour of eating to have been fixed since the distant past: even the manna—the food miraculously supplied to the Israelites in the desert—was supposed to have remained until the fourth hour of the day; after that, it would melt in the mounting heat.[49] Eating at this time was understood to have health benefits, as well; Rabbi Isaac warns that vegetables should not be eaten before this

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[45] See, for example, yBerakhot4:1, 7b.
[46] See Leviticus Rabbah 12:5. A different version, found in Leviticus Rabbah 10:4 adds that Pharaoh's daughter (who was Solomon's wife) further aided the king's confusion by placing star-like jewels in the king's bedroom, making him believe it was still night. See also Midrash on Proverbs 31:4.
[47] bBavaMetzia83b.
[48] Masekhet Kallah Rabati 9:10–11; Masekhet Derekh Eretz 5:3.
[49] Midrash Tanḥuma (Buber ed.), Beshalaḥ 21; Midrash Tehillim 78.

hour.[50]

This schedule for eating was also codified into law: on Passover Eve, the rabbis agree that the fourth hour is the last time during which *ḥametz* may be consumed.[51] The timing of the morning *tamid* has legal consequences, as well; because the prayers had a relationship to the defunct Temple service, one rabbinic opinion held that the fourth hour was the time by which the morning prayers must be said.[52]

Fifth hour

With the fifth hour, we return to obscurity. From Pesaḥim12b, quoted above, we know that people were still eating the morning meal in the fifth hour. Beyond this, however, the fifth hour is mainly understood as a transition between the fourth hour and the sixth. As with the first hour, the fifth hour is mentioned almost exclusively in series with other hours. Beyond these instances, the fifth hour appears only in the context of Passover Eve. There, its status as a liminal hour—the status of *ḥametz* is said to literally "hang" during this hour—becomes the focus of disputes concerning the transition process between *ḥametz*'s permissibility in the fourth hour and its prohibition in the sixth.[53]

Sixth hour

The sixth hour, unlike the fourth or ninth, is not associated with any specific daily event. Nonetheless, it is the hour of the day mostly frequently mentioned in rabbinic

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[50] bBerakhot44b.
[51] mPesaḥim1:4–5.
[52] mBerakhot4:1; bBerakhot26b–27a; bNiddah8a.
[53] mPesaḥim1:4–5.

texts. Much of this has to do with the fact that it was easier to reckon noon—which comes at the conclusion of the sixth hour—than any other time between sunrise and sunset. As we have seen above, many of the most rudimentary timekeeping devices were intended only to indicate noon.

Because of its recognizability, the sixth hour appears in a wide variety of contexts. It seems to have been the hour at which children came home from school,[54] and was also apparently the hour until which nations waged war.[55] With respect to mealtimes, the sixth hour represents the firm end of the first meal. For this reason it is (according to one opinion) the time by which the morning prayer must be said;[56] it is also for this reason that one is required to eat something by this time on Shabbat so that one does not appear to be fasting on this joyous day.[57] On Passover Eve, the sixth hour is the time by which *ḥametz* (leavened bread) must be burned.[58] There are also many biblical events which the rabbis describe as having occurred in the sixth hour. These include the time at which the Jews left Egypt, the time at which angels departed from Abraham on their way to Sodom, the time at which the Israelites began to make a golden calf, and the time at which Moses' father-in-law Jethro joined up with the Israelites travelling in the desert.[59]

Finally, and perhaps most tellingly, the sixth hour is the only hour mentioned when

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[54] Pesiqta Rabbati §43.
[55] Mekhilta de-Rabbi Shimon bar Yoḥai 17:12; Mekhilta de-Rabbi Yishmael. Beshalaḥ §1. This is a somewhat puzzling statement, since the hours at which battles began and ended were actually quite well documented, as we saw in the discussion of Josephus.
[56] mBerakhot4:1.
[57] See yTaʿanit3:11 and yNedarim8:1. Cf. yTaʿanit4:6.
[58] mPesaḥim1:4–5.
[59] On the Jews leaving Egypt, see Mekhilta de-Rabbi Yishmael, Bo §5. On the timing of the angels' departure from Abraham's dwelling, see Genesis Rabbah 50:1; Midrash Tanḥuma Vayera §21. On the making of the golden calf, see Pesiqta Rabbati §10; bSanhedrin105b; yTaʿanit4:5; yShekalim2:3; Pesiqta de-Rav Kahana §2; Midrash Tanḥuma (Warsaw ed.), Ki Tisa §7 and §10; Exodus Rabbah 36:12 and 41:7; Numbers Rabbah 15:21. On Jethro's arrival, see Midrash of Psalms §78.

the rabbis wish to describe a finite interval that begins or ends at a point other than sunrise or sunset. Thus, for example, tNiddah9:2 elaborates on what it would mean for a woman to keep track of her menstrual cycle according to “days and hours” with the example of a woman who “is accustomed to seeing [her period] from the 20th day [of the month] to the 20th day [of the next month], from six hours to six hours.”

The sixth hour is also the time by which a farmer must deposit the key to his olive storehouse with a priest in order to ensure that the crop does not become impure.[60] According to Rabbi Shimon, the individual has *me-ʿet le-ʿet*, (literally “from time to time”), a phrase used through rabbinic literature to describe a 24 hour period counted from some arbitrary point during daylight until that same point on the next day. To illustrate that this rule applies even on Friday—when the 24-hour window runs into Shabbat—Rabbi Shimon adds, “Even if one finished [harvesting] one’s olives on Shabbat Eve at six hours, one can bring [him] the key from now until six hours after Shabbat [i.e. until the sixth hour on Sunday].”[61] While the appearance of menstrual blood and the completion of one’s harvest can occur at any time during the day, it is noteworthy that the six hour mark is the *only* mark used to illustrate these seemingly arbitrary examples. This, too, may reflect a disparity between theoretical timekeeping ability and practical expectations.

Seventh hour

On the whole, the afternoon hours are mentioned far less frequently than the

[60] tTaharot10:9.
[61] Cf. mTaharot9:4, which contains R’ Shimon’s opinion but not this elaboration. This same 48-hour time period appears the context of an unusual fast in Avot de-Rabbi Natan (Version A), chapter 6.

morning hours in rabbinic writings. Outside of its appearance in the hourly series discussed above, the seventh hour appears in only a few contexts. The first is a midrash that describes Adam as entering Eden in the seventh hour.[62] Within the legal realm, the seventh hour was the time by which the *musaf* sacrifice had to be offered and, as a result, the time by which the *musaf* prayer had to be said.[63] The timing of the sacrifice may simply have been a way of firmly differentiating the *musaf* sacrifice from the *tamid*, mentioned earlier, as there is nothing particularly special about the seventh hour other than its adjacency to the sixth.

Eighth hour

The eighth hour, like the first hour, is only ever mentioned in series with other hours. We will discuss the phrase *shemoneh u-meḥtzah* ("eight and a half") below.

Ninth hour

The ninth hour is associated with mealtime in both Greco-Roman and rabbinic sources; in both, it is specifically royalty who eat at this hour. As late as the fourth century CE, the historian Ammianus Marcellinus was able to note that, "Among them, only at the king's court is there a fixed dinner-hour; otherwise each person's stomach serves as a sundial, and at its prompting they eat whatever is available."[64] In rabbinic literature, the ninth hour is the time at which the prudent arrive at a king's meal when no

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[62] Pirkei de-Rabbi Eliezer, chapter 18.
[63] mBerakhot4:1.
[64] This translation taken from Talbert, *Roman Portable Sundials: The Empire in Your Hand*, 165.

other time has been specified.[65] King Agrippa is said to have eaten his first meal at this time.[66] King David, who famously awoke each midnight, is described as *concluding* his meal in the ninth hour and sleeping until then.[67] The Assyrian king Merodakh-Baladan is said to have eaten at noon and then slept until the ninth hour.[68]

Since most people did not stay awake much past nightfall, the ninth hour also marked the winding down of the workday and the transition into rest. Just as a sick person appears healthier in the first three hours after dawn, she looks worse in the last three hours of the day.[69] A *baraita* instructs that one should not eat on the eve of Shabbat or holidays from the ninth hour onward.[70] A later rabbinic source specifies that one should not work from this point, either.[71]

Tenth, eleventh, and twelfth hours

The remaining hours are barely mentioned at all outside of the abovementioned series. The sole independent mention of the tenth hour is in a midrash which describes God as having once brought the day to a close in this hour in order to prevent Esau from capturing Jacob.[72] Neither the eleventh hour nor the twelfth hour is ever mentioned outside of a series.

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[65] Masekhet Semakhot 8:10.
[66] bPesaḥim107a.
[67] Lamentations Rabbah 2:22.
[68] Pesiqta de-Rav Kahana §2; Midrash Tanḥuma (Warsaw ed.), Ki Tisa §5; Song of Songs Rabbah 3:2; Esther Rabbah 3:1.
[69] bNedarim40a.
[70] bPesaḥim99b.
[71] Masekhet Derekh Eretz §10. Earlier rabbinic sources also prohibit work during this period, but the timing is tied to *minḥah*, not a specific hour. See mShabbat1:2.
[72] Midrash Tanḥuma, Vayetze §3.

Night hours

References to night hours are exceedingly rare. Beyond the fact that sundials were largely useless at night (though some could utilize moonlight), the high cost of interior lighting meant that most people went to bed quite early.[73] Even the "watch" (*ashmurah*), equivalent to either one third or one fourth of the night, is rarely used, and even then it is only the first watch (or its end) which has any legal significance.[74]

Nonetheless, the early night hours do make a few appearances in rabbinic literature. In one text, the second night hour is when kings go to sleep. This is presumably quite late; since interior lighting was costly, it was only the wealthy who could regularly afford to stay up long past sunset.[75] A late rabbinic source describes individuals showing up to a king's meal late, returning home at "two or three hours at night."[76] Both of these texts suggest that the night begins in earnest at this point, just as the day begins in earnest when royalty awakens.

Finally, the night hours are associated with a quiet—specifically, a quiet through which crying can be acutely heard. The relationship between sound and nighttime is elucidated in another midrash: "The voice travels only at night."[77] In Esther Rabbah 9:4, God hears the cries of the Jews, "as at two hours of the night;" another midrash describes hearing crying after the night's third hour.[78] There appears to be little relation-

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[73] There is a rich literature on the historic cost of interior lighting. The classic study is W.T. O'Dea, *The Social History of Lighting* (London: Routledge & Keegan Paul, 1958). See also A. Roger Ekirch, *At Day's Close: Night in Times Past* (New York: W.W. Norton & Company, 2005). See as well the important economic analysis in William D. Nordhaus, "Do Real-Output and Real-Wage Measures Capture Reality? The History of Lighting Suggests Not," *The Economics of New Goods* 58 (1997): 29–66.
[74] See mBerakhot1:1 and mYoma1:8.
[75] Mekhilta de-Rabbi Shimon bar Yoḥai 12:30. Note, for example, bBerakhot2b, which specifies the time that a *poor* man eats his bread, since this is somewhat earlier than the meals of the wealthy.
[76] Masekhet Semaḥot 8:10.
[77] Lamentations Rabbah 1:24.
[78] Midrash Aba Gurion §5. This midrash was first published by Jellinek in 1853.

ship between these events and these specific hours other than the fact that they occur at the beginning of the night, when people are awake and thus more likely to hear. In Roman sources, the silence of night appears in time terminology itself; Marcus Terentius Varro (d. 27 BCE) says that the period of the night known as *concubium* ("rest") is followed by *silentium* ("silence") and then *conticinium* ("stillness").[79]

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In the beginning of this section, I cited two examples—one regarding contracts, the other witness testimony—in which the law expected a high level of awareness about the hour, whatever hour that might be. Judged within the larger context, it is clear that the rabbis interest in specifying the in these cases is exceptional; the rabbis were able to expect more in these contexts because (a) the gravity of contracts and courtrooms demanded greater-than-average precision and (b) it was only necessary to *document* the hour after the fact, not to coordinate the rhythms of the day.[80]

Indeed, it is quite telling that the laws of *niddah*, which require menstruating women to make note of the time of day on a regular basis, largely avoid speaking in terms of hours. Instead, the laws of *niddah* consistently employ the term *me-ʿet le-ʿet*, a standard which requires only that a woman note the lighting conditions and wait until the recurrence of those conditions on the following day. This standard neatly avoids both the need to reckon the exact hour and the difficulty of tracking intervals that begin and end at arbitrary points. Commentators are quick to translate *me-ʿet le-ʿet* as "a 24-hour period," but there is good reason to believe that the number of hours was only of sec-

[79] *De Lingua Latina*, VI.6.7.

[80] Josephus' hour-by-hour recounting of military maneuvers (discussed above) is precise for the same reason.

ondary importance.[81]

This analysis of specific hours shows that interest is centered around the third, fourth, sixth, and ninth hours—that is, the end of the morning work period and the beginning of the first meal, noon, and dinner. The prominence of these hours can be explained in two ways. First, with the exception of the third and fourth hours, they are sufficiently far apart from one another that they cannot be easily confused. Second, the fact that these hours were easy to recognize—both because they require only a general awareness of the sun's position and because they were already associated with daily rhythms—allowed the rabbis to ascribe legal significance to them without creating new timekeeping burdens. It is no surprise that the sixth hour, which was the most recognizable of all, also appears in more contexts—and in more *legal* contexts—than any other hour.

If it is only the third/fourth, sixth, and ninth hours which are significant for setting the rhythms of the day, then the day can be divided into early morning, late morning, early afternoon, and late afternoon. This quadripartite division is organized around the two daily meals, but it appears to be so well ingrained that it is largely maintained even on fast days, as articulated in the Babylonian Talmud:

> What do they do [on public fast days]? Abaye said, "From morning until midday, they examine the deeds of the town. From midday until evening: for a quarter of the day they read [from the Torah] and the haftarah, and for a quarter of the day they ask for mercy, as it is said, "And they read from the book of the Teaching of the Lord their God for a quarter of the day and for a quarter they con-

[81] The phrase "24 hours" (כ"ד שעות or כ"ד שעי') does appear in Late Antique rabbinic literature, but only occasionally; see yNedarim10:8, bPesaḥim20b, and bRoshHashanah20b.

> fessed and bowed themselves before the Lord their God" (Nehemiah 9:3).[82]

Perhaps even more remarkably, the four-part division of the day is upheld even by God:

> Rav Yehudah said that Rav said: "There are twelve hours in the day. For the first three, God sits, engaged in Torah study. For the second [set of three], He sits in judgment of the entire world. When he sees that the world has made itself worthy of destruction, he arises from the Throne of Judgment and sits on the Throne of Mercy. For the third [set of three], He sits and sustains the entire world, from the horns of the oryx to the eggs of lice. For the fourth [set of three], he sits and plays with the Leviathan, as it says, "The Leviathan you formed to play with" (Psalms 104:26).[83]

Since God presumably has the ability to apportion the day any which way—indeed, there is no reason for God's rhythm to be bound by sunrise and sunset at all—these divisions are a reflection of human activities, which God is understood to emulate both here and throughout rabbinic literature.[84] It is therefore telling that God, in the rabbinic imagination, divides the day into quarters, transitioning from one activity to the next in lock step with mortals. It is even possible that there is supposed to be some correspondence between divine and human activities: whereas humans work in the early morning, God studies Torah; whereas humans spend the final quarter of the day winding down and preparing for sleep, God spends this time playing. In addition, Roman courts and the Roman senate often convened during the second quarter of the day; this may have motivated Rav, an emigre from Palestine, to describe God as sitting in judg-

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[82] bMegillah30b. Cf. bTaʿanit12b.
[83] bAvodahZarah3b.
[84] God's emulation of human behavior in rabbinic texts has been discussed extensively. Most recently, see Dov Weiss, "The Humanization of God," in *Pious Irreverence: Confronting God in Rabbinic Judaism* (Philadelphia: University of Pennsylvania Press, 2017).

ment at the same time.[85]

Origins of the four-part rabbinic day

The rabbinic four-part day that may be inferred from the foregoing analysis is a direct outgrowth of Roman timekeeping practices.[86] We have already noted that Rabbi Yehudah's quadripartite division of the night and duodecimal subdivision of the hour are both in line with Roman timekeeping. In Roman society the four nightly watches, which were mostly of interest to the military, resulted in a quadripartite division of the day, as well. While Roman sources differ on which hours were publicly announced, the most common practice appears to have been the announcement of every third hour, with the names of those hours—*hora tertia*, *hora sexta*, and *hora nona*—generally referring to the *conclusion* of a three-hour period, as is the case in rabbinic texts.[87]

1. Rabbinic culture was not alone in adopting the quadripartite division of the day. In both the New Testament and other early Christian writings, the four-part day is embraced in much the way it is in rabbinic writings, i.e. through emphasis on the third/fourth, sixth, and ninth hours but only a nominal interest in the rest of the twelve-hour system. In the Gospels, key stages of Jesus' death take place at the sixth and ninth hours.[88] In addition, Acts 3:1 calls the ninth hour "the hour of prayer," and Peter prays at noon in Acts 10:9. These same hours show up in early Christian prayer, as well. As with the

[85] See Hermeneumata Pseudodositheana, *Colloquia Celtis* §73, and Acta Martyrum, *Passion of Saints Maxima, Donatilla and Secunda* §1. The middle quarters of the day, in which God's anger rises and then falls, perhaps corresponds with the temperature's rise and subsequent fall, but this is only conjecture.
[86] It would be possible to trace it back to Neḥemiah 9:3 (discussed in the previous chapter), except that Neḥemiah does not pretend to be using some other, more complicated system.
[87] See, for example, Varro, *De lingua latina* 6.89. In general, see Gerhard Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders* (University of Chicago Press, 1996), 19.
[88] See Matthew 27:45–50 and its parallels.

rabbis, early church texts take Daniel 6:11 as their model for prayer; this verse describes Daniel praying three times daily but does not indicate the timing of these prayers. For the rabbis, these prayer times are linked to the timing of Temple sacrifices. Even without these linkages to sacrifice, however, the first century *Didache* already indicates that the three prayers should be said at the third, sixth, and ninth hours. These same hours (*tertia*, *sexta*, and *nona*) are recommended by Tertullian (d. after 220 CE) who links them to events in Jesus' life and martyrdom. The same three hours are noted as customary by Clement of Alexandria (d. 215 CE) and are recommended by Hippolytus of Rome (d. 235), Basil of Cappadocia (fl. fourth century) and Jerome (d. 420).[89] Just as in rabbinic literature, the use of these few hours did not indicate an interest in the full twelve; as Anthony Turner puts it, for the purposes of Christian prayer, "the twelve-fold division of the Greco-Roman dial was superfluous."[90] By the same token, the presence of sundials at early Christian sites, like the presence of sundials in early synagogues, does not suggest a greater fastidiousness with regard to timekeeping.[91]

While the quadripartite division of the day is clear in early Christian writings, in rabbinic literature it is obscured by rabbinic fealty to the idea that prayer times should correspond to the rhythms of the Temple. Because the Temple schedule was relatively complicated, the quadripartite day ended up being obscured in rabbinic literature. We

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[89] Joseph A. Jungmann, *Christian Prayer through the Centuries* (Paulist Press, 1978), 3. On Jerome, see *Epistles* 22.37. It should be noted that not all Christian prayer was so carefully regimented; her forms of Christian prayer were somewhat looser. On the distinction between "cathedral" and "monastic" prayer, see Schiffman, "Minchah: A Halakhic and Historical Analysis," and references there.
[90] Turner, "A Use for the Sun in the Early Middle Ages, The Sun-Dial as Symbol and Instrument," 30.
[91] Turner, 30–31.

shall see in chapter 3 that the Karaites, who did not preserve such a link between Temple sacrifice and prayer, specified prayer times somewhat differently. However, as they did not emerge in the context of Roman culture, they did not create mandates based on the duodecimal day.

The "naïve" hour

In the medieval period, Jewish scholars began to form opinions about whether the hour, as used in Late Antique rabbinic literature, was used to refer to seasonal hours (most frequently rendered as *shaʿot zemaniyyot*) or equinoctial hours (*shaʿot shavot*). This debate, which will be explored at length in chapters 3 and 5, stemmed from a curious fact: despite rabbinic literature's *apparent* use of both seasonal and equinoctial hours, the two types of hour are never differentiated or even explicitly named.

In this section, I wish to argue that this absence is quite meaningful: the distinction between seasonal and equinoctial hours was not made because the rabbis did not think that any such distinction needed to be made. Despite the fact that the rabbis use the term "hour" in ways that often match up with one kind of hour or the other and despite the fact that the distinction between seasonal and equinoctial hours had long been established in Greek astronomical texts, the rabbis of Late Antiquity betray no indication that they understood the difference.

At first glance, this position seems implausible for two reasons. First, the distinction between seasonal and equinoctial hours is quite old. It is well attested in Babylonian astronomy;[92] in Greek literature, seasonal hours (*hōra kairikē*) and equinoctial hours

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[92] Francesca Rochberg-Halton, "Babylonian Seasonal Hours," *Centaurus* 32, no. 2 (1989): 146–147.

(*hōra isēmerinē*) appear by the third century BCE.[93] Thus, by the time of the composition of the earliest rabbinic texts, the distinction between seasonal and equinoctial hours had long been established.

Second, the argument seems implausible because, in many instances, rabbinic use of the word "hour" *appears* to fit into one of these two categories, even though the categories themselves are never named in Late Antique rabbinic literature. Thus, for example, when the rabbis discuss the "*n*th hour," it *appears* obvious to us that the *n*th seasonal hour is intended. On occasion, it even *appears* that this assumption has being corroborated; bShabbat129b, for example, discusses days when the planet Mars is dominant during "even" hours—a statement which assumes that there are always twelve hours in a day, a characteristic of seasonal hours.[94] In other circumstances, it is also *appears* obvious that equinoctial hours are intended. For example, a debate about the difference between bread which has been leavened for one or for two "hours" suggests an equinoctial usage, since the length of the leavening process surely would not vary with the seasons.[95] The same is true about the claim that speaking for three hours renders one's spittle tasteless, the discussion about a load which will break a bench in either one or two hours, and another about cooking a food item for one or two hours.[96] In each of these cases hours are being used to describe a duration; as a result, one might hypothesize that the rabbis use seasonal hours when discussing the time of day and equinoctial hours for measurement purposes.

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[93] Bowen and Goldstein, "Hipparchus' Treatment of Early Greek Astronomy: The Case of Eudoxus and the Length of Daytime," 238f.
[94] On the origins and use of the planetary hours system, see Solomon Gandz, "The Origin of the Planetary Week or the Planetary Week in Hebrew Literature," *Proceedings of the American Academy for Jewish Research* 18 (1948): 213–254.
[95] bAvodahZarah68b.
[96] bNiddah63a, bBavaKamma10b, and bAvodahZarah38a, respectively.

Problems arise, however, whenever the rabbis attempt to describe a duration that is connected to a specific time of day; in these contexts, the meaning of the word "hour" either seems to fluctuate from sentence to sentence or cannot be assigned a clear meaning at all. In a passage in bAvodahZarah25a, various rabbis deliberate on precisely how long the sun stopped in the sky during the events described in Joshua 10:13: "And the sun stood in middle of the sky, and did not hasten to go down for a complete day (*ke-yom tamim*)."[97]

> How long? Rabbi Yehoshua ben Levi said, "24 hours: It traveled six, stood six, traveled six, and stood six. The whole matter was 'a complete day (*yom tamim*).'" Rabbi Eleazar said, "36 [hours]. It traveled for six and stood for twelve, travelled for six and stood for twelve. [Thus] its pausing was 'a complete day.'" Rabbi Shmuel bar Naḥmani said, "48 [hours]. It travelled for six and stood for twelve, travelled for six and stood for twenty-four, as it says, 'and did not hasten *to go down* for a full day.' It can be inferred [from the latter part of the verse] that initially [the sun's descent] was *not* 'a complete day.'"

Is this passage employing seasonal or equinoctial hours? It is very difficult to tell. If the hours are seasonal, then the prooftext used by all three rabbis—that "a full day" means 24 hours—leads to a contradiction, since (with the exception of the equinoxes) 24 seasonal daylight hours do not add up to "a complete day." If, on the other hand, equinoctial hours are being used in the text, the sun's normal twelve hours of travel time will not add up to the full daylight period (again with the exception of the equinoxes).[98]

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[97] Mark Leuchter has suggested, in personal correspondence, that this incident may reflect scribal uncertainty regarding the actual length of the battle.

[98] The passage continues with a slightly different iteration of these three opinions, with the same problems persisting. A similar problem exists around the midrashic claim that the primordial light which God

This ambiguity exists in discussions of non-miraculous events, as well, such as when the Talmud applies an absolute measure to a changing duration. In a discussion in bShabbat34b, the rabbinic scholar Shmuel is quoted as saying that the length of twilight (*bein ha-shmashot*) is either the time it takes to walk “three parts of a *mil*,” or “two parts of a *mil*,” a *mil* being a unit of distance.[99] These units are somewhat obscure, since the definition of *mil* is not given. Nonetheless, these measures of length are confusing: walking speed does not change with the seasons, but the duration of twilight certainly does.

The same categorization problem arises in bPesaḥim93b, which states that a person can walk 10 *parsa'ot*—equivalent to 40 *mil*—in a day: 5 *mil* from dawn to sunrise, 15 *mil* from sunrise until midday, another 15 *mil* from midday until sunset, and another 5 *mil* from sunset to nightfall. Not only are these statements made without reference to the time of year, but they are given scriptural validation, suggesting that they cannot be changed by empirical measurement.[100]

The indeterminate or inconsistent use of the word “hour” in each of these passages points to an important feature of the timekeeping regime of this era: for most people living in the centers of rabbinic scholarly production—including the rabbis themselves—the difference between seasonal and equinoctial hours was either of purely theoretical interest or not understood at all. It is this lack of awareness which explains why rabbinic sources do not at any point explicitly indicate which type of hour they are

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created on the first day of creation shone for 36 hours. See Genesis Rabbah 11:2, 12:6, 82:15; Pesiqta Rabbati §23.

[99] See also bPesaḥim93b–94a.

[100] This text would become problematic in medieval European sources; as we shall see below, it is an important prooftext for those wishing to argue that the generic rabbinic “hour” must have been an equinoctial hour. An additional prooftext, located on bEruvin56a, is discussed below, page 124.

employing and occasionally make statements about the "hour" which cannot be easily classified as either seasonal or equinoctial.

To illustrate how this could be so, consider the city of Pumbeditha, located in modern-day Iraq. Among the important centers of rabbinic activity in Late Antiquity, it is the most northerly, and therefore the one that experienced the greatest fluctuations in the length of the seasonal hour over the course of the year. On the summer solstice, a seasonal hour in Pumbeditha would last for 72 minutes; on the winter solstice, it would last for 50 minutes.[101] With a maximum difference of only twelve minutes between the seasonal and equinoctial hour, only those with access to a water-clock could have differentiated between the two. This remains the case over longer durations, as well: even on the summer solstice, five seasonal hours and five equinoctial hours only differ by a combined total of 60 minutes, which, as we have seen, was still within the margin of error for most people. Thus, for most people, the distinction between a seasonal and equinoctial hour had no practical relevance—and because it had no practical relevance, it probably was not widely understood.

The rabbinic quadripartite division of the day, combined with these moderate latitudes, would have presented additional room for ambiguity. If one understands the hour as maintaining its duration irrespective of the seasons, it is impossible that there will be exactly twelve hours in the day; with the exception of the equinoxes, there will either be additional daylight after the conclusion of the twelfth hour or (for someone living in Pumbeditha) darkness will fall sometime in the eleventh or twelfth hour. This would seem to be a problem—but, as we have already seen, the eleventh and twelfth hours are barely ever mentioned in rabbinic literature; they could be cut short or fail to

[101] These calculations were made using the calculator at http://www.dawnsun.net/astro/suncalc/.

cover the entire day with few practical consequences.

Despite the fact that the rabbinic "hour" sometimes seems to coincide with what we called seasonal and equinoctial hours, it is inappropriate to use these categories to describe the "hour" when it is used in a technical sense by the rabbis of Late Antiquity. Instead, the lack of terminology to distinguish the two types of hour and the instances in which rabbinic usage of the term does not appear to be coherent suggest that the rabbis did not in fact understand any such distinction; the use of a quadripartite day and the rabbis' residence in relatively moderate latitudes suggests that they did not need to. Instead of trying to shoehorn rabbinic usage of "hour" into these two categories, we should instead follow the evidence, which suggests that the rabbinic "hour" was *always* one twelfth of a day (or night), *but also always* did not change in length with the seasons. These two characteristics contradict one another, but the evidence cited above suggests that the rabbis either did not realize this or did not think it very important.[102] I call this contradictory definition the "naïve" hour. While it is *internally* incoherent, it fits all of the available evidence. Use of the "naïve" hour explains why the rabbis do not specify whether they are using seasonal or equinoctial hours. By reading the "naïve" hour into the problematic passages cited above, we can also understand the incoherence of those texts as stemming from the incoherence of the rabbinic definition of the hour.

[102] This argument, while original, has a medieval precedent. Whereas most medieval and early modern rabbis assumed the rabbinic hour to be a fundamentally coherently concept, Isaac Israeli (d. ca. 1322) complained that some of those charged with calendrical calculations "acted as though the days and nights of the year were equal in length to one another, meaning that each one constituted twelve equal hours (*shaʿot shavot*);" see *Yesod ʿOlam* (Berlin, 1848), 30–31. This passage is discussed on page 237.

The conceptual progression from "naïve" hours to seasonal and equinoctial hours

Because the distinction now seems quite intuitive, it is hard to imagine that, historically, the distinction between seasonal and equinoctial hours took quite a long time to fully crystallize; if nothing else, the annual fluctuations in daylight's duration surely should have made the need for such a distinction obvious. There is strong evidence, however, that the distinction was not at all obvious to the public and in fact remained difficult to grasp even after the concept had become widely disseminated in rabbinic literature (see Chapter 5).

In a twelfth-century responsum sent to Maimonides, a questioner asks if a Talmudic passage (bPesaḥim94a) is correct in stating that the sun is always overhead during the second half of the sixth hour and the first half of the seventh hour. Maimonides responds by explaining the concept of seasonal hours.[103] Two centuries later, a question coming from a similar place of ignorance was posed to Rabbi Shimon ben Tzemaḥ Duran (d. 1444): "Is it true that there are 'big hours' and 'little hours?'"[104] Despite its prevalence, these responsa suggest that the idea of variable-length hours remained difficult to grasp.[105] Alternatively, it is possible that the concept was not considered essential to the public's understanding of time and may have been restricted to the realm of scholars. In short, we should be cautious in reading an understanding of seasonal hours into a given source unless the concept is made explicit.

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[103] *Teshuvot Ha-Rambam* (Jerusalem: Meḳitse nirdamim, 1958), vol. 1 #134, pp. 251–251. See also *Shut Ha-Rambam,* Qiddush ha-Ḥodesh, 9:3

[104] *Sefer HaTashbets: Teshuvot* (Jerusalem, 1998), vol. 1:109.

[105] This struggle is made more understandable when one considers that the seasonal hour is alone among popular metrics in being inherently variable; no measure of length, area, volume, or weight shares this quality. It is understandable that both Muslim and Jewish astronomers came to call them "crooked" while equinoctial hours were called "straight," suggesting that the former were in some way deviant.

In order to understand the emergence of a distinction between seasonal and equinoctial hours, it is helpful to see it as the end result of a historical three-stage thought process for which I offer speculative reconstruction.

In using this framework, I am arguing not only that seasonal and equinoctial hours are difficult concepts, but that they are *distinct* concepts which could and in fact did develop independently of one another, perhaps even at different points in time. Thus, while the idea that the length of the hour might vary is a natural outgrowth of the varying length of the day itself, it would not have been necessary to give this definition of the hour a special name ("*seasonal* hours") until a competing definition of the hour had also been theorized ("*equinoctial* hours") and both had been recognized as *conventions*, with each appropriate for particular contexts. Conversely, it would not have been necessary to give a name to the concept of hours that stay the same length until some other definition of the hour had been theorized.

The three conceptual stages are embodied in the following set of propositions. I will refer to them by number over the course of this discussion.

(1) The length of the day (or night) fluctuates with the seasons over the course of the year.

(2) Daylight fluctuations imply one (but not both) of the following propositions:

  a. Fluctuations in the length of the day or night imply that the *number* of hours in a given day or night must change over the course of the year.

  b. Fluctuations in the length of the day or night imply that the *length* of the hour must fluctuate over the course of the year.

(3) Propositions 2(a) and 2(b) in fact simply represent two distinct and equally valid ways in which the concept of "hour" can be extended to adjust for fluctuations in daylight.

Late Antique Jewish texts are aware of (1), but they do not progress beyond it. Thus, for example, the Babylonian Talmud refers to the solstices as “the long(est) day” and “the short(est) day;”[106] a tannaitic text asserts that the length of the day and night are equal on “the first day of the vernal *tequfah* (season, pl. *tequfot*) and the first day of the autumnal *tequfah*,”[107] an idea which is later expanded into a depiction of the day and night “borrowing” and “repaying” each other over the course of the year.[108] Indeed, in the rabbinic imagination Adam is said to have been frightened by the progressively shortening days in the world’s first year of existence and so relieved upon perceiving them to be lengthening once more that he celebrated.[109]

Despite these understandings, Late Antique rabbinic sources do not indicate what impact the shifting intervals of daylight should have on the hour; the “borrowings” of the day and night are never clarified. In reality, it would have been difficult to quantify these recurring fluctuations since, as we have seen, the hour was in practice the smallest unit of time to be employed.

It is perhaps more surprising that the rabbis do not even reach (2) when discussing astronomical/mathematical matters. This is most apparent in the discussion of *tequfot*—astronomical quarters of the year, corresponding to the seasons—in bEruvin56a:

> Shmuel said, “The vernal equinox occurs only at [the beginning of one of] the four quarters of a day: either at the beginning of the day, or at the beginning of the night, or at midday, or at midnight. The summer solstice occurs only [at certain times of the day]: either at [the conclusion of] one and a half hours, or [of]

[106] bEruvin56a.
[107] yBerakhot1:1.
[108] See Leviticus Rabbah 26:4. See also Midrash Tanḥuma (Buber ed.) Emor 20, Midrash Tanḥuma (Buber ed.) Mishpatim 7:7, Midrash Tanḥuma (Warsaw ed.) Mishpatim. See especially Midrash on Psalms (Buber ed.) §19.
[109] bAvodahZarah8a. In the rabbis’ story, Adam is able to perceive the inflection point on the solstice day itself and immediately ceased the fasting and prayer in which he had been engaged.

> seven and a half hours, of the day or night. And the autumnal equinox occurs only [at certain times]: either at [the conclusion of] three hours, or [of] nine hours, of the day or night. And the winter solstice occurs only [at certain times]: either at [the conclusion of] four and a half hours, or [of] ten and a half hours, of the day or night."

Shmuel's statement is predicated on the fact that each *tequfah* begins 91 days and 7½ hours after the previous one has ended. As a result, each of the four *tequfot* shifts six hours from one year to the next (because of 7½ hours x 4 = 24 hours + 6 hours), and, for this reason, each of the four *tequfot* can only occur at four specific points in the 24-hour day.

This much, at least is clear. What is unclear is the way in which Shmuel explains how this cycle plays out in practice. Whereas the astronomical context of the *tequfot* makes it reasonable to assume that the 91-days-and-7½-hour interval does not vary with the seasons, Shmuel illustrates how the system works in practice using a system that assumes twelve hours each for the day and night.

Unfortunately, the theory and practice are incompatible. An example illustrates the problem: Shmuel indicates that the summer solstice will occur at 1½ hours of the day one year, then at 7½ hours of the day in the following year, since the cycle shifts by six hours each year. If these six hours are equinoctial, we have a problem: a summer day is quite long, and so 7½ hours on a summer day is more than six hours removed from 1½ hours. If, on the other hand, the six hours are seasonal, the *tequfot* are no longer of equal length. In short, Shmuel's mathematical operations have not fully engaged with the realities of daylight's shifting duration; his use of equinoctial hours for mathematical purposes is inconsistent.[110]

While the rabbis of Late Antiquity never reckoned with the implications of daylight's fluctuations on the definition of the hour, the first evidence of (2) in Jewish sources actually predates the rabbis. *Astronomical Book*, discussed at length in the previous chapter, can be understood to be asserting (2a) if its term "part" is taken to be the conceptual equivalent to the hour. Although *Astronomical Book* seems to have had little direct impact on the Late Antique rabbis, certain Hebrew writings suggest that rabbis had access to advanced astronomical knowledge even before the advent of Islamic astronomy.[111] Evidence for this can be seen in a liturgical poem of Eleazar ha-Qalir (d. 640), a Jewish Byzantine liturgist, whose composition *Or ha-Ḥamah* contains a great deal of astronomical information. In the fifth section, which is devoted to the *tequfot*, one couplet states:

> The fourth [month, i.e. Tammuz] is the time of the second [*tequfah*],
> doubling day over night:
> the day is sixteen hours,
> the night is eight.[112]

Though this poetic passage is linked to the Babylonian Talmud's discussion of *tequfot*, the liturgist surpasses the Talmudic discussion by implying (2a) in stating not just that summer days are *longer* than other days, but that they have *more hours* than other

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[110] Shmuel's inconsistency here has an echo in the first extant Greek text to describe equinoctial hours; see Bowen and Goldstein, "Hipparchus' Treatment of Early Greek Astronomy: The Case of Eudoxus and the Length of Daytime," 239–240. In chapter 4, we shall see that the difficulties of this Talmudic passage particularly vexed Jewish scholars in Christian Europe.

[111] On the early medieval reception history of Enoch, see Annette Yoshiko Reed, *Fallen Angels and the History of Judaism and Christianity: The Reception of Enochic Literature* (Cambridge University Press, 2005), 233ff.

[112] Shalom Spiegel, *Avot Ha-Piyuṭ: Meḳorot u-Meḥḳarim Le-Toledot Ha-Piyutt Be-Erets Yisra'el* (New York: Jewish Theological Seminary of America, 1996), 132.

days. While the *piyyut* reflects the same understanding of the hour as *Astronomical Book*, there is no clear link between the two documents.

To summarize: most Late Antique rabbinic texts about timekeeping display no interest in giving the hour a precise definition; instead, they use the incoherent "naïve" hour. The idea that a day contains a variable number of hours does appear, but only in a liturgical work. Nowhere is there evidence that the rabbis conceived of an hour whose length varied with the seasons. The next steps in the conceptual development of the hour—what I have called (2b) and (3)—would not occur until after the Islamic conquest.[113]

Subdividing the hour: absolute and comparative metrics

Where intervals smaller than an hour were concerned, the rabbis' language—and their expectations of the public—are even less precise. On some occasions, intervals of this length are presented in absolute terms. The hour is divided into halves, thirds, and, on one occasion, fourths. In addition to these fractions, a passage in the Tosefta, quoted above, defines a number of small subdivisions: the *ʻonah* is 1/24 of an hour, the *ʻet* is 1/576 of an hour, and the *regaʿ* is 1/13,824 of an hour.[114] These intervals are incredibly short: if we take the "hour" in the passage to be 60 minutes, then an *ʿonah* would be 2.5 minutes, an *ʿet* would be 6.25 seconds, and a *regaʿ* just 260 milliseconds. Clearly, these intervals were far finer than anything that the public—or even specialists—could reasonably be expected to compute.[115]

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[113] See below, page 127.
[114] tBerakhot1:1.
[115] Had Rabbi Yehudah defined the *ʿonah* as 1/12 of an hour, this would not have been the case; some Roman clepsydras ran for approximately the length of an *uncia* (1/12 hour).

While these terms for short intervals give the impression of rigor, they are never actually employed to mean what the Tosefta says they mean: the *'et* is elsewhere used to describe an interval *greater* than an hour,[116] the *'onah* is elsewhere taken to mean anything from half a day to a day and a half,[117] and the *rega'* is defined on four separate occasions, each time given a different value.[118] The only subdivision of the hour with a consistent meaning and a practical application is the *ḥeleq*, understood to be 1/1080 of an hour, but even this unit appears in only a single instance in Late Antique rabbinic writings. Moreover, scholars since the eighteenth century have argued that this passage, which defines the minimum interval between lunar cycles, is actually a later interpolation by the early geonim (rabbinic leaders in Muslim-controlled Babylonian and Palestine).[119] In short, the hour is the smallest time unit to be used with any consistency.

Whereas formal units for sub-hourly intervals were rare and virtually never used, non-traditional time units occur relatively frequently. The legally significant transitions from night to day and from day to night are frequently subdivided by noting natural phenomena like crow of the rooster, light levels, the color of the sky, or the appearance of the horizon. The interest in these transitional periods is another inheritance from Rome, whose timekeeping vocabulary paralleled its rabbinic counterpart but outstrips it in terms of richness. In some instances there is direct overlap between

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[116] See bSanhedrin65b. *'Et* appears in both tPesaḥim3:11 and tNedarim6:1 but is not used in a technical sense in either instance.
[117] See bNiddah65a–b and bAvodahZarah75a. The interpretation of the term *'onah* is explored in greater detail beginning on pages 192 and 265, below.
[118] See note 161, below.
[119] The *ḥeleq* is mentioned in bRoshHashanah25a, but it is not defined there. On the possibility that this definition is a later interpolation, see Alan Edouard Samuel, *Greek and Roman Chronology: Calendars and Years in Classical Antiquity, Part 1, Volume 7* (Verlag C.H. Beck, 1972), 13, as well as notes there. The earliest reference to the 1080-part division of the hour is poem by Rabbi Pinḥas, written in the latter half of the eighth century.

terms: *gallicinium* ("cock's crow") corresponds with *qeri'at ha-gever*, *vesperum* (related to the Greek for "west") with *ʿarvit*, and *solis ortus* ("sunrise") with *netz ha-ḥamah*.

Other than these transitional periods at the day's beginning and end, timekeeping units describe short intervals by comparing them to activities whose duration would be fairly uniform and widely known.[120] The most common activity is walking. Thus, one should not pray if one would not be able to hold in one's urine for the amount of time it takes to walk a *parsah* (parasang).[121] Between going to the bathroom and having intercourse, one should wait for the time equivalent of walking half a *mil*, for fear of a lingering demonic presence.[122] According to one opinion, it takes the equivalent of walking four *mil* for a meal to be digested; the same amount is the minimum time necessary for one to tan a hide by treading upon it.[123] Another opinion instructs a person who has been praying to wait the amount of time it takes to walk four cubits before urinating.[124] One who has let blood should not eat for the equivalent of a half *mil*'s walk.[125] A "light sleep" is defined as the time it takes to walk 100 cubits.[126]

In some instances, times are given in terms of the distance between *specific* places. Thus, a mixture of flour and water will produce leaven in the time it takes to walk from

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[120] I am including here only those measures which have no direct relevance to the task at hand. This is, admittedly, a subjective measure. For instance, the Talmud's stipulation in bShabbat21b that Ḥanukkah candles be lit "from the time it gets dark until foot traffic in the market has ceased," could be understood either as relevant to the holiday or simply as an unconventional time measure. On the other hand, it is logical that the legal definition of interruption with regard to the slaughter of an animal is given in terms of tasks associated with animal slaughter (see bḤullin9a and bḤullin32a).

[121] bBerakhot23a; see also bBerakhot22b. It is possible to read this passage as suggesting that if there is no place to urinate within a *parsah* one should not pray, but this reading is unlikely; then and now, most people would probably be unable to say how many feet or miles they are from the nearest bathroom. By contrast, most people are at least vaguely aware of how much time it would take to get to the nearest bathroom.

[122] bGittin70a.

[123] bBerakhot53b. For this measure, see also bPesaḥim46a. On the tanning of hides, see bḤullin122b.

[124] bMegillah27b.

[125] bShabbat129b.

[126] bSukkah26a.

Migdal Nunia to Tiberias, which is understood to be a *mil*.[127] Abaye's daily nap is said to have endured for the amount of time it takes to walk from Pumbeditha to Bei Kuvei.[128]

Eating and cooking measures—which anthropologists have cited as some of the oldest metrics of all—are also frequently cited.[129] A very fast ship is described as being able to travel 60 *parsah* in the time it takes to warm a water kettle.[130] One does not become ritually impure after entering an impure house until the time that it takes to eat a piece of bread has elapsed; several other laws use this same standard.[131] One *baraita* recalls a custom of sounding a shofar six times before the onset of Shabbat; after that, one should wait for the time it takes "to roast a small fish or to stick bread to the side of an oven," referring to a baking process in which the dough lies flat against the inner wall of the oven for a few minutes.[132]

For time periods lasting only a few seconds, speech is the most common measure. The amount of time for speaking—*kedei dibbur*—is significant when making vows; this period is also defined as the amount of time it takes for a student to greet a teacher.[133] The *regaʿ*, already described above, is alternatively (and quite elegantly) defined as the amount of time it takes to say "*regaʿ*."[134]

Many of the abovementioned activities come together in a remarkable tannaitic texts cited in bSotah4a in which the rabbis discuss how long a man and a woman (married to a different man) must be secluded together before it can be plausibly claimed

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[127] bPesaḥim46a.
[128] bSukkah26b.
[129] See E.P. Thompson, "Time, Work-Discipline, and Industrial Capitalism," *Past & Present*, no. 38 (1967): 58.
[130] bBavaBatra73b.
[131] bBerakhot41a. See also bBerakhot37b, bḤullin35a, bMenaḥot75b, bNazir36b, bYoma80b, bPesaḥim44a, bPesaḥim114b, bSukkah42b, mNegaʿim13:10 and mKeritot3:3.
[132] bShabbat35b. In later chapters we shall explore the relationship between cooking and timing.
[133] bNazir20b–21a; cf. bMakkot6a; bBavaBasra129b–130a; bBavaKama73a–b; bNedarim87a–b.
[134] bBerakhot7a and yBerakhot1:1.

that intercourse had been initiated and an adulterous act had occurred.

> What is the duration of the seclusion? Enough for defilement [which is] enough for intercourse [which is] enough for [initial] sexual contact. Enough to circle a palm tree: this is the position of Rabbi Ishmael. Rabbi Eliezer says, "Enough to mix a cup [of wine]." Rabbi Yehoshua says, "Enough to drink it." Ben Azzai says, "Enough to roast an egg." Rabbi Akiva says, "Enough to swallow it." Rabbi Yehudah ben Beteira says, "Enough to swallow three eggs, one after another." Rabbi Eleazar ben Yirmiyahu says, "Enough for a weaver to tie a string." Ḥanin ben Pinḥas says, "Enough for her to reach her hand into her mouth in order to remove a wood chip." Pelimo says, "Enough for her to reach her hand into a basket and remove a loaf." Even though there is no proof for this position, there is an allusion to it [in the verse], "For because of a harlot a man is brought a loaf" (Proverbs 6:26).

Of the nine opinions stated here, one involves walking, another involves a common professional task, and five involve cooking or eating.[135] The final two positions seem to have been selected as fitting for this particular circumstance; Pelimo's position alludes to the Bible, while both Pelimo and Ḥanin ben Pinḥas may be making comments about sex acts.

To summarize: while there are theoretically quite a few ways of dividing up the hour, none of the available technical terminology is actually employed, except in mathematical contexts. In situations where it is critical for people to be able to reckon a short period, comparison is always made to human activities instead. Nowhere is there a suggestion that a clepsydra or any other short-duration-measuring device should be employed.

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[135] Even without the benefit of stopwatch, it is clear that there is quite a range between these positions. This would seem to reflect a genuine disagreement between the rabbis about how long it takes to initiate sexual contact. As the rabbis did not make their bedrooms available to their students for pedagogical purposes (see bBerakhot62a), it is understandable that little consensus was reached.

Exceptions to the rule

Thus far, I have painted a large swath of rabbinic literature with a broad brush; indeed, attitudes towards timekeeping are remarkably consistent across hundreds of years. Nonetheless, the rabbis occasionally display a keener interest in precise times or precise durations.

Half hours, third hours, quarter hours, and *ḥalaqim*

In a very few instances, times or time intervals are expressed in terms of fractions of the hour. This is done for one of two reasons: (a) mathematical or astronomical necessity or (b) a desire to distinguish two events taking place in close proximity.

Of these, mathematical necessity is much more common. An extended discussion of the intervals between solstices and equinoxes—called a "*tequfah*"[136]—yields several measurements involving the half hour, based on the fundamental principle that, "From *tequfah* to *tequfah* is 91 days and seven and a half hours,"[137] since this represents exactly one quarter of a solar year (assuming that a year is 365¼ days long). It is presumably also for this same reason that Rabban Gamliel states, "Thus I received from my father's father's house: the renewal of the moon [takes] no less than twenty-nine and a half days, two thirds[138] of an hour and 73 *ḥalaqim*."[139]

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[136] *Tequfah* can refer to either a season or the day of transition between seasons (i.e. the solstice/equinox). The term appears in Qumranic sources, but it is not until the rabbinic period that it is so precisely defined. See Jonathan Ben-Dov, "The 364-Day Year in the Dead Sea Scrolls and Jewish Pseudepigrapha," *Calendars and Years II*, 2011, 72.

[137] See bEruvin56a.

[138] In several late rabbinic versions of this text the phrase *shetei yadot shaʿah* is used to mean "two thirds of an hour;" see Pirkei de-Rabbi Eliezer (Heger ed.), chs. 6, 27; Pesiqta Zutrata, Parshat Bereishit 1:14, Bereishit Rabbati, Bereishit, p. 3. The phrase *shetei yadot* is not specific to timekeeping and always means "two thirds;" see tMenaḥot9:10, mEruvin9:10, mMakkot3:13, and mKelim17:11. On this "fractional" valence of the term *yadot*, see also Genesis 47:24 and Nehemiah 11:1.

A similar type of calculation explains *plag ha-minḥah*, "half of *minḥah*," the oddly specific end time for the afternoon prayer specified by Rabbi Yehudah in mBerakhot4:1. Though the Mishnah itself does not define the term, the Tosefta (tBerakhot3:1) explains it to mean, "eleven hours less a quarter," i.e. ten and three-quarter hours. As the afternoon *tamid* sacrifice was normally brought at nine-and-a-half hours, *plag ha-minḥah* represents the midpoint between that time and the end of the day. Here the terminology is somewhat confusing: the term *minḥah* in *plag ha-minḥah* simply refers to the (late) afternoon, which itself was so named because of the sacrifice that regularly took place at that time.[140] In turn, the *minḥah* time period is differentiated from the period during which the afternoon prayer can be said, which begins at six-and-a-half hours. This larger period—which covers most but not all of the afternoon—is called *minḥah gedolah* ("greater" *minḥah*) in both the Tosefta and in bBerakhot26b.[141]

It is somewhat more difficult to explain why these six-and-a-half hour and nine-and-a-half hour markers were employed in the first place. As it turns out, the afternoon *tamid* is unique in this regard; in all of rabbinic literature, it is the only event to be specifically designated at a half-hour mark. This is true not only on regular days (on which

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[139] bRoshHashanah25a. The choice to divide the hour into thirds appears to be somewhat arbitrary; Rabban Gamliel's duration could just as easily have been expressed as 29 and a half days, half an hour, and 253 *ḥalaqim.* Two explanations suggest themselves. First, it is possible that Rabban Gamliel, understanding that the *ḥeleq* was an obscure unit, wished to describe as few of them as possible, and so chose a fractional division of the hour which minimized them. An alternative explanation—which is to my mind more compelling—is that the phrase "two thirds of an hour" is an unambiguously precise duration; "half an hour," as indicated by both Cetius Faventius' sundial handbook (see above) and the usage I describe in the following paragraphs, could have been misunderstood as an approximation.

[140] Which sacrifice is a matter of debate; see yBerakhot4:1. On occasion, the term *minḥah* is used to refer specifically to this late-afternoon period. See, for example, mPe'ah4:5, which specifies that fields are open to the poor during three times: morning (*shaḥarit*), midday (*ḥatzot*) and afternoon (*minḥah*). See also mTaʿanit4:1 and tTaʿanit3:1, both of which list the same three time periods in the same order. For a short general history of *minḥah*, see Schiffman, "Minchah: A Halakhic and Historical Analysis." For another rationale about for the timing of the *minḥah* sacrifice, see yPesaḥim5:1.

[141] In the Talmud, the period from nine-and-a-half hours onwards is designated *minḥah qetanah* ("Lesser" *minḥah*).

the animal was slaughtered at eight-and-a-half hours and offered up at nine-and-a-half hours), but also on Passover Eve, when it was slaughtered at seven-and-a-half hours and offered up at eight-and-a-half hours. The same pattern was in place when Passover Eve occurs on a Friday; in this case it was slaughtered at six-and-a-half hours and offered up at seven-and-a-half hours.[142]

Here it is important to note that the specific rabbinic terminology appears to be a direct translation from the Latin, e.g. *ab hora quarta et dimidia* ("from four-and-a-half hours").[143] Unlike the contemporary, "six thirty," the phrase, "six-and-a-half hours" (*shesh shaʿot u-meḥtzah*) does not mean halfway into the sixth hour, but rather half an hour after the conclusion of the sixth hour. This literal translation cannot be what is intended, however, since reckoning the precise conclusion of an hour and timing a half-hour interval were both beyond the reach of most individuals in this period. Instead, the phrase "*n*-and-a-half hours" must mean, "sometime after the *n*th hour has concluded" or "some time before the $(n+1)^{th}$ hour has begun." With this clarification, it is easy to understand why *minḥah gedolah* (six-and-a-half-hours) was established as the earliest time at which the afternoon prayer could be said; since the end of the sixth hour is also noon, six-and-a-half hours simply meant the point at which it was clear that noon had passed. For people without access to timekeeping equipment, this was effectively the earliest time at which human activities tied to the afternoon could be permitted or mandated.[144]

The notion that the six-and-a-half hour mark was established for practical purposes

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[142] See mPesaḥim5:1; cf. *Pesiqta* Zutrata, Shemot 36:24, Tzav 18b; Sifrei Zuta 9:3.
[143] Marcus Aurelius Fronto, *Ad M. Caesarem* 2.4.
[144] Cf. the comment of Abraham ibn Ezra (d. 1167) in his commentary to Psalms 55:18: "Noon cannot be determined by shadow until about half an hour has passed."

is further supported by a passage in bYoma28b, which explains that the patriarch Abraham would begin praying as soon as the walls would begin to blacken (i.e. immediately after the sun's zenith), but that this method was not used by the public—or even priests in the Temple—because the it relied on Abraham's extraordinary astronomical knowledge.[145] This understanding is also made explicit in the Palestinian Talmud, which restates the window for praying *minḥah* in slightly different terms:

> R' Yehoshua ben Levi used to instruct his students, "If you have [an invitation to] a feast *and the sixth hour will have passed* before you go to the feast, pray *minḥah* before you go."[146]

Similarly, the standard timing for the afternoon *tamid* sacrifice (and for the *minḥah qetanah* sacrifice) is best understood in relation to the timing of dinner in the ninth hour. Slaughtering the *tamid* at eight-and-a-half hours meant that the afternoon sacrifice process would begin *before* dinnertime—that is to say, at exactly the same time that mortals would have been preparing dinner for themselves.[147]

Beginnings and endings of hours

Generally, rabbinic references to hours do not specify which part of the hour is under discussion. One exception is the half-hour, discussed above. There are also a few

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[145] This explanation is further fleshed out in a geonic response located in the Cairo Genizah; see CUL: T-S G2.79, fol. 1r-v.

[146] Emphasis mine. See yBerakhot4:1. The difficulty of determining the time around noon lingered into the medieval period; it was common enough that Gersonides explained the "miracle" of Joshua stopping the sun in the sky as nothing but confusion about the motion of the sun around noon; see *The Wars of the Lord*, Volume 3, Part 2, Chapter 12.

[147] The timing of the afternoon *tamid* is another example of the slippery usage of the word "hour." If the hour between slaughtering and offering the animal is a seasonal hour, it is implied that the sacrifice preparation time fluctuates with the seasons, which makes little sense. This same problem persists in the Palestinian Talmud. Here the early timing for the Passover *tamid* is explained as a precautionary measure, since the rest of the afternoon was dedicated to sacrificing the nation's Passover lambs, a process which was divided into three groups (mPesaḥim5:1). Since the turnover time for each group was approximately an hour, offering the *tamid* at seven-and-a-half hours would leave four and a half hours left in the day, allowing for "half an hour between groups." (ibid.)

mentions of the beginning and ending of hours. Tellingly, the Talmud brings up these terms not for any legal purpose but to suggest ways in which people might err about the hour. For example: an event might occur at the end of the third / beginning of the fourth hour; one witness might report this event as occurring in the third hour, and the other might say it occurred in the fourth hour.[148]

The only activity specifically mandated for the beginning of an hour is the burning of *ḥametz*, which must be done on Passover Eve by the beginning of the sixth hour.[149] Given the tight schedule that prevails for this day,[150] it is possible that the beginning of the hour is indicated in order to stress that the burning must take place while it is unambiguously still morning, as end of the sixth hour (when the sun is at its zenith) is indistinguishable from the beginning of the seventh hour, by which point the burning is rendered moot by the now-changed status of the *ḥametz*.

Technicalization of non-technical terms

Above, we interpreted the "hour" which the first pietists [*ḥasidim*] waited before praying to mean a short period of time. The Talmud, however, disagrees at bBerakhot32b:

> The sages taught [in a *baraita*]: The first pietists would pause for a *shaʿah*, pray for a *shaʿah*, and pause again for a *shaʿah*. But since they spend nine *shaʿot* each day in prayer—how is their Torah preserved? And how does their work get done? Rather: because of their piety their Torah was preserved and their work

[148] See the discussions in bPesaḥim11b–12b and bSanhedrin42a.
[149] mPesaḥim1:4–5.
[150] The status of *ḥametz* in the morning and the Passover sacrifice and Passover *seder* in the afternoon together make Passover Eve the most highly scheduled day of the Jewish calendar by a wide margin. It is unclear to me whether this is simply a coincidence or whether it emerges from the rabbinic depiction of the day during Temple times as being a highly coordinated and highly centralized public affair.

was blessed.

Here a tannaitic variant on mBerakhot5:1 is interrogated by the Talmud, which begins with the premise that *shaʿah* here must mean a seasonal hour and therefore arrives at the incredible conclusion that these pietists would spend the vast majority of their days in prayer. The reason for positing this absurd premise is unclear; the technical valence of *shaʿah aḥat* is just as rare in the Talmud as it is in the Mishnah.

The meaning of "*ḥatzot*"

Because the sixth hour of the day concludes with noon and the sixth hour of the night concludes with midnight, the terms *shesh shaʿot* ("six hours") and *ḥatzot* ("noon" or "midnight") are at times taken to be equivalent and, at other times, understood to impinge upon one another. Closer inspection reveals that these terms have distinct functions. This is because *shesh shaʿot* was consistently understood to be an identifiable part of the day (or night), whereas the term *ḥatzot* evolved from being a term too vague to be measured to a term so precise that only God could identify it accurately.

Though *ḥatzot* never appears by itself in the Bible, the phrases *ḥatzot* (*ha-*)*laylah* and *ḥatzi ha-laylah* appear a total of six times.[151] In none of these instances must the event described have occurred precisely at midnight; instead, the phrases are better read as referring to the middle of the night generally. Furthermore, none of these instances portrays the middle of the night as a legally-significant boundary.

With the absorption of Hellenistic culture, the word *ḥatzot* gained prominence in rabbinic literature as a standalone term, one which carried a more precise meaning and

[151] Exodus 11:4 and 12:29; Judges 16:3; Job 34:20; Ruth 3:8; Psalms 119:62.

whose passage could carry legal significance. Both noon (*meridies*) and midnight (*media nox*) are regularly used in Latin writings; importantly, the latter was the legal boundary between one civil day and the next.[152]

In both the Mishnah and Tosefta—i.e., the earliest strata of Late Antique rabbinic literature—*ḥatzot* is frequently used both descriptively and prescriptively to describe human activity. In one instance, a day is divided into *shaḥarit* (morning), *ḥatzot*, and *minḥah* (afternoon); here, *ḥatzot* must mean "the middle of the day," since the tripartite division does not make sense if the middle term is only a dividing line between morning and afternoon.[153] More frequently, *ḥatzot* is the dividing line between morning and afternoon. Used in this matter, it was never important to know precisely when morning turns into afternoon; instead, the rabbis only expected that one be able to reckon which of the two it was at that moment. Because of this, *ḥatzot* normally appears in compounds: "before *ḥatzot,*" "after *ḥatzot*," and "until *ḥatzot*."[154]

The definition of the nighttime *ḥatzot* also held legal significance, but for different reasons. Unlike the daytime *ḥatzot*, no celestial body could easily mark its passage and, as we have already seen, the rabbis did not expect people to be awake at *ḥatzot* in the first place. Whereas the daytime *ḥatzot* was imbued with legal significance because its

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[152] Samuel, *Greek and Roman Chronology: Calendars and Years in Classical Antiquity, Part 1, Volume 7*, 13. It is worth emphasizing that *media nox,* despite its familiarity through correspondence with the modern "12 a.m.," was by no means an obvious demarcation; indeed, following the collapse of the Roman Empire, it ceased to have legal meaning until the invention of the mechanical clock and in Italy it did not take hold again until the seventeenth century (See Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 38–39, 115.) Monasteries did ring bells around midnight for the vigil prayer, but the exact timing was discretionary. The oddity of having *ḥatzot* as a ritually significant time had not faded even in the eighteenth century; Shneur Zalman of Lyady (d. 1813) still felt it necessary to emphasize that its timing did not change with the seasons; see his *Shulḥan ʿArukh ha-Rav* O.Ḥ. 1:8. For the continuation of this discussion, see below, page 311.
[153] See mPe'ah4:5; see also mTaʿanit4:1, and tTaʿanit3:1. There is some evidence that Jews in Christian Europe divided the day into thirds, as well; see below, page 206.
[154] See mBerakhot1:1, 4:1; mPesaḥim 4:1, 4:5–6, 5:3; mTaʿanit3:9; tBavaMetzia8:8; tBerakhot3:1; tZevaḥim; tMeʿilah1:15; tPesaḥim1:8, 3:18; 9:8.

passage would have been readily apparent to all, the nighttime *ḥatzot* was imbued with legal significance because it was readily apparent to approximately nobody, since, as we have already seen, almost everyone was asleep by the third night hour. Since midnight always occurred during sleeping hours, specifying midnight as a legal boundary was effectively equivalent to distinguishing between "before one goes to bed" and "after one wakes up." For example: while *ḥatzot*, according the sages, is the deadline by which one must say the evening *shemaʿ* and eat certain sacrifices, Rabban Gamliel asserts that these deadlines are only, "in order to distance a person from transgression;" they are simply stringencies to ensure that these activities are not delayed or prolonged until the morning.[155] In reality, he says, "whenever the sages said, 'until midnight,' the command is [actually] until the break of dawn," when most people awoke.[156] To specify a midnight deadline, in other words, was simply to say, "by the time one goes to sleep."[157]

In the Babylonian Talmud, the term underwent a further transformation. Shamma Friedman has pointed out that amoraic texts quoting tannaitic material replace the term *ḥatzot* with *shesh shaʿot*.[158] This is not a case of easy slippage between equivalent terms; rather, this substitution reflects a deliberate attempt to differentiate the terms from one another. To wit: *shesh shaʿot* was a time period that people could reliably reckon and that corresponded to many activities associated with the rhythms of life such as

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[155] mBerakhot1:1.
[156] Recall, as well, that even the Community Scroll did not expect people to stay up in prayer and study for more than the first third of the night (1QS VI, 6–7).
[157] For more examples, see mZevaḥim 5:3, 5:5–6, 5:8, 6:1, 9:6; mPesaḥim10:9; tZevaḥim6:16, 8:10; tPesaḥim5:13, 9:15.
[158] Shamma Friedman, "Ha-Baraitot Ba-Talmud Ha-Bavli ve-Yaḥasan Le-Makbiloteihen She-Ba-Tosefta," in *Atarah Le-Ḥayyim: Meḥkarim Be-Sifrut Ha-Talmudit ve-Ha-Rabbanit Le-Kevod Professor Haim Zalman Dimitrovsky* (Jerusalem: Magnes Press, 2000), 166–7.

waging war, coming home from school,[159] and the end mealtime. As a result, it was reasonable to prescribe or proscribe activities for *shesh shaʿot*. *Ḥatzot*, on the other hand, no longer a portion of the day but an instant in time, one which occurred precisely at noon and precisely at midnight. As a result, the amoraic *ḥatzot* is almost never used to describe human activity; instead, it is almost always connected either with legal boundaries or divine actions. On Passover Eve, for example, the "sixth hour" is when people *burn* their remaining leaven, but the legal status of leaven does not change until "*ḥatzot*."[160] *Ḥatzot* is also relevant for moon sightings; the date on which the new month begins is dependent on whether the new moon occurs before or after. Indeed, we shall see below that two divine performances which take place at midnight—David's nightly wake-up music and the death of the Egyptian firstborn—are understood to be manifestations of God's superiority over mortals.

The rabbinic *ḥatzot*, therefore, differs from its biblical counterpart not only in its application to both day and night, but in its transformation first into a technical term for legally-significant portion of the day (or night) then into an instant of time which could be reckoned only by God. This transformation is a useful early example of a retroactive reinterpretation of an early time reference to abide by new, more accurate timekeeping standards.

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To summarize: rabbinic sources do sometimes divide time into units smaller than the hour. However, with the notable exception of mathematical and/or astronomical necessity (and perhaps the Babylonian Talmud's interpretation of the behavior of the

[159] Pesiqta Rabbati §43.
[160] See bPesaḥim7a and 21b.

first pietists), such divisions are never intended to be precise; their purpose can only be determined in context.[161]

Divine timekeeping vs. human timekeeping

In the rabbinic mind, the stark disparity between theoretical and practical time-keeping was projected onto the distinction between divine and human capabilities. In one passage, keeping time with extreme precision is actually equated with divine knowledge.

> It was taught in a *baraita*: "God is angry every day" (Psalms 7:12). How long is his anger? A moment (*regaʿ*). And how long is a *regaʿ*? It is one [part] out of 58,888 in an hour. This is a *regaʿ*, and no creature is able to reckon that time (*otah shaʿah*) except for Balaam the Wicked, as it is written, "He knows knowledge of the Most

[161] Although not conclusive on its own, a passage from bRoshHashanah13a highlights that the general rabbinic tendency towards precise measurements does not extend to temporal measurements. In rebutting Rabbi Yirmiyahu—a figure who is rebutted by the other rabbis throughout the Babylonian Talmud for the unlikely hypothetical edge cases he frequently raises—Rabbi Zeira states that measurements determined by the rabbis are intended to be precise and are not approximations:

> [A person may] ritually immerse in 40 *se'ah* [of water]; in 40 *se'ah* less a *kortov*, one may not immerse in them. [Similarly], an egg's volume worth of impure food can defile food, but an egg's volume less [the volume of] a sesame seed cannot defile food. [A piece of cloth that is] three by three [handbreadths] can become impure by being tread upon; three by three less a hairsbreadth cannot become impure through being tread upon.

Although this is an argument from absence and so is not in itself conclusive, Rabbi Zeira's examples are notable given what we already know about rabbinic timekeeping expectations. In the world of Late Antiquity, only length/area, volume, weight, and time are understood to be quantifiable (temperature, though measured by the rabbis, was not *quantified* until the seventeenth century; see Hasok Chang, *Inventing Temperature: Measurement and Scientific Progress* (Oxford University Press, 2004)). Rabbi Zeira's examples describe precision in length/area and volume, but not in weight or time. The strong association of weight and coinage perhaps explains the former; since a *zuz* was a discrete physical unit, it would not have made sense to talk about a *zuz*-minus-a-miniscule-amount as, say, an incomplete repayment of a contract; determining the correct quantity of *zuzim* meant counting the coins, not weighing them. Time, on the other hand, could not be subject to Rabbi Zeira's rigor because doing so was impossible; rabbinic time-dependent or duration-dependent regulations could not be precise in the way that other rabbinic regulations were precise. (My thanks to Sarah Wolf for bringing this text to my attention.) This absence is similar to what we have already noted about the biblical priestly source's lack of interest in time quantifications. See, as well, the fifteenth century rabbi Jacob Moelin's remark that "measuring time is not technically 'measuring'"; this is discussed below, page 261.

> High" (Numbers 24:16).[162]

The same skepticism about the human ability to reckon time with precision is evidenced in the Talmud's skepticism about David's famed ability to rise at midnight. Accurate timekeeping is here associated with a supernatural occurrence: at midnight, a wind would blow against the strings of David's lyre, waking him.[163] As we have already noted, the Talmud does not that think that humans are capable of doing things "at midnight."

In another passage, which is attempting to resolve an unrelated textual question, God is described as having specified the time of redemption with extreme precision.

> "A night of watches [*shimurim*] for God." (Exodus 12:42) — This means that the first redemption had been reserved [*nishtamrah*] to occur [after a specific number of] generations, jubilee cycles, *shemittah* cycles, years, months, weeks, days, hours, times (*ʿittim*), and periods (*ʿonot*).[164]

Here, God's plan to liberate the Israelites is depicted as being both longstanding and precisely timed; the ability to specify to the exact second an event which will happen years into the future is obviously beyond the reach of perhaps everyone but the scientists and engineers who design interplanetary satellites.

Finally, a midrash elaborating on God's pronouncement that the final plague to be-

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[162] bBerakhot7a. Cf. the version of this passage in bAvodahZarah4a, where a *regaʿ is* one part out of 53,848 in an hour. In yBerakhot1:1 it is one part out of 56,848 in an hour. (See also bSanhedrin105b, which does not define the term.) It is worth noting that *none* of these definitions correspond to tBerakhot1:1, quoted above, which defined a *regaʿ* as $1/24^3$ of an hour, i.e. one part in 13,824 of an hour. Note, as well, that the word *shaʿah* is here used in both a technical and non-technical sense in the space of two sentences.
[163] bBerakhot3b, bSanhedrin16a, and yBerakhot1:1. On David's habit of rising at midnight, see also Lamentations Rabbah (Buber ed.) §2; Pesiqta de-Rav Kahana §7 and §17; Numbers Rabbah 15:16; Ruth Rabbah 6:1. Compare this device to the description of Plato's water-organ-cum-alarm-clock in Athenaus, *Philosophers at Dinner* 4.174c.
[164] Mekhilta de-Rabbi Shimon bar Yoḥai 12:42. The same progression of time units appears in the reverse order in bḤullin91b, with *ʿittim* and *ʿonot* omitted. Note that Rabbi Yehudah's definitions in tBerakhot1:1 have the *ʿonah* as larger than the *ʿet*. For another early midrash in which God determines future events down to the hour, see *Seder Olam* §30.

fall the Egyptians would occur precisely at midnight describes God's timekeeping precision with reference to the sundial.

> "*In the middle of the night* (ḥatzot ha-laylah)." (Exodus 12:29) — Moses [in relaying God's word] told the Israelites, "I shall pass through the land of Egypt that night" (Exodus 12:12), but did not specify a time in order that [the Israelites] would not be sitting and pondering wicked thoughts, saying, "The hour has already arrived and we have not been redeemed!" But when Moses said this to Pharaoh, what did he say? "Thus says God: at *around* midnight (*ka-ḥatzot ha-laylah*)" (Exodus 11:4). [Moses] said to them, "The matter has been set for when the night is halved—[not] a hair's breadth above or a hair's breadth below. But as for God, [God] said, "In the middle of the night," for God sits on a sundial (*even shaʿot*) and specifies the time (*shaʿah*) to a hair's breadth.[165]

In the Talmud's rendition of this tale, it is Moses himself who is uncertain of the precise moment of midnight; his hedging statement in Exodus 11:4 was not for Pharaoh's benefit, but for his own. Either way, the message is clear: God's sundial is better than the sundials of mortals. Perhaps humans do not even "have" a sundial: with the exception of the Mishnah's discussion of the gnomon's ritual purity, every Late Antique rabbinic text which describes a timekeeping device does so in the context of divine/human interaction.[166]

[165] Mekhilta de-Rabbi Shimon bar Yoḥai 12:29. In her work, Lynn Kaye notes a very similar sentiment expressed in Genesis Rabbah 10:9, concerning God "finishing" creation at the precise moment that Shabbat began: "It is like this: he hits a hammer on an anvil, lifting it while it is still day and bringing it down when it has become dark [i.e. precisely at day's end.] Rabbi Shimon ben Yoḥai says, '[A person of] flesh and blood, who does not know [Shabbat's start] times (*ʿitav*), moments (*regaʿav*), or hours (*shaʿotav*) adds from mundane to holy [time, i.e. begins observing Shabbat early so as not to violate Shabbat by accident], but the Holy One Blessed Be He, who knows its moments (*regaʿav*), times (*ʿitav*), and hours (*shaʿotav*) enters it like the breadth of a hair.'" In some instances, divine timekeeping might be projected onto certain rabbis; thus, for example Rabbi Yoḥanan ben Zakkai was apparently able to tell the time without a clock in a complete darkened room (Lamentation Rabbah 1:31).

[166] In her discussion of timekeeping in the Babylonian Talmud, Lynn Kaye understands *simultaneity* as an aspect of divine precision; only God, for example, can say two things at the same time. This principle is important in rabbinic stories during which two events take place at exactly the same time in different places; understanding God to be coordinating the events, Kaye argues that this is further attestation of

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Timekeeping in Late Antique rabbinic literature presents something of a contradiction. On the one hand, it is in this moment that Jewish law first absorbs a timekeeping system; at the same time, this system was far more advanced than what the rabbis needed in most scenarios. The rabbis were very conscious of their own timekeeping limitations; despite the availability of timekeeping devices and water-clocks, rabbis do not seem to have used either on a regular basis and instead associated sophisticated timekeeping with God. In the next chapter, we shall see how this inherited Hellenistic system fared after the Islamic conquest.

divine precision. See Kaye, *Time in the Babylonian Talmud: Natural and Imaginative Times in Jewish Law and Narrative*, 67ff.

Chapter 3: Timekeeping after the Islamic Conquest

Participation in Islamicate culture had a profound effect on the development of both Jewish thought and Jewish law. With respect to timekeeping, Islam's influence was most strongly felt in the realm of the sciences, where improved astronomical techniques and improved precision measurement tools were adopted—both directly and indirectly—by Jewish scholars. At the same time, discussions of timekeeping in both Rabbanite and Karaite texts, as well as assorted documents from the Cairo Genizah, demonstrate that expectations about the public's ability to reckon time had not fundamentally changed from Late Antiquity. Roman conceptualizations adopted by the rabbis—such as the twelve-hour day, the watches of the night, the understanding of *ḥatzot* as a precise instant, and interest in the various stages of sunrise and sunset—remained unchanged, as well.

I. Timekeeping in Islamic lands

Defining prayer times in Islamic law

The earliest strata of Arabic literature suggest that Roman timekeeping concepts either had not yet penetrated the Arabian Peninsula or were of only minimal importance. Though the Qur'ān uses the words *sāʿah* or *sāʿāt* ("hour, hours") no less than 47 times, the meaning is always non-technical, i.e. it is never intended to refer to a well-defined time interval. In 33 instances, the *sāʿah* under discussion is the "Last Hour," meaning the Day of Judgment.[1] In six instances, the valence is "a short period of time."[2] The phrase *samm sāʿāt*, "instant poison," also points to the early Arabic "hour" as an indica-

[1] See C. Pellat, "Layl and Nahār," in *Encyclopaedia of Islam, Second Edition*, n.d.
[2] See Q7:34, 10:49, 16:61, 30:55, 34:30, and 46:35.

tor of brevity. This usage is very similar to what we encountered in post-biblical Second Temple literature; a technical hour is not excluded, but it was certainly not of great importance. A similar pattern of usage of the words *sāʿah* and *sāʿāt* is in evidence in the major *ḥadīth* collections.[3]

There are a few pieces of evidence suggesting that uniquely Jewish methods of reckoning the time were absorbed into early Islam. In several traditions, Muḥammad is recorded as praying the morning *fajr* prayer from the time that he could recognize the person sitting next to him.[4] This is very similar to a position in the Babylonian Talmud which states that the day begins from the time that one can recognize a friend from a distance of four cubits.[5] A second clue is the appearance of a "middle prayer" (*al-ṣalāt al-wusṭā*) in a Qur'ānic passage revealed to Muḥammad in Medina, a city which, unlike Mecca, had a sizable Jewish population. This middle prayer may have been added to the morning and evening prayers in order to mirror the afternoon *minḥah* prayer, discussed in the last chapter.[6]

A third Islamic criterion for determining the start of the day seems to be in conversation with rabbinic material, as well. The Mishnah defines the earliest time at which the *shemaʿ* may be recited as the pre-dawn moment at which one is able "to distinguish between blue (*tekhelet*) and white. Rabbi Eliezer says: between blue and leek-green."[7] Both the Babylonian and Palestinian Talmud understand these color differentiations as

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[3] A.J. Wensinck, *Concordance et Indices de La Tradition Musulmane* (Brill, 1936), vol. 3 p. 26. A few Qur'ānic passage possibly refer to night vigils at "periods (watches?) of the night" (*ānā' al-layl*); see Q3:133 and 39:9.
[4] *Saḥīḥ al-Bukharī*, Volume I, Book 10, #516, #522, #552, and #573.
[5] bBerakhot9b.
[6] Q2:238; see Gerhard Böwering, "Prayer," in *Encyclopedia of the Qur'ān2*, 2001, 224.
[7] mBerakhot1:2.

referring to color differences within a piece of fabric;[8] furthermore, the use of the term *tekhelet* suggests that the individual is looking down at his *tzitzit*, a prominent garment with fringes of that particular shade.[9] A very similar criterion is employed by the Qur'ān in 2:187, which proscribes eating on fast days from the time when "the white thread is distinct to you from the black thread at dawn." Curiously, multiple *ḥadīth* traditions both recognize and reject the amoraic (i.e. later rabbinic) position on the nature of this distinction; Muḥammad instead interprets the verse as referring to different hues in the morning sky. The most dramatic version reads as follows:

> Abū Kuraib reported to us, saying: Ibn Numayr and ʿAbd Al-Raḥīm ibn Sulaiman told us in the name of Mujālid in the name of Saʿīd in the name of ʿĀmir in the name of ʿAdī ibn Ḥātim, saying: I went to the Messenger of God (may God honor him and grant him peace) [=Muḥammad] and he taught me Islam and described to me the prayers, i.e. how I should perform each prayer in the appropriate time. Then he said, "When Ramaḍān arrives, eat and drink until you can distinguish the white thread from the black thread of the dawn; then fast until nighttime." I didn't know what this meant, so I made two threads from white and black and I inspected them at dawn; they looked identical to me. I went to the Messenger of God (may God honor him and grant him peace) and I said to him: O Messenger of God, I have complied with everything you have prescribed except for "the white thread from the black thread." He said, "What is preventing you, Ibn Ḥātim?" and he smiled as though he knew what I had done. I said, "I twisted together two threads, of white and black, and inspected them at night and I found them to be identical." The Messenger of God (may God honor him and grant him peace) laughed [so hard that] his molars could be seen. Then he said, "Didn't I say, 'at dawn?' [The white thread and the black thread] are only

[8] See bBerakhot9b and yBerakhot7a.

[9] Numbers 15:38. This position is explicitly endorsed by some later commentators, including the Tosafists.

the light of the day and the darkness of the night."[10]

This *ḥadīth* is particularly interesting given that the Qur'ānic verse, which specifies a "thread" of each color, is less ambiguous than the Mishnah. Muḥammad's clarification that these threads are part of the sky might have been a conscious attempt to distinguish his community of believers from Jewish prayer practices.[11]

It is still possible that the Qur'ānic and tannaitic metrics are unrelated.[12] Still, it is notable that the polymath Muḥammad ibn Aḥmad al-Bīrūnī (d. 1048), who took it upon himself to document the prayer times of all religious groups, indicates that one of the three Jewish prayers is to be said when "a white thread can be distinguished from a black [one]."[13] This indicator of morning does not appear in Latin sources.

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As in both early Jewish and Christian sources, much of the early Islamic discussion of timekeeping derives from the need to calculate prayer times. The Qur'ān speaks about the requirement to pray on several occasions but does not firmly indicate frequency or timing.[14] There is some evidence in the *ḥadīth* literature that, in its first stag-

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[10] al-Ṭabarī, *Tafsīr*, 2:187. See also *Saḥīḥ al-Bukharī*, Vol. III, Book 31, #140–1 and Book 60, #38–38.
[11] This link between Jewish and Muslim texts is also made by K. Wagtendonk, *Fasting in the Koran* (Brill, 1968), 51.
[12] A small piece of evidence that the Qur'ānic "threads" may be threads of light is the use of the term *aswad*, "black," which does not appear in the Mishnah. Qur'ānic color terms do not map precisely onto Hebrew terms, so it is possible that the white and black threads are actually bright and dark threads; see Alexander Borg, "Towards a History and Typology of Color Categorization in Colloquial Arabic," in *Anthropology of Color: Interdisciplinary Multilevel Modeling*, ed. Robert E. MacLaury, Galina V. Paramei, and Don Dedrick (John Benjamins Publishing Company, 2007), 263–294; Amna A Hasan et al., "How Colours Are Semantically Construed in the Arabic and English Culture: A Comparative Study," *English Language Teaching* 4, no. 3 (2011): 206–13.
[13] Translation found in Muḥammad bin Aḥmad Al-Bīrūnī, *The Exhaustive Treatise on Shadows*, ed. E.S. Kennedy (Aleppo, Syria: Institute for the History of Arabic Science, 1976), vol. I, p. 225. Note that al-Bīrūnī's identification of the three prayers is incorrect; according to him, the first is at sunset, the second at dawn (*saḥar*) and the third at the time when white and black threads can be distinguished. This conflates the afternoon and evening prayer while mistaking two of the regulations concerning the morning prayer for two distinct prayers.
[14] For discussion of Qur'ānic statements concerning prayer, see Leaman, "Salat," and Böwering, "Prayer."

es, Muḥammad prayed twice a day, saying the *ḍuḥā* prayer immediately after sunrise and the *ʿaṣr* immediate before sunset. Ignác Goldziher (and, more recently, Uri Rubin) have suggested that these times reflected an affinity with Jewish ritual; in particular, the *ʿaṣr* prayer may have been modelled after *minḥah*.[15]

By the eighth century, the system of five daily prayers had emerged. A *ḥadīth* which appears in several versions gives a sense of how these prayers were defined.

> [The Prophet] said: Gabriel came to me and led me in prayer: the *ẓuhr* [prayer] was when the sun had declined [from the meridian] and the shadow [of objects] was equal to [the width of] a thong of a sandal; the *ʿaṣr* when the shadow of every object was the same as its [length]; the *maghrib* when the sun had set and when a person fasting would have started to break the fast; the later *ʿishāʾ*[16] when evening twilight had disappeared; and the *ṣubḥ* when morning twilight had appeared.
>
> The next day he lead me in prayer (again): the *ẓuhr* when the shadow of every object was the same as [its length]; the *ʿaṣr* when the shadow of every object was the same as twice [its length]; the *maghrib* when the sun had set and a person fasting would have started to break the fast—and he did not delay [this prayer]; the last *ʿishāʾ* when one half of the night had passed, or one third of the night in another version—and the *fajr* when the sky had begun to glow.[17]

In these two paragraphs, Gabriel demonstrates for Muḥammad the earliest and latest times for each of five prayers. As with Jewish prayer, two of the prayers—*ṣubḥ*/*fajr* and *maghrib*—are directly linked to the rising and the setting of the sun. The timing of a further prayer, *ʿishāʾ*, is easy to determine, since it is the only nighttime prayer. However, the two remaining prayers— *ẓuhr* and *ʿaṣr*—both take place in the afternoon and

[15] See the thorough treatment of sources in Uri Rubin, "Morning and Evening Prayers in Early Islam," *Jerusalem Studies in Arabic and Islam* 10 (1987): 40–64.
[16] It is called "later" in order to distinguish it from *maghrib*, which was sometimes also called *ʿishāʾ*; see *Sunan al-Nasāʾī*, ch. 6, #534.
[17] Translation modified from David King, *In Synchrony with the Heavens* (Brill, 2005), 545–546.

their times are demarcated by the relative length of shadows.[18] While other early legal sources suggest alternative reckoning methods—the Caliph ʿUmar (r. 634–644) is recorded as having defined prayers relative to the sun's appearance and to riding distances, and a few *ḥadīth*s even employ seasonal hours—all Islamic legal schools ultimately defined afternoon prayer times in terms of shadow measurements: the ratio of height to shadow length, the movement of shadows, and a shadow's minimum width.[19]

The standard definitions for the prayer times largely emerge before Islamicate culture had begun to assimilate, consolidate, and expand upon the scientific knowledge of Greco-Roman and Indian cultures, an effort which began in earnest only in the ninth century. Acquiring this knowledge thus did not significantly change the way in which Muslims reckoned prayer times. Instead—as we have seen in the case of other cultures—scientific and practical reckoning remained separate.

This separation can actually be seen in two sets of texts which developed side by side. When prayer times were interpreted in scientific contexts, the shadow metrics were translated not into seasonal hours but into equatorial degrees (discussed below). Thus, for example, an anonymous treatise on the astrolabe describes the earliest time for the *ẓuhr* prayer—traditionally defined as the time at which shadows were at least the width of a sandal thong—as one degree past the sun's zenith.[20] Mathematical definitions of this sort are rare and do not appear in legal contexts.

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[18] Although it can be assumed that Jews used the directionality of shadows to determine that noon had passed—indeed, the very thin "thong of a sandal" measure likely serves the same function as the "and-a-half" part of the "six-and-a-half" definition of *minḥah gedolah*, discussed in the previous chapter—the length here is only relevant for the purpose of clarity, not for the determination of a ratio.
[19] For references, see King, *In Synchrony with the Heavens*, 555–559.
[20] King, 569.

At the same time, shadow metrics became enshrined in a genre of legal texts called *kutub al-mawāqit* (Books of Times); these contained practical definitions for the prayer times which relied exclusively on shadow length. Much remains to be learned about these sources, but it is clear from scholarly legal texts that nothing more precise than these metrics was expected.[21] Indeed, a *ḥadīth* in the prayer-times manual of one Ibn Raḥīq (eleventh century?[22]) quotes Muḥammad as condemning those "who take their knowledge [of prayer times] from the infidels and the Sindhind," referring to the Hellenistic and Indian astronomical knowledge, respectively.[23] The insistence that scientific calculations not usurp shadow metrics can be found, for example, in the work of thirteenth-century scholar al-Aṣbaḥī, who writes that "the times of the prayers are not to be found by the degrees of the astrolabe and not by calculation using the science of the astronomers; they are only to be found by observation...The astronomers took their knowledge from Euclid...and from Aristotle and other philosophers: all of them were infidels."[24] Nonetheless, it also seems that water-clocks were used on occasion to announce prayer times.[25]

The first major shift towards greater precision occurred only in the thirteenth century (after the period under consideration here), with the development of the Mamluk office of *muwaqqit* (timekeeper), who was tasked with, among other things, determining prayer times, prayer directions, and maintaining the calendar. This embrace of astronomy seems to reflect a conscious attempt to head off the potential epistemological

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[21] King, 549–550.
[22] For more on this figure, see Petra G. Schmidl, *Volkstümliche Astronomie Im Islamischen Mittelalter: Zur Bestimmung Der Gebetszeiten Und Der Qibla Bei Al-Aṣbaḥī, Ibn Raḥīq Und Al-Fārisī* (Brill, 2007).
[23] David A. King, "A Fourteenth Century Tunisian Sundial," in *Islamic Astronomical Instruments* (London: Variorum Reprints, 1987), 194–195. King notes the irony of this statement: Indian astronomy was responsible not just for informing Islamic astronomy, but for supplying some of its shadow tables, as well.
[24] Translation modified from King, *In Synchrony with the Heavens*, 636.
[25] Frank Griffel, *Al-Ghazālī's Philosophical Theology* (Oxford: Oxford University Press, 2009), 237.

threat of scientific knowledge by incorporating that knowledge into religious traditions; it did not reflect a sudden desire for more precise calculations.[26]

Timekeeping terminology

The Arabic of early Islam contained a large number of non-numerical terms to describe different portions of the day and night, and many of these terms overlap. It is unclear precisely when the seasonal hour entered Islamic texts; given its usage by both Byzantines and Jews (and perhaps also Sasanians), there would have been numerous opportunities. Even if the seasonal hour was an early development, it was almost never used, though a few prayer definitions cite it and it does make an occasional literary appearance.[27]

The adoption of Babylonian astronomy via the Greeks brought with it the division of the sphere (*minṭaqah*) into 360 "degrees" (*darajah*, pl. *darajāt*) or "parts" (*juzʾ*, pl. *ajzāʾ*); this "degree" is equivalent to the Greek *khronos*[28] or *moirē khronikē* (degrees of times). Since the earth rotates through 360 degrees every 24 equinoctial hours, 1 degree is equal to 1/15 of an hour, or 4 minutes.[29] Each degree could in turn be divided into 60 "minutes" (*daqīqah*, pl. *daqāʾiq*), the minute into 60 "seconds" (*thāniyah*, pl. *thawānī*), and the second into 60 "thirds" (*thālithah*, pl. *thawālith*). These labels were almost certainly

[26] For this position, see Justin Stearns, "Writing the History of the Natural Sciences in the Pre-Modern Muslim World: Historiography, Religion, and the Importance of the Early Modern Period," *History Compass* 9, no. 12 (2011): 923–51.
[27] On the evidence, see King, *In Synchrony with the Heavens*, 553ff.
[28] Henry George Liddell, Robert Scott, and Henry Jones, *A Greek-English Lexicon* (Oxford: Clarendon Press, 1940), χρόνος.
[29] Bowen and Goldstein, "Hipparchus' Treatment of Early Greek Astronomy: The Case of Eudoxus and the Length of Daytime," 240.

appropriated from Ptolemy, who set forth a similar sequence of degrees, minutes, seconds, thirds, etc.[30]

With the adoption of the hour as an astronomical unit, vocabulary for the two forms of "hour" were adopted, as well. Greek astronomy had already established a distinction between seasonal hours (*hōra kairikē*) and equinoctial hours (*hōra isēmerinē*).[31] In Arabic the latter category was designated *sāʿāt muʿtadilah* ("equal hours") or *sāʿāt falakiyyah* ("astronomical hours"), while seasonal hours were called either *sāʿāt zamāniyyah* ("temporal hours") or *sāʿāt muʿwajjah* ("crooked hours").[32] We shall see these terms again below.

Timekeeping technology

It is not clear that any wholly new timekeeping device emerged in medieval Islam; many of the cultures which fell under Islamic rule already contained both practical and theoretical knowledge on building sophisticated timekeeping instruments. Nonetheless, developments in Islamic societies led to significant advancement in all existing devices, both because of a renewed interest in astronomy and astrology and because of several state-sponsored attempts to establish observatories; these fostered the creation

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[30] George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, Massachusetts: MIT Press, 2007), 79. Equivalent to *juzʾ/ajzāʾ* is the Latin *part/partes*, mentioned by Bede; see next chapter. It is important to note that the *daqīqah* is *not* equal to the modern minute or the Modern Hebrew *daqah*; instead, a *daqīqah* is but 4 seconds (see W. Hartner and P. Kunitzsch, "Minṭaḳat Al-Burūdj," in *Encyclopaedia of Islam, Second Edition*, n.d.). Nonetheless, other evidence suggests that *daqīqah* was also sometimes used to refer to 1/60 of an hour. See R. Ramsay Wright, *The Book of Instruction in the Elements of the Art of Astrology by Abu'l-Rayḥān Muḥammad Ibn Aḥmad Al-Bīrūnī* (London: Luzac & Co., 1934), 55. The relevant passage is quote and discussed below.

[31] Bowen and Goldstein, "Hipparchus' Treatment of Early Greek Astronomy: The Case of Eudoxus and the Length of Daytime," 239.

[32] Pellat, "Layl and Nahār."

of new and very accurate measuring tools.[33] For our purposes, the three relevant instruments are the clepsydra, the sundial, and the astrolabe. Research into the use of all three of these devices during this period is relatively rudimentary.

Water-clocks

Water-clocks were used in Byzantium up until the Islamic conquest, and Islamic water-clocks seem to be entirely continuous with these devices.[34] While these devices may not have been more widespread than they had been previously, Islamic advances in mechanics and engineering have left us with sophisticated exemplars and with several valuable engineering texts concerning the construction of elaborate water-driven timekeeping devices.[35]

Two texts stand out in particular: (1) Though the engineering books of Banū Mūsā, a group of ninth century scholars, do not describe any clocks, many of their devices share the same mechanical techniques used in clocks, and one of their lamps is described as being capable of telling time.[36] (2) The *Book of Knowledge* by the polymath al-Jazarī (d. 1206 CE) describes many of the clocks, his monumental castle clock among then, that divide the day into twelve parts. In addition, some of al-Jazarī's clocks were designed execute elaborate mechanical performances at six, nine, and twelve hours

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[33] On the relationship between observatories and mechanical instruments, see Aydın Sayılı, *The Observatory in Islam* (Arno Press, 1981).
[34] Hill, *Arabic Water-Clocks*, 14.
[35] For the key innovations, see Donald R. Hill, "Islamic Fine Technology and Its Influence On the Development of European Horology," in *Studies in Medieval Islamic Technology: From Philo to Al-Jazarī from Alexandria to Diyār Bakr*, 1998, 9–28.
[36] Hill, *Arabic Water-Clocks*, 14.

(though not three hours). This interest in the quarter-marks of the day is reminiscent of the Greco-Roman four-part day described in the previous chapter.[37]

Al-Jazarī's Castle Clock. Note the twelve circles on the arch.

Although the relative abundance of primary material on the clepsydra might suggest that the devices existed in large numbers, there is little evidence that the engineering works in which they are described were widely consulted as construction blueprints. Even large-scale building projects—such as the construction of naval vessels or buildings—were often done without the benefit of any kind of guiding document. Such projects were often overseen by a *muhandis*, but during the medieval and early modern

[37] For more on Islamic water-clocks, see Donald R. Hill and Uri Rubin, "Sāʿa," in *Encyclopaedia of Islam, Second Edition*, n.d.

period this individual essentially served as a foreman, not an architect or (as the term indicates in modern Arabic) an engineer; even if this individual were interested in precise design, the unstable supplies building materials meant that much construction needed to be performed an on ad hoc basis. If al-Jazarī's devices were built at all, it is likely that they were built by al-Jazarī or someone close to him, using the abundant resources available only to rulers and nobles.[38]

Nonetheless, evidence for a few significant clepsydras survives. Because of their relationship to Byzantine devices, Islamic water-clocks seem to have adopted both equinoctial and seasonal hours for their markings; some multipurpose devices even allowed one to switch between them, and all seem to have embraced the twelve-hour division of the day/night.[39] This adoption is quite evident on one of the most impressive clocks of the period. In his Hebrew description of the monumental clepsydra in the Great Mosque of Damascus, Benjamin of Tudela (d. 1173) describes a device that contained a gate for each day of the year, through which the clock's depiction of the sun would enter and descend twelve steps "corresponding to the hours of the day."[40] The same device is described in detail by the geographer Ibn Jubayr (d. 1217), who describes movements for twelve night hours, as well.[41] Further evidence regarding the design comes from the *Risālah fī ʿamal al-sāʿāt wa-'stiʿmālihā* ("Treatise on the Construction of Clocks

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[38] Maya Shatzmiller, *Labour in the Medieval Islamic World* (Brill, 1994), 210–213. The gap between books about construction and actual construction was not unique to the Islamic world; see, for example, John Peter Oleson, "Well-Pumps for Dummies: Was There a Roman Tradition of Popular, Sub-Literary Engineering Manuals?," in *Problemi Di Macchinismo in Ambito Romano: Macchine Idrauliche Nella Letteratura, Nelle Fonti Storiografiche e Nelle Evidenze Archeologiche Di Età Imperiale* (Musei civici, 2004), 65–86.
[39] Hill, *Arabic Water-Clocks*, 112.
[40] Marcus Nathan Adler, *The Itinerary of Benjamin of Tudela: Critical Text, Translation and Commentary* (London: Oxford Univer, 1907), fol. 47. Adler's translation omits the number "twelve," although he indicates that it appears in all editions.
[41] See Guy Le Strange, *Palestine Under the Moslems: A Description of Syria and the Holy Land from A.D. 650 to 1500. Translated from the Works of the Medieval Arab Geographers* (Cambridge: Houghton Mifflin and Company, 1890), 250.

and their Use") by Ibn al-Sāʿātī (d. ca. 1230), literally "son of the clockmaker," which deals in large part with the design of the Damascus clock, which had been built by his father.[42]

As in the Greco-Roman period, the most sophisticated water-clocks were constructed for astronomical purposes. A notable treatise on their construction by the twelfth-century astronomer al-Khāzinī, who describes a device—to be filled with either water or sand—which contains not only markings for each of the 24 hours, but also six divisions of 60 parts each (one for each degree), and 24 divisions of 60 parts for each of the hours.[43]

Sundials

As with the water-clock, sundial technology was continuous with previous cultures, although precious few Islamic sundials have survived.[44] As early as the beginning of the eighth century, the caliph Umar II (r. 717–720) is said to have used a sundial to determine prayer times.[45] More primitive "time sticks"—essentially freestanding gnomons—were likely used, as well.[46] The earliest known theoretical work on the sundial in Arabic is found in the writings of the ninth century astronomer al-Khwārizmī, and the oldest known exemplar is a partially-intact specimen located in Cordoba.[47] Under Islam the

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[42] See H. Suter and J. Vernet, "Ibn Al-Sāʿātī," in *Encyclopaedia of Islam, Second Edition*, n.d. A translation and summary of Ibn al-Sāʿātī's description of the clock can be found in Hill, *Arabic Water-Clocks*, chap. 5.
[43] A translation of the relevant chapter can be found in Hill, *Arabic Water-Clocks*, chap. 4.
[44] For evidence of pre-conquest Byzantine sundials, see J.V. Field and M.T. Wright, "Gears from the Byzantines: A Portable Sundial with Calendrical Gearing," *Annals of Science* 42, no. 2 (March 22, 1985): 87–138.
[45] D. A. King, "Astronomical Instrumentation in the Medieval Near East," in *Islamic Astronomical Instruments* (London: Variorum Reprints, 1987), 10.
[46] Barbara Freyer Stowasser, *The Day Begins At Sunset: Perceptions of Time in the Islamic World* (I.B. Tauris Publishers, 2014), 143–144.
[47] This sundial is described in detail in David A. King, "Three Sundials from Islamic Andalusia," *Journal for the History of Arabic Science* 2 (1978): 358–392.

sundial flourished; several entirely new varieties of device were invented, although this seems to be have for the purpose of greater specialization, and does not reflect increased public adoption.[48]

As with the water-clocks, many Islamic sundials contain markings for seasonal hours.[49] They are additionally distinguished by their inclusion of markings corresponding to the times of the *ẓuhr* and *ʿaṣr* prayers.[50]

Astrolabes

The astrolabe (Ar. *asṭurlāb* or *aṣṭurlāb*) is a device of considerably greater complexity than either the sundial or clepsydra. Though specimens vary in design and functional capabilities, all astrolabes have two fundamental abilities. First, they are measuring devices, capable of determining the angle between a celestial body and the horizon. Second—and more importantly—they are some of the earliest examples of analog computers, in that they use supplied inputs to calculate any number of important pieces of information, including latitude (and therefore also prayer direction), sunrise and sunset times, and, most importantly for our purposes, the time of day. These computations were accomplished by rotating several connected discs and bars and reading the result.

The astrolabe is thought to have been a Greek invention; indeed, evidence from the Antikythera Mechanism—a unique mechanical device from the first century BCE, recovered from a shipwreck in 1901—suggests that Greek analog computing was actually

[48] King, "Astronomical Instrumentation in the Medieval Near East," 10–11.
[49] See, for example, King, "A Fourteenth Century Tunisian Sundial."
[50] King, "Astronomical Instrumentation in the Medieval Near East," 11.

quite sophisticated.[51] Nonetheless, not a single Greek astrolabe survives and Islamic sources that attempted to analyze the term *asṭurlāb* sometimes miss its Greek origins entirely, although Ibn Khallikān claimed that Ptolemy came upon the device by accident when a spherical instrument he was carrying was squashed by an elephant.[52] The material history of this device only begins with the advent of Islam, and it was Islamic astrolabe designs that served as the basis for medieval and early modern European models.[53] Many medieval Arabic treatises on the construction and use of the astrolabe remain in existence.[54] Unfortunately, the vast majority are still in manuscript.

While astrolabes were primarily used in specialized technical settings, there is some evidence for their ritual use, as well. Just as some sundials contained special marks to indicate prayer times, astrolabe plates contained similar marks for determining the correct direction of prayer, as well as prayer times.[55]

Candle clocks

Candle clocks also existed in Late Antiquity, and they, too, were imported into Islamic culture. A few Arabic treatises on the candle clock exist. The tenth century astronomer Ibn Yūnus describes a chandelier containing twelve candles, all lit at midnight, each filled with a precise quantity of oil such that one candle would burn out each hour. The description of the clock includes a table indicating how much oil is needed for each candle at different times during the year; however, the table is not cal-

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[51] There have been a great number of studies of the Antikythera Mechanism over the past century. For a recent analysis and survey of previous scholarship, see Jian-Liang Lin, *Decoding the Mechanisms of Antikythera Astronomical Device* (Heidelberg: Springer, 2016).
[52] David A. King, "The Origin of the Astrolabe," in *Islamic Astronomical Instruments* (London: Variorum, 1987). On the Ptolemy anecdote, see page 45.
[53] Saliba, *Islamic Science and the Making of the European Renaissance*, 225.
[54] See King, "Astronomical Instrumentation in the Medieval Near East," 4–5.
[55] King, 6.

ibrated for Cairo, where Ibn Yūnus lived, but rather Babylonia, suggesting that the ideas had been imported but not fully digested, and that the treatise was never intended to be a blueprint for construction.[56]

As in Antiquity, these clocks were not in common use. Whereas the water in a water-clock could be reused indefinitely, a candle clock was, of necessity, a disposable product and a considerable expense in an era when interior lighting was expensive.

II. Jewish timekeeping under medieval Islam

As existing scholarship has extensively documented, many arenas of Jewish cultural activity—jurisprudence, poetry, linguistics, philosophy, mysticism, medicine—either first emerged or were radically transformed by the encounter with Islamic thought and literature. This was especially true for astrology and astronomy, fields which Dimitri Gutas identified as the original instigators of the Islamic project of translating knowledge from Persian, Sanskrit, and Greek.[57] From at least the tenth century, Jewish scholars began interpreting older texts using not just the language of Islamic astrology, but also of Islamic astrology's critics among the scholars of *kalām* (scholastic theology).[58]

Exposure to Islamic astronomy created a new class of Jewish scholar, who, like their Muslim counterparts, were lettered in both the intricacies of religious law and of the new Islamic astronomy. While much of the impetus for the adoption and deployment of

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[56] E.S. Kennedy and Walid Ukashah, "The Chandelier Clock of Ibn Yūnis," *Isis* 60, no. 4 (1969): 543–545. David King doubts the authorship of this work; see David A. King, "Medieval Mechanical Devices: A Review of D.R. Hill, The Book of Knowledge of Ingenious Mechanical Devices," *History of Science* 13, no. 284–289 (1975): n. 2.

[57] This is the argument made in Dimitri Gutas, *Greek Thought, Arabic Culture: The Graeco-Arabic Translation Movement in Baghdad and Early ʿAbbāsid Society (2nd-4th/8th-10th Centuries)* (Routledge, 1998).

[58] See, for example, Marla Segol, "Astrology in Hebrew Texts Before and After Islam," *Magic, Ritual, and Witchcraft* 12, no. 1 (2017): 10–38.

this discipline lay in the construction of the Jewish calendar, these scholars also emphatically adopted the new or improved astronomical devices and terminology.[59] Importantly, it was this class of scholars that imported into Hebrew the timekeeping terminology that would eventually—sometime only centuries later—become commonplace in the interpretation of Jewish texts.

Paradigmatic of this kind of scholar was Abraham ibn Ezra (d. 1167), who penned at least four treatises on the astrolabe, the first Hebrew books ever to be devoted to a single instrument.[60] While Ibn Ezra is otherwise known as one of the most important medieval biblical commentators, his work on the astrolabe does not engage with his scriptural writings and at times even puts forwards positions that are not found in his exegetical works. For example, in the context of his writings on the astrolabe, Ibn Ezra admits that the rabbis were sometimes incorrect in their astronomical calculations.[61] Thus, despite his expertise in both exegesis and astronomy, Ibn Ezra compartmentalized each area of expertise, and his adaptations of Islamic astronomical terminology were not used by others even within his own cultural milieu. It would only be with the popularization of astronomy among non-specialists in the fourteenth century that his scientific work, together with the work of Bar Ḥiyya and Maimonides, gained greater popularity.

While the inner workings and precise mathematical construction of timekeeping devices were known only to specialists, Islamic culture seems to have brought all Jew

[59] On the earliest Jewish ventures into astronomy, see Bernard R Goldstein, "Astronomy and the Jewish Community in Early Islam," *Aleph*, no. 1 (2001): 17–57.
[60] Ibn Ezra may have even been personally responsible for a Latin work on the subject. See Josefina Rodríguez Arribas, "Medieval Jews and Medieval Astrolabes: Where, Why, How, and What For?," in *Time, Astronomy and Calendars in the Jewish Tradition*, ed. Sacha Stern and Charles Burnett (Leiden: Brill, 2014), 240.
[61] Arribas, 234 n. 34.

into much closer contact with timekeeping devices themselves. This was, at least in part, because of the presence of public, monumental devices, which would have been visible by all. In his commentary on the Mishnah, for example, Maimonides offers a detailed description of the sundial which is quite similar to an eleventh-century Cordoban exemplar, which also happens to be the oldest Islamic sundial still in existence.[62] In addition, there is evidence of Jewish astrolabe makers (*asṭurlabī*) in Iraq from as early as the eighth century.[63] Finally, a basic understanding of smaller devices seems to have become more common even non-specialists, in particular as solutions to exegetical problems. Thus, for example, a geonic responsum demonstrates its familiarity with water-clock technology in an interpretative solution to the meaning of *shenatot* (שנתות); this term appears in mMenaḥot9:2 and describes the markings on the side of a Temple vessel that helped priests in determining the correct amount of liquid needed for different animal sacrifices—in essence, a measuring cup.[64] The responsum hypothesizes:

> Or perhaps they were dots (*nequdot*), as there are in copper bowls pierced on their undersides, made to measure the hours when placed in water, and where water enters up to this dot (*shenat*) for half an hour, up to this dot for an hour, and up to this dot for an hour and a half, for here [in this context] dots are called *shenatot*.[65]

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[62] This link is made in Joel L. Kraemer, *Maimonides: The Life and World of One of Civilization's Greatest Minds* (New York: Doubleday, 2008), 79.

[63] Shatzmiller, *Labour in the Medieval Islamic World*, 114. In addition, Israel Abrahams lists water-clock manufacture as a Middle Eastern Jewish occupation, although he is somewhat vague about the source of this information; see his *Jewish Life in the Middle Ages* (Philadelphia: Jewish Publication Society of America, 1896), 245. Neither sundial manufacture nor water-clock manufacture is listed by Shatzmiller as a Jewish occupation.

[64] See also bShabbat80b and bBavaBatra86b.

[65] B.M. Lewin, *Otzar Ha-Geonim Vol. II: Tractate Shabbath* (Haifa, 1930), 80f. The clepsydra design described here is most likely a sinking-bowl water-clock. In India and Persia this was long the dominant design, whereas it was relatively uncommon in Islamic lands; see Anthony J. Turner, *Time-Measurement Instruments* (Rockford, 1984), 9–11. Wischnitzer cites this responsum as evidence that geonic-era Jews

Even though the existence of timekeeping devices was of much greater relevance to Rabbanites, as we shall see below, exegetical solutions of this sort were also voiced outside of this camp. An early example can be found in the solution to a small textual problem put forward by the influential tenth-century Karaite, Yaʿaqūb al-Qirqisānī. In the course of the Bible's Joseph saga, Joseph instructs that his silver goblet be placed in the sack of his brother Benjamin. The cup is described as one which Joseph "uses for divination (*naḥesh yenaḥesh bo*)." This presented a problem for biblical interpreters, since divination is explicitly prohibited by the Bible.[66] Al-Qirqisānī provides this explanation:

> This term is ambiguous. It is possible that this vessel contained an item employed in matters of measuring, as well as the measuring through which one learns times (*awqāt*) and durations (*miqdār al-sāʿāt*), like the time of the noon prayer (*ṣalāt al-ẓuhr*), and including the knowledge of what [portion] of the day has elapsed, as well as [knowledge of] the quarter-mark of the day, and the half, and the like <gap in the text> And this is similar to the measuring tools that we see rulers possess today, from which they learn the times for prayer, for eating, for sleeping, and for other things; it is these [tools] which are called *finjān* (water-clock).[67]

Al-Qirqisānī's interpretation was perhaps inspired by the term *finjān* itself, a Persian loanword which normally referred to a drinking cup but which was occasionally used to refer to a particular form of clepsydra, as well.[68] A strikingly similar interpretation,

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produced clepsydras, but this does not seem to be supported by the text. Mark Wischnitzer, *A History of Jewish Crafts and Guilds* (New York: J. David, 1965), 57.

[66] See Leviticus 19:26 and Deuteronomy 18:10–11.

[67] RNL Yevr.-Arab. I 4529, 86b–87a.

[68] Reinhold Röhricht, *Geschichte Des Ersten Kreuzzuges* (Innsbruck, 1901), 243.

can be found in the Bible commentary of the Rabbanite Shmuel ben Ḥofni Gaon, and is quoted below.[69]

Timekeeping devices as human constructions

Use of the term *finjān* in this particular context bears witness to al-Qirqisānī's knowledge of the clepsydra, and it also attests to a broader shift in attitude towards timekeeping devices themselves: the expression of a new willingness to accept timekeeping devices as technologies of human, rather than divine, construction.

As we saw in the last chapter, references to timekeeping devices in Late Antique rabbinic literature are few and far between; the references that do exist are always associated with God in some way and are almost always metaphorical, suggesting that the devices were understood to be more powerful as ideas than practical tools. Under Islam, this understanding of the devices underwent a radical shift; indeed, it is possible that, in medieval Islamicate societies, changes in the *perception* of timekeeping technology outweighed changes wrought by the technologies themselves. Whereas Late Antique rabbinic literature depicted timekeeping devices as being owned or controlled by God, in medieval Islamic societies Jews perceived them as essentially secular objects. To return to the previous example: it is useful to interpret Joseph's cup as a *finjān* because, unlike divination, it has nothing to do with the supernatural (although it *appears* sufficiently supernatural that the verb *naḥesh* ("to divine") might reasonably be used to describe it).

[69] CUL T-S G2.98. The wording in this and the al-Qirqisānī text are quite similar; it is possible that one has been misattributed.

A notable feature of geonic reinterpretations is their willingness to read these human-made objects not just into biblical texts but into older rabbinic texts, as well. At times these reinterpretations are straightforward; Hai Gaon (d. 1038 CE), for example, identifies both the gnomon mentioned in the Mishnah and the biblical Dial of Aḥaz with the *horologium* (אורולוגון) of the natural philosophers (*ḥakhamim*).[70] At other times, the geonim are more inventive; one responsum suggests that the walls of the Temple contained markings "like there is on the dial's shadow (i.e. the Dial of Aḥaz), which is a sundial (*even shaʿot*)," in order to determine when the afternoon had arrived.[71]

In another reinterpretation, a geonic text converts a rabbinic tale about the awesomeness of the universe into a story about the sophistication of Greek engineering. In the Babylonian Talmud, Rabba bar bar Ḥana recounts a series of tales about his journeys and the incredible sights he saw, among them a fish so large that it was mistaken for land and a bird of almost incomprehensible magnitude. On one trip with an Arab guide, Rabba states:

> [This Arab] said to me, "Come, I will show you where earth and heaven (*rakiʿa*) meet." I took my basket and placed it in a window of the heaven. After I had prayed, I searched for it but did not find it. I said to him, "Are there thieves here?" He said to me, "This is the rotating heavenly sphere. Wait here until tomorrow and you will find it."[72]

It is hard to picture what is being described here, but both the passage and its context suggest that Rabba bar bar Ḥana is referring to some naturally-occurring feature of

[70] *Peirush Geonim Al Seder Taharot* (Berlin, 1921), 26.
[71] CUL T-S G2.79, fol. 1r–v. This reading is based on an interesting synthesis of bYoma28b and yEruvin5a—both of which can be construed as referring to astronomical *knowledge* and neither of which makes any mention of a timekeeping device.
[72] bBavaBatra74a.

the physical world. A geonic interpretation rejects this reading and instead presents the story as describing a monumental work of human design.

> Our rabbis taught that one of the Greek kings fashioned a large bronze wheel which had 360 arms [*amot*][73] arranged in the shape of the heavens, one degree [*ḥayyil*][74] per arm. He set it in motion so that it would move under of its own accord, using wind or water. Each 24 hours it would make one revolution. In it he placed window-like holes which moved slowly (*tenudot keveidot hayu*), such that it would rotate through 360 arms in 24 [hours]. This is what "that Arab" showed Rabba bar bar Ḥana. [Rabba] saw it, took off his shoes, put down his *tefillin* bag and placed [the shoes and bag] in one of its holes and turned his face to pray.[75] He tarried, and that hole rose up higher than the height of a person. [Not knowing this, Rabba] searched in the hole nearest to him. Having not found it, he said, "Is there a thief in the heavens?" By this he meant: can something *that resembles* the heavens contain a thief?[76]

This interpretation is doubly humanizing. First, in making this wheel of heaven into a grand human creation, the author has posited for humans a level of ingenuity and engineering prowess that itself borders on the mythical.[77] Beyond this, the text reinterprets Rabba bar bar Ḥana's question so that he, too, can be ascribed some level of technological awareness. True, he was not aware that the machine in which he placed his items was capable of movement; nonetheless, he *was* at least aware of engaging with a

[73] For this meaning of *amah*, see bSotah12b.
[74] On the meaning of this term, see footnote 102, below.
[75] On removing one's shoes before praying, see Elisha Russ-Fishbane, *Judaism, Sufism, and the Pietists of Medieval Egypt: A Study of Abraham Maimonides and His Times* (Oxford University Press, 2015), 161.
[76] RNL Evr. II, A 32, 9r; emphasis mine. Two versions of this responsum, neither identical to the Genizah fragment, were published in Albert Harkavy, *Zikaron La-Rishonim ve-Gam La-Aḥaronim, Volume 1*, 1887, para. 12 and 374. On the minor differences between them, see Uziel Fuchs, "The Role of the Geonim in the Textual Transmission of the Babylonian Talmud [Hebrew]" (Hebrew University, 2003), 240.
[77] Whether such a device actually existed is highly unlikely; indeed, the idea of such a large revolving timepiece more closely recalls the Islamic monumental devices described above. Still, I know of no device quite like that of Rabba bar bar Ḥana.

machine. In short, he knew the difference between divine and human creations, even when they resemble one another.

Perhaps the most dramatic geonic reinterpretation of a rabbinic passage concerns King David's ability to wake himself each midnight which, as noted in the previous chapter, was understood by the rabbis of Late Antiquity to have been enabled by divine assistance in the form of a northerly wind blowing across the strings of his lyre.[78] In his interpretation of the passage, Hai Gaon both removes any suggestion of a miraculous element, instead identifying the lyre's midnight sounds as a standard feature:

> David had a signal in his lyre to determine the middle of the night. [It was] like a *finjān*, which is a timekeeper (*even shaʿot*).[79] As for the lyre, there are those who say [it operated] via a northerly wind and there are others who say otherwise, that its movement is measured by water or air on one side and that each night [the timekeeping device] is set up according to the length of that night, such that a sound is heard from the lyre at the night's midpoint.[80]

For Hai Gaon, David's lyre was undoubtedly a timekeeping device, although he was not sure precisely what kind of timekeeping device it was. Leaving open the possibility that a northerly wind operated the device (although this, too, was understood to be a harnessing of natural forces for timekeeping purposes), Hai allowed that this "lyre" was a conventional clepsydra, one which would have needed nightly adjustments to ensure that its sound was activated precisely at midnight. Regardless, Hai seems to have been well aware of the devices of his day; his remark that a *finjān* could operate via the

[78] See bBerakhot3b.
[79] *Even shaʿot* cannot here refer to a sundial, since these events are taking place at night. The most likely explanation is that *even shaʿot* is here being employed as a generic term for a timekeeping device, like the Latin *horologium*.
[80] Quoted by Shlomo ibn Aderet in *Ḥidushei ha-Rashba*, Berakhot 3b. Quoted, as well in Simha Assaf, *Tekufat Ha-Geonim ve-Safruta* (Jerusalem: Mossad HaRav Kook, 1955), 139–140.

measurement of either water or air suggests a familiarity with both inflow clepsydras, which measure water levels, and outflow clepsydras, which measure the absence of water, i.e. air.[81]

Timekeeping devices as metaphors for divinity

Despite the new geonic willingness to divest timekeeping devices of their supernatural valence, Jews in Islamic lands continued to treat timekeeping devices as objects of extreme complexity. If they were not directly associated with the divine, they at least simulated to a reasonable degree the sophistication and precision with which God was understood to act.

In medieval Islamicate culture, this new perspective caused a key shift in the way timekeeping devices were spoken of in relation to God. Whereas Late Antique rabbis had understood these precise and complex timekeepers to be symbols for God, both Jewish and Muslim scholars now viewed them as *analogies* for the world which God had fashioned. For both Jewish and Muslims scholars, the complexity of these manufactured devices made them ideal metaphors (or foils) for God's perfect universe.[82] It was in this manner that timekeeping devices first began to feature in Jewish philosophical discourse.

While the clock as a metaphor for nature is more commonly associated with the mechanical clocks of early modern Europe, it appears as early as Cicero (d. ca. 43 BCE), who was one of the first to use the devices for this purpose:

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[81] The "on one side" remark refers to the different chambers into which all clepsydras are divided.
[82] The historian of technology Lynn White, Jr., noted that, prior to the development of the clock, the most complicated piece of technology had been the pipe organ, a machine which does not appear to be self-moving and has few visible moving parts. See Lynn White, Jr., *Medieval Religion and Technology* (University of California Press, 1978), 65.

> When we see something moved by machinery (*cum machinatione*), like an orrery (*sphaera*) or clock (*hora*) or many other such things, we do not doubt that these contrivances are the work of reason; when therefore we behold the whole compass of the heaven moving with revolutions of marvelous velocity and executing with perfect regularity the annual changes of the seasons with absolute safety and security for all things, how can we doubt that all this is effected not merely by reason, but by a reason that is transcendent and divine?[83]

Cicero's argument was adopted by Islamic astronomers, and it appears in the Jewish philosopher Baḥya ibn Paqūda's eleventh-century work, *al-Ḥidāya ilā farā'iḍ al-qulūb* ("Guide to the Duties of the Heart," in Hebrew *Ḥovot ha-Levavot*), in a form that closely resembles an argument made in the work of "Pseudo-Jāḥiẓ," a scholar of the late tenth or early eleventh century.[84] In this version of the argument, the designed instruments are a waterwheel (*dawlāb yadūr li-saqyi qiṭʿa min al-arḍ*) and an astrolabe.[85]

While the invocation of timekeeping devices to demonstrate the *existence* of God has its origins in Hellenistic philosophy, their use to describe the nature of God's universe and the manner in which God acts are both innovations of the medieval Islamic period. One of the first to use the clock as a theological metaphor in these new ways was Muḥammad al-Ghazālī (d. 1111) who used the device in two of his minor later works to elucidate themes he had earlier set forward in his opus, *Iḥyā' ʿulūm al-dīn* ("Revival of the Religious Sciences").[86] In the first—a commentary on the names of God—al-Ghazālī elaborated on his idea that all of creation is determined by a series of three divine actions. The first of these is akin to an engineer designing a water-clock (*ṣundūq al-sāʿāt*);

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[83] *De Natura Deorum* II:37; see also II:34 (trans. H. Rackham, 1933).
[84] This identification made in Diana Lobel, *A Sufi-Jewish Dialogue: Philosophy and Mysticism in Bahya Ibn Paquda's "Duties of the Heart"* (Philadelphia: University of Pennsylvania Press, 2013), 62.
[85] Y. Tzvi Langermann, *The Jews and the Sciences in the Middle Ages* (Ashgate, 1999), 42–43.
[86] My summary of al-Ghazālī's arguments is chiefly derived from Griffel, *Al-Ghazālī's Philosophical Theology*, 236–242.

this corresponds to God's creation of a design (*ḥukm*) for the world. The second is the construction of the actual clock; this is similar to the divine decree (*qaḍāʾ*) in which God brought a static world into existence. Finally, there is the opening of the aperture, which initiates the water-clock's movement. This corresponds to predestination (*qadar*), i.e. the process by which God sets everything in motion by adjusting the universe's initial parameters. Once the aperture is open, the clock may appear to be moving of its own volition, al-Ghazālī asserts that this is not the case, just as it is not the case for the universe.

The first Jewish scholar to employ the water-clock as a metaphor is Maimonides, who had either direct or indirect access to the work of al-Ghazālī.[87] While both employ the water-clock as a fitting metaphor for the universe, Maimonides uses the metaphor to make a point about epistemology, not predestination. In *Guide for the Perplexed* 3:21, Maimonides distinguishes between the types of knowledge one acquires through manufacture and through observation. Taking the complex water-clock as his example, Maimonides notes that while the clock maker will have complete knowledge of the clock as a result of having constructed it, an observer will be at a disadvantage. In order to have complete knowledge of the clock, the latter individual must observe the clock over an infinite number of "movements." Since this is impossible, the observer's knowledge of the clock—and, by analogy, human knowledge of the inner workings of the world—will of necessity always be incomplete.

[87] Many scholars have attempt to determine the relationship between the two scholars. Shlomo Pines, in his introduction to the *The Guide of the Perplexed*, finds it unimaginable that a scholar of Maimonides' caliber would have been ignorant of al-Ghazālī, despite his absence from the former's work (*The Guide of the Perplexed*, ed. Sholomo Pines (Chicago: University of Chicago Press, 1963), cxxvii–cxxviii.). For more recent scholarship on the topic, see Herbert Davidson, *Moses Maimonides: The Man and His Works* (Oxford, 2005), 95.

New units

Like Late Antique rabbinic sources, geonic materials employ a number of sub-hourly units, some of which are recurring but none of which serve any practical purpose. The introduction to *Halakhot Gedolot*, a mid-ninth century legal work of uncertain origin, elaborates on a Talmudic narrative concerning the 2000-year period before the creation of the world, during which 974 "generations" elapsed.[88] Doing the math for us, the text says that this means each generation endured for, "2 years, 19 days, 11 hours, 2 *shlishim*, and 14 *ḥalaqim*."[89] This complete equation conveniently allows us to infer the exact meaning of its terms. In particular, the "day" here must be one of 365, the hour must be equinoctial, a *shelish* is simply a third of an hour, and a *ḥeleq* is 1/1080 of an hour, consistent with previous sources.[90]

Mathematical necessity also leads Maimonides to offer a new definition for the term *regaʿ* which it at odds which the many conflicting definitions we examined in the previous chapter; for him it simply means 1/76 of a *ḥeleq*.[91] As with the *ḥeleq* itself, the definition was chosen in order to allow all calendrical math to be done using whole num-

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[88] See bShabbat88b and bḤagigah13b–14a. On the origins of *Halakhot Gedolot*, see Brody, *The Geonim of Babylonia and the Shaping of Medieval Jewish Culture*, 223.

[89] The use of the term *shelish* here is presumably connected to its use in Rabban Gamliel's definition of the *molad*. On the reason for its use there, see note 139 in the previous chapter.

[90] Note that the year *cannot* be the 365.25 days established by the Julian calendar. Were this the definition, each of the 974 generations would have instead spanned 2 years, 19 days and 12 hours. Curiously, the Julian year allows for a much simpler and more accurate division; despite its apparent precision, *Halakhot Gedolot*'s equation is actually just an approximation, since it leaves around 0.045 *ḥalaqim* unaccounted for (by comparison, the *regaʿ* as defined in tBerakhot1:1 is approximately 0.078 *ḥalaqim*). However, it is difficult to conclude from this that the number of generations was intentionally set at 974 to yield an easy division, since the 974 figure is arrived at by subtracting 26 (the number of generations between Adam and Moses) from Psalms 105:8, which alludes to a thousand-generation promise. The Talmud suggests that the thousand generations consist of 974 hypothetical generations prior to the world's existence, as well as 26 actual generations. None of this would seem to be dependent on the Julian calendar.

[91] Maimonides, *Mishneh Torah*, Qiddush ha-Ḥodesh, 10:1.

bers.[92] That Maimonides is comfortable employing the term without reconciling it with his own (or reconciling them with each other) further confirms that the term had previously been practically inconsequential.

An important perspective on Jewish timekeeping terminology is provided by the Muslim polymath al-Bīrūnī:

> The hour, like everything that can be measured, assessed [with regards to volume], or weighed, is divided into sixty parts (*daqīqah*) and so on [meaning, subsequent units are also divided into sixtieths]. Jews divide the hour into eighteen-times-sixty, that is, 1080 parts. In Hebrew they call them *ḥalaq*.[93] They do not divide them into anything smaller other than perhaps half a *ḥalaq*.[94]

Al-Bīrūnī's assessment of his own faith's metrics is problematic; while it is true that several Islamic units of length, volume, and weight were divisible into 60 parts, other units were not.[95] Nonetheless, al-Bīrūnī's mention of the *ḥeleq* is an important affirmation that the unit was actually used. Indeed, al-Bīrūnī's identification of the unit with Jews suggests that—among all timekeeping units which appear in Jewish sources—the *ḥeleq* is the only one which is unique to Jews.

The emergence of seasonal and equinoctial hours in Jewish texts

The previous chapter presented a conceptual progression from the "naïve" hour used by rabbis in Late Antiquity to the recognition that both seasonal and equinoctial

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[92] This point is made in Irv Bromberg, "Hebrew Calendar Studies: Why Divide Hours into 1080 Parts?," n.d., individual.utoronto.ca/kalendis/hebrew/chelek.htm.
[93] Arabic does not have the vowels necessary to transcribe the Hebrew term. This is my attempt to vocalize حلق .
[94] Wright, *The Book of Instruction in the Elements of the Art of Astrology by Abu'l-Rayḥān Muḥammad Ibn Aḥmad Al-Bīrūnī*, 55. I have used Wright's facsimile of the manuscript but not his translation, which contains significant inaccuracies. My thanks to Ari Gordon for showing me this source.
[95] For a survey, see Ulrich Rebstock, "Weights and Measures in Islam," *Encyclopaedia of the History of Science, Technology, and Medicine in Non- Western Cultures*, 2008, 2255–67.

hours are reasonable ways of dealing with seasonal fluctuations in daylights, and that the choice to use one over the other is simply a matter of convention, rather than necessity.[96] I shall refer to that conceptual rubric—specifically, to propositions (1), (2a), (2b), and (3)—in the discussion below.

The rise of Islam led to conceptual advances in timekeeping, but these did not come immediately. The earliest relevant text is Pirke de-Rabbi Eliezer (PRE), a midrashic composition of the eighth century, which famously alludes to the Islamic conquest and Muslim rule, and which has been discovered to contain numerous allusions to Second Temple literature, including Enochic texts.[97] Timekeeping views in PRE are reminiscent of both the Ethiopic *Astronomical Book* as well as Eleazar ha-Qalir's aforementioned *piyyut*:

> Rabbi Ḥanina said, "In the third month [i.e. Sivan], the day is twice [the length of] the night, so [on the day of the giving of the Torah] the Israelites slept until two hours into the day, for the sleep of ʿ*Atzeret* (i.e. the holiday of Shavuot) is sweet and the night is short. Moses went out of the Israelite camp and roused them from their sleep. [...][98]

This story is not unique to PRE; a similar version is located an earlier midrash.[99] Both midrashim are already somewhat unusual in that they indicate that a person's daily schedule might change as a result of the shifting seasons. What PRE adds, however, is the information that Sivan's night is not just short, but is in fact half the length of

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[96] See above, page 79.
[97] While the first round of critical scholarship on PRE was criticized for its "parallelomania" in finding copious allusions in the text to older works, evidence of a link between PRE and Enoch had withstood further source critical scholarship; see discussion in Steven Daniel Sacks, "Midrash and Multiplicity" (De Gruyter, 2009), chap. 1. For the particular text under discussion here, see Eliezer Treitl, "Pirke De-Rabbi Eliezer: Text, Redaction and a Sample Synopsis (Hebrew)" (Hebrew University, 2010), 211.
[98] Pirke de-Rabbi Eliezer (Heiger ed.) §40.
[99] Song of Songs Rabbah 1:12.

the day. This information is incorrect, but it is the same error made by both *Astronomical Book* and Eleazar b. Qalir.[100] Nonetheless, unlike these earlier works, PRE's acknowledgement of shifting daylight is not accompanied by an awareness of a shifting number of hours per day.

It was roughly simultaneous to PRE's composition that Jewish texts first began implying (2b)—that is, an awareness that shifts in the length of the day might lead to shifts in the length of the hour. Evidence of this development can be traced to *Baraita de-Shmuel*, an early Jewish astrological text likely dating to the ninth or late eighth century.[101] In the third chapter, for example, the text states that, beginning in Cancer (i.e. the month of Tammuz), a daylight hour is considered eighteen "*ḥayyil*" (חיל)[102] while a

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[100] Note that PRE is incorrect in an additional way, since Sivan is one month short of the summer solstice. As in *Astronomical Book*, the assertion of a 2:1 day/night ratio long perplexed PRE scholars. Given the connection between Enoch and PRE, it is likely that whatever interpretation fits the former also explains the latter. In his dissertation on PRE, Eliezer Treitl claimed that the text simply used *kaful* (lit. "double") to mean "more;" given the state of scholarship on *Astronomical Book*, this does not appear to be the most likely reading. See Treitl, "Pirke De-Rabbi Eliezer: Text, Redaction and a Sample Synopsis (Hebrew)," 210–211.

[101] *Baraita de-Shmuel*, together with *Baraita de-Mazzalot* (with which it is sometimes confused), are apparently descendants of a now-lost anonymous Hebrew astrology text. *Baraita de-Shmuel* is also known through the references of Shabbetai Donnolo (d. ca. 985). It was first printed in the nineteenth century. The sole manuscript, itself damaged, is now apparently lost. For more information, see the references in Reimund Leicht, "Towards a History of Hebrew Astrological Literature," in *Science in Medieval Jewish Cultures*, ed. Gad Freudenthal (Cambridge University Press, 2011), 258.

[102] The origins of the term חיל are quite murky and my transliteration is speculative. For other uses of the phrase, see *Baraita de-Sod ha-ʿIbbur* and the geonic responsum contained in RNL Evr. II, A 32, discussed above. It is possible that it is a noun derives from Arabic and is related to the root *ḥ-w-l*, meaning something like, "shift," or perhaps event "rotational shift," referring to the movement of the Earth. This is supported by the related term *ḥawl*, which means "year," i.e. a complete rotation of the Earth (or the Sun). Unfortunately, Islamic sources do not use *ḥiyal* in the technical manner described here. Alternatively, the correct vocalization may be the Hebrew *ḥayyil*, "army," with the term being an allusion to a statement of Resh Lakish in bBerakhot32b:

> God said [to Israel], "My daughter, I have created twelve constellations (*mazzalot*) in the firmament. Upon each constellation I have created 30 armies (*ḥayyil*). Upon each army I have created 30 legions (*ligyon*). Upon each legion I have created 30 marching routes (*rihaton*). Upon each marching route I have created 30 enclosures (*karton*). Upon each enclosure I have created 30 camps (*gastera*). Upon each camp I have hung 365,000 stars, corresponding to the days of the solar year—and I have created it all for your sake, yet you say that the Lord has forsaken me and forgotten me?

This sequence is highly reminiscent of Islamic astronomical divisions. If the twelve constellations were read as representing half a day, then one *ḥayyil* would indeed represent one equatorial degree. It is possinighttime hour is twelve *ḥayyil*; beginning in Capricorn (i.e. the month of Nisan) the numbers are reversed. A quick calculation on our part determines that there are always 360 *ḥayyil* in a day, and thus one *ḥayyil* is equivalent to one equatorial degree (*juzʾ*/*dara-jah*). The *ḥayyil* unit only appears in Jewish texts produced in Islamic lands, but it was not adopted by the major medieval Jewish astronomers, who prefer to use a direct translation from the Arabic—*ḥeleq*—instead.[103]

Though *Baraita de-Shmuel* is clearly dealing with hours of shifting length, it never explicitly says so, since it does not entertain the notion that an hour could be anything else. It is only at stage (3) that the two types of hour are held in tandem.[104] The first evidence for this stage comes slightly later in the Islamic period, and it is in this context that the phrase *shaʿot zemaniyyot* emerges.

Shaʿot zemaniyyot is a Hebrew translation of the Arabic *sāʿāt zamāniyyah*; Maimonides states explicitly that this term was borrowed from the astronomers (*munajjimūn*).[105] It was in its Judaeo-Arabic form that the term first circulated in Jewish literature. The earliest usage of the phrase I have been able to locate appears in a Cairo Genizah fragment attributed to the Babylonian gaon Shmuel ben Ḥofni (d. 1034), a scholar known to

ble that, under Islamic cultural influence, the term was revived and technicalized as a way of re-appropriating Islam's re-appropriation of Greek astronomy. If this is the case, a shift in interpretation would have had to take place; as noted in the previous chapter, Late Antique rabbinic sources do not use the sexagesimal system for dividing up units of time.

[103] This is, of course, somewhat confusing, since *ḥeleq* already has a meaning in the Talmud. This leads Abraham bar Ḥiyya to distinguish between *ḥeleq* and *ḥelqeinu* ("our *ḥeleq*"); see Gad B. Sarfatti, *Mathematical Terminology in the Hebrew Scientific Literature of the Middle Ages [Hebrew]* (Jerusalem: Magnes Press, 1968), para. 140.

[104] It is worth noting that *Baraita de-Shmuel*, an astrological text, employed seasonal hours, while Eleazar ha- Qalir's hours are defined on the basis of astronomy.

[105] *Teshuvot Ha-Rambam*, vol. 1, #134: והדה אלסאעאת הי אלתי יסמונהא אלמנגמון אלסאעה אלזמאניה ויסמונהו איצא אלסאעה אלמעוגה. In Ptolemy's *Geographia*, the length of the longest day is given as the chief means for determining the latitude of a given location. (See O. Neugebauer, *A History of Ancient Mathematical Astronomy* (Springer, 1975), 853. For a contemporary overview, see Dmitriy A. Shcheglov, "Ptolemy's System of Seven Climata and Eratosthenes' Geography," *Greographia Antiqua* 13 (2004): 21–37.) As a result, knowledge of astronomy always implied an understanding of the two types of hours.

have been well read in Islamic philosophy and theology.[106] The fragment is part of the gaon's Torah commentary, and it offers an interpretation of Joseph's cup that is quite similar to that of al-Qirqisānī, cited above.[107] According to Shmuel ben Ḥofni, the cup was, in fact, a water-clock that "measured a seasonal hour (*sāʿah zamāniyyah*) from the day or night,"[108]—as opposed to an equinoctial water-clock, both of which would have been available to Shmuel ben Ḥofni.

Timekeeping knowledge among Jewish astronomers

As described above, Arabic terminology around the two types of hours—including the phrase *sāʿāt zamāniyyah*—appears mainly in astronomical contexts; outside of this context, as noted, the *sāʿah* was rarely used at all. It is therefore unsurprising that the first three medieval Jewish scholars who use these concepts also happen to be the authors of the three seminal medieval Hebrew works on calendrical calculations: Abraham bar Ḥiyya (d. 1136), Abraham ibn Ezra (d. 1167), and Maimonides (d. 1204).

The earliest and (for our purposes) most important of these is Abraham bar Ḥiyya, who lived in Christian Spain but was thoroughly familiar with Arabic scientific works.[109] In his *Sefer ha-ʿIbbur*, one of the seminal works on the intercalation of months, he states:

> "We have seen that [the rabbis] reckon *moladot* (lunar cycles) and *tequfot* (seasons) according to hours and *ḥalaqim* which are identical in duration throughout the year. They did not command us to change the duration of hours [to account for changes in] day and night, nor for winter or summer days—neither in the

[106] For a thorough analysis of his cultural interactions, see David E. Sklare, *Samuel Ben Ḥofni Gaon and His Cultural World: Texts and Studies* (Brill, 1996).
[107] Shmuel ben Ḥofni was aware of al-Qirqisānī; in general, his relationship with the Karaites was less combative than that of his colleague, Saʿadiah Gaon (d. 942); see Sklare, 56.
[108] Cambridge, CUL: T-S G2.98.
[109] Carlebach, *Palaces of Time*, 15.

> reckoning of the *tequfot* nor in the reckoning of the *moladot*. The elegant explanation [is] clear to us: there is no doubt that this entire reckoning is determined according to the days at the equator (*qav ha-shaveh*)."[110]

Bar Ḥiyya's comment is intended to salvage Shmuel ben Ḥofni's problematic remarks regarding the possible start times for each *tequfah*, and it demonstrates knowledge of the two distinct conventional manners in which the term "hour" had been used. In Bar Ḥiyya's understanding, Shmuel ben Ḥofni made his declarations from the perspective of an observer at the equator, where the distinction between equinoctial and seasonal hours becomes moot.[111] Of course, it is not at all clear that Shmuel ben Ḥofni understood the relationship between latitude and day length.

An image from Abraham bar Ḥiyya, Tzurat ha-Aretz, fol. 7r.
Note that the seven climes are defined both in terms of degrees and in terms of day length.

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[110] Abraham bar Ḥiyya, *Sefer ha-ʿIbbur*. Essay 1, Gate 10.

[111] Some medieval geographers believed that the equator was uninhabitable, but Bar Ḥiyya was not among them. See Abraham bar Ḥiyya, *Sefer Tzurat Ha-Aretz* (Offenbach, 1720), fol. 7v.

The two conceptions of the hour are used even more extensively (and explicitly) explored in Hebrew writings by Abraham ibn Ezra, who employs the Arabic-derived terminology *yesharah* and *meʿuvetet* (straight and crooked) to describe the equinoctial and seasonal hour, respectively.[112] The terms do make a minor appearance in his Bible commentaries, but it is only in his astronomical work—most especially *Sefer ha-Moladot* (Book of Lunar Cycles)—that they are used extensively.[113]

Maimonides' calendrical treatise—written at the age of 23 and later incorporated into his legal code, *Mishneh Torah*—does not explicitly differentiate between the two types of hour;[114] in fact, he confusingly states that a day has 24 hours, "twelve in the daytime and twelve in the nighttime,"—implying that he will be using the seasonal hour—before stating that an hour has 1080 *ḥalaqim*, employing a unit designed for astronomical calculation, whose utility relies on all *ḥalaqim* being identical in length.[115] Regardless, it is Maimonides who first posits that the rabbis of Late Antiquity had been using seasonal hours all along. This is made explicit in his Judaeo-Arabic commentary on the Mishnah:[116]

> Know that all of the hours mentioned throughout the Mishnah are only seasonal hours (*sāʿāt zamāniyyah*). "Seasonal" refers to those hours of which there are twelve during the day and likewise at night. Thus the [Mishnah's] saying, "Until three hours," is like saying, "until a quarter of the day has elapsed," whether the

[112] Abraham bar Ḥiyya employs *yesharah* and *ʿaqulah* instead of *yesharah* and *meʿuvetet*, possibly because these terms are both applied to the term *mishpat* (rules) in the Bible (Nehemiah 9:13 and Habakkuk 1:4), although this seems speculative to me; see Sarfatti, *Mathematical Terminology in the Hebrew Scientific Literature of the Middle Ages [Hebrew]*, para. 140.

[113] The term *yesharah* is used in Ibn Ezra's long commentary to Exodus 12:31; see, as well, Ibn Ezra's comment on Ecclesiastes 12:2, which uses the phrase *ha-shaʿot ha-shavot*. The term is also used in the first section of his philosophical treatise, *Yesod Mora*.

[114] Carlebach, *Palaces of Time*, 15–16.

[115] Maimonides, *Mishneh Torah*, Qiddush Ha-Ḥodesh, 6:1.

[116] Commentary on mBerakhot1:2. The statement is reiterated in Maimonides's commentary on mSanhedrin5:3; it is also used in mBerakhot4:1.

day is in the summer or the winter.[117]

In the Hebrew translation of this passage rendered by Judah al-Ḥarīzī (d. 1225), *sāʿāt zamāniyyah* is rendered as *ha-shaʿot ha-zemaniyyot*; this is likely the Hebrew term's first appearance.[118] Elsewhere in his commentary Maimonides also employs the Arabic *sāʿāt al-iʿtidāl* ("equinoctial hours") to clarify that his assessment of the time between dawn and sunrise as, "about an hour and a fifth," does *not* refer to seasonal hours, but is rather an absolute measure. Importantly, this terminology only appears in Maimonides' commentary; his *Mishneh Torah*, which was far more influential, does not make any claims about how the Mishnah's hours are to be understood.[119]

Despite the popularity of all three authors' works, (particularly *Sefer ha-ʿIbbur* and eventually Maimonides' Mishnah commentary), it appears that neither the *zemaniyyot/shavot* (seasonal/equinoctial) terminology nor the *yesharot/meʿuvatot* (straight/crooked) terminology was adopted by anyone other than those with direct exposure to Islamic science. In fact, the concepts do not become widespread until the sixteenth century.[120]

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[117] Literally, "*tequfah* of Tammuz or the *tequfah* of Tevet."

[118] As Joseph Qafiḥ points out, printed editions of Maimonides incorrectly used the term *zemaniyyot* here. This error appears to be quite old; its discovery is noted with a great deal of excitement in an Alexandrian responsum by Yaʿakov Feraji Mahmah (d. 1730); see *Shut Maharif* (Alexandria, 1901), sec. 47, 40r. Note that Maimonides does not make any claims about the use of "hour" in the Talmud. Indeed, his assessment of the time between dawn and sunrise is an absolute value. While incorrect, the statement is reminiscent of Shmuel's claim in bShabbat34b that the duration of twilight is an absolute value. As we shall see, giving approximations in equinoctial hours is entirely in keeping with Maimonides' style.

[119] Note, as well, Maimonides' comment that a person should sleep for eight hours each night; these hours "should be at the end of the night so that there are eight hours from the beginning of one's sleep until sunrise, and he should rise from his bed before sunrise." This rule implies that the night is always *at least* eight hours long and perhaps several more, since it is possible to distinguish going to bed at nightfall from going to bed "at the end of the night."

[120] In outlining the genesis of this terminology, a final caveat is in order. The association between equinoctial hours and mathematical astronomy meant that some equinoctial values were quite precise on paper, even if they could not have been measured in practice. While it is tempting to understand equinoctial hours as being a more precise measure than their seasonal counterparts, this is not inherently the case; in fact, both Maimonides and Ibn Ezra use equinoctial hours in one situation—the time between

The limited adoption of the seasonal/equinoctial terminology boldly illustrates that *scientific* and *technological* advances in timekeeping need not have similar effects. Notwithstanding the new availability of useful terminology, lack of development in timekeeping technology meant that most people still could not distinguish seasonal from equinoctial hours; as a result, the terminology remained the purview of astronomers. The adoption of these distinctions in non-astronomical Jewish texts would not take place for several centuries, as will be discussed in the following chapters.[121]

Hour approximations: a new development

From what we have seen so far, advances in science did not radically change how the Jews spoke about time. Nonetheless, as will be seen below, medieval Jewish texts in Islamicate cultures—both in Hebrew and Judaeo-Arabic—employ timekeeping terminology as *approximation* tools with noticeably greater frequency than had their Late Antique predecessors. The reason for this is not entirely clear since, as we have seen, the hour did not retain its important in Arabic parlance.

The use of these terms seems to suggest that people were now estimating time in terms of hours even in situations which did not lend themselves to precise measurement. The strongest evidence for this point comes from an unlikely source: a thir-

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dawn and sunrise—where a seasonal hour measure would have been more appropriate, as any astronomer would have known. It is possible, then, that equinoctial hours are sometimes invoked not because they are technically correct but because they convey the idea that the duration being measured is (practically speaking) static, even if (theoretically speaking) it is not. Some later rabbis were apparently confused by these positions; see Hayim Pinhas Benish, *Sefer Ha-Zemanim Ba-Halakhah* (Bnei Brak, Israel, 1996), 1:159–160.

[121] A few modern scholars have adopted the term "rabbinic hours" (*shaʿot derabanan*) as a way of referring to seasonal hours. This usage is confusing, as the phrase *shaʿot derabanan*, found at bPesaḥim2b, does it refer to a particular type of hour but is instead the expression of a principle, namely, the position that any legal changes which come into effect during the day (as opposed to end of a day) must have been instituted by the rabbis and not by the Bible itself.

teenth-century Cairo Genizah fragment of a letter from man to his sister in which the man describes the experience of being imprisoned and tortured. Amid its gruesome details is a description of a form of torture in which the man was put into some kind of press. The man writes, "they fastened the press to my feet, and they did not stop pressing my feet for *half an hour* until the bone started to show."[122]

The writer, who must have been in excruciating pain, would hardly have had the wherewithal to track the duration of his torture by some external means; he was either giving his internal sense of the passage of time, or was repeating information he knew about how long the torture was "supposed" to have lasted. If the former, we have evidence that the half hour was used as a mental category. If the latter, we have evidence of a state program which required the ability to reckon time to at least the half hour.[123]

Far from being a linguistic curiosity, the growing interest in the hour as a universal metric led medieval Jewish scholars to translate unconventional terms for periods of time into standard units. Below I list some critical examples.

Hour-related metrics in applied Jewish law

How long must Ḥanukkah candles remain lit?

The obligation to light candles to mark Ḥanukkah appears in the Mishnah, but most of the rules regarding the candles are only fleshed out in two *baraitot* cited in the Talmud at bShabbat21b. Both of these indicate that candles should be lit from sunset until

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[122] T-S 10J7.4, 2v lines 9–10. Emphasis mine. This translation was published in: Esther-Miriam Wagner, "'Only Death Remains for Him', T-S 10J7.4," n.d., http://www.lib.cam.ac.uk/Taylor-Schechter/fotm/may-2011/index.html.
[123] For an example of the latter, see William Thomas Walsh, *Isabella of Spain* (London: Sheed & Ward, 1935), 240. See also the anonymous vision described in Elizabeth Spearing, ed., *Medieval Writings on Female Spirituality* (Penguin, 2002), 213.

some sort of marketplace activity has ceased, whether general market activity or the activity of people from Tadmor (Palmyra). This duration, which is not a fixed measure, has a straightforward rationale: given the general lack of street lighting in most cities during this period, this was the time at which the candles—which were supposed to be visible to the public—were most likely to be noticed.[124]

In its elaboration of the rule, the Talmud ponders contingency plans if one is unable to light at nightfall, or if the lights are prematurely extinguished. One anonymous comment suggests that a person must prepare enough oil for the stipulated duration, even if the candle is not actually lit for the entire time. Although the Talmud understands that the *baraitot* were mandating a specific duration, it makes no attempt to translate that duration into absolute or universally comprehensible terms.

The first evidence of change appears in a gloss of difficult Talmudic terms attributed to the ninth century scholar Natronai Gaon. In explaining the relevance of the Tadmoreans in the marketplace, Natronai explains that these individuals linger "an hour or half an hour" (*shiʿur shaʿah o ḥatzi shaʿah*).[125] The same language is employed in the code/gloss of Isaac al-Fāsī (d. 1103), who quotes the rule and then adds that the people of Tadmor linger in the market "about half an hour" (*kemo ḥatzi shaʿah*) after sunset.[126] A similar approximation is adopted by Maimonides, whose *Mishneh Torah* defines the time between sunset and the cessation of market activity as "about half an hour or more."[127]

Natronai, al-Fāsī, and Maimonides all engage in approximation without assigning the approximation normative value. Their remarks indicate a general sense of comfort

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[124] For references, see note 73 in the previous chapter.
[125] Bodl. MS heb. d.48/11 - MS heb. d.48/12.
[126] al-Fāsī, *Hilkhot ha-Rif*, Shabbat9a–b.
[127] *Hilkhot Megillah u-Ḥanukkah* 4:5. Note that Maimonides seems to disagree with al-Fāsī regarding which *baraita* has normative import; nonetheless, they arrive at the same half-hour approximation.

with the half hour as unit of measure. Still, all three provide their approximations together with Talmud's rule about Tadmoreans. By contrast, "half an hour" is as given direct normative value in an undated Judaeo-Arabic siddur fragment:

> The Ḥanukkah candles [should be lit] with the setting of the sun, neither earlier nor later. And the amount of oil which is burned in the candle is as much as will burn in half an hour (*niṣf sāʿah*) after the setting of the sun.[128]

While there was general agreement about how long the candles should be lit in practice, it is only this vernacular fragment—perhaps written for those without Hebrew reading facility, or perhaps simply written with an eye towards practical usefulness—which separates the approximations from the original rule.

How long before a flour-water mixture leavens?

In modern times one of the most frequent uses of the clock in the household is for cooking. It is almost inconceivable to imagine a recipe book which did not indicate baking times and the like. In the ancient and medieval worlds, however, the intervals of time for the different stages of the cooking process were simply too small for easy measurement, a fact which can be seen in the cookbooks of the time.

One of the first known cookbooks, written in the first century CE and published as *De re conquinaria*, indicates no durations shorter than "overnight."[129] The earliest known Islamic cookbook, by the tenth century author Ibn Sayyār al-Warrāq, frequently calls for items to be cooked "as long as they need." When a more precise measure is needed the term *sāʿah* is often used, but the term is modified with adjectives so as to mean any-

[128] New York, JTS: ENA 2888.54. The orthography is problematic in a number of places; my translation takes this into account.
[129] This is the result of a search in Joseph Dommers Vehling, *Apicius: Cooking and Dining in Imperial Rome* (New York: Dover, n.d.).

thing from "briefly" (*sāʿah laḥzah*) to "around an hour" (*sāʿah suwayʿah*) to a "technical" hour (*sāʿah ṣāliḥah*).[130] Finally—and most germane to our discussion—there are some medieval European cookbooks which describe the length of various steps in terms of how long it take to walk various distances.[131]

Kitchen timekeeping provides the context for understand ancient and medieval descriptions of the time it takes for a flour/water mixture to become leavened. Defining this duration is very important, since leavened bread (*ḥametz*) is prohibited on Passover. The Talmud describes the period as "*shiʿur mil*," the amount of time it takes for a person to walk a Roman mile.[132]

No further attempt to define this measure was made until the advent of Islam. Maimonides, in his commentary on mPesaḥim3:2, explains that "the measure [for leavening] is long enough for a person to walk one *mil* at an average pace, which is two-fifths of an equal hour (*min sāʿāt al-istiwāʾ*)." This definition, while reasonable, is noteworthy for two reasons. First, the use of fractions instead of the available smaller units (such as 24 minutes, 6 *ḥayyil*, or 432 *ḥalaqim*) confirms that the hour is still the smallest time unit for practical purposes. Second, Maimonides' oddly specific definition—he does not say *approximately* two-fifths of an hour—requires explanation. It is most likely that the precision of this measure results from Maimonides' attempt to understand

[130] Nawal Nasrallah, *Annals of the Caliphs' Kitchen: Ibn Sayyār Al-Warrāq's Tenth-Century Baghdadi Cookbook* (Brill, 2007), 45. Christian European use of time measurements in cookbooks will be treated in chapter 5.
[131] *Ein Buch von Guter Spise*, 1844, n. 14. (The text can be found at http://www.medievalcookery.com/etexts/buch.html). See also Bridget Ann Henisch, *Fast and Feast: Food in Medieval Society* (Pennsylvania State University Press, 1976), 144.
[132] bPesaḥim46a. The Talmud actually defines the duration as the time it takes to walk from Migdal Nunia to Tiberias. Problematically, the Palestinian Talmud lists the duration as the time it takes to walk between these places as four *mil*. Furthermore, empirical measurements and cotemporaneous geography texts contradict both positions. On possible solutions to these differences of opinion, see Efraim Vaynman, "Chametz in Eighteen Minutes? An Inquiry into the Correct Text of the Talmud," *Hakirah* 18 (2014): 159–70.

"*shiʿur mil*" in light of another passage involving *mil* units, in bPesaḥim93b. The latter reads as follows:

> Rabbi Yoḥanan said: How far can a person walk in a day? Ten parasangs [i.e. 40 *mil*]. From dawn to sunrise: five *mil*. From sunset until the emergence of stars: five *mil*. There remain to him 30 [*mil*]: 15 from morning until midday and 15 from midday to evening.

A little arithmetic takes us the rest of the way. If one can traverse 30 *mil* during the twelve hours between morning and evening, one can traverse 2.5 *mil* in an hour, or one *mil* in two-fifths of an hour.[133] Thus, Maimonides' definition is precise because it is based on a reconciliation of texts rather than empirical observation.

A second definition is implied by a very small Judaeo-Arabic Genizah fragment, perhaps from a practical guide to the laws of Passover:

> If he kneaded dough and some hindrance prevented him from baking it, he can suppress it (*yubaṭṭilaha*, i.e. prevent it from becoming leaven) until a third of an hour (*thulth sāʿah*) has passed.[134]

Since it would not have been practical to distinguish two-fifths of an hour from one-third of an hour, we can say that this guideline accords with Maimonides' theoretical calculation, although it does not necessarily stem from Maimonides. As in the previous example, this fragment provides only the approximation, eliding the reasoning and the concept of *shiʿur mil* itself.

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[133] It is also possible to take 40 *mil* as the relevant value, in which case one *mil* can be traversed in eighteen minutes. The reconciliation of these verses is somewhat problematic, since the amount of time one can travel in a single day surely changes with the length of the hour. Maimonides, who resided at a relatively moderate latitude, does not address this; such issues only begin to emerge among the rabbis of Ashkenaz, as we will see in the next chapter. Cf. *Mishneh Torah*, Hilkhot Terumot 7:2, which suggests that Maimonides' interpretation of *shiʿur mil* was not consistently applied.

[134] Oxford: MS heb. e.108/60. This appears to be referring to dough that was kneaded on Passover itself.

How long must one wait between eating meat and milk?

The Bible contains three prohibitions against cooking a kid in its mother's milk.[135] In rabbinic law, these statements were understood as three related prohibitions against consuming, cooking, or benefiting from combinations of meat and milk. Elaborating on the rule that meat and milk cannot be eaten together, the Babylonian Talmud cites two positions on precisely how much time must elapse after eating foods from one category before eating foods from the other.

> Rav Ḥisda said, "One who eats meat is forbidden to eat cheese." [...]
> Mar Uqva said, "In comparison to my father in this matter, I am vinegar son of wine, for when my father ate meat, he would not eat cheese until that same time the next day. I, however, do not eat [cheese] at this meal, but eat it at the next meal."[136]

In Mar Uqva's understanding, waiting between consuming meat and dairy is a virtuous activity; the longer one waits, the better. His own personal practice is not a fixed duration; even if it were, he does not state that it is the minimum duration allowed by the law.

Early medieval interpretations of this text saw Mar Uqva's position as allowing for a lot of flexibility. Neither the legal compendium *Halakhot Gedolot* nor Hai Gaon thought a mandatory waiting period was necessary at all; instead, they simply require that one rinse one's mouth between courses.[137]

Why this lenient position became defunct is unclear. It is possible that the tenth century development of Karaite law—which did not recognize the rabbinic interpreta-

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[135] Exodus 23:19, 34:26, and Deuteronomy 14:21.
[136] bḤullin105a.
[137] *Halakhot Gedolot*, Hilkhot Berakhot, chapter 9, p. 76. Hai Gaon's position is cited in *Ḥidushei ha-Rashba*, Ḥullin 105a.

tion of the biblical prohibition—led to a Rabbanite desire for a distinct and conspicuous practice.[138] Regardless of the reason, from the eleventh century onward, Mar Uqva's statement was understood to be a requirement that some time elapse between consuming one food and the other.

Initially, the amount of time that must elapse was not specified, other than to say that it is the time interval between meals. Rabbeinu Ḥananel (d. 1050), the first to put forward this position, is quoted as saying:

> We do not find anyone who allows eating cheese after meat within less than 24 hours (*me-ʿet le-ʿet*) other than Mar Uqva, who ate meat at one meal and cheese at the next. [Mar Uqva] said about himself, "In this matter, I am vinegar son of wine." Thus, it is impossible to permit [a waiting period] less than this [i.e. the practice of Mar Uqva].[139]

The North African scholar Rabbi Yitzḥaq al-Fāsī (d. 1103) gives a similar interpretation in his gloss on the Talmudic passage:

> One is not permitted to eat cheese after meat until one waits the amount of time necessary for another meal.[140]

Neither Rabbeinu Ḥananel nor al-Fāsī indicate whether they are referring to the time that people *normally* wait between meals or the time that an individual *actually* waits on any given day. By the end of the twelfth century, authorities had reached consensus on the former interpretation, and the standard time between meals was given a shorthand: six hours.

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[138] On this theory, see Tzvi H. Adams, "Waiting Six Hours for Dairy- A Rabbanite Response to Qaraism," The Seforim Blog, 2015, http://seforim.blogspot.com/2015/08/waiting-six-hours-for-dairy-rabbanite.html.
[139] Cited in *Ḥidushei ha-Rashba*, Ḥullin 105a
[140] Al-Fāsī, *Hilkhot ha-Rif*, Ḥullin 37a–b. It is also possible that al-Fāsī is saying that one must wait until one is able to *prepare* another meal.

The six-hour shorthand appears in three late-twelfth century texts. In his response to al-Fāsī's gloss, Rabbi Zeraḥiah ha-Levi of Lunel (d. 1186) states that one should wait "six hours, [which is] the amount of waiting from meal to meal."[141] Similarly, the Provençal scholar Rabbi Isaac ben Abba Mari (d. ca. 1193) states in his *Sefer ha-ʿIttur* that the waiting period cannot be shortened by rinsing one's mouth: "Even with rinsing [the waiting period is] six hours, in accordance with the amount of time that people drink water from one meal to the next."[142] Finally, Maimonides states in his *Mishneh Torah*: "One who eats meat first...cannot have milk afterward until he waits between [the eating of meat and milk] enough time for a new meal. This is around six hours, because of the meat between one's teeth, which is not removed through rinsing."[143]

While all three sources indicate that, practically speaking, a six-hour wait is mandatory, they are clear that this interval is only meaningful insofar as it is an agreed-upon approximation of the time between meals; it is an implementation of the rule, not the rule itself. Maimonides makes this clear by indicating that the six-hour interval is an estimation, while the two other authorities first indicate that the rule is six hours and then link this interval to normal eating patterns. Despite the difference in emphasis, all three opinions are in practice identical: since, as we have already seen, the two daily meals—one mid-morning and one in mid-afternoon—were central to the way in which most people kept track of time, the *only* six-hour interval that could have been reliably reckoned was the period between the two daily meals. Instead, all three rulings should simply be understood as reactions against the earlier position that a simple mouth rinse is sufficient.

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141 *Sefer ha-Meʿor ha-Qatan*, Ḥullin 37a.
142 *Sefer ha-ʿIttur, Shaʿar Aleph*, Hekhsher ha-Basar 13b.
143 *Mishneh Torah*, Hilkhot Ma'akhalot Asurot 9:28.

How long before sunrise should one begin praying?

According to mBerakhot1:2, the morning *shema*ʿ prayer can be said once there is sufficient light, even though it is not yet sunrise; the ʿ*amidah* prayer, by contrast, cannot be said before sunrise. Both the Babylonian and Palestinian Talmuds indicate that it is praiseworthy to begin the ʿ*amidah* immediately after concluding the *shema*ʿ;[144] in addition, it is praiseworthy to pray as early as possible. Since the *shema*ʿ takes only a few minutes to recite, this means that the ideal time to begin the *shema*ʿ is just before sunrise, such that it is concluded just as the sun rises.

Exactly how long before sunrise one should say the *shema*ʿ is not initially indicated. Maimonides, however, species that the correct time is "approximately one tenth of an hour."[145] I am aware of no other instances of this quantity.

III. Karaite perspectives

Despite the durability of the Egyptian idea of the twelve-hour day and its nominal adoption by virtually every society in which Jews resided, that system, like the seven day week, has never been anything other than a social convention; it is suggested neither by human anatomy (as is the base-ten numbering system) nor observation of the heavens (as are the length of the month and the solar year). Alternate systems, while nowhere near as popular, have always existed; indeed, the author of the Aramaic *Astronomical Book* appears to have adopted a day and night of fourteen hours apiece.[146]

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144 bBerakhot9b and yBerakhot1:1.
145 *Mishneh Torah*, Hilkhot Qeriat Shema 1:11. In some manuscripts, the phrase עישור שעה is changed to שיעור שעה ("the length of an hour"), which is far longer than it could possible take to recite the *shema*ʿ.
146 See page 24, above.

Having been born in the Hellenistic milieu, rabbinic culture accepted the twelve-hour day as an unquestionable assumption and never entertained alternate systems, even when a much more primitive timekeeping system was used in practice (as seen in the last chapter). This twelve-hour day was carried forward seamlessly by the Rabbanites, despite Islamicate culture's promotion of shadow-based timekeeping, its marginalization of both the twelve-hour day and the concept of "hour" itself, and its promotion of shadow-based timekeeping.[147]

Karaites, by contrast, explicitly rejected the rabbinic tradition in which the twelve-hour day had first become embedded and instead chose to construct Jewish law on the basis of the Bible itself, a document which does not contain the concept of a technical hour. As a result of this ideology, Karaite legal texts provide us with one of the few opportunities to examine what Jewish law might have looked like in the absence of an inherited Hellenistic system.[148]

The most notable aspect of Karaite timekeeping is the fact that, unlike Rabbanite law, Karaite law was largely unconcerned with reckoning short durations or the precise time of day or short durations.[149] In some instances this was because the relevant areas of law were altogether absent from Karaite law; Ḥanukkah candles, for example, were

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[147] In the next chapter we shall see that rabbis in Christian Europe did precisely the same thing, even though there is evidence that the rabbis themselves did not find this to be their "natural" way of keeping track of time.

[148] Classifying Karaites is notoriously difficult; Anan, who in the Rabbanite imagination was the founder of Karaism, was considered the leader of a separate sect by many later Karaites. (On this see Moshe Gil, "The Origin of the Karaites," in *Karaite Judaism: A Guide to Its History and Literary Sources*, ed. Meira Polliack (Brill, 2003), 73–113.) In this section, for purposes of convenience, I am using "Karaite" to refer to all figures who ideologically oppose the Rabbanite and Late Antique rabbinic tradition.

[149] In constructing this section, Daniel Lasker both confirmed the absence of a Karaite interest in timekeeping but suggested that this may reflect a broader Karaite rejection with measurements of any kind; indeed, Aaron ben Elijah's *Gan Eden*, a key Karaite word, at one point refers to Rabbanite as *ba'alei ha-shiʿurim*, perhaps best translated as, "the people of measurements." While it is true that the proscriptions of Karaite law are far less granular than their Rabbanite counterparts, there is at least *some* regimentation of the day, as we shall see. Furthermore, we have already seen the difficulty of tracking time meant that it was not always considered "measuring." See above, page 101, note 161.

not lit because Ḥanukkah was not observed.[150] By the same token, Karaite law did not contain any statements about the waiting period between meat and milk because the biblical prohibition upon which the rabbinic law is based was understood by Karaites to forbid only the cooking of a kid in its mother's milk.[151]

However, even where the underlying Karaite and Rabbanite laws did coincide, Karaite law did not demand the same level of rigorous time-reckoning. The rabbinic ruling concerning the leavening time of a flour-water mixture does not appear in Karaite law. Similarly, the sequence of events on Passover Eve in Karaite law was not coordinated to the degree set forth in both tannaitic and amoraic sources; there is simply the expectation that the Passover sacrifice be brought, and any remaining unleavened bread must be burned.

It is only on issues of prayer that Karaite law made some attempt to subdivide the day, but even these subdivisions lacked the sophistication of Rabbanite regulations. On the basis of Psalms 119:164 ("Seven times a day I praise You for Your just laws") some Karaites seem to have advocated for seven prayer services per day; Yehudah Hadassi, the Karaite author of *Eshkol ha-Kofer*, lists these as early morning (*shaḥarit*), morning (*boqer*), midday (*tzaharayim*), evening (*ʿerev*) and the three night watches.[152] Others ad-

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[150] See, for example, al-Qirqisānī's statement (cited in Salo W Baron, *A Social and Religious History of the Jews: The High Middle Ages, 500–1200* (Columbia University Press, 1952), 407 n. 55.): "What is more strange than a person pronouncing a blessing over a Sabbath-Eve lamp and saying in the blessing that God commanded it? Likewise, over the lamp of Ḥanukkah?")

[151] On this point Karaites are in universal agreement. See, for example: Albert Harkavy, *Liḳutei Ḳadmoniyot* (Saint Petersburg, 1903), opp. 151–152. and *Kitāb Al-Anwār Wal-Marāqib: Code of Karaite Law* (Alexander Kohut Memorial Foundation, 1939), vol. XII 25:4. The ruling is codified in Judah Hadassi, *Eshkol Ha-Kofer* (Yevpatoria, 1836), fol. 308.

[152] Hadassi, *Eshkol Ha-Kofer*, fols. 10b–c. See, as well, Percy Selvin Goldberg, *Karaite Liturgy and Its Relation to Synagogue Worship* (Manchester University Press, 1957), 1.

vocated the recitation of six prayers (three during the day and three at night),[153] and still others report ten daily prayers. (It is not clear precisely when these would have been said.)[154] Most Karaites, however, concurred with the rabbis that the prayers should correspond to the daily sacrifices,[155] and, as result, concluded that at least two daily prayers were necessary. However, whereas the Rabbanite morning prayer could be said until either the fourth or sixth hour, Karaites expected the morning and evening prayers to be said during their respective twilights.[156] This timing, which conspicuously resembles the timing of the Muslim *fajr* and *shafaq* prayers, respectively, obviated the need to subdivide the day.[157]

Even the Karaite afternoon prayer—which, like the Rabbanite *maʿariv*, had a somewhat liminal status[158]—was not defined in terms of the twelve-hour day; indeed, it did not actually need to be prayed in the afternoon. While al-Qirqisānī suggests that the prayer be said at the time when shepherds take their mid-day nap, any time during the second or third quarter of the day is fine.[159] This window of opportunity does abide by a quadripartite division of the day—which, as seen in the designs of al-Jazarī, was preva-

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[153] Goldberg, *Karaite Liturgy and Its Relation to Synagogue Worship*, 1. Yoram Erder, on the basis of Genizah evidence (CUL T-S 10 G3, f. 9b) argues that Daniel al-Qūmisī advocated for six daily prayers. However, al-Qūmisī's choice of language might simply be poetic.
[154] Israel Friedlaender, "Jewish-Arabic Studies," *Jewish Quarterly Review* 3, no. 2 (1912): 298.
[155] Yoram Erder, "Daily Prayer in Karaite Halakha in Light of the Times of Islamic Prayers," *Revue Des Études Juives* 153, no. 1–2 (1994): 11–12.
[156] Erder, 16–17. These prayer times were codified in the *Seder Tefillot* (Book of Prayers) of Aaron ben Joseph (d. ca. 1320). It is possible that earlier Karaites were *more* flexible with the timing of the prayers; see Goldberg, *Karaite Liturgy and Its Relation to Synagogue Worship*, 4 n. 3.
[157] See Q11:114, 20:130 and Böwering, "Prayer," 223.
[158] bBerakhot26a.
[159] See Leon Nemoy, "Studies in the History of the Early Karaite Liturgy: The Liturgy of Al-Qirqisānī," in *Studies in Jewish Bibliography, History and Literature in Honour of I. Edward Kiev*, ed. C. Berlin (Ktav, 1971), 310.

lent in the Islamic world—but it adopts neither the twelve-hour day nor the universal rabbinic determination that the midday prayer begin after noon.[160]

The relative laxity around timekeeping in Karaite law should be understood as both a rejection of the rabbinic law and a faithful continuation of biblical timekeeping language; as described in the previous chapter, the Bible expresses little interest in creating subdivisions of the day.

With the decline of Karaite scholarship, this distinctive feature of Karaite law became diminished. Later Karaite writings, especially those from Byzantium, began to adopt some aspects of Rabbanite law, as well as rabbinic legal language.[161] Thus, Judah Hadassi's twelfth-century legal compendium *Eshkol ha-Kofer* already makes reference to *ḥalaqim*, a decidedly rabbinic unit of measurement;[162] it further asserts that the Passover sacrifice should be slaughtered at the seventh hour.[163]

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The development of Islamic astronomy undoubtedly had a major impact on the way in which Jews discussed the passage of time. Aside from the development of important works on the calendar, Marina Rustow has suggested that Abbasid advances in astronomy were the impetus for the development of an independent Babylonian calendar and for the subsequent major political disagreements between Babylonian and Palestinian

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[160] The division of the day into quarters may need no explanation. Alternatively, it is possible that al-Qirqisānī drew on Nehemiah 9:3, which describes a Torah reading which continues for "a quarter of the day."
[161] For a review of this process, see Daniel J Lasker, "Byzantine Karaite Thought," in *Karaite Judaism: A Guide to Its History and Literary Sources* (Brill, 2003), 505–528.
[162] Hadassi, *Eshkol Ha-Kofer*, 53c, 78a.
[163] Ibid., 78d; see also 92d.

rabbinic authorities, one of which reached a turning point in the Ben Meir controversy of 921–22 and subsequently continued for more than two centuries.[164]

However, Islamic science exerted a far smaller effect on timekeeping within the day itself. While Jewish scholars with a direct interest in astronomy did adopt some scientific vocabulary—most notably the acknowledgement of a distinction between seasonal and equinoctial hours—this vocabulary was not widely adopted, despite its utility in understanding older rabbinic texts. Indeed, the need to clarify the distinction was itself predicated on the use of the Roman day; Karaites, who never adopted the twelve-hour day in the first place, had no need for it. The most substantial practical change of all—the use of the "hour" as a colloquial way of estimating periods of time—is not clearly linked to scientific developments; in fact, consistent use of the hour as a term of *estimation* indicates that it did not derive from the domain of precise astronomical terminology.

Medieval Jewish texts written in Islamic lands pointedly illustrate that the need to distinguish between the history of science and the history of technology as they pertain to Jewish history. Islam's relatively major effect on Jewish timekeeping terminology but minor effect on practical timekeeping constitutes a useful foil for the case of the mechanical clock, a device which represented a major technological leap forward even though it was not preceded by a major scientific breakthrough. While scientific developments could and did impact Jewish conceptions of timekeeping, it was only with the development of a new technology that timekeeping would undergo a radical shift.

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[164] On the influence of Islamic astronomy, see Marina Rustow, *Heresy and the Politics of Community: The Jews of the Fatimid Caliphate* (Cornell University Press, 2008), 18. On the controversy's long tail, see Stern and Rustow, "The Jewish Calendar Controversy of 921–922: Reconstructing the Manuscripts and Their Transmission History."

Chapter 4: Timekeeping in Medieval Christian Europe

Before the Mechanical Clock

At its most sophisticated, the timekeeping discourse that developed in Rabbanite literature represented a synthesis of Roman civic timekeeping terminology and Islamic science made possible by Jews' comprehension of Arabic and a high level of interreligious knowledge exchange, especially in the area of astronomy.

The Christian Europe timekeeping discourse was different in many respects. First, rabbinic access to astronomical knowledge was significantly limited by Christian Europe's own lack of sophisticated astronomical knowledge. While rabbis in Christian Europe continued to develop those notions of timekeeping originally developed in Late Antique rabbinic literature and through a select number of translated works and transplants from Islamic lands, Jews in Christian Europe never produced works of the caliber of Bar Ḥiyya, Ibn Ezra, or Maimonides. As a result, the rabbinic understanding of *theoretical* timekeeping represents a step back from what had been achieved under medieval Islamic rule.

Second, the availability of complex timekeeping devices was significantly diminished relative to the Islamic world in all places other than churches and monasteries. While these devices had not always been very accurate and were often simply ornamental, their basic availability resulted in their appearance in both rabbinic and Rabbanite texts. Jews writing in Christian Europe, on the other hand, tend not to speak of these devices. In addition, there is some evidence that the Hellenistic twelve-hour day was itself no longer in active use, although this is difficult to confirm, since the nature of medieval Ashkenazic legal literature means that much time-related languages is borrowed verbatim from early rabbinic texts.

In many respects, then, this chapter is a study of things that are absent. No rabbinic milieu was less conducive for discussion of timekeeping than that of medieval Christian Europe. Understanding the ways in which the discourse around timekeeping did *not* develop will be critical for understanding the impact of the mechanical clock that was to come.

I. The state of timekeeping in medieval Christian Europe

Northern Europe: geographical considerations

Three accidents of geography—two detrimental and one advantageous—likely played a role in the development of both Jewish and Christian timekeeping discourse in Europe in general and northern Europe in particular. First, northern Europe is quite cloudy. In Jerusalem and Cairo the sun shines for more than 70% of daylight hours, whereas in Mainz and London the figure is below 40%.[1] In this respect the rabbis of Christian Europe would have been at a disadvantage compared to the rabbinic groups we have discussed thus far. Not only had timekeeping devices not improved, but the effectiveness of the sundial was radically diminished.[2] Geography also impacted the other major timekeeping tool of the age, although for an entirely different reason: the

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[1] These figures are calculated using data from the World Meteorological Organization and the National Climatic Data Center, located at data.un.org. I have used annual sunshine duration and divided it by 4,380 hours, which the theoretical maximum number of daylight hours per year for any point on earth.

[2] Jacob Katz has argued that the cloudiness of the sky meant that time was not measured at all; see "Alterations in the Time of the Evening Service (Ma'ariv): An Example of the Interrelationship between Religion Customs and Their Social Background (Hebrew)," in *Divine Law in Human Hands: Case Studies in Halakhic Flexibility* (Jerusalem: Magnes Press, 1998), 101. This claim is highly exaggerated, as we shall see below.

climate in northern Europe is cold and water-clocks cannot operate at subzero temperatures. In practice, the cold weather would have meant that the water-clock was not a reliable timekeeper for more than half the year; furthermore, it would have been least reliable during the months in which nights were longest and the need greatest, since people were likely to be awake for larger portions of these long nights.[3]

Despite these drawbacks, which rendered the two most important timekeeping devices of the ancient and early medieval world less effective, their relatively northerly location meant the rabbis of northern Europe, unlike their counterparts in the Middle East and North Africa, were forced to treat the length of the day (or night) as essentially unstable. None of the rabbinic centers of Late Antiquity were located north of the 34th parallel north; below this parallel, the difference between the maximum and minimum daylight duration never exceeds 4.5 hours. (The Islamic conquest of Spain brought Jews somewhat farther north; Barcelona is above the 41st northern parallel.[4]) By contrast, the rabbis of both Latin and Byzantine Christian Europe never wrote *south* of the 38th parallel north and were frequently situated much farther north: Worms, Mainz, and Cologne—three of the most important centers of rabbinic activity in the period under discussion—are all situated around the 50th parallel north. At these latitudes

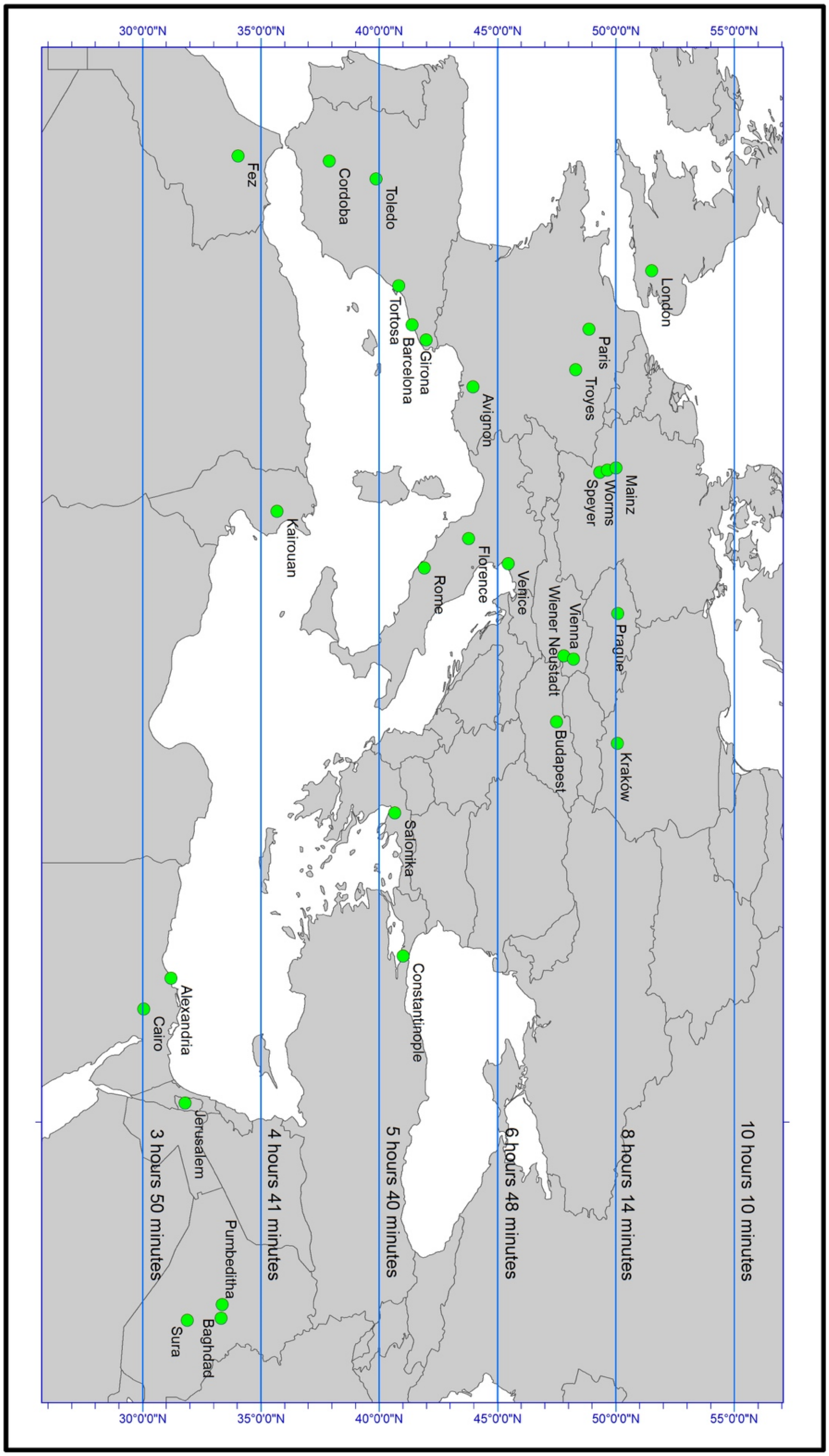
[3] The replacement of water with sand would have solved these problems, but the sandglass did not emerge until *after* the invention of the mechanical clock, sometime in the middle of the fourteenth century. The reasons for its slow development are unclear but may have had to do with the difficulty of constructing appropriately shaped glass vessels and/or technical problems of fluid dynamics which made the movement of sand less predictable or easy to interpret. For a careful study of these problems see R. T. Balmer, "The Invention of the Sand Clock," *Endeavour* 3, no. 3 (1979): 118–22.

[4] Islamic scholars would later climb somewhat farther north, peaking at Ottoman Empire's failed 1529 Siege of Vienna, a city located above the 48th parallel. A contemporary cleric had suggested that those praying at extreme latitudes should simply adopt the prayer times of the northernmost point historically under Islamic control, i.e. somewhere in Hungary. See Karim Meziane and Nidhal Guessoum, "The Determination of Islamic Fasting and Prayer Times at High-Latitude Locations: Historical Review and New Astronomical Solutions," *Archaeoastronomy* 22 (2009): 99–101.

the difference between winter and summer day length is more than eight hours; every year, the length of the daylight essentially doubles and is halved again.[5]

This idea is illustrated in the map below, which indicates major centers of rabbinic culture in Late Antiquity and the medieval period, with the difference between the length of the shortest and longest day of the year indicated at five-degree intervals. As can be seen, the major centers of Late Antiquity—in Jerusalem, elsewhere in Palestine, and in the academies of Babylonia—lie farther south than almost any of the later centers of activity, where daylight variation is small. By contrast, many of the centers of activity discussed in this chapter—in Germany and northern France—are quite far north, concentrated around the 50th parallel north.

[5] These calculations were made using the calculator at http://www.dawnsun.net/astro/suncalc/.



Map of major centers of rabbinic activity in Late Antiquity and the medieval period. The difference between the length of day on the summer and winter solstice is indicated.

This latitudinal stratification between medieval Islamic and medieval Christian civilization led to a curious effect. As we have seen, Islamic astronomers were well aware of the changes in the length of the day, but they did not consider what this might mean for prayer times at extreme latitudes. A few rare Arabic travelogues of the far north make this legal lacuna more conspicuous; they highlight that the law did not provide guidance for these latitudes, even though Muslims living at these latitudes sometimes struggled to follow the law's strictures. The author of one such travelogue noted (correctly) that, north of a certain latitude, day and night will each last for six months; another traveler describes meeting a muezzin (person charged with reciting the call to prayer) who claimed that he had not slept for a month out of fear that he would not wake up before it was time to signal the morning prayer.[6]

While there certainly were Muslims who experienced the extreme fluctuations of northerly latitudes, medieval Islamic scholarship was not produced at these latitudes. As a result, even the most sophisticated medieval astronomers did not take into account the possibility of living in northern regions when calculating prayer times; indeed, Islamic legal scholars did not deliberate on the possibility of prayer at extreme latitudes until well into the twentieth century.[7]

[6] This passage by al-Masʿūdī (d. 956) is quoted in Ibn Fadlān, *Ibn Fadlan and the Land of Darkness: Arab Travellers in the Far North* (Penguin, 2012), chap. 19. The second story is told by Ibn Fadlān (fl. early tenth century); Aḥmad ibn Faḍlān, *Mission to the Volga*, ed. James E. Montgomery (New York University Press, 2017), para. 49.

[7] Meziane and Guessoum, "The Determination of Islamic Fasting and Prayer Times at High-Latitude Locations: Historical Review and New Astronomical Solutions," 101.

Case study: the climes

The difference between medieval European and medieval Islamic attitudes towards seasonal fluctuations in daylight is nowhere more apparent than in their understandings of the relationship between the length of the day and geographic latitude. Islamic science adopted from Ptolemy both an awareness of this relationship and the theory of "climes" (*īqlīm*, pl. *aqālīm*), in which the habitable world is divided into some number of latitudinal bands, with the central Islamic territories always occupying the temperate middle band and the environment becoming increasingly inhospitable as one travels either north or south.[8] Importantly, the climes were only meant to describe habitable land; they did not cover the entire globe or even the entire northern hemisphere.

On the one hand, Islamic treatments of the climes show a clear understanding of the relationship between latitude and day length. In the common seven-clime rubric, a popular Islamic rule of thumb was that the day length increased by an hour[9] each time one travelled from a clime to its northern neighbor.[10] On the other hand, the lack of empirical knowledge to back up the theory of climes is readily apparent in theoretical treatments of the far north; in these cases, predictions of habitability radically diverged from reality. For example, the polymath al-Khwārizmī (d. ca. 850) writes that the world was in fact not habitable north of the 48th parallel north, a realm which in fact includes

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[8] A. Miquel, "Iḳlīm," in *Encyclopaedia of Islam, Second Edition*, n.d.; see also J. T. Olsson, "The World in Arab Eyes: A Reassessment of the Climes in Medieval Islamic Scholarship," *Bulletin of the School of Oriental and African Studies* 77, no. 3 (2014): 487–508.

[9] Whether a seasonal or equinoctial hour is meant is not indicated. This is probably the "naïve" hour, discussed previously. Indeed, the fact that it is not specified is itself quite typical of scholarship produced at moderate latitudes.

[10] Emily Burnham, "The Edges of the Earth: An Epistemology of the Unknown in Arabic Geographies from the 5/11th–7/13th Centuries" (New York University, 2012), 95.

many major European cities, such as London.[11] The philosopher Ibn Sīna (d. 1037) indicated that the only inhabitable part of the world lies between the equator and the halfway point to the North Pole, the other three quarters being hostile to human life.[12] Other geographers were confused as to how the sun behaved at extreme northerly latitudes. The eleventh-century al-Bakrī, for example, suggested that the sun might not shine at all north of the most northerly clime.[13] Latitudes south of the equator were just as poorly understood; the southern hemisphere was commonly believed to be entirely uninhabitable.[14]

Practical church timekeeping

Christian Europeans, by contrast, had access neither to Ptolemy nor to the theory of climes.[15] Nevertheless, the scheduling of church time suggests an early and persistent awareness of fluctuations in the duration of the day, though the nature of these fluctuations remained poorly understood.

As noted above, Greco-Roman timekeeping structures were influential in both early rabbinic and Christian corpora. The New Testament frequently makes use of the twelve-hour day,[16] but, as in rabbinic writings, only certain hours—namely, the third, sixth, and ninth—receive any amount of attention. Particular reference is made to the third and ninth hours in the story of Jesus' crucifixion and resurrection. By the early

[11] Eilhard Ernst Gustav Wiedemann, Aufsätze Zur Arabischen Wissenschaftsgeschichte, Mit Einem Vorwort Und Indices, 1970, vol. 1, p. 787, n. 1.
[12] Dallal, *Islam, Science, and the Challenge of History*, 78.
[13] Emily Burnham, "The Edges of the Earth: An Epistemology of the Unknown in Arabic Geographies from the 5/11th–7/13th Centuries," 117–118.
[14] Emily Burnham, 117–118.
[15] Stephen C. McCluskey, *Astronomies and Cultures in Early and Medieval Europe* (Cambridge University Press, 1998), 190.
[16] See, for example, John 11:9: "Jesus answered, 'Are there not twelve hours of daylight? Those who walk during the day do not stumble, because they see the light of this world."

third century, Christian writings had built these references into the structure of the emerging liturgy, which was ultimately constructed around a quadripartite division of the twelve-hour day.[17] These "canonical hours" (*horae canonicae*)—matins (sunrise), prime (first hour), terce (third), sext (midday), none (ninth), vespers (sunset), and compline (nightfall)—were seven in number in accordance with Psalms 119:164, where the psalmist describes praying this number of times each day. The middle five terms were absorbed into lay usage. Thus, while the Greco-Roman twelve-hour day fell into general disuse, its presence in the New Testament meant it was never totally abandoned; a simplified version was preserved in the form of the canonical hours.[18]

While the general adoption of the canonical hours gives the appearance of a relatively well-structured day, the actual meaning of the specific terms for the canonical hours fluctuated between regions and over time; most conspicuously, the time of *none* slowly migrated to an earlier point in the day, ultimately becoming associated with midday, hence the word *noon*.[19]

To understand why the meaning of the terms was not stable, it is helpful to compare the ways in which Christians and Muslims defined their respective prayer times. Islamic law was aware of the twelve-hour day, but this system played only a minor role in defining prayer times. Instead, prayer times were normally linked to the appearance of the sun or to the relative length of shadows. Because they were linked directly to physical phenomena, the times for prayers within the twelve-hour day remain relatively constant. The church, by contrast, described the times for prayer in terms of hours—but because the hours were so strongly associated with specific prayers, a shift in the

[17] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 29.
[18] Dohrn-van Rossum, 30.
[19] Dohrn-van Rossum, 31.

time that a prayer was said might also shift the meaning of the associated canonical hours. To use a modern example: "lunchtime" can mean either midday or the time in the general vicinity of midday at which any given person happens to be eating lunch.[20] In monasteries, this bi-directional linkage between hours and prayers meant that late-rising monks might say *prime* well after the first hour; nonetheless, that prayer was considered *prime* simply because *prime* was being said.[21] This also helps explain how it is possible that monasteries could simultaneously require monks to follow rigorous, time-based daily schedules while lacking tools for timekeeping, even for the statutory mid-night prayer.

Several methods of timekeeping were used in monasteries; given the aforementioned cold temperature, candle clocks were particularly useful. Nonetheless, it is more likely that—like the Egyptians who invented the system of night hours in the first place—most monks simply looked at the stars; celestial timekeeping is recommended and described in the texts of a number of orders.[22] Indeed, because they were recited at a standard tempo, the psalms themselves were recognized as being their own effective timekeeper; often nothing was needed beyond the prayers themselves.[23]

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[20] See, as well, the contemporary British English term for light refreshments, "elevenses," which was coined only to the late nineteenth century. Though the term derives from the hour of the morning at which these refreshments are served, in current usage the term may be applied to any snack between breakfast and lunch, regardless of when it happens. See "Elevenses, N.," OED Online, n.d.
[21] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 36.
[22] Helms, "Before the Dawn: Monks and the Night in Late Antiquity and Early Medieval Europe," 183. A system for tracking the time by watching the movement of the stars was developed by Gregory of Tours as early as the sixth century; see Bruce Stansfield Eastwood, "Astronomy in Christian Latin Europe, c. 500 – c. 1150," *Journal for the History of Astronomy* 28 (1997): 248–250. See also McCluskey, *Astronomies and Cultures in Early and Medieval Europe*, 111.
[23] McCluskey, *Astronomies and Cultures in Early and Medieval Europe*, 111. See notes there.

Theoretical timekeeping in the church

While ancient astronomy never entirely disappeared in the Latin West, the decline of the Roman Empire led to an almost total loss of the mathematical knowledge that was required to understand highly technical treatises on the subject. From the sixth century until the tenth century—when Arabic translations of astronomical treatises began circulating in Christian Europe—discussions of astronomy essentially preserved the Ptolemaic universe in a highly abstracted form, divested of its quantitative elements.[24] Nonetheless, calculations could not be entirely ignored. Two realms in particular continued to demand some theoretical knowledge: the determination of daily monastic schedules and the fixing of the Christian yearly calendar.

Monastic schedules

Seasonal daylight fluctuations are first addressed in European monastic rulebooks. The determination was particularly important for the nighttime singing of Psalms, which were supposed to last through the night. According to a fifth century *Ordo Monasterii* which regulated life in Augustinian abbeys, monks were required to sing eighteen psalms on winter nights, but only twelve during the summer. Different ratios are found in the regula of other monastic orders.[25]

These rulebooks make clear that awareness of seasonal daylight fluctuations was present but quite primitive. Monastic rules typically divided the year into between two and four parts without paying precise attention to the actual solstices and equinoxes.

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[24] Robert E. Bjork, "Astronomy," in *The Oxford Dictionary of the Middle Ages*, 2010.
[25] Helms, "Before the Dawn: Monks and the Night in Late Antiquity and Early Medieval Europe," 182. *Ordo Monasterii* is the title of many works in this genre.

An *Ordo Monasterii* produced at the end of the fourth century divides the year into only three parts:[26]

> November–February: 12 antiphons, 6 psalms, 3 lessons
> March–April & September–October: 10 antiphons, 5 psalms, 3 lessons
> May–August: 8 antiphons, 4 psalms, 2 lessons

Other monasteries divided the year into just two seasons, with the transitions happening on religiously significant days like Easter rather than on the astronomically significant equinoxes or solstices.[27]

The ratios between the prayer lengths at different times of the year suggest a fundamental misunderstanding of the relationship between latitude and day length. Thus, for example, the *Regula ad monachos* of Caesarius of Arles (d. 542) expanded the nightly requirement to 36 psalms in the winter and eighteen in the summer despite the fact that night on the winter solstice is only around 70% longer than the night of the summer solstice.[28] The *Regula monachorum*, produced in Ireland by St. Columban (d. 615), required the singing of 24 psalms in the summer and 36 in the winter (i.e. only 50% more), despite the fact that the night of the Dublin winter solstice is *more than twice as long* as the night of the summer solstice.[29]

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[26] Augustine of Hippo, *The Monastic Rules* (New York: New City Press, 2004), 106.
[27] Helms, "Before the Dawn: Monks and the Night in Late Antiquity and Early Medieval Europe," 182. The Benedictine Order, for example, transitioned at Easter and the Calends of November (November 1) of each year. See Leonard J. Doyle, *St. Benedict's Rule for Monasteries* (Collegeville, MN: The Liturgical Press, 1948).
[28] This calculation was made using the calculator at http://www.dawnsun.net/astro/suncalc/.
[29] How monks dealt with the mismatch between the regulations and physical reality is not recorded in these works.

Here, too, these errors reflect a deep ignorance of astronomy in general and of Ptolemy in particular. Though aware of seasonal daylight fluctuations, monasteries were not up to the task of properly calculating them.[30]

Setting the calendar

Establishing monks' daily schedules only required a rudimentary awareness of fluctuations in the length of daylight. Setting the calendar, on the other hand—and in particular determining the date of Easter—demanded real mathematical knowledge. As is the case with the Jewish calendrical cycle, medieval Christian *computus* calculations were luni-solar in nature and were thus dependent on precise knowledge of the moon's period.[31] Familiarity with these calculations thus seems to have been transmitted orally for several centuries before being fully synthesized in the writings of Bede (d. 735). His *De temporum ratione* is the first authored work on the subject.[32]

In the context of setting forth calculations for the next half millennium, Bede goes into some detail about all possible divisions of time, from the largest to the smallest. Discussing the divisions of the hour and the difference between seasonal and equinoctial hours, Bede writes:

> An hour has four *puncti*, 10 *minuta*, 15 *partes*, 40 *momenta*, and in some lunar calculations, five *puncti*. These divisions of time are not natural, but apparently are

[30] One caveat here is that the climes as set out in Ptolemy's *Geographia* do not have day length gradually shifting with the latitude; instead, the longest and shortest day lengths remain the same anywhere within the clime. As a result, it would be understandable if the monasteries' numbers were slightly off. This may explain the Arles numbers, since Arles lies in the fourth clime, in which the summer solstice day is understood to be only 60% longer than the winter solstice day. Dublin, however, is well into the seventh clime, where Ptolemy indeed indicates that the day length doubles between the solstices.

[31] Until the twelfth century the Christian *computus* also developed in isolation from Jewish timekeeping; see C. Philipp E. Nothaft and Justine Isserles, "Calendars beyond Borders: Exchange of Calendrical Knowledge between Jews and Christians in Medieval Europe (12th-15th Century)," *Medieval Encounters* 20, no. 1 (2014): 6.

[32] On the history of the *computus*, see Carlebach, *Palaces of Time*, chap. 1.

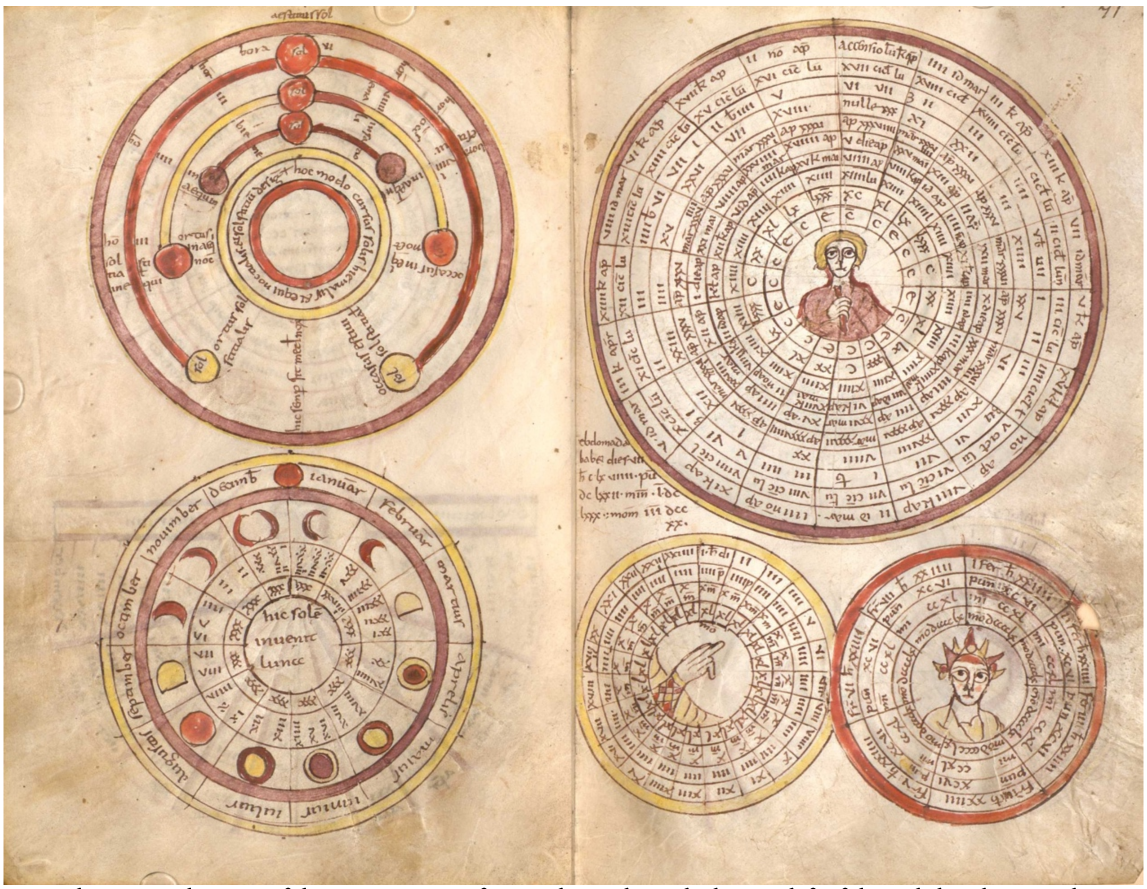
> agreed upon by convention. For since it was necessary for calculators to divide the day into 12, or the hour into 4 or 10 or 15 or 40 or other segments, whether larger or smaller, they sought out terminology for themselves by which they might designate what they wished, and might denote one thing or another. What [constitutes] the margin (*ora*) of a certain [span of] time, they call an "hour" [*hora*], even as we are accustomed to call the boundaries of garments, rivers, or of the sea "margins" (*oras*). *Puncti* they name after the swift passage of the point (*punctus*) on a sundial, *minuta* after an even smaller (*minore*) interval, and *partes* from the partition of the zodiacal circle, which they divided into thirty days for each month. Then they name *momenta* after the swift motion (*motu*) of the stars, when it was observed that something moved and succeeded itself in a very brief space of time.[33]

This dense bit of text is worth unpacking, as it contains a good overview of medieval Christian thought about the hour and its subdivisions (as well as larger units). Although Bede recognizes that the hour can be subdivided, his etymological explanation of the term *hora* actually suggests that the hour is quite literally a marginal unit; it is being imagined from the perspective of larger units, rather than smaller one. This is consistent with the non-technical valence of the term ("a short amount of time"), which we have encountered previously.[34] Bede's reference to "calculators" suggests that units smaller than the hour (the margin of the margin, so to speak) are outside of the public's perception of time.

Bede takes the subdivisions of the hour be a matter of convention; he lists them because of their relevance to calendrical calculations. Much like Maimonides' assertation that the *ḥeleq* is 1/1080 of an hour because 1080 is an easily divisible number, Bede as-

[33] Faith Wallis, *Bede: The Reckoning of Time* (Liverpool University Press, 1988), 15–16.
[34] Bede's etymology is in fact borrowed from Isidore of Seville (d. 636); see *The Etymologies of Isidore of Seville: Translated by Stephen A. Barney, W.J. Lewis, J.A. Beach, Oliver Berghof* (Cambridge University Press, 2006) V.xxix.2.

serts that the hour can be cut up many ways for the sake of convenience. Nonetheless, these divisions are not entirely random. Most obviously, the division into fifteen *partes* implies a 360-*pars* day, each section of which represents 1 degree. This unit is both numerically equivalent and etymologically homologous to the Arabic *juzʾ*, discussed in the previous chapter. Both are ultimately inheritances from Ptolemy.



A ninth-century diagram of the various units of time. The circle on the bottom left of the righthand page indicates that the equinoctial hours of the 24-hour day can also be divided into fourths (puncti)*, tenths* (minuta)*, and fortieths* (momenta)*.* (MSS München, Clm 14456 fol. 71r)

Importantly, Bede does not think that *pars*-length intervals can be accurately marked by any device; for him, the very point (*punctus*) of the sundial is only capable of indicating quarter-hour distinctions. (The water-clock is conspicuously not mentioned).[35] Most accurate of all is the movement of the stars; it is the smallest perceivable shift in their position (relative to the horizon, presumably) that that the *momentum* measures, although this perception was apparently not measurable by any device.[36] While Bede believed that there is a smallest time unit, which he terms an "atom," he also believed that there are hard epistemological limits on our measuring abilities. Thus, he does not expect timekeeping technology to improve and certainly does not think it could become more accurate than the movement of stars. His system does not allow for the ability to accurately measure the modern minute (1/60 hour).[37]

It is not surprising that we find a higher degree of time awareness in the monasteries and among the Christian *computus* creators; as seen in previous chapters, finer temporal calculations and heightened timekeeping expectations are both common in religious contexts. Still, even in these small, controlled contexts, the Christian European understanding of time appears to have been quite primitive; its experience of shifting daylight hours did not connect to the concept of latitude, and its *theoretical* division of the hour evince a skepticism about the possibility of improved measurement in the future.

[35] This interpretation of Bede is found in Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 41–42. That a sundial *could* measure quarter hours certainly does not mean that sundials always did, as the material evidence indicates.

[36] See also Isidore, *The Etymologies of Isidore of Seville: Translated by Stephen A. Barney, W.J. Lewis, J.A. Beach, Oliver Berghof*, V.xxix.1.

[37] Other church figures came to slightly different conclusions. Hrabanus Maurus (d. 856) uses all of Bede's terminology and adds *ostenta*, each of which is 1/60 of an hour, i.e. a modern minute. (See McCluskey, *Astronomies and Cultures in Early and Medieval Europe*, 150.) Another manuscript divides the hour into five *puncta* and each of these into twelve *ostenta*, although it implies that clocks can only measure to an accuracy of one third of a *puncta*, i.e. four modern minutes. See David S. Landes, *Revolution in Time: Clocks and the Making of the Modern World* (Belknap Press, 2000), 61, as well as notes there.

Timekeeping technologies

In one sense, the use of timekeeping devices in Christian Europe differed little from what we have seen previously: there was a sharp division between what was available to the general public and what was in the hands of clerics and kings. At the same time, the paucity of theoretical knowledge, the lack of mechanical engineering competence, and the abovementioned harsh environmental conditions meant that, even for those with the greatest resources, timekeeping devices were relatively primitive.

Christian Europe also differed in the relative invisibility of its timepieces. Both Hellenistic and Islamic societies created monumental public devices to demonstrate wealth, power, and engineering prowess. In Christian Europe, by contrast, even the most sophisticated devices tended to be out of the public eye. Even more so than in other societies, timepieces were here very closely associated with the church and with monasteries in particular.

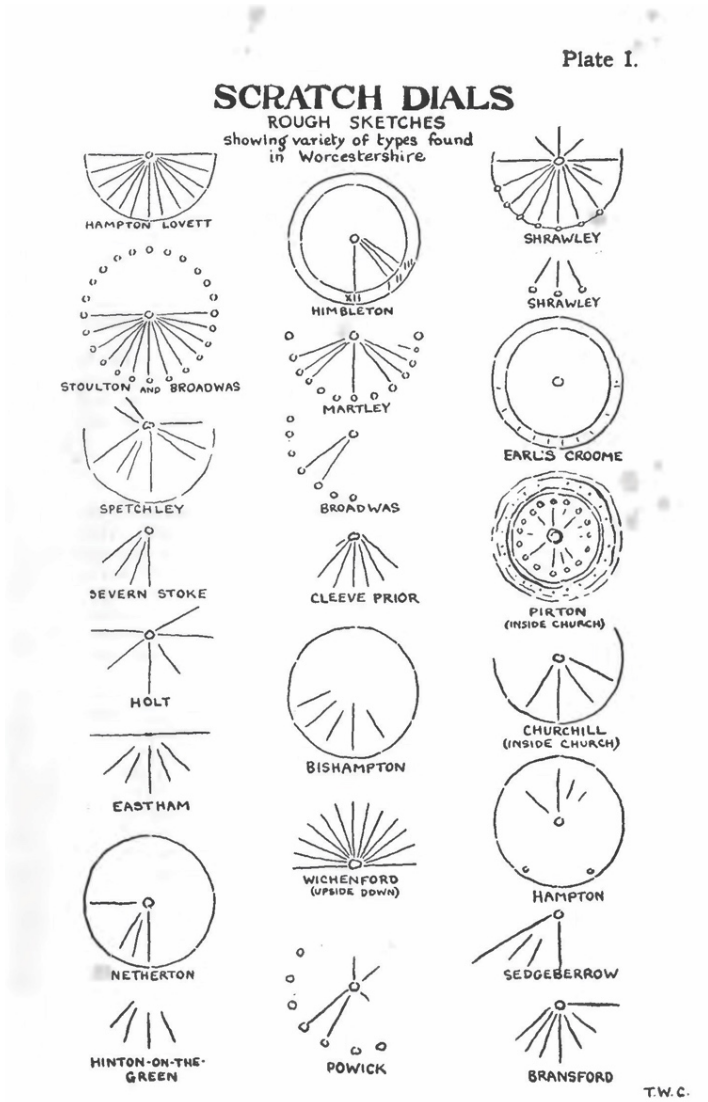
Despite these limitations, we do know a fair amount about the timekeeping devices used in early Christian Europe, both through textual evidence and through of several thousand surviving exempla, mostly in England, France, and Germany.

Sundials

The sundial in Christian Europe has been indelibly tied to the church since at least the early seventh century, when Pope Sabinian apparently issued an edict stating that all churches must have a sundial for reckoning prayer times.[38] Justinian (r. 527–565)

[38] Schechner, "The Material Culture of Astronomy in Daily Life: Sundials, Science, and Social Change," 194.

supposedly placed sundials in the Hagia Sophia, as well.[39] Thousands of dials across Europe have been catalogued, although the distribution within a given region is usually uneven.[40]



Sketches of English scratch-dials. Note the complete lack of conformity.

[39] See Emerson Howland Smith, *Hagia Sophia* (New York: Columbia University Press, 1940), 180.
[40] Ernst Zinner, *Alte Sonnenuhren an Europäischen Gebäuden* (Wiesbaden, Germany: Franz Steiner, 1964), 24–26.

Despite their ubiquity, most dials that have survived are not of high quality;[41] many were so crudely constructed, strangely positioned, or oddly designed that it was not until the late nineteenth century that they were catalogued as sundials at all.[42]

A large portion of the known dials in England and France are so-called "scratch dials," also known as Mass dials or tide dials. These devices are nothing more than a few lines carved on the southern face of a church, all radiating from a central hole where a gnomon would have been set.[43] These dials, which are probably a highly degraded form of the planar dials of Antiquity, are present as early as the seventh century.[44] Their accuracy is so slight that it has been suggested they be considered "event markers," with the marks indicating specific events but having no relation to any larger timekeeping system at all.[45]

The earliest exemplars, known as Saxon dials, are most consistent in design. Most divide the daylight into four parts (half-marks were later added), corresponding to the Anglo-Saxon division of the day/night cycle into eight equal parts, called *tīd*.[46] Lines were added between each of the major lines, and the major lines were given short perpendicular lines near their end, forming the shape of an inverted cross.[47]

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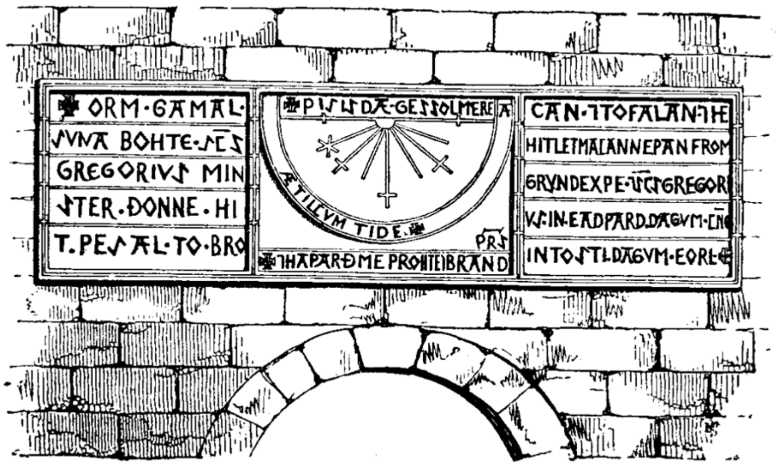
[41] T.W. Cole, "Medieval Church Sundials," *Suffolk Institute of Archaeology & History* 23, no. 2 (1938): 149.
[42] Tony Wood, "Mass Dials in Gloucestershire by Tony Wood," *Gloucestershire History* 21 (2007): 16. For an early history, see Dom Ethelbert Horne, *Primitive Sun Dials or Scratch Dials: Containing a List of Those in Somerset* (Taunton: Barnicott & Pearce, 1917), 4ff.
[43] Notwithstanding the crudeness of these devices, a horizontally-oriented gnomon is not inherently less accurate than a vertically-oriented gnomon.
[44] Allan A. Mills, "Seasonal-Hour Sundials on Vertical and Horizontal Planes, with an Explanation of the Scratch Dial," *Annals of Science* 50 (1993): 86f. See also Mike Scott, David and Cowham, *Time Reckoning in the Medieval World: A Study of Anglo-Saxon and Early Norman Sundials* (British Sundial Society, 2010), 1.
[45] Mills, "Seasonal-Hour Sundials on Vertical and Horizontal Planes, with an Explanation of the Scratch Dial," 93.
[46] Hence the terms noon-tide, even-tide, etc. See John Wall, "Anglo-Saxon Sundials in Ryedale," *Yorkshire Archaeological Journal* 69 (1997): 94.
[47] A.J. Turner, "Anglo-Saxon Sun-Dials and the 'Tidal' or 'Octaval' System of Time Measurement," *Antiquarian Horology and the Proceedings of the Antiquarian Horological Society* 15 (1984): 76–77. See also Arthur Robert Green, "Anglo-Saxon Sundials," *The Antiquaries Journal* 8 (1928): 489–516. A few Saxon dials



Typical Saxon Dial at Kirkdale, Yorkshire.[48]

Later dials, by contrast, show quite a bit of variation. With the basic purpose of indicating prayer times, most scratch dials usually have lines to represent *terce*, *sext*, and *none*; other hours, however, are often lacking. Variations in the carvings are sometimes the result of locally-important daily events, such as the beginning of school. While lines corresponding to the twelve-hour day are sometimes represented, it is sometimes possible to determine that these lines were added only in the fourteenth or fifteenth century, after the advent of the mechanical clock had led to the widespread popular adoption of clock time and the twelve-hour day.[49] While the prayer-related marks on scratch dials were ostensibly tied to the third, sixth, and ninth seasonal hours (for *terce, sext*, and *none*), in reality the lines are often badly calibrated; they do not represent even seasonal hours accurately.[50] Germany, which did not experience the same proliferation of mass dials, has many dials of this type.[51]

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further create quarter-*tīd* divisions; a few even evince the twelve-hour-day system. See Wall, "Anglo-Saxon Sundials in Ryedale," 95–96.

[48] Green, "Anglo-Saxon Sundials," 491.

[49] T.W. Cole, *Origin and Use of Church Scratch-Dials* (Wimbledon: Hill Bookshop, 1934).

[50] Mark Lennox-Boyd, *Sundials: History, Art, People, Science* (Frances Lincoln, 2006), 38.

[51] Zinner, *Alte Sonnenuhren an Europäischen Gebäuden*, 9.

Dials of greater sophistication were available, but in smaller numbers; they are mentioned by Bede as objects by which one might make accurate observations.[52] One design which seems to have been carried over from the Romans was the portable dial (also known as the traveler's dial, shepherd's dial, or pendant dial), which was known in Europe from at least the eleventh century and possibly earlier.[53] These objects, which were small and roughly conical, were etched with lines indicating where the shadow should fall at different times of the year and holes in which a gnomon might be placed; they invariably divide the day into twelve hours. Whether the medieval versions represent a decrease in accuracy in comparison to their Roman ancestors is a matter of debate.[54]

Water-clocks

Much as medieval European sundials are associated with churches, water-clocks are associated with monasterie; evidence for their presence dates back to at least the tenth century.[55] The connection with Cistercian monasteries is particularly strong, since these were almost always built on rivers, whose water could be used for ablutions, laundry, operating mills, agriculture, and even fishing. These same water flows provided an ever-ready source of kinetic energy for operating the alarms that delineated the parts of the night and the monks' chanting obligations.[56] While it remains unclear how

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[52] C. P. E. Nothaft, "Bede's Horologium: Observational Astronomy and the Problem of the Equinoxes in Early Medieval Europe (c.700-1100)," *The English Historical Review* 130, no. 546 (2015): 1081.
[53] See the discussion in Mario Arnaldi, "An Ancient Rule for Making Portable Altitude Sundials from an 'Unedited' Medieval Text of the Tenth Century," *Journal for the History of Astronomy* 42, no. 2 (2011): 141–160.
[54] Arnaldi, 153.
[55] E.R. Truitt, *Medieval Robots: Mechanisms, Magic, Nature, and Art* (Philadelphia: University of Pennsylvania Press, 2015), 142.
[56] Terryl N. Kinder, *Cistercian Europe: Architecture of Contemplation* (Eerdmans, 2002), 85–86.

frequently these devices were actually deployed, they retained both a cultural value and served as a critical precursor to the mechanical clock.

Unlike the clepsydras of Late Antiquity which worked by transferring water from one container into another (and which perhaps would have been more susceptible to freezing), the water-clocks in monasteries were probably based on existing waterwheel technology, which had been employed since Antiquity but whose usage greatly diversified in the medieval period.[57] It is possible that Christian Europe received the waterwheel clepsydra through Spain, where the natural movement of the waterwheel was used to sell water in fixed time units to farmers seeking irrigation.[58] A depiction of the waterwheel clepsydra appears most prominently in a thirteenth century biblical depiction of the Dial of Aḥaz.[59] A report from 1198 about a fire being extinguished with water from the "*horologium*" suggests that they were relatively large.[60] Despite the relative sophistication of Christian European clepsydras, they were used in far fewer contexts than their Late Antique counterparts.[61]

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[57] A.A. Mills, "The Mercury Clock of the Libros Del Saber," *Annals of Science* 45 (1988): 333. On the development of the waterwheel, see Terry S. Reynolds, *Stronger than a Hundred Men* (Baltimore: Johns Hopkins Press, 1983), chap. 2. For the design of a late twelfth century water-clock, see Francis Maddison, Bryan Scott, and Alan Kent, "An Early Medieval Water-Clock," *Antiquarian Horology and the Proceedings of the Antiquarian Horological Society* 3 (1962): 348.

[58] See Thomas F. Glick, "Medieval Irrigation Clocks," *Technology and Culture* 10, no. 3 (1969): 424–428.

[59] The details of this clock have been frequently scrutinized. See J.D. North, "Monasticism and the First Mechanical Clocks," in *Stars, Mind and Fate: Essays in Ancient and Mediaeval Cosmology* (Hambledon Press, 1989), 175. For an attempt to understand how the device worked, see C.B. Drover, "A Medieval Monastic Water-Clock," *Antiquarian Horology and the Proceedings of the Antiquarian Horological Society* 1, no. 54–58 (1954): 58. An interesting, non-miraculous explanation for the Dial of Aḥaz is given by Bede (*In Regum,* XXV and XXVIII), who suggests that Hezekiah experienced something similar to what happens on the far-north island of Thule "where during the night the Sun moves low in the sky from west back to east without setting, although this is never seen in southern regions."

[60] John Scattergood, "Writing the Clock: The Reconstruction of Time in the Late Middle Ages," *European Review* 11, no. 4 (2003): 457.

[61] Lynn White and others have argued that there must have been demand for these devices based on the existence of a street for a clockmaker's guild in Cologne from 1183. The evidence for this guild is quite thin, however; it has been successfully criticized in Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 96–99.

MSS Bodl. 270b fol. 183v (detail): The Dial of Aḥaz depicted as a waterwheel clepsydra.

Islamic contributions to Christian timekeeping

The adaptation of the clepsydra to monastic use is the rare case in the early history of mechanics in which Christian Europeans seem to have made technological advances on their own.[62] This was the exception, rather than the rule: Islamic devices and imported Islamic knowledge are evident in Christian Europe from at least the ninth century, and their prevalence and importance grew up until the invention of the mechanical clock itself.

Islamic culture's first and most visible contribution was the development of complex geared mechanisms. As discussed in the last chapter, medieval Islamic culture had long cultivated the mechanical engineering skills needed to make these devices. Indeed, the first known automaton (a moving machine in the form of a person or animal) in Christian Europe was a gift of the caliph Harūn al-Rashīd (d. 809) to Charlemagne (d.

[62] North, "Monasticism and the First Mechanical Clocks," 172.

814) in 807 CE.[63] Attitudes towards the device reflect a lack of understanding of its underlying function; until the emergence of locally-built automata at the beginning of the fourteenth century these devices were treated not as artisanal products but as magical ones.[64] In the realm of theory, Islamic theoretical contributions aided in the calibration of Christian European scientific devices; the markings on a portable sundial from the eleventh century may be the result of this influence.[65] A tenth century description of the astrolabe by Gebert d'Aurillac, produced in Catalonia, contains translations of Arabic technical terms. [66]

Jews played a critical role in this scientific exchange.[67] We have already seen that Ibn Ezra likely wrote a Latin treatise on the astrolabe. Another key text, the Spanish *Libros del Saber*, contains designs for several weight-driven water-clocks; this book was commissioned by Alphonso X (r. 1252–1284) and compiled and translated from Arabic by three Jews.[68]

Donald Hill has noted that, while the final breakthrough in timekeeping technology occurred somewhere in Europe, all of the clock's supporting mechanisms—its use of sequential gears, high-torque gear trains, and well-calibrated parts—were derived from Arabic texts.[69] There is good reason to think that increased Christian awareness of timekeeping devices and theoretical designs correspond with an increased awareness on the part of Jews living in the same region.

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[63] *Annales regni Francorum*, ann. 807, *MGH, SS. rer. Ger.*, ed. F. Kurze (Hanover: Hahn, 1895), 123–124.
[64] Truitt, *Medieval Robots: Mechanisms, Magic, Nature, and Art*, 117–118.
[65] Arnaldi, "An Ancient Rule for Making Portable Altitude Sundials from an 'Unedited' Medieval Text of the Tenth Century," 146.
[66] Hill, "Islamic Fine Technology and Its Influence On the Development of European Horology," 22.
[67] Sara Offenberg, "Isaac Ibn Sahula and King Alfonso X: Possible Connections between the Book Meshal Haqadmoni and the Cántigas de Santa Maria," *Arts and Social Sciences Journal* 5, no. 2 (2014): 2.
[68] Hill, *Arabic Water-Clocks*, 126. See also Mills, "The Mercury Clock of the Libros Del Saber."
[69] Hill, "Islamic Fine Technology and Its Influence On the Development of European Horology," 21.

The use of bells

Despite its relative lack of sophistication in matters of timekeeping, the church possessed an unparalleled instrument for broadcasting information about time. The earliest known bells date to the third millennium BCE, but outside of East Asia manufacturing difficulties meant that they always remained quite small.[70] It was in this diminutive form that bells were adopted by the church.[71] In France and southern Italy, bells may have been used in monasteries from as early as the sixth century CE, although the purpose they served is not entirely clear.[72] By the ninth century the Carolingian Empire had widely adopted the use of bells, which began appearing regularly in "bell towers." (Ironically, the towers predated the bells themselves). The bell's widespread adoption by the church coincided with the application of the lost-wax technique to bell construction; this process had previously been used only in the creation of bronze statuary. With this advance, bells could be made larger and louder, and large bells became prestige items, produced in a handful of properly-equipped foundries.[73]

The fact that these large bells could be heard many miles from the church ultimately cemented their status as auditory declarations of Christian space. In Spain, the Christian bell and the Muslim muezzin sometimes occupied the same space to the frustration of members of both faiths, for whom the prayer calls of the religious other were

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[70] Consider, for example, the bells on the high priest's garments, described in Exodus 28. On the size of priestly garment bells, see Jonathan L. Friedmann, "The Magical Sound of Priestly Bells," *Jewish Bible Quarterly* 46, no. 1 (2018): 41–46.
[71] John H Arnold and Caroline Goodson, "Resounding Community: The History and Meaning of Medieval Church Bells," *Viator* 43, no. 1 (2012): 102.
[72] Arnold and Goodson, 111. Medieval sources saw Rome as the originator of the bell, but this does not appear to be the case.
[73] Arnold and Goodson, 104.

sometimes met with disapproval or cursing.[74] Subduing, silencing, and transforming bells (often into lamps) became an important marker of Muslim dominance over conquered Christian communities. It was attacks like these that transformed the bell into an essential symbol of the Christian faith, thereby ensuring its proliferation across Europe.

Notwithstanding the ubiquity of the bell in Christian European communities, the sound of the bell had no one fixed meaning beyond the walls of the monasteries. Bells in public spaces were rung for the canonical hours, but they were also rung for funerals, festivals, and even as a way of warding off evil.[75] Overtly secular uses abounded, as well: bells were rung to announce local events, to sound the alarm in case of a fire or (when one had been enacted) the beginning of the nightly curfew.[76] Different towns had different expectations about how often bells should be sounded; they sometimes also debated the ownership of the bells themselves, as well as who had the right to ring them.[77] References to a particular tolling of the bell might be cited by witnesses to anchor a given moment—for example, a person might testify that an event had occurred at night after the bells had tolled—but this was not done consistently.[78] In the same way that a person living next to an elementary school might ignore the school bell because she does not consider the sounds to be intended for her ears, countryfolk in medieval

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[74] Arnold and Goodson, 112. For a bigger-picture perspective on the tension, see Olivia Remie Constable, *Regulating Religious Noise: The Council of Vienne, the Mosque Call and Muslim Pilgrimage in the Late Medieval Mediterranean World*, *Medieval Encounters*, vol. 16, 2009.
[75] Percival Price, *Bells and Man* (Oxford University Press, 1983), 122.
[76] Price, 135.
[77] Arnold and Goodson, "Resounding Community: The History and Meaning of Medieval Church Bells," 126.
[78] Michelle E. Garceau, "'I Call the People.' Church Bells in Fourteenth-Century Catalunya," *Journal of Medieval History* 37, no. 2 (2011): 199–200.

Europe would not have seen church bells—even those which rung out the time—as authoritative delineators of their daily schedule.

II. Jewish timekeeping in Christian Europe

The abovementioned developments constitute the best that Christian Europe had to offer with regards to timekeeping, yet it represents a far lower level of sophistication than that available in the Hellenistic cultures of Late Antiquity, where specialized settings—like courtroom speeches and astronomical observations—required the use of advanced timekeeping techniques. While both clergy and laity theoretically used the canonical hours to mark time, the meaning of these terms in practice was quite fluid and experienced notable drift over the centuries. On a practical level, timekeeping devices themselves were far less accessible than they had been in either the Late Antique Hellenistic environment or medieval Islamic societies, and the most sophisticated devices were generally found within the walls of monasteries, places where Jews were less likely to go.[79]

Despite the religious barrier between Jews and the most sophisticated timekeeping devices of the region, the same geographical realities that led monasteries to acknowledge shifts in daylight hours also led Jews in Christian Europe to do the same. In medieval Islamic societies, rabbis achieved an advanced theoretical understanding of timekeeping through exposure to Islamic science, and like their Muslim contemporaries did not take the reality of living at extremely northerly latitudes into account. Still, the shifts in daylight's duration could not be ignored in northern Europe, even if the

[79] Jews did have exposure to quite a variety of Christian religious artifacts as collateral for loans; see Shatzmiller, *Cultural Exchange: Jews, Christians, and Art in the Medieval Marketplace*. Monastery water-clocks, however, were quite large, not easily moved, and of uncertain financial value.

rabbis lacked the scientific sophistication to put numbers to the fluctuations. This empirical awareness led the rabbis of Christian Europe to pursue avenues of inquiry that their counterparts in the Islamic world and their predecessors in Late Antiquity had not considered.[80]

Theoretical timekeeping capabilities

As Raymond Leicht has noted, the medieval Ashkenaz encounter with astronomy and astrology is typified by a lack of originality; we should therefore not expect that their own astronomical works reflect a level of timekeeping sophistication concerning timekeeping that is not present elsewhere in the region.[81] Still, knowledge of astronomy among Jews in Christian Europe varied significantly on the basis of proximity to Arabic sources of knowledge (and later, Latin knowledge). As well, some of the most sophisticated works from this community remain in manuscript form. As a result, it is difficult to state conclusively what Jews in Christian Europe did or did not understand about timekeeping.

Like their Jewish counterparts in the Islamic world (as well as their Christian clerical counterparts in Europe), Jewish works in Christian Europe demonstrate their greatest astronomical knowledge in their treatment of the calendar. Also like their counterparts, these northern European calendrical discussions usually have little to say about timekeeping over the course of the day, other than their use of the *ḥeleq* unit in their

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[80] While medieval rabbis do consider the legal implications of extremely long and extremely short days, the first consideration of the sun not setting at all comes from Jacob Emden (d. 1776). This, too, is likely the result of limitations on Jewish areas of settlement. See J. David Bleich, "Survey of Recent Halakhic Periodical Literature: Mitzvot in the Polar Regions and in Earth Orbit," *Tradition* 36, no. 3 (2002): 62.
[81] Reimund Leicht, "The Reception of Astrology in Medieval Ashkenazi Culture," *Aleph* 13, no. 2 (2013): 230.

calculation of the lunar cycle.[82] Rashi (Rabbi Shlomo Yitzḥaqi, d. 1105) conceivably could have had access to the concept of seasonal hours through *Baraita de-Shmuel*, a work with which he would have been familiar through quotations in *Sefer Ḥakmoni* of Shabbetai Donnolo (d. ca. 982); Rashi cites *Sefer Ḥakmoni* frequently and in at least one instance cites *Baraita de-Shmuel* directly.[83] Nowhere, however, does he indicate that he understands the concept.

In Ashkenaz, astrology seems to have been particularly well regarded; indeed, early manuscripts of Maḥzor Vitry contain tables of "planetary hours," a system which, Shlomo Gandz has argued, Jews may have popularized in Europe.[84] Contained in the planetary hour system is the assumption that there will always be twelve hours in the day and twelve hours in the night, but this is usually not explicitly acknowledged.

Knowledge of timekeeping devices

Like their counterparts in the Islamic world, Jewish texts written in Christian Europe demonstrate an awareness of timekeeping devices, but this awareness is more primitive in three important ways. First, descriptions of devices are usually only mentioned in order to explain the biblical Dial of Aḥaz or to elucidate the sundial's brief mention in the Mishnah; unlike in Islamic lands, they are not mentioned as solutions to new exegetical problems, nor are they employed as philosophical analogies. Second,

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[82] Sacha Stern and Justine Isserles, "The Astrological and Calendar Section of the Earliest Maḥzor Vitry Manuscript (MS Ex-Sassoon 535)," *Aleph* 15, no. 2 (2015): 210.
[83] Leicht, "The Reception of Astrology in Medieval Ashkenazi Culture," 210. *Sefer Ḥakmoni* itself contains one obscure reference to the night and day containing twelve "short" hours each; see Piergabriele Mancuso, *Shabbetai Donnolo's Sefer Ḥakhmoni* (Brill, 2010), 332.
[84] On the manuscripts, see Stern and Isserles, "The Astrological and Calendar Section of the Earliest Maḥzor Vitry Manuscript (MS Ex-Sassoon 535)." On planetary hours, see Gandz, "The Origin of the Planetary Week or the Planetary Week in Hebrew Literature."

the descriptions which do appear are extremely concise; they say little about the shapes of the devices or the mechanisms by which they function. Finally—and perhaps most tellingly—are three attempts to explain the Mishnaic phrase *even shaʿot* with a paraphrastic quotation of the definition provided in the *ʿArukh*, Rabbi Nathan ben Yeḥiel's eleventh-century Talmudic glossary.[85] The explanations can be found in the writings of Rabbi Shimon ben Avraham of Sens (twelfth-century France), Rabbi Asher ben Yeḥiel (thirteenth-century Toledo), and the author of the *Sefer ha-Agudah* (late thirteenth century Germany); all translate the term into Aramaic, but not into the local vernacular.[86] Taken together, these three factors strongly suggest that rabbis in Christian Europe had little access to timekeeping devices in their quotidian existence.

Jews and bells

Earlier I noted that church bells, despite their ubiquity, do not seem to have become the *de facto* timekeeping standard even for those within earshot. Had Jews responded differently we might have expected church bells to appear in Hebrew writings as indicators of time, but this does not seem to have happened—although church bells may have served as inspiration for the notion, put forward by Rashi, that the purpose of small bells on the mantles of Torah scrolls is to indicate to children that school has begun.[87] In truth, church bells are barely mentioned; one of the only direct references to church bells I have encountered—a poem by Todros Abulafia in his collection *Gan ha-*

[85] Natan ben Yeḥiel of Rome, *Sefer Ha-ʿArukh* (Venice, 1553), fol. 3r.
[86] See Rashi on Isaiah 38:8 and 2 Kings 20:9; in both instances the word אורלוגין (or אורלויי"ן) is used.
[87] It is unclear if this was the actual practice in Rashi's community. See his comment on bShabbat58b; the use of bells to calm infants is also mentioned. On the latter, see also Maimonides, *Mishneh Torah*, Laws of Shabbat 23:4. The bells on the High Priest's clothing are mentioned somewhat frequently in liturgical poetry, especially in those poems recited on Yom Kippur, since the High Priest's activities had been the centerpiece of the day's rituals while the Temple stood.

Meshalim from the second half of the thirteenth century—describes the author's experience of the sound as inherently pagan, although he admits that it still stirs him to pray:

> Could young men sing to pagan demons, and I not praise the Lord in heaven?
> Could they rise to pray in the dark of night or at dawn for other gods, for nothing,
> and I not wake for the Living God, the source and secret of all things?
> [...]
> But do not put your faith in time. Time is only chance—not truth:
> for it contains both bitter and sweet,
> and in its way, does what bees do.[88]

In short, church bells do not appear to have had any significance as timekeeping devices for Jews in Christian Europe.[89] Nonetheless, it was necessary to wake people for prayers, though the signal could not be loud, since this might arouse the ire of Christian neighbors. In order to solve this problem, many communities hired someone to knock on individual doors with a wooden mallet each morning. The role of the *schulklopfer* (sometimes appended to the role of the *shamash*/groundskeeper), as it came to be known, is attested from as early as 1225.[90] That such a figure was necessary, de-

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[88] Translated in Peter Cole, *The Dream of the Poem: Hebrew Poetry from Muslim and Christian Spain, 950–1492* (Princeton University Press, 2007), 267–268. Additional references can be found in the poetry of Yitzḥaq ibn Ezra, the son of Abraham ibn Ezra. Most interesting of this is an unambiguous reference to time-telling bells: "I will make ringing bells / And instruments of hours and moments (*u-khlei ha-shaʿot u-regaʿim*)" ("Ish Mahir Ani," line 119, in *Shirim U-Zemirot ve-Tishbaḥot*). See, as well, a passing poetic reference: "I shall ring my bell...I shall give my tongue a bell" (see JTS Ms. 8386). Finally, see the end of *Song of Songs Rabbah* VII, 9:1, which intriguingly describes repentant heathens destroying their idols and turning them into bells for their dogs and asses.

[89] For further evidence, see the discussion of Prague's Jewish Town Hall in the next chapter.

[90] Abrahams, *Jewish Life in the Middle Ages*, 56. See, as well, *Beit ha-Beḥirah*, Eruvin 104a, and *Leqet Yosher*, 4b (MSS. Nos. 404, 405). Both Eliezer ben Joel ha-Levi (*Ra'aviah* §795) and the Mordekhai (*Mordekhai* §696) cite a passage from the Jerusalem Talmud (yBeitzah5:2) in which Rabbi Shmuel bar Rav Yitzḥaq states that his grandfather would "knock for the synagogue" on Shabbat (סבי אקישיה דבי כנשתא). This suggests that the practice is quite a bit older, and Abrahams cites the Mordekhai's wording of the passage as evidence. Modern manuscripts, however, simply have Rabbi Shmuel positing that one may knock (in celebration) for a new synagogue (סבר מקושה דכנשתא חדתא).

spite the presence of morning church bells, provides further evidence that the bare existence of a time signal need not force others to use it.

Folk timekeeping techniques: keeping time with noses and hands

We have already noted that most people in Christian Europe did not have access to sophisticated timekeeping equipment. Nonetheless, primitive or ad-hoc methods of tracking time were probably employed. Some of these methods were not quite rooted in science. The German pietists, for example, indicate that it is possible to tell time at night by noting which of one's nostrils is blocked, since respiration switches between them every hour.[91] Based on recent studies of the nasal cycle, this method does not work.[92]

Another method has a stronger basis in reality. A passage in the Talmudic commentary of Eliezer ben Joel ha-Levi (also known as Ra'aviah, d. ca. 1235) offers a literal "rule of thumb" method for reckoning the hour on Passover Eve, when the imperative to stop eating leavened bread by mid-morning meant that accurate timekeeping was of the utmost importance.

> One who wishes to know the time with precision (*be-kivvun*) should, on the 14th of [the month of] Nisan, go to a place where the sun is shining clearly through a small window. He should turn his back to the window and extend his arm and palm. He should extend his fingers, with the exception of his thumb, which

[91] *Ḥokhmat ha-Nefesh* §336, quoted in David I Shyovitz, *A Remembrance of His Wonders: Nature and the Supernatural in Medieval Ashkenaz* (University of Pennsylvania Press, 2017), 117. See notes there for additional sources. For a possible later usage, see the manuscript JTS Budapest K 83, 16b–19b.

[92] Recent empirical studies have determined that the "nasal cycle" is highly variable—25 minutes to eight hours, on average 1.5 to 4 during wakeful hours, generally becoming longer at night. (See Roni Kahana-Zweig et al., "Measuring and Characterizing the Human Nasal Cycle.," *PloS One* 11, no. 10 (2016), and Akihiro Kimura et al., "Phase of Nasal Cycle during Sleep Tends to Be Associated with Sleep Stage," *Laryngoscope* 123, no. 8 (2013): 2050–55.)

> should be stretched up towards the sky. His thumb and forefinger should thus appear like a bent [letter] *nun* (נ).[93] His thumb should be casting a shadow on his forefinger. With his left hand he can turn his right thumb so that its width and circumference are well exposed with respect to the [fore]finger; alternatively, he can fix its form (i.e. the rough shape of the thumb) in iron, since the thumb wavers from side to side. He will know that the first hour has passed when the sunlight reaches to [the level of?] his head to the tip of his finger. [When the sun hits] the next segment (i.e. knuckle)—two hours [have passed]. At its middle crease (*qesher*)—three hours. At the terminus of the finger, at the end of where the fingers split off—four hours. At the middle crease of the palm—five hours. [At the crease] next to the thumb itself—six hours. When "the shadows of evening grow long" (Jeremiah 6:4), after noon—if he wants to reckon the hours until night, he should reverse direction together with the direction of the sun's rays, from west to east, so that his back is now to the west.[94]

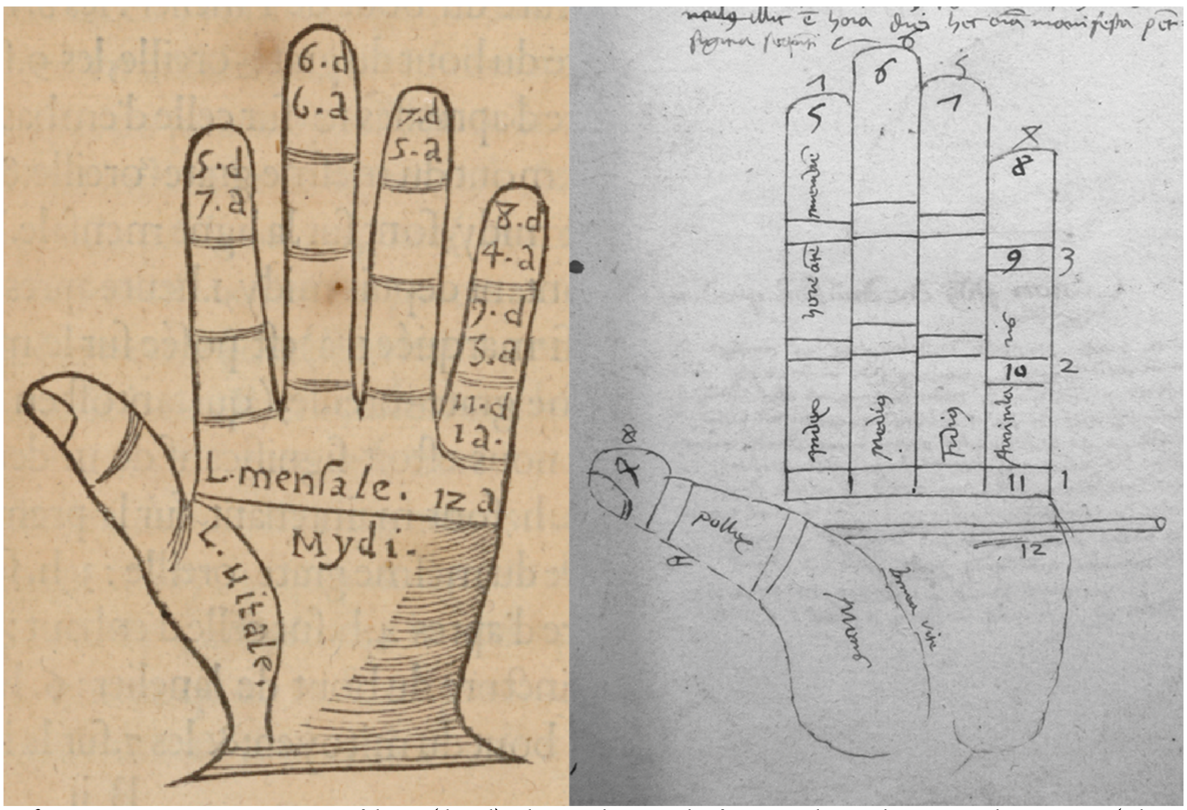
The history of this technique and the manner in which it was used it hard to discern; Halevi is the first medieval European writer known to have described anything like it. Several early modern works make explicit reference to the method. In one—a French instruction book for learning party tricks—a very similar technique is described as "a quite ingenious way of serving you in the fields instead of a watch (*montre*)." The author continues:

> [P]lace the wrist of your left hand to point towards the sun; that is to say, turn your back to the sun and hold your hand and its fingers stretched out fully, so that the rays of the sun strike your wrist from behind. Then take a straw or a small peeled stick (to serve as an indicator) of the length there is from the root of the thumb to the tip of the index finger. Hold it by one end, between the

[93] I.e. a non-final *nun*; see bShabbat104a.
[94] *Ra'aviah*, Vol. 2, Pesaḥim §432. This is a very technical passage describing a complex visual; cf. Catherine Eagleton, "Time on Your Hands: A Sixteenth-Century Digital Sundial," in *The Body As Instrument: The Cambridge Latin Therapy Group* (Cambridge University Press, 2006), 7.

thumb and the mount of the index finger, at the beginning of the life line.[95]

None of the book's other chapters deal with timekeeping of any sort. Though the author's description is quite thorough and a useful diagram is provided (see below), it is unclear whether this technique was simply an interesting gimmick or a method of real usefulness. We can assume a greater level of practicality for the method's appearance—in much abbreviated form—in *The Shepherd's Kalendar, or the Countryman's Companion*, a seventeenth century book, printed in London, which went into many editions.[96]



Left: *J. Prévost, La Première Partie, fol. 10v (detail). The numbers on the fingers indicate the time in the morning ("d" = "du matin") and afternoon ("a" = "apres midy"). Note that an a.m./p.m. system is being employed, with possible values ranging from 5 a.m. to 7 p.m.* Right: *A description and illustration from Nicholaus Kratzer's notebook. MSS Corpus Christi College 152, 23r.*

[95] J. Prévost, *La Première Partie Des Subtiles et Plaisantes Inventions*, 1584, fol. 9r.
[96] See, for example, *The Shepherd's Kalender*, 12th ed. (London: J. Hollis, n.d.), 84.

More serious treatments can be found in several early sixteenth century German publications, beginning with an anonymous 1509 manuscript.[97] A 1515 notebook belonging to the scientific instrument manufacturer Nicholaus Kratzer (d. after 1550) contains a version of the digital sundial; Kratzer indicates that some of the notes in the notebook were copied from a monastery in Auerbach.[98] A more thorough discussion of the technique was published in 1532 by Jacob Koebel, a printer from Oppenheim;[99] Koebel published a simplified version of the material again in 1534 in a farmer's almanac entitled *Bauren Compas* ("Farmer's Compass").[100] Koebel was a prolific writer and published a number of works on both mathematics and astronomy; his interest in the rule-of-thumb is probably best understood as an extension of these interests.[101]

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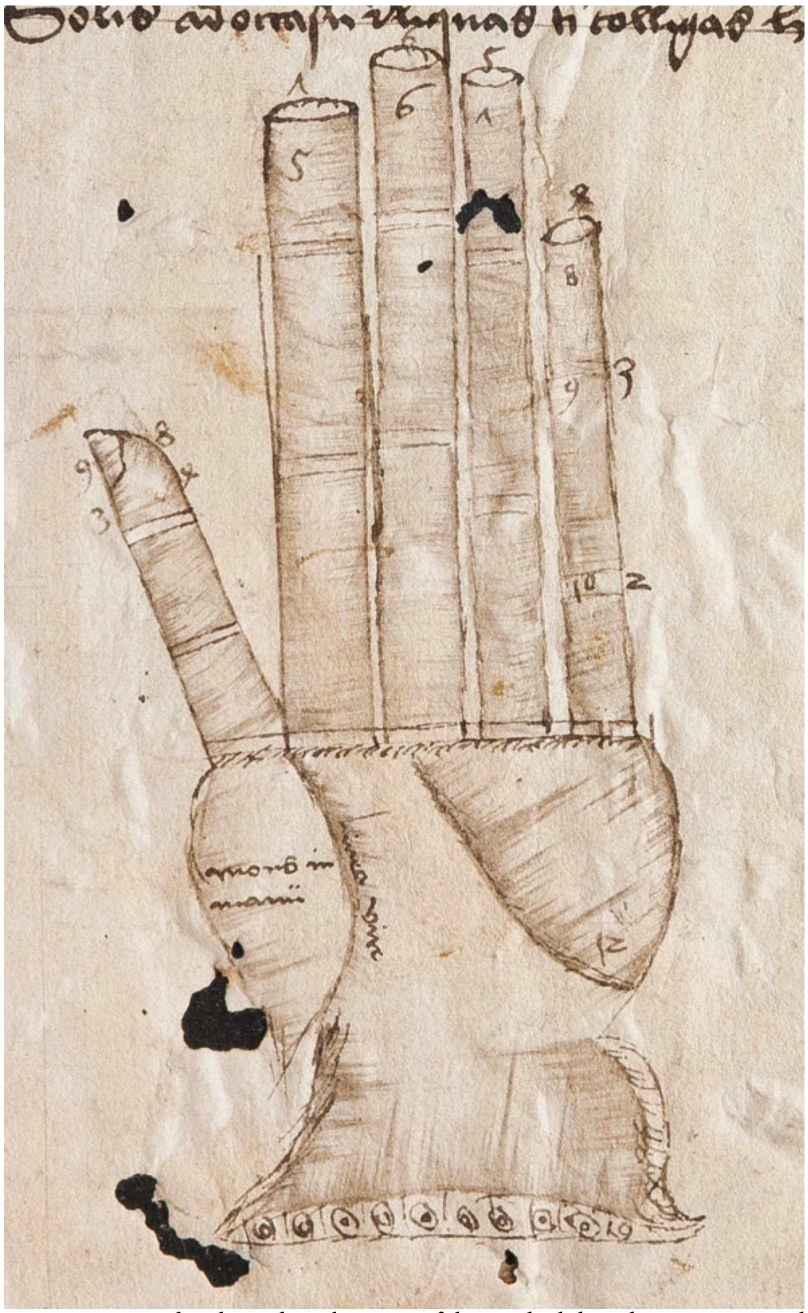
[97] Heinemann-Nr. 4070. See Ernst Zinner, *Deutsche Und Niederländische Astronomische Instrumente Des 11.–18. Jahrhunderts* (Munich, 1956), 77–78.

[98] While others have claimed that this applies to the hand diagrams, the catalogue description suggests caution, as the order of materials in the book of collected notes is somewhat haphazard. See Rodney M. Thomas, *A Descriptive Catalogue of the Medieval Manuscripts of Corpus Christi College, Oxford* (Cambridge University Press, 2011), op. 152. (The relevant portion appears to be #4.) See also Margaret Gatty, *The Book of Sun-Dials* (London: George Bell and Sons, 1900), 21. Kratzer's work is mentioned in Fred Sawyer and Mario Arnaldi, "Digital Sundials — Time at Your Fingertips," *The Compendium: Journal of the North American Sundial Society* 7, no. 3 (2000): 18–23. On Kratzer himself, see Günther Oestmann, "Kratzer, Nicolaus," in *Oxford Dictionary of National Biography*, 2004. In addition to the digital sundial, Kratzer's notebook contains copies of scientific treatises by Jacob ben Makhir ibn Tibbon (Profatius Iudeaus) and Gersonides (Leo de Balneolis).

[99] Josef Benzing, *Jakob Köbel Zu Oppenheim 1494–1533: Bibliographie Seiner Drucke Und Schriften* (Wiesbaden, Germany: G. Pressler, 1962), secs. 135–6.

[100] This work is catalogued in Benzing, sec. 137. It is discussed briefly in Claire Richter Sherman, *Writing on Hands: Memory and Knowledge in Early Modern Europe* (The Trout Gallery, 2000), 170–171.

[101] Howard W. Winger, "The Cover Design," *The Library Quarterly: Information, Community, Policy* 39, no. 1 (1969): 111.



Heinemann-Nr. 4070, 55. This the earliest depiction of this method that I have encountered thus far.

While the technique described in these books is similar to that of Eliezer ben Joel ha-Levi, the former represents a somewhat more advanced form of the ad-hoc sundial. Whereas he allows the thumb itself to be used as a gnomon, both Prevost and Koebel require the use of a stick. More importantly, the diagrams indicate that the entire hand is to be used as the sundial plane; Eliezer ben Joel ha-Levi, by contrast, requires only the length of the forefinger. Because it was an essentially one-dimensional system, his method was necessarily less accurate; it is in fact quite similar to the Egyptian shadow clocks described in chapter 1.[102] At the same time, it is difficult to use the German works to infer anything about the popularity of Eliezer ben Joel ha-Levi's method, since the former were written well after the advent of the mechanical clock, while people in Eliezer ben Joel ha-Levi's time would have had far fewer options.[103]

Left: *Jacob Koebel, Eyn Künstliche Sonn-Uhr Inn Eynes Yeden Menschen Lincken Handt (Mainz: Peter Jordan, 1532), fol. 3r.* Right: *Koebel, fol. 1r. Note that the figure is standing with his back to the sun with his hand at eye level.*

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[102] See page 2, above. Both Prevost and Koebel indicate that the left hand should be used, while ha-Levi speaks of the right hand. While the former have astronomical reasons for choosing one hand and not the other, it is not clear why ha-Levi should care what hand is being used.

[103] Evidence of this technique appears later on, as well. See Alice Morse Earle, *Sundials and Roses of Yesterday: Garden Delights Which Are Here Displayed In Every Truth And Are Moreover Regarded As Emblems* (Cambridge University Press, 1902), 162. A reference to a similar device is briefly mentioned in a 1899 play; see Lionel Haweis, "The Rose of Persia," *The Drama* 11 (1921): 200–213. In addition, a friend has informed me that the following method was been used in 2010 and 2011 at the Burning Man festival: "You'd face the mountain to the west and hold your hand up, palm facing you, fingers together, and make plans to meet other people when the sun was a certain number of finger widths above the mountaintop."

Is Eliezer ben Joel ha-Levi's technique a forerunner of these sixteenth century techniques? It is difficult to tell. Research by Catherine Eagleton has uncovered three early sixteenth-century manuscript editions of a Latin text that describes the more advanced technique; all were produced somewhere in Germany and all are compilations of astronomical information.[104] These manuscripts, together with the books of Kratzer and Koebel and the anonymous 1509 manuscript, are earlier than all other witnesses to the method; perhaps they bear witness to a German folk practice, one which Eliezer ben Joel ha-Levi is articulating in an earlier, cruder form. Indeed, it is even in the realm of possibility that he invented the method himself, though this is unlikely: Jews are known to have borrowed other rules-of-thumb, including the "finger-reckoning technique" for performing calculations, from their Christian neighbors.[105] Nonetheless, I have found no other evidence of the technique's use in any other source before the arrival of the printing press and it is absent from almost all comprehensive scholarly studies of sundial construction.[106]

Regardless of its inventor, Eliezer ben Joel ha-Levi's method sheds helpful light on a popular timekeeping practice. That he sees it as being useful specifically on the morn-

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[104] Munich MS Lat 24105; Augsburg 2° Cod 207; Munich MS Lat 19689. See Eagleton, "Time on Your Hands: A Sixteenth-Century Digital Sundial." These are the medieval manuscripts to which Eagleton makes reference in Catherine Eagleton, "Clocks and Timekeeping," in *Medieval Science, Technology, and Medicine: An Encyclopedia* (Routledge, 2014).

[105] See, for example, Talya Fishman, *Becoming the People of the Talmud: Oral Torah as Written Tradition in Medieval Jewish Cultures* (University of Pennsylvania Press, 2012), 205. On the techniques themselves, see Debby Banham, "'The Very Useful and Very Accessible Skill of Bending the Fingers': Finger Counting from Bede's De Temporum Ratione," in *The Body As Instrument: The Cambridge Latin Therapy Group* (Cambridge University Press, 2006), 8–15. These techniques are also discussed in Nina Gockerell, "Telling Time Without a Clock," in *The Clockwork Universe: German Clocks and Automata 1550–1650*, ed. Klaus Maurice and Otto Mayr (New York: Neale Watson Academic Publications, 1980), 133–134. The practice has existed since at least Late Antiquity; see Plutarch, *Regum Et Imperatorum Apophthegmata*, Ar. *Ach.* 367.

[106] It is absent, for example, from the otherwise quite thorough work by Waugh, *Sundials: Their Theory and Construction*.

ing of Passover Eve may imply that this primitive technique was not used on a regular basis.

Reactions to living at northerly latitudes

Just as their Christian counterparts displayed a sensitivity to changing day length, Jewish sources from medieval Christian Europe—northern France and Germany in particular—display a sensitivity that frequently goes beyond what is found in older Jewish texts or in contemporaneous texts written at more southerly latitudes.

We can see this development by examining whether the rabbis felt it necessary to incorporate the changing seasons into a legal framework. It is noteworthy that, for the vast majority of Late Antique and geonic texts, the seasons (*tequfot*) are not associated with shifting day length at all. Instead, they are most commonly mentioned in connection with (1) the temperature and weather;[107] (2) agricultural phenomena;[108] and (3) celestial movements.[109]

Late Antique rabbinic sources identify four situations in which the seasons are connected with the length of the day. One instance, already described in chapter 2, concerns Adam's observation of the first winter solstice.[110] Another set of texts describe the day and night as being of equal length on the first day of the vernal and autumnal *tequfot* (seasons).[111] A third case discusses why the amount of oil supplied daily for the

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[107] See bShabbat53a; bShabbat129a; bEruvin79b; bYoma35b; bḤagigah14b; bTaʿanit14b; bTaʿanit24b; bKetubot61a; bAvodahZarah3a; bḤullin57b; yShabbat18:2; Genesis Rabbah (Vilna ed.), Genesis 6; Midrash Tanḥuma (Buber ed.), Tetzaveh 6, etc.
[108] Genesis Rabbah (Vilna ed.), Genesis 13:12; Lamentations Rabbah (Buber ed.) §1.
[109] See bEruvin56a; bRoshHashanah21a; bBerakhot59b; yEruvin5:1; yḤagigah2:1.
[110] bAvodahZarah8a.
[111] yBerakhot1:1. This concept is expanded in several later midrashim that describe the day and night as borrowing and repaying one another over the course of the year. See page 112.

Temple's menorah did not need to be adjusted with the seasons.[112] Finally, three related rabbinic passages suggests that the definition of ʿ*onah* (an interval of time related to a woman's menstrual cycle, described below) might vary depending on the season.[113] While the last two cases suggest that the changing of the season might have legal ramifications, in both cases these ramifications are suggested only in order to resolve textual problems in tannaitic sources (i.e. the earliest strata of Late Antique rabbis); the tannaitic sources themselves do not suggest that any modification is necessary.[114]

In medieval Islamic contexts, Jewish scholars do not seem to have identified any additional situations in which seasonal shifts in daylight length was significant, although Maimonides' initial explanation of the concept of seasonal hours does state that it means the hours of prayer will remain the same, "both in the summer *tequfah* and the winter *tequfah*."[115] It is notable that both Maimonides and Ibn Ezra, who were some of the first scholars to adopt the equinoctial/seasonal hour distinction, incorrectly state that the time between dawn and sunrise is a constant value, when in fact it changes over the course of the year.[116] While these statements were likely intended to indicate that the duration of daylight is *approximately* static, such an approximation is itself only possible due to the claimants' relative proximity to the equator.

Jewish texts written in medieval northern France and Germany retain all of the original seasonal associations, but they add a newfound concern for seasonal shifts in

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112 yYoma2:2 / 11b; see also bShabbat22b; bYoma15a; bZevaḥim11b. The Palestinian version suggests that the wicks might have been modified to make the oil burn faster or slower; neither Babylonian version suggests that any modifications were made over the course of the year.
113 bAvodahZarah75a; bNiddah65b; and yAvodahZarah5:14.
114 With regards to the menorah, bMenaḥot89a in fact states that the half-*log* of oil used daily was determined empirically; the amount of oil was either slowly increased or slowly decreased until the half-*log* was eventually found to be optimal. The changing of the seasons does not appear to have been important in these experiments.
115 Commentary to mBerakhot1:1.
116 See Ibn Ezra's long commentary to Exodus 12:31 and Ecclesiastes 12:2; for Maimonides, see page 122.

the length of the day. For this reason, they problematize older rabbinic texts which did not take these shifts into account or, alternatively, re-read them as though they had taken them into account all along. The following texts are indicative of these trends:

- In a passage in the Babylonian Talmud, Rabbi Yehudah asserts that "night is only for sleep."[117] An anonymous comment in the printed edition of Tosafot (largely compiled from twelfth- and thirteenth-century rabbis in France and Germany) limits this statement to summer nights; for longer nights, it cannot be assumed that they will be spent *entirely* in sleep.
- A passage in the Mishnah states, "One who does not increase [their Torah knowledge] decreases it."[118] Maḥzor Vitry, a twelfth century French liturgical text, suggests that this "increase" might mean nighttime Torah study beginning from the summer solstice around the 15th day of Av, since from this point until the winter each night will be longer than the last.[119]
- A passage in the Babylonian Talmud asks how far a person can walk in a day.[120] Rashi (who lived primarily in Troyes, France) says that the inquiry concerns a person "who is average (*beinoni*), on an average day, meaning during the spring or autumn, since the days and nights are equal."
- In the winter, Rabbi Meir of Rothenburg (Germany, d. 1293) reportedly ate the third and final Shabbat meal—the first two being Friday night dinner and Shabbat lunch—immediately after saying the Grace after Meals for lunch.[121]

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[117] bEruvin65a.
[118] mAvot1:13.
[119] *Maḥzor Vitry* §424.
[120] Pesaḥim93b.
[121] *Sefer Tashbetz Qatan* §21.

- A passage in the Babylonian Talmud states that meat soaked in milk "all day" (but not cooked) remains permissible for consumption according to Biblical law.[122] Meir of Rothenburg clarifies that "all day" must mean a full day and night; were it to mean daylight alone the meaning of the rule would be contingent on the length of the day.[123]
- The laws of menstruation mandate that a woman with a regular period not be intimate with her husband during the ʿ*onah*, an interval during which she expects her period to begin. The rabbis debated whether an ʿ*onah* is (1) either a full day or night; or (2) half a day and half a night. The Talmud resolves this debate by suggesting that the first definition could apply during the spring and fall, while the second definition would be suitable for the winter and summer, presumably because the second definition designates an interval that is always roughly half of a 24-hour period. This reconciliation of the two definitions, however, is ignored by the virtually all later scholars, who exclusively apply the first definition.[124] The two notable exceptions are both German authorities: both Rabbi Eliezer ben Joel ha-Levi (Bonn, d. ca. 1235) and Rabbi Eliezer ben Nathan (also known as Ra'avan, Mainz, d. ca. 1170) rule that the second definition should be followed during the winter and summer, as the Talmud had proposed.[125]

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122 bNazir37a.
123 See Rabbeinu Yeruḥam of Provence, *Toldot Adam ve-Ḥavah*, Track 15, Part 5, 13.
124 See, for example: al-Fāsī's gloss on Shavuot, 1b; Maimonides' commentary on mMikva'ot8:3; *Halakhot Gedolot* §41; *Mordekhai*, Hilkhot Niddah §731; *Sefer Rokeaḥ*, Niddah §317; Asher ben Yeḥiel's commentary on Niddah, ch. 1; *Piskei Rid*, Shavuot 18b.
125 Ha-Levi's position is stated in his *Aviasaf*, a work which is no longer extant. The position is recorded in *Hagahot Maimoniyot*, Hilkhot Isurei Bi'ah, ch. 4. For Eliezer ben Nathan's position, see *Ra'avan*, Niddah §318. A third exception is Menaḥem Meiri; his position will be described in the last section of this chapter.

- The shifting durations of the day and night over the course of the year is critical to Tosafot's discussion of Talmudic statements regarding the length of the seasons and the length of the lunar month. Both are described in the next section.
- According to the Talmud, the evening prayer was supposed to be said after nightfall. By the geonic period, however, there is evidence that the evening prayer was being pushed back into the late afternoon. In geonic responsa, this practice is acknowledged but condemned; in southern France, it was given post-facto legal validation as a result of its status as a communal custom (*minhag*). In Ashkenaz, by contrast, both Ra'avan and Rabbeinu Tam apply an unlikely reading of mBerakhot1:1 in order to argue that the practice is *de jure* valid. Jacob Katz has argued that Ashkenazic authorities were more inclined to be accepting of the practice because, in northern Europe's cloudy environment, Christian and Jewish schedules were not moored to specific times and instead strongly adhered to a sequence of events—namely, the afternoon prayer, the evening prayer, and then dinner.[126] Katz is likely correct that location is relevant, but the length of long summer days was probably more important than cloud coverage.

Taken together, these sources demonstrate that latitude mattered for medieval European Jews in much the same way that it did for medieval Christians. While other Jewish scholars of the medieval period *spoke* about seasons in terms of day length,[127] it ap-

[126] See Katz, "Alterations in the Time of the Evening Service (Ma'ariv): An Example of the Interrelationship between Religion Customs and Their Social Background (Hebrew)."
[127] See, for example, Maimonides' commentary on mBerakhot1:1; Ibn Ezra on Daniel 1:1; and David Kimḥi on Joshua 10:12.

pears that it was *only* at these northerly latitudes that the fluctuations warranted normative adjustments and reinterpretation of older rabbinic texts.[128]

The emergence of Ashkenazi awareness of seasonal and equinoctial hours

In chapter 2, I articulated the sequence of conceptual steps that lead from an awareness of shifting daylight to the complementary concepts of seasonal and equinoctial hours. As noted, perceiving seasonal fluctuations in daylight—even severe fluctuations—is necessary but not sufficient for the development of the twin concepts; among Jews in medieval Islamic countries, they become available only through direct borrowing from Islamic astronomy. Thus, despite their everyday awareness of shifts in the length of the day, Jewish texts produced in Christian European lands—even those produced in northern France and Germany—spend very little time on the concept of the hour until the very end of the thirteenth century.[129]

There are two important exceptions. In most instances, rabbis living at northerly latitudes grappled with difficult Talmudic passages that seemed to imply a stable number of daylight hours by saying that those passages referred only to specific times of the year. In two instances, however, problems stem directly from the way in which the Talmud uses the term "hour." In both of these instances, medieval tosafists were forced to engage directly with the meaning of the term; it is in one these instances that the

[128] These latitude-specific problems do not melt away with the invention of the clock; see next chapter.
[129] While both Shabbetai Donnolo in the tenth century and (much later) the Zohar mention in an offhand manner that the day and night contain twelve hours each, neither pursues the matter further; see Piergabriele Mancuso, *Shabbetai Donnolo's Sefer Ḥakhmoni* (Brill, 2010), 332, as well as Zohar Vayakhel 195b and Vayeḥi 231b. It is perhaps relevant that Donnolo lived in southern Italy and the Zohar was composed in Spain, both significant farther south than the centers of Ashkenazi scholarly production.

idea of seasonal and equinoctial hours is first expressed in Ashkenaz. These two passages are worth examining in detail.

The interval between the old and new moon

The Mishnah describes how Jewish months were, at one time, determined on the basis of moon sightings reported by witnesses in front of a rabbinic court. In order for the witness testimony to be valid, however, it needed to be consistent with the rabbis' understanding of what was astronomically plausible. In one passage, the Babylonian Talmud states that there is always a 24-hour period between the disappearance of the old moon and the appearance of the new moons; as such, a witness who testified to seeing both within a shorter span was to be disregarded.[130] A few pages later, however, Rabbi Gamliel states that this is not always the case: "I received from the house of my father's father that sometimes [the moon] arrives slowly and sometimes quickly."[131] Attempting to reconcile these two passages, Tosafot problematizes the word "hour," stating:

> It is possible to distinguish between "hours," for there are small daylight hours, as in the winter *tequfah*, and there are average (*beinoniyot*) hours, as during vernal and autumnal days, and there are large hours, as during the summer *tequfah*.[132]

This comment understands that the meaning of "hour" must be affected by the length of the day, though it only considers one of the two ways in which the length of

[130] bRoshHashanah20b.
[131] bRoshHashanah25a.
[132] Tosafot on bRoshHashanah24b.

the hour could be affected—namely, they vary in length.[133] As noted in the conceptual framework, this idea first comes into Jewish thought in *Baraita de-Shmuel*, a text from the late eighth or ninth century that the Tosafists may have been able to access through the writings of Shabbetai Donnolo.[134] Nonetheless, because this passage does not acknowledge the possibility of any other way of thinking about hours, it cannot be said to be a complete understanding of seasonal and equinoctial hours.[135]

The length of a tequfah (season)

A passage in bEruvin56a defines a *tequfah* as 91 days and 7½ hours; at the same time, it specifies that the transition between the *tequfot* can only take place at specific hours of the day and night. These two conditions are in tension, for while the first condition frames the *tequfot* as always being of fixed length, the second condition suggests that their length may vary. In chapter 2, I noted these internal inconsistencies as evidence of the "naïve" rabbinic understanding of the hour. In chapter 3, I described how Abraham bar Ḥiyya solves this problem (without ever stating it explicitly) by asserting that the Talmud was speaking from the perspective of a person standing at the equator. The Tosafists, lacking an understanding of the relationship between latitude and day length, nonetheless tried very hard to reconcile this text internally and in relation to another Talmudic passage, in keeping with their overarching project of harmonizing the Talmud with itself:

> *From* tequfah *to* tequfah *is only 91 days and 7½ hours.* — This is problematic for

[133] Tosafot does say that hours are "average" in some seasons. This is not the same as claiming that hours are equinoctial, which entails hours maintaining their length in all seasons. This is misunderstood in Mancuso, *Shabbetai Donnolo's Sefer Ḥakhmoni*, 332 n. 140.
[134] See Leicht, "The Reception of Astrology in Medieval Ashkenazi Culture," 209.
[135] In the language of my framework from chapter 2, this is a stage (2b) understanding of the hour; see page 109, above.

Ri (= Rabbi Yitzḥaq ben Shmuel, northern France, d. ca. 1184), for if there are always twelve hours in the day and twelve hours at night—both on short days and long days—the *tequfot* cannot be identical; one will always be longer than another.

For if the vernal *tequfah*[136] will occur at the beginning of Wednesday night,[137] the summer *tequfah* will occur at 7½ hours of the night and the autumnal *tequfah* at 3 hours in the day. Thus, instead of [91 full days and] 7½ shortened summer night hours—for the summer *tequfah* did not fall at the *beginning* of a night[138]—we complete 91 days and 7½ autumnal night hours, which are of average length. Moreover,[139] the 7½ [hours] at the end of the vernal *tequfah*—those in excess of the 91 days—are shortened, while [the 7½ hours at the end of] the summer *tequfah* are of average length.

If you say that hours are always equal (*sheha-shaʿot leʿolam shavot*), and a long day is eighteen hours and a short night is six hours, or the reverse,[140] then Shmuel would not have said, "The vernal *tequfah* only occurs [at certain hours], the summer *tequfah* only occurs [at certain hours], etc." [The Talmud] also would not have said [in bShabbat129b] that Mars is dominant on the third and sixth days of the week but not on other days; instead, it could be [dominant] on the rest of the days but not [dominant] on these [days].

The Tosafist's initial question resembles the one I posed earlier: if the final 7½ hours of each *tequfah* are seasonal (as is suggested by the Talmud's implied use of a twelve

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136 The four *tequfot* are Nisan, Tammuz, Tishrei, and Tevet; they are sometimes referred to as the vernal equinox, summer solstice, autumnal equinox, and winter solstice, respectively. I have used the seasonal terms instead of the month names for clarity, but have retained the word *tequfah* to emphasize that (1) the *tequfah* here means a point in time, not a full day, (2) the single term *tequfah* is used for all four, and (3) the *tequfot* bear an ambiguous relationship to the astronomical equinoxes and solstices.

137 Wednesday is indicated because, in the initial configuration of the universe, the first equinox was vernal and it took place on a Wednesday; see bBerakhot59b.

138 Emphasis mine. The point of this parenthetical is simply to reaffirm that the final 7½ hours of the *tequfah*-to-*tequfah* span took place during the shortened summer night hours and not the lengthened summer day hours.

139 This seems to be a restatement of the previous point, rather than a new argument; see *Tosafot ha-Rosh*, Eruvin 56a, which contains an argument structured in an identical manner.

140 Here correcting וביום ארוך ובלילה ארוך י״ח שעות ובלילה קצר ו׳ או להפך to ובלילה ארוך י״ח שעות ובלילה קצר ו׳ או להפך.

hour day and twelve hour night), the *tequfot* cannot be the same length.[141] At the same time, as the Tosafist notes, equal hours cannot be intended because the astrological system of "planetary hours" (to which bShabbat129b alludes) assumes that certain planets will always be "dominant" during specific hours of the day or night, yet this cannot be assured if the number of hours in each is in flux.[142] This is a dilemma which the tosafists are unable to resolve.[143]

Unlike his contemporaries in Islamic lands, Rabbi Isaac does not have a word to describe "seasonal" hours; instead, he simply says that, under one definition, there are always twelve hours in the day and twelve hours in the night. Nonetheless, he is likely the first Jewish scholar in Christian northern Europe to reflect on the fact that "hour" has more than one possible meaning. This is an important conceptual development.

Despite its sophistication, Rabbi Yitzḥaq's thinking still falls short of the conceptualizations of Ibn Ezra and Maimonides, who not only recognize the *theoretical* validity of the two types of hour, but also understand that both have long been in use. Instead, Rabbi Yitzḥaq operates under the assumption that only *one* of his suggested definitions can ultimately be correct.[144]

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[141] This is presumably a problem because Rabbi Yitzḥaq assumes that they are supposed to be of equal length, although this is never stated.

[142] Both of the original statements are difficult to parse. Shlomo Gandz questioned whether there is anything in the planetary system that makes Tuesday and Fridays a Mars-dominant day; see Gandz, "The Origin of the Planetary Week or the Planetary Week in Hebrew Literature," 226–227. Regardless, what is clear is that the tosafistic objection assumes that it matters whether a given planetary hour occurs during the day or night.

[143] Curiously, Bar Ḥiyya does not seem to have been at all bothered by the slight variation between *tequfot*. See Ilana Wartenberg, "The Hebrew Calendrical Bookshelf," in *Time, Astronomy, and Calendars in the Jewish Tradition*, ed. Sacha Stern and Charles Burnett (Brill, 2013), 103.

[144] In practice, it seems that the *tequfot* were calculated using "naïve" hours; see page 58. A clear articulation of the arithmetic by which the *tequfot* were calculated is given in *Sefer Abudraham* in its chapter on *tequfot.*

Both of these tosafistic comments relate to the concept of the day's fluctuating length without attempting any quantification. Hours, days, and nights are either short, average, or long; indeed, Rabbi Yitzḥaq's supposition that equal hours would result in six hour days and eighteen hour nights (or the reverse) would not have been realized anywhere south of the 59th parallel north, a line which in Europe transects only Russia and the Nordic countries. In its empirical but not theoretical awareness of these matters, the tosafists are entirely consistent with the monastic orders described above.

Practical timekeeping in Jewish legal texts

In Chapter 2, we noted that the twelve-hour day adopted by the rabbis masked a much simpler practical division of the day; this was unearthed by noting that certain hours of the day are used in normative contexts and with much higher frequency than others. The rabbis of Late Antiquity had adopted the twelve-hour day because it was familiar to them from their Hellenistic environment; it was, so to speak, their native system.

This adoption presents us with a methodological problem. Because their predecessors had adopted elements of the Hellenistic timekeeping system, medieval rabbis continued to use these elements, but this does not tell us whether they were still in common use or instead simply represented a vestige of a different culture's legal terminology.[145] To give a concrete example: it is not surprising that medieval rabbis continued to speak about the legal obligations of Passover Eve in terms of the fourth, fifth, and

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[145] Few sub-hour units appear in medieval Ashkenaz; the *regaʿ* is occasionally mentioned but usually not defined; see Rashi on Pesaḥim 12a and Ḥullin 58b; *Tosafot ha-Rosh*, Avodah Zarah 4a; *Rabbeinu Yehonatan al ha-Rif*, Taʿanit 4a; *Ḥiddushei ha-Rashba*, Bava Batra 9a. Rabbeinu Tam does show an interest in reconciling the definition of *regaʿ* on bAvodahZarah4a on the basis of tBerakhot1:1. He calculates that one *regaʿ* is 1/13824 (that is, one in 24^3) of an hour, as we did in chapter 2. See *Sefer ha-Yashar* §691.

sixth hours, but it is hard to know whether these terms would have appeared archaic or unusual to the average person. Given our current inability to address this methodological problem, it is hard to assess the cultural significance of many medieval comments about timekeeping in the legal writings of medieval rabbis.

By contrast, the medieval text considered below present the mode of timekeeping employed when there was no pre-existing reason to choose one timekeeping system over another. With regard to these instances, we can devise a simple test: Use of Hellenistic timekeeping terminology in new medieval cases suggests that the system was still in active use; conversely, the absence of such terminology or the use of a *different* set of terminology would suggest that the Hellenistic system had retained its legal importance but was otherwise not used in the culture. Almost all evidence points towards the latter position, as I will now demonstrate.

The use of hour approximations

In the previous chapter, I examined a number of legal situations where Late Antique rabbinic texts articulate a legally significant time interval in terms of some non-standard metric, e.g. the time between sunset and when people leave the marketplace, the time it takes to walk a *mil*, etc. I showed that, in Islamic lands, many of these non-standard metrics were translated into an approximated number of hours (or fractions of an hour), suggesting that the hour unit had become part of general parlance among Jews, even despite the relatively minimal usage of precision timekeeping devices.

If we re-examine those same legal situations from the perspective of texts written by Jewish scholars in medieval Christian Europe, it is clear that no similar effort was made to relate the terminology to a metric known from experience. Instead, non-standard units are simply repeated without much additional commentary. Thus, for example, there is no attempt to "translate" or further codify the Talmudic regulation that stipulates how long Ḥanukkah candles must burn,[146] nor is there any temporal explanation of the Talmudic rule that a flour-and-water mixture will become *ḥametz* in the time it takes to walk a *mil*.[147] In the same vein, the Talmud's proscription against eating cheese after meat is not given any further temporal articulation.[148]

This result is somewhat surprising, given that the church had a formal interest in preserving the Roman timekeeping as a result of its appearance in the New Testament and its use by early church fathers, while Islamic law was not constructed on this framework. Regardless, the evidence suggests that medieval Jews in Islamic lands were more comfortable with hour approximations than their counterparts in Christian Europe.[149]

"A third of the day"

The weakness of the above argument is that it is made on the basis of an absence of evidence, which is not by itself evidence of absence. The claim is strengthened, however, by a phenomenon that repeats in several places: the translation of a timekeeping measurement *out* of the Roman timekeeping system into something more rudimentary.

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[146] bShabbat21b.
[147] bPesaḥim93b.
[148] bḤullin105a.
[149] This result is sometimes overlooked by scholars. Thus, for example, Havlin's discussion of Rabbeinu Tam's position regarding the length of twilight assumes that the latter is thinking about phrases like "three quarters of a *mil*" and "four *mil*" in terms of minute equivalents. (See Shlomo Zalman Havlin, "Twilight and the Determination of Sunset (Hebrew)," *Asufot* 14, no. 9–40 (2002): 11.) The earliest attempt to translate Rabbeinu Tam's position into temporal terms is located in *Shut ha-Rid* §116, discussed below. While later authorities understood Rabbeinu Tam to be arguing that twilight is relatively long, this understanding is premised on a translation between *mil* and time units which is not found in medieval Ashkenaz prior to 1300. Indeed, it is not clear to me that Rabbeinu Tam understood his arguments in this matter as having any legal significance at all.

In a short comment, the Provençal scholar Rabbi Yehonatan of Lunel (d. 1209) makes the following remark about the Sukkot-holiday obligation to gather the "Four Species" (a citron, palm branch, and sprigs of myrtle and willow) and wave them. Rabbi Yehonatan considers whether one can fulfill this obligation if one waves each of the Four Species at a different point during the day:

> If he wishes he may take one [of the Four Species] in the morning, the second at [the conclusion of the first] third of the day (*shelish ha-yom*), and the fourth and fifth in the afternoon [at different points].[150]

Because he is simply sketching a hypothetical itinerary for the day, Yehonatan is able to use whatever timekeeping system he wishes. Rather than employ the hour system, he divides the first half of the day into "morning" and "third of the day," the latter presumably meaning something like "late morning."

Yehonatan is not the only medieval Jewish scholars to divide up the morning using this fraction.[151] Maḥzor Vitry contains an analogy in which someone knocks on a door "until a third of the day [has elapsed]."[152] In addition, the *Mordekhai*, composed by a thirteenth century German rabbi, describes how one might undertake a partial-day fast:

> If he wishes to fast for part of the day (*le-shaʿot*), he should say, "I hereby [obligate myself] tomorrow with a *taʿanit shaʿot* until a third of the day [has elapsed] or half [the day]," or less or more, according to his desire.[153]

[150] *Rabbeinu Yehonotan ʿal ha-Rif*, Sukkah 16b.
[151] See also *Rabbeinu Yehonatan ʿal ha-Rif*, Shabbat 17b, Bava Metzia 52b.
[152] *Maḥzor Vitry* §287.
[153] Mordekhai, Taʿanit, 622. Cf. Sekhel Tov (Buber ed.), Genesis, chapter 19. See also *Sefer Ra'aviah*, vol. 1, Berakhot 83.

These texts establish that the phrase "third of the day" was recognized in a way that is not attested in Late Antique rabbinic sources. More interesting, however, is that the phrase is sometimes presented as a *translation* of a rabbinic term. This suggests that the twelve-hour system known to Late Antique rabbis would not have been fully understood by Jews living in medieval Christian Europe. An example of this appears in *Sefer Mitzvot Gadol*, a popular thirteenth century French legal compilation. The time window for saying the morning prayer is described here as "until the fourth hour, which is a third of the day," suggesting that the reader might not know what "the fourth hour" meant.[154] A more explicit reference is made in *Sefer ha-Niyyar*, an anonymous French work from the late thirteenth or early fourteenth century.[155] Here, in the context of the ban on eating leavened bread on Passover Eve, the author writes that one should eat, "before four hours, which is called 'a third of the day.'"[156] A similar formulation appears in the Talmudic commentary by Menaḥem Meiri (d. 1306).[157]

While the formulation is still rare, the instances in which the term "a third of the day" is used in medieval writings—combined with its absence from both Late Antique rabbinic texts and medieval texts written in the Islamic sphere—suggest that the phrase was in colloquial usage. Furthermore, the use of the phrase to clarify the meaning of "four hours"—which, as we have noted, was one of the most popular hours of

[154] *Sefer Mitzvot Gadol* §19.

[155] This work was only first published in 1994. Gerson Appel suggests that the unusual title (literally "Paper Book") is due to French adoption of paper at the end of the thirteenth century; this compilation may have been one of the first French Hebrew texts to be written on paper pages. See Gerson Appel, ed., *Sefer Ha-Niyyar* (Jerusalem, 1994), 18–19.

[156] *Sefer Ha-Niyyar*, Laws of Passover. The relationship between "four hours" and "a third of the day" would become more complicated after the development of the mechanical clock. We shall deal with this in the next chapter. See, as well, *Peirush Siddur ha-Tefillah le-Rokeaḥ*, Parashat ha-Tamid, p. 28, El Adon, p. 523-4.

[157] *Beit ha-Beḥirah*, Berakhot 26a.

Late Antiquity—suggests that the Roman twelve-hour day had lost some of its status as the timekeeping system of choice among medieval Jews living in Christian Europe.[158]

Tequfah customs and timekeeping expectations

Did Jews in Christian Europe have lower expectations than their counterparts in Islamic lands regarding how well people reckoned time over the course of the day? It is hard to answer this question definitively. Because Jews in Late Antiquity underutilized the Hellenistic timekeeping system, it is hard to argue that an indifference towards Roman timekeeping terminology reflects a shift in expectations about how well people kept track of time or what amount of timekeeping error was deemed acceptable in a given society. In order to assess these expectations, it may help to examine a widespread folk custom involving the *tequfah*.

The moment of transition between each of the four annual *tequfot* is called, confusingly, a *tequfah*; because it is determined through a mathematical calculation, the time at which it takes place is always well-defined. The notion that these moments of transition needed to be heeded by humans first appears in an eleventh-century responsum of Hai Gaon of Baghdad, who writes that "people are warned not to drink water in those hours."[159]

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[158] Two medieval midrashim may also attest to the influence of the "third of the day" framework. Both Eliyahu Rabbah (ch. 14 and 24) and Yalqut Shimoni (Ki Tisa #391) describe God as dividing his work day into thirds. This is quite reminiscent of the bAvodahZarah3b, in which God is described as dividing his day in four three-hour blocks; this was quoted above as evidence of the rabbinic use of a quadripartite day. With these medieval sources, more caution is warranted. First, it is not clear whether God is dividing up the daylight hours or a complete 24-hour cycle. Second, the European provenance of Eliyahu Rabbah has not been confirmed. Finally—and most importantly—it is only the *first* third of the day which appears to have entered popular usage; it is not clear whether the rest of the day was divided into thirds. The relationship between these midrashim and the texts cited above must be left for further study.

[159] Israel M Ta-Shma, "The Danger of Drinking Water During the Tequfa: The History of an Idea," *Jerusalem Studies in Jewish Folklore*, 1995, 21. See also Carlebach, *Palaces of Time*, 168–169.

While this Jewish custom was widespread throughout both Christian Europe and Islamic lands,[160] only in Ashkenaz was it given quasi-legal status.[161] An example from *Sefer Ḥasidim* is instructive: if a person says the blessing on water at a time when it might be the *tequfah*, "he should wait and not speak until he is confident that the time of the *tequfah* has passed. Then he should drink without saying [another] blessing."[162] Since blessings on food and the consumption of food itself are normally supposed to follow in quick succession, the *tequfah* must have been taken quite seriously.[163]

That a person is being asked to sit quietly and wait to drink water suggests that the potential window in which the *tequfah* might occur is of long duration. Other sources, however, suggest that it is the hours around the *tequfah* or even the entire day of the *tequfah* that matters. In Ashkenaz, this position appears in the context of the custom to bake matzah using water which has "rested" overnight.[164] Since the vernal *tequfah* usually occurs just before Passover,[165] precisely when many people baked their matzah, several twelfth- and thirteenth-century German authorities debated whether water which was standing on the *day* of the *tequfah* could be used for this purpose.[166] There is thus at least some evidence that, as a practical matter, the precision of the *tequfah* did not translate into expectations of precision among the Jewish population.[167]

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[160] Indeed, al-Bīrūnī mentions it in his description of the Jewish calendar. See Edward Sachau, ed., *The Chronology of Ancient Nations* (London, 1879), 162–163.
[161] Ta-Shma, "The Danger of Drinking Water During the Tequfa: The History of an Idea," 24.
[162] *Seder Ḥasidim* (Margoliot ed.) §851.
[163] Whether this position is radical depends on whether an extended silent pause between a blessing on food and eating the food constitutes an "interruption." On this, see *Olat Tamid* on *Shulḥan ʿArukh*, O.Ḥ. 206:3.
[164] bPesaḥim42a.
[165] The vernal equinox occurs on March 19 or 20; Passover begins sometime between March 25 and April 24. Over the course of centuries, the Hebrew calendar shifts slightly in relation to the solar calendar; 1000 years ago, the earliest start date for Passover could have been one or two days before Passover.
[166] Ta-Shma, "The Danger of Drinking Water During the Tequfa: The History of an Idea," 23–25.
[167] See also Wartenberg, "The Hebrew Calendrical Bookshelf," 106.

Importing knowledge from Islamic lands

In the thirteenth century, rabbinic timekeeping discourse experienced a significant shift as Maimonides' *Mishneh Torah* and geonic materials found their way into the hands of rabbis living in Christian Europe, beginning with Spain and Provence. Maimonides' code makes explicit reference to the concept of seasonal hours and it periodically translates Talmudic non-standard intervals into hour approximations; geonic codes speak of direct experience with timekeeping devices. As a result, the timekeeping discourse in Jews writings in Christian Europe around the turn of the fourteenth century began to look like its counterpart in Islamic lands.

The earliest evidence for the use of Maimonides' ideas about timekeeping might be located in a responsum of Rabbi Isaiah of Trani, an Italian scholar of the first half of the thirteenth century.[168] As part of his attempt to understand Rabbeinu Tam's position regarding the determination of sunset, Rabbi Isaiah notes that the Talmud (bPesaḥim93b) states that an average person can walk ten parasangs in a day, "which is 40 *mil*, meaning 3⅓ *mil* for each hour, and in 1¼ hours more than four *mil*."[169] The use of this particular Talmudic passage to translate distances into time units was pioneered by Maimonides, whose understanding of mPesaḥim3:2 seems to rely on it.[170] Furthermore, as already noted, *any* translation of distances into hour units in Jewish writings in Christian

[168] There is, as well, an idiosyncratic mystical/calendrical work entitled *Sefer Ha-Ḥayyim*, composed in northern France around 1200. This is the only medieval Ashkenazi work that demonstrates knowledge of Ibn Ezra's astronomical works. However, it does not seem to represent the beginning of a trend. See Leicht, "The Reception of Astrology in Medieval Ashkenazi Culture," 230.
[169] *Shut ha-Rid* §116. 1¼ hours is relevant because it is the amount of time between the deadline for saying the evening *shemaʿ* and the end of the day according to Rabbi Yehudah.
[170] Note that Maimonides does not cite bPesaḥim93b; he simply states that the time it takes to walk a mile is two-fifths of an equinoctial hour. Rabbi Isaiah is the first to spell out the logic.

Europe is unusual and noteworthy.[171] Although Maimonides' *Guide for the Perplexed* features prominently in Rabbi Isaiah's Bible commentary, the Italian rabbi cited quite sparingly in his legal writings.[172] It is certainly possible that Maimonides' technique—along with Maimonides' general interest in expressing durations in terms of hours—was appropriated by Rabbi Isaiah.[173]

Menaḥem Meiri is the most prominent adopter of the new timekeeping language. It is in his writings that phrase *shaʿot zemaniyyot* ("seasonal hours") first appears in Christian Europe.[174] Meiri also engages in hour approximation with regard to Ḥanukkah candles, which he says must be lit for half an hour.[175] He adopts Maimonides' approximation of the length of time it takes for a flour and water mixture to leaven,[176] as well as the rule than one cannot consume dairy after meat, "for six hours or thereabouts."[177] Finally, and perhaps most significantly, he not only supports the *Aviasaf*'s position regarding the length of a woman's *ʿonah* (see above, p. 194), but states for the first time that the intent of position is to preserve the *ʿonah* as "twelve [equal] hours."[178]

Other scholars adopted these concepts and rulings, as well. The approximation regarding the waiting interval between eating meat and cheese can be found in the *Kol Bo*, an anonymous Provençal legal compilation likely composed in the late thirteenth or

[171] bPesaḥim93b is sometimes cited in order to extrapolate how many *days* it would take a person to go from one place to another. See, for example, Rashi on Pesaḥim94b, s.v. *ve-khein*; Tosafot on Rosh Hashanah 23b, s.v. *kamah*.
[172] Israel Ta-Shma, *Creativity and Tradition* (Harvard University Press, 2006), 177–178.
[173] Maimonides' statement appears in his Mishnah commentary but not in the *Mishneh Torah*. As a result, this argument relies on Isaiah having access the commentary.
[174] *Beit ha-Beḥirah*, Berakhot 2a, 26a, and Pesaḥim 99b.
[175] *Beit ha-Beḥirah*, Shabbat 21b.
[176] *Beit ha-Beḥirah*, Pesaḥim 45a.
[177] *Beit ha-Beḥirah*, Ḥullin 105a.
[178] *Beit ha-Beḥirah*, Niddah 65a.

early fourteenth century.[179] Shlomo ben Aderet (also known as Rashba, d. 1310) mentions this approximation, as well;[180] he also mentions two hour intervals,[181] six hour intervals,[182] twelve hour intervals,[183] and a three-hour interval describing how long a man must be stuck in a body of water before it can be assumed that he has drowned.[184] Neither of these authors references seasonal or equinoctial hours.

Reception of more sophisticated astronomical knowledge also led to significant advances in Jewish astronomical terminology. Shlomo Sela has described a *Sefer ha-Kolel*, written around 1256 in southern France or northern Italy, which apparently uses the same terminology as Ibn Ezra and Bar Ḥiyya.[185] An encyclopedic work, entitled *Midrash ha-Ḥokhmah*, was translated from Arabic into Hebrew by its author, Judah ibn Mathkah, when he arrived in Lombardy.[186] This work uses the term *maʿalot* to mean a 1/360 part of a circle (i.e., a degree);[187] in addition, it adopts the Ptolemaic system of "seconds," "thirds," and "fourths," in which each unit of time is 1/60 of the preceding unit.[188]

Finally, access to the Maimonides' writings, geonic writings, to Arabic scientific materials resulted in the first detailed Hebrew descriptions of the timekeeping devices themselves. Writing in thirteenth century Spain, Rabbi Shlomo ben Aderet cites Hai

[179] *Kol Bo* §106. See also *Kol Bo* §10, which adopts what is probably a corrupted reading of *Mishneh Torah*, Hilkhot Qeriat Shema 1:11 (reading שיעור instead of עישור).
[180] *Ḥidushei ha-Rashba,* Ḥullin 105a; *Torat ha-Bayit ha-Qatzar*, House 3, Gate 4, 86a; *Mishmeret ha-Bayit*, House 3, Gate 4, 86a.
[181] *Shut Torat Emet* §6.
[182] *Mishmeret ha-Bayit*, House 4, Gate 1, 3a.
[183] *Torat ha-Bayit ha-Arokh*, House 5, Gate 6, 66a; *Torat ha-Bayit ha-Arokh*, House 3, Gate 3, 74a; *Torat ha-Bayit ha-Qatzar*, House 3, Gate 3, 72b; *Mishmeret ha-Bayit*, House 3, Gate 3, 73a.
[184] *Shut Torat Emet* §3.
[185] Shlomo Sela, "The Astrological-Astronomical Encyclopedia in MS Paris 1058," *Aleph* 14, no. 1 (2014): 189–241.
[186] Shlomo Sela, 222.
[187] Shlomo Sela, 229.
[188] Shlomo Sela, 230.

Gaon's explanation that David's lyre was in fact a water-clock (*finjān*).[189] Menaḥem Meiri provides a fairly detailed explanation of the function and construction of the sundial in explaining the phrase *even shaʿot*.[190] Lastly, and most intriguingly, the Zohar describes a rabbi who, like King David, has a "signal" (*simana*) which rings out exactly at midnight (*befalgut leilya mamash*). The device is described as a "weighted thing" (*tiqla*) filled with water that then drips out. At precisely midnight, "this cogwheel (*qitfa*) spins and clangs."[191] The Zohar's description of a geared clepsydra evokes designs which Jews had made available to Alfonso X from Arabic sources.[192]

Marking the inception of Maimonidean influence is important for two reasons. First, the timekeeping concepts of the *Mishneh Torah* are far more sophisticated than anything that had existed in Jewish writings in Christian Europe previously; as a result, the incursion of the *Mishneh Torah* effectively brought "homegrown" timekeeping discourse in the Jewish writings of Christian Europe to an end.

At the same time, these concepts emerged slightly *before* the advent of the mechanical clock and are separate from the changes that came with the clock itself. Shlomo ben Aderet, for example, states that it was still not the practice to time-register contracts.[193] While the introduction of texts written by Jews in Islamic lands and the final mechanical breakthrough that resulted in the clock are both direct results of the importation of knowledge transfer from Islamic lands in the latter half of the thirteenth

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[189] *Ḥidushei ha-Rashba,* Berakhot 3b. See above, page 123.
[190] *Beit ha-Beḥirah*, ch. 3.
[191] Zohar 1:92b. Both *tiqla* and *qitfa* are Zoharic neologisms and their precise meaning has been a matter of debate. *Qitfa* is literally rendered as "resinous thing," perhaps in reference to a particular method of cogwheel construction. See notes in Daniel C. Matt, *The Zohar: Volume Two* (Stanford University Press, 2004), 81–82. For a slightly different explanation, see Ruth Kara-Ivanov Kaniel, "Lot's Daughters and the Mothers of Davidic Dynasty in the Zohar: The Enigma of the Term 'Tiqla,'" *English Language Notes* 50, no. 2 (2012): 113–26.
[192] Yitzhak Baer, *A History of the Jews in Christian Spain* (Jewish Publication Society, 1992), 1:267–8.
[193] *Shut ha-Rashba* II:86.

century, Jews encountered the clock at least several decades after these texts had been introduced. Thus, by the time Jews in Christian Europe began to encounter mechanical clocks, they had already imbibed more advanced ways of talking about timekeeping. These advances are distinct from the changes wrought by the introduction of the mechanical clock; the latter will be discussed in the next chapter.

Chapter 5: Timekeeping in the Era of Mechanical Clocks: From Invention to 1657

I. Background

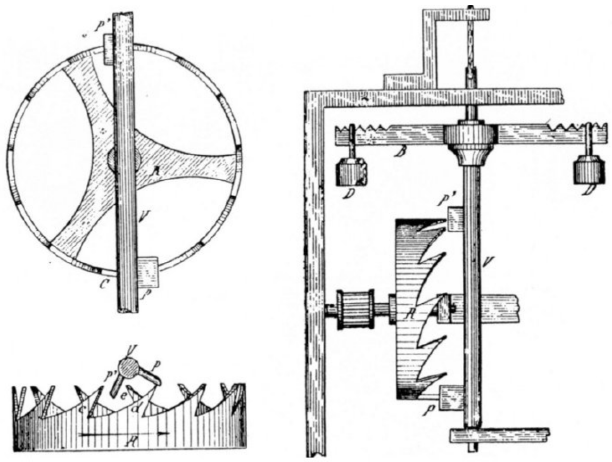
This chapter begins with the origins of the mechanical clock and ends in 1657, when improvements on clock and watch design led to increases in accuracy, which in turn led people to interact with the devices in new and different ways. This "first stage" of the mechanical clock's development saw major advances in the proliferation and miniaturization of timekeeping devices, but the precision and utility of the devices remained essentially uniform. As a result, this chapter is essentially the story of the rise in access to a specific new type of timekeeping system. It is also the story of the sandglass, a technology which happened to arise at precisely the same time and which had a real but more minor effect on Jewish timekeeping notions.

Until around 1300, all timekeeping instruments operated on the basis of a single technique: they began with a phenomenon which changed in a predictable and uniform way (the movement of the sun across the sky, the dripping of water from a vessel, the melting of a wax candle) and the creating of subdivisions (the lines on a sundial, the marks on a clepsydra's walls, the volume of the clepsydra) in order to partition that phenomenon into useful units.

This technique has two significant flaws. First, the phenomena on which it relies are not entirely uniform: it is difficult to force water to flow at an absolutely constant rate, just as it is difficult to make a candle whose burn rate never varies. The sun's movement is constant (or is effectively so), but the amount of time it spends above the horizon each day varies. The concept of seasonal hours accommodates this variation, but for such a basic unit to have no absolute value was certainly not ideal. As we have already seen, Late Antique rabbis were never able to fully grasp the concept.

The second problem concerns the subdivisions. A sundial or clepsydra is only as accurate as the inscriptions it bears. Greater accuracy requires greater precision in marker placement, but this gets progressively more difficult as one attempts to delineate smaller and smaller units of time. The demand for precision meant that the creation of timekeeping devices was expensive. The most accurate devices were the largest (and least mobile) and building them required the expertise of a specialist. Even these large devices had limits: as we saw in the last chapter, Bede did not think that *any* sundial could measure increments shorter than fifteen minutes. Despite more than 2,800 years of continuous use, neither the sundial nor the clepsydra was able to surpass either of these problems in any significant way.

The introduction of the mechanical clock solved both of these problems through an entirely new approach to timekeeping, one which proved to be so successful that, in the twentieth century, it precipitated the decline of the mechanical clock itself. Instead of marking the hour (and the minute, second, etc.) by *dividing* a longer motion, the mechanical clock marks off each by *accumulating* and *enumerating* small, regular motions—in other words, by counting "ticks." Creating these regular movements required a major technological breakthrough, since all of the power sources used to operate geared clocks (water flows, heavy weights, etc.) conveyed power in an uninterrupted stream of that varied in strength. In order to make a better timepiece, it was necessary to divide this power stream into bursts and then mitigate variations in the strength of those bursts.



A typical verge-and-foliot escapement mechanism. The image on the bottom left shows the interaction between the crown mechanism and the two pallets.

The escapement mechanism, initially in what is known as verge-and-foliot configuration, solved this problem and opened the door to a timekeeping revolution. By inserting this mechanism into the weight-driven clocks, which had become popular only a few decades earlier,[1] variations in force were smoothed over by braking and then releasing a gear at regular intervals.[2]

In verge-and-foliot escapements, a heavy weight—or, for watches, a tightly wound spring—causes a crown-shaped, toothed wheel (the "crown" escapement) to turn. The movement of this wheel is then imparted to a rod (the verge), out of which project two flaps (pallets). The pallets are designed to take turns catching the escapement's teeth, each time momentarily stopping the gear and thus breaking the force from the weight or spring into discrete units. It is this momentary breaking that results in "ticks."

Ticks, however, are not sufficient, since nothing in this system regulates how long each tick will be; the escapement gear will simply stop and start faster or slower depending on how much torque is being exerted on it. The device which regulates these

[1] Linne Ruth Mooney, "The Cock and the Clock: Telling Time in Chaucer's Day," *Studies in the Age of Chaucer* 15 (1993): 101.
[2] Landes, *Revolution in Time: Clocks and the Making of the Modern World*, 10–11.

oscillations is the foliot, a weighted bar (later a wheel) sitting atop the verge that can rotate in either direction. With each movement of the escapement, the verge imparts momentum to the foliot, making it rotate in one direction. Since the next "tick" cannot occur until the foliot stops and rotates in the other direction, the amount of time between ticks is determined by how long it takes the verge and escapement to bring the foliot to a complete stop and reverse direction. Because this time is dictated by how heavy the foliot is, the time between ticks can be shortened or lengthened at will by carefully adding to or removing weights from the foliot.

Striking the equinoctial hours

As John Scattergood has put it, "Medieval clocks became complex before they became accurate."[3] Though precision eventually came to be the mechanical clock's key advantage over other instruments, precision *per se* was not the first way in which the escapement changed popular timekeeping. Indeed, the first mechanical clocks were not appreciably more precise than their pre-escapement counterparts: in the early stages, it was still common to calibrate mechanical clocks by means of a sundial.[4] While the introduction of the mechanical clock led to a change in the way Europeans kept track of time, it has been known for more than a century that it was their striking system, not their precision, which was initially responsible for this change.[5]

What the clocks also offered was an accessible timekeeping system based on equinoctial hours. Though these hours had been used by specialists for thousands of years,

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[3] Scattergood, "Writing the Clock: The Reconstruction of Time in the Late Middle Ages," 461.
[4] Scattergood, 462.
[5] Rothwell, "The Hours of the Day in Medieval French," 242; Rothwell relies on the research in Gustav Bilfinger, *Die Mittelalterlichen Horen Und Die Modernen Stunden: Ein Beitrag Zur Kulturgeschichte* (Stuttgart, 1892), 157.

marking them for the public had never been easy; sundials were more naturally calibrated to track seasonal hours, and clepsydras large enough to track a full day were both very rare and—because water is dense—required constant, laborious maintenance.[6] As a result of these challenges, all popular timekeeping in Europe, North Africa, and the Middle East used sunset, sunrise, or the sun's position in the sky as the default reference frame.

As it turned out, even the crudest mechanical clocks were capable of changing this default. While many of the automata using the new gearing systems were built for purely aesthetic purposes, the escapement mechanism also enabled more advanced striking systems; as a result, it suddenly became possible for the bells to announce not just *that* a new hour had arrived, but *which* hour had arrived, ringing once for the first hour, twice for the second hour, and so on. Crucially, the mechanism which performed this task was tightly bound to the equinoctial hour; unlike the clepsydra, it was not thought possible to use it to ring out seasonal hours.[7] This small change—the shift to equinoctial hours—which is attested as early as 1336, had major implications.[8] Whereas previously a bell's ring could not be deciphered without context (how many times the

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[6] Whether these construction and maintenance costs were greater than those for the first public mechanical clocks is not clear.

[7] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 112. An interesting caveat should be inserted here. The earliest type of mechanical clock, known as the verge-and-foliot design, did not perfectly translate the force of the weights to the required frequency; as a result, verge-and-foliot clocks contained small weights for manual calibration, ensuring that an individual timepiece's hours would be neither too long nor too short. While these weights were used to ensure regularity, they could have just as easily been used to allow the clock's hours to grow and shrink with the seasons—which is precisely what Japanese clockmakers did when verge-and-foliot clocks, stripped of any instruction manuals or cultural memory, arrived on Japanese shores in the sixteenth century. Thus, while it is true that Europeans *understood* their new clocks to be inextricable from the equinoctial hour, this was not in fact the case; it cannot be said that the technology forced their hand. Why they did not use the devices to reinforce the use of seasonal hours is a question worthy of study. On the Japanese adaptation of European clocks, see Yulia Frumer, *Making Time: Astronomical Time Measurement in Tokugawa Japan* (University of Chicago Press, 2018), 43ff.

[8] See reference in Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 108 n. 176.

bell had rung previously that day and/or the approximate time of day), the new clocks' ringing did not need to be combined with other pieces of information in order to understand its meaning. Furthermore, the ringing of the new clocks, unlike the ringing of church bell, had no inherent religious meaning; they were intended for general use.[9]

In short, the revolution in timekeeping was initially marked by the public embrace of equinoctial hours; only later did the clocks' accuracy become important. By introducing complex striking mechanisms into cities, the new clocks popularized and secularized timekeeping via a system which, by virtue of the escapement mechanism, promoted the use of equinoctial hours.

The mechanical clock's first century

"The development or the invention of the mechanical clock," wrote Gerhard Dorhn-van Rossum in his book on the subject, "has been more frequently discussed, and can be considered to have been more thoroughly researched, than any other aspect of the history of technology prior to the industrial revolution."[10] Despite this widespread interest, neither the year of the clock's invention nor the earliest stages of its development have been definitively determined.

In his 1271 commentary on an astronomical work by Johannes de Sacrobosco (d. c. 1256), Robert Anglicus wrote the following:

> Nor is it possible for any clock (*horologium*) to follow the judgment of astronomy with complete accuracy. Yet clockmakers (*artifices horologiarum*) are trying to

[9] Jacques Le Goff, *Time, Work, and Culture in the Middle Ages* (University of Chicago Press, 1980), 29–32. As we will see below, Jews did not entirely agree with this assessment of the clock's religious connotations.
[10] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 46. While this may be true, a considerable amount of this scholarship does not engage directly with primary sources, and much can still be traced directly back to the foundational work of Gustav Bilfinger in the late nineteenth century.

> make a wheel which will make one complete revolution for each [revolution of] the equinoctial circle, but they cannot quite perfect the work. If they could, it would be a really accurate clock and worth more than an astrolabe or other astronomical instrument for reckoning the hours if one knew how to do this according to the method aforesaid.
>
> The method of making such a clock would be this: that a man makes a disk of uniform weight in every part, as far as could possibly be done. Then a lead weight should be hung from the axis of that wheel, and this weight should move that wheel so that it would complete one revolution from sunrise to sunrise, minus approximately as much time as it takes about one degree to rise.[11]

Anglicus' comment, which describes a yet-unfulfilled desire to create a mechanical clock, was first highlighted by Lynn Thorndike in the 1940s, and it is often treated as the *terminus post quem* for the clocks' eventual invention.[12] Exactly when this invention happened, however, is not at all clear; Anglicus' description of clockmakers' work on the problem suggests that the mechanical clock, like many other important inventions, was developed incrementally by skilled artisans, rather than in one fell swoop by a solitary genius.[13] This hypothesis is supported by the term *horologium* and its various linguistic cognates, which in the fourteenth century referred to both mechanical and pre-mechanical clocks without differentiation;[14] "clok," which derives from a Celtic/Germanic word for "bell," is not attested before 1371.[15] Indeed, the escapement—that key, final European breakthrough—was buried in the bowels of the clock and would

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[11] Translation modified from North, "Monasticism and the First Mechanical Clocks," 176.
[12] Lynn Thorndike, "Invention of the Mechanical Clock about 1271 A.D.," *Speculum* 16, no. 2 (1941): 242–243.
[13] Joseph Needham, as part of his study of Chinese technology, pointed to a Chinese invention from the eighth century which might have been the "missing link" between European weight-driven water-clocks and the mechanical clock. This hypothesis has been successfully critiqued by both David Landes and Dohrn-van Rossum; see Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 84ff.
[14] Dohrn-van Rossum, 46.
[15] Mooney, "The Cock and the Clock: Telling Time in Chaucer's Day," 101. A full etymological analysis is given in "Clock, n.1," OED Online (Oxford University Press, n.d.).

have been invisible to the public. The public, meanwhile, would have been far more enamored by the increasingly sophisticated automata, which adorned complex water-clocks and mechanical clocks alike.[16]

Because the mechanical clock's monumental importance was not registered in the moment, the date of its invention and the first few decades of its development are murky. A clock built in 1283 has been cited by some historians as the first known mechanical clock, but others have disputed this.[17] Texts from the late thirteenth century show an increased interest in clocks and an increased rate of clock construction, but we do not know with certainty that these clocks were of the new mechanical variety.[18] One possible early witness is Dante Alighieri (d. 1321), whose *Divine Comedy* describes a clock with wheels moving in opposite directions at different speeds.[19] For some scholars, this represents one of the earliest references to the mechanical clock.[20] For others, Dante instead bears witness to a monastic alarm mechanism. This mechanical element—which is not a clock—had developed in complexity between the thirteenth and fourteenth centuries as part of Christian Europe's newfound ability to create complex mechanical objects.[21]

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[16] Jean Leclercq, "The Experience of Time and Its Interpretation in the Late Middle Ages," *Studies in Medieval Culture* 8–9 (1976): 143.
[17] See North, "Monasticism and the First Mechanical Clocks," 176. Dohrn-van Rossum disputes this; see Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 95.
[18] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 94.
[19] *Paradiso* X.139–48 and XXVI.13–15. A shortened Hebrew version of the work, by Immanuel of Rome (d. 1328) contains no such description.
[20] Landes, *Revolution in Time: Clocks and the Making of the Modern World*, 57.
[21] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 92–94.

The first clocks and their makers

Even if the evidence from these earliest decades cannot be clarified completely, most scholars agree that mechanical clocks had been developed by the 1330s. Despite the secularizing effect of the devices, the earliest mechanical clocks were developed in and for monastic settings.[22] By the middle of the fourteenth century, however, mechanical clocks had found favor at royal courts, who commissioned the clocks both for their prestige and, like other automata, as a kind of devotional practice. It was also around this time that the production of these devices, initially made entirely of iron, moved out of the workshops of gunsmiths, blacksmiths, and locksmiths, although clockmaker guilds did not become commonplace until the sixteenth century.[23] Manufacturing specialization resulted in the first monumental designs; most notable among these are the clock of Richard of Wallingford (d. 1336) in St. Albans Abbey, the astrarium of Georgia de' Dondi (d. 1388) presented to Duke Gian Galeazzo Visconti, and finally the astronomical clock of Jean Fusoris (d. 1436), which was installed in the Bourges cathedral.[24] All three of these inventors brought to their designs a formal education in mathematics; for all of them, creating of these clocks was as much about tracking the movement of the celestial spheres as about indicating the hour.

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[22] Stephen C. McCluskey, "Gregory of Tours, Monastic Timekeeping, and Early Christian Attitudes to Astronomy," *Isis* 81, no. 1 (1990): 8–22. A partial list of such clocks can be found in Mooney, "The Cock and the Clock: Telling Time in Chaucer's Day," 105.

[23] Scattergood, "Writing the Clock: The Reconstruction of Time in the Late Middle Ages," 460. On the history of clockmaking guilds, see Anthony Turner, "'Not to Hurt of Trade': Guilds and Innovation in Horology and Precision Instrument Making," in *Guilds, Innovation, and the European Economy, 1400–1800*, ed. S.R. Epstein and Maarten Prak, 2008, 264–287. Many early clock smiths were members of locksmithing guilds; see Gerhard Dohrn-van Rossum, "Migration Technischer Experten Im Spätmittelalter: Das Beispiel Der Uhrmacher," *Migration in Der Feudalgesselschaft*, 1988, 309.

[24] Víctor Pérez Álvarez, "The Role of the Mechanical Clock in Medieval Science," *Endeavour* 39, no. 1 (2015): 64–65.

In the previous chapter, we noted that medieval advances in bell production techniques led to bell manufacture becoming specialized; whereas previously bells could be made anywhere, they were now manufactured in a handful of foundries staffed by specialist artisans. As Gerhard Dohrn-van Rossum has shown, the rise of the mechanical clock caused something similar to happen to clock manufacture; the result was a bifurcation between the relatively large number of artisans who were able to make older timekeeping devices and the select few who could construct the new mechanical clock. The latter group—initially just a small group of Italian artisans—became itinerant creators, travelling far and wide across Europe in response to growing demand. It was not until the late fifteenth century that clockmaking became a widely practiced art.[25]

Clocks for the public

Much like the earliest computers, early mechanical clocks were large, immovable, and required significant investment. Also like the earliest computers, acquisition of one of these clocks endowed the owner with a certain status. As a result, interest in building clocks quickly blossomed as cities competed with one another to build larger or more impressive movements.

Tower clocks, as the first public clocks were known, first appeared in Italy, and Italian craftsmen had a hand in designing many of the earliest clocks in Austria, Bohemia, England, France, the Netherlands, Poland, and Spain.[26] Large urban centers were the first to adopt clocks; the timekeeping revolution took somewhat longer to

[25] Dohrn-van Rossum, "Migration Technischer Experten Im Spätmittelalter: Das Beispiel Der Uhrmacher," 295. Some clocks, like the creation of de' Dondi, were so complex that they fell into disrepair soon after their creator's death, as no one else had the skill to maintain or repair them; see Scattergood, "Writing the Clock: The Reconstruction of Time in the Late Middle Ages," 462.
[26] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 134.

reach more rural settings.[27] Adoption in major cities began in earnest in the 1370s. As interest in the devices exploded, expertise in construction became decentralized, as well.[28] By century's end, public clocks were available in most of Christian Europe's cities.[29]

Construction of the earliest mechanical clocks was an expensive proposition. On top of the construction costs, maintaining a clock meant employing a "governor," who was tasked with recalibrating the clock; this was initially done twice a day.[30] Financing of the clocks varied; some were funded by the church, some by local sovereigns, others by guilds, and still others were paid for through new or higher taxes. Though the placement of the clock tower produced some argument, it was generally understood that the devices were a public good; even when built on the grounds of a monastery, they might be built in such a way that the public could enter without disturbing the residents.[31] The prestige of the mechanical clock was such that even some of those towns that could not afford the devices employed workers to ring the hours manually until an automated system could be acquired.[32] This fact, perhaps more than any other, speaks to the clock's transformation of popular timekeeping, and is further evidence that new system of striking the hours held importance even in the absence of clocks themselves.

[27] Leclercq, "The Experience of Time and Its Interpretation in the Late Middle Ages," 144.
[28] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 160.
[29] There have been several attempts to construct a chronology of construction for the earliest clocks. See Dohrn-van Rossum, 391–392; Samuel Guye and Henri Michel, *Time & Space: Measuring Instruments from the 15th to the 19th Century* (Praeger, 1971), 21–26.
[30] Carlo M. Cipolla, *Clocks and Culture, 1300–1700* (London: Collins, 1967), 41. See notes there.
[31] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 145.
[32] Dohrn-van Rossum, 126.

<u>The fifteenth and sixteenth centuries: diffusion and miniaturization</u>

By the time the fourteenth century had come to a close, tower clocks could be found in most of Europe's cities. The prestige of these clocks, together with their decreasing price, now placed them within reach of smaller towns; so important were these devices that their production was sometimes coordinated or even financed by regional rulers.[33] With ubiquity, clocks gained a new cultural importance, and they began to feature regularly in depictions of towns.[34] Multiple clocks within a single city also became common; the largest cities, like Paris, Rouen, and Milan, had at least four apiece.[35] It is also in this century that clocks began to have faces, allowing their signals to be transmitted visually as well as sonically.[36]

Beyond incremental developments, the sixteenth century saw the rise of timepieces that were truly portable, if not yet pocket-sized. Stationary timepieces were powered by weights, and so could not function while in motion; in order to create portable devices, clockmakers turned to the coiled spring (called a mainspring in this context), which had been used first in locks and then in firearms since the fifteenth century. The earliest known mainspring-powered clock—a table clock of great sophistication—dates to 1430, but it was not until the beginning of the sixteenth century that watches begin

[33] Dohrn-van Rossum, 152.
[34] Gerhard Jaritz, "Medieval Mechanical Clocks," in *Time: Sense, Space, Structure* (Brill, 2016), 215.
[35] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 162.
[36] Dohrn-van Rossum, 146.

to appear, initially in Germany and soon across Europe.[37] (The term "watch" is related to "awaken;" one of the first uses was as a portable alarm.[38])

The first spring-driven movements performed abysmally. Though their intricacy and exorbitant cost made them widely desired status symbols, these clocks far underperformed their weight-driven counterparts in accuracy.[39] Verge-and-foliot mechanisms had always been sensitive to fluctuations in force, but mainsprings exacerbated the problem because they needed to be wound multiple times per day, exerting less and less power as they unwound. Two sixteenth-century developments attempted to address this problem: first the stackfreed and then the fusee, both of which made mainspring's power more regularly.[40] Despite these advances, early watches were primarily decorative objects, erring by as much as thirty minutes per day.[41]

Reception of the mechanical clock in Islamic lands

Though Islamic innovation was responsible for the complex gearing and precision instrumentation that undergirded the new clocks, it was not until the introduction of European timepieces that Islamicate societies gained access to mechanical clocks and watches.[42] During the centuries in which Europeans were developing the mechanical

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[37] Abbott Payson Usher, *A History of Mechanical Inventions: Revised Edition* (New York: Dover Publications, 1954), 305–307. White, Jr., *Medieval Religion and Technology*, 126. On the first mainspring-driven clock and argument for its antiquity and authenticity of its mainspring mechanism, see Ernst von Basserman-Jordan, *The Clock of Philip the Good of Burgundy* (Leipzig: Wilhelm Diebener, 1927).
[38] See "Watch, n., IV," in *OED Online*, n.d.
[39] Landes, *Revolution in Time: Clocks and the Making of the Modern World*, fol. 91. In economics terms, these clocks would be considered Veblen goods, i.e. demand was positively correlated with price.
[40] Lynn White, Jr., *Medieval Technology and Social Change* (Oxford University Press, 1962), 127–128.
[41] Landes, *Revolution in Time: Clocks and the Making of the Modern World*, 91, 139.
[42] On the Islamic contributions, please see page 157, above.

clock, Muslim countries continued to construct large, sophisticated water-clocks and sundials.[43]

The Safavids had constructed tower clocks by the beginning of the sixteenth century; these were built under the direction of European craftsmen.[44] The Ottomans, by contrast, initially showed little interest in large, public clocks. Far more popular were smaller timepieces for use in mosques and private residences; these timepieces had become affordable as a result of streamlined European production processes.[45] Just as Harūn al-Rashīd had once sent a clepsydra to the court of Charlemagne, European ambassadors now regularly brought timepieces to Constantinople.[46]

Besides of the practical difficulty of transporting large movements from Europe, many Ottomans perceived the tower as a threat to the minaret, and—like Jews—they associated the tower's bell with Christianity:[47] Muḥammad himself reportedly objected to the use of both the bell and the *shofar* to call worshippers to prayer.[48] While smaller clocks gained increasing popularity throughout the early modern period, it was not until the middle of the nineteenth century that the Ottoman administration began building towers in earnest.[49]

For the Ottomans, this stream of timepieces was encouraged in no small part through treaties with European powers and through tribute requirements. As early as

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[43] See, for example, Derek J. De Solla Price, "Mechanical Water Clocks in the 14th Century in Fez, Morocco," *Proceedings of the International Congress of the History of Science*, 1964, 599–602.
[44] Stephen P. Blake, *Time in Early Modern Islam* (Cambridge University Press, 2013), 51.
[45] Mehmet Bengü Uluengin, "Secularizing Anatolia Tick by Tick: Clock Towers in the Ottoman Empire and the Turkish Republic," *International Journal of Middle East Studies* 42, no. 1 (2010): 18.
[46] See Truitt, *Medieval Robots: Mechanisms, Magic, Nature, and Art*, 20–21; O. Kurz, *European Clocks and Watches in the Near East* (Brill, 1975), 30f.
[47] Uluengin, "Secularizing Anatolia Tick by Tick: Clock Towers in the Ottoman Empire and the Turkish Republic," 20. As we saw in the previous chapter, the bell's strong status as a Christian noisemaker is itself the product of Muslim antagonism.
[48] Umar ibn Kathīr, *The Life of the Prophet Muḥammad: Volume II*, n.d., 222–223.
[49] Kurz, *European Clocks and Watches in the Near East*, 99.

1477, Mehmed II (known for his interest in cannon technology during the conquest of Constantinople) requested that the Venetians deliver a clockmaker as part of a 1477 treaty, and the 1547 Treaty of Adrianople also led to a sharp increase in the number of clocks given in tribute.[50] Simultaneously, the Ottomans began to establish their own clockmaking industry. Around 1565, the polymath Taqī al-Dīn (d. 1585) authored the first technical treatise (in any language) on clockmaking, *Al-kawākib al-durriyyah fī al-binkāmāt al-dawriyyah* ("The Brightest Stars for the Construction of Mechanical Clocks"). The work contains designs for tower clocks, astronomical clocks, and even pocket watches, though the last would not become common until the following century.[51] Taqī al-Dīn's work is a mixture of imported knowledge and innovative designs; apart from his technical work, his administrative role as chief astrologer allowed him to institutionalize and transmit this knowledge, although his interest was primarily scientific.[52] By the end of the sixteenth century, a clockmaking guild had been established in Constantinople and European ambassadors no longer brought clocks as gifts for Ottoman rulers.[53] The Safavids, by contrast, did not take up clockmaking and they continued to ask the Europeans for clocks into the early eighteenth century.[54]

New conventions for numbering hours

Once the mechanical clock could ring out 24 equinoctial hours each day, the public was forced to consider how those hours should be numbered. Because it was neither

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[50] Frédéric Hitzel, "De La Clepsydre à l'horloge. L'art de Mesurer Le Temps Dans l'Empire Ottoman," in *Les Ottomans et Le Temps*, ed. Suraiya Faroqhi, Halil İnalcık, and Boğaç Ergene (Brill, 2012), 21, 26.
[51] Donald R. Hill, "Clocks and Watches," in *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Westen Cultures* (Springer, 1997).
[52] Blake, *Time in Early Modern Islam*, 74.
[53] Blake, 69.
[54] Kurz, *European Clocks and Watches in the Near East*, 62–63.

possible nor necessary to coordinate time between cities, each city was free to pursue its own convention; as a result, many systems developed. Four timekeeping systems are particularly important for our purposes. Three of these emerged before the end of the fourteenth century; the last one is associated with Ottoman usage. Among both Jews and Gentiles, mention of these systems is one of the first signs that mechanical clocks were in use in a given area; as a result, understanding and being able to identify these systems is highly important for understanding how clocks (and later watches) were being used, beginning in the fourteenth century.[55]

The earliest system, often called "Italian" or "Bohemian" hours, started anew each day at sunset and ran for 24 hours.[56] In this system, daylight hours are "high" numbers; to use an early example: a man who died in 1339 in mid-afternoon is described having died in the twentieth hour.[57] While this system was used in Italy, Bohemia, and Poland until the seventeenth century, the need to ring a bell 24 times posed mechanical difficulties; as a result, this system eventually lost out to systems that divided the day into more than one cycle.

A second system, called "Nuremberg" hours or "great clock" hours, also began the count at sunset, but this count restarted each morning. As a result, the number of hours in the nighttime and daytime series varied over the course of the year. From a mechanical perspective, this system offered a slight advantage over "Italian" hours, because a single gearing system for 24 hours was more complicated to maintain than a system

[55] Mooney, "The Cock and the Clock: Telling Time in Chaucer's Day," 100.
[56] The Christian calendar sometimes treats sunset as the beginning of a new day; thus, for example, the Easter Triduum begins on a Thursday evening and ends in the evening on the following Sunday.
[57] Bilfinger, *Die Mittelalterlichen Horen Und Die Modernen Stunden: Ein Beitrag Zur Kulturgeschichte*, 185. See also Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 109.

which could restart during the day. There is evidence for this system as early as 1374, but it did not gain widespread traction in comparison to the other European systems.[58]

The “Italian” and “Nuremberg” systems’ deference to sunrise and sunset was likely borrowed from the church, which had preserved the Hellenistic system of two sets of twelve hours, one during the night and one during the day. A third system, called “French” or “small clock” hours, or (in Italy), “transalpine” hours, unmoored the count of equinoctial hours from sunset and sunrise altogether, instead beginning a twelve-hour series each noon and midnight. While all three systems had been established by the fourteenth century, the simplicity of the “French” hours system led to its ultimate triumph.[59]

Finally, a fourth system, called “*alaturka*” hours, became popular in Ottoman lands in the late sixteenth century. Like the “Italian” system, the *alaturka* system began at sunset, but instead of a single 24-hour series, it counts two twelve-hour series instead. This system remained in use within the Ottoman Empire until the twentieth century; its co-existence with other systems is described in the next chapter.[60]

The invention of the sandglass

The mechanical clock is undoubtedly the most important timekeeping technology to have swept across Europe in the late medieval period. Nonetheless, because the two curiously emerged at exactly the same time and complemented one another’s function-

[58] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 114–115.
[59] On the antiquity of the three systems, see Bilfinger, *Die Mittelalterlichen Horen Und Die Modernen Stunden: Ein Beitrag Zur Kulturgeschichte*, 187f.
[60] See Avner Wishnitzer, *Reading Clocks, Alla Turca: Time and Society in the Late Ottoman Empire* (University of Chicago Press, 2015).

ality in important ways, it is impossible to talk about the clock without also talking about the sandglass.[61]

Why it took so long for the sandglass to emerge is difficult to say. It has been hypothesized that sand clocks were challenging to calibrate and read, since, unlike water-clocks, the top surface did not stay flat as the matter within descended; alternatively, the sand grains themselves may have worn down the bottleneck of their glass container, causing the sandglass to slowly pick up speed.[62]

Though the sandglass' sophistication pales in comparison to that of the mechanical clock, it nonetheless allowed for the measurement of smaller periods of time in the years before mechanical clocks and watches were up to the task. As a result, its usage overlapped considerably with the clepsydra of Late Antiquity. One configuration, which remained popular into the eighteenth century, featured four sandglasses in a wooden frame; they would be calibrated for a quarter-hour, half-hour, ¾-hour, and full hour.[63] A common use for the sandglass was the timing of sermons, a task quite similar to the clepsydra's usage as a timer for speeches in Roman courts, although the former may have been installed to ensure *longer* sermons, not shorter ones.[64] The sandglass was also used for classroom lessons and for the determination of hourly wages, although when

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[61] There is something of a terminological problem here. The term "hourglass" suggests that the devices always measured hours, which is not correct. While the granular substance in these timekeepers was not always sand (powdered eggshell might also be used, for example), it was always granular and almost always encased in glass. As with the mechanical clock, fourteenth century sources frequently resort to generic terms like *horologium*. See A. J. Turner, "The Accomplishment of Many Years: Three Notes towards a History of the Sand-Glass," *Annals of Science* 39, no. 2 (1982): 161–162.
[62] Balmer, "The Invention of the Sand Clock," 113.
[63] Balmer, 119.
[64] Tiffany Stern, "Time for Shakespeare: Hourglasses, Sundials, Clocks, and Early Modern Theatre," *Journal of the British Academy* 3 (2015): 5. On the length of sermons, see Turner, "The Accomplishment of Many Years: Three Notes towards a History of the Sand-Glass," 169. On the use of clepsydras in courts, see page 11.

these practices began is not clear.[65] The sandglass could be used for signaling bell-ringers when to ring quarter-hours and half-hours and was at times even used as a stop-gap measure when a clock's escapement mechanism was not available.[66] Some hour-length sandglasses apparently even came with counters from 1 to 12 so that one might (crudely) mark off the hours of the day.[67] It was not until the end of the seventeenth century that mechanical clocks became sufficiently accurate to replace the sandglass for short durations.[68]

What mechanical clocks did not change

Notwithstanding their ubiquity, the earliest mechanical clocks left much to be desired. Beyond their overall imprecision, many of the early clocks had no faces; even when faces did emerge, it was not until the early eighteenth century that minute and second hands became common.[69] This state of affairs led to a curious situation whereby durations of more than an hour were spoken of using conventional time units, whereas fractions of the hour were still spoken of in non-conventional terms, often the same ones that had been used in the era of the sundial and clepsydra.

Evidence for the continued use of non-conventional units exists in the English of the time. Late medieval English contains a number of words to describe such periods; from the fifteenth century we have "pater noster wyle," "miserere wyle," (i.e. the time

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[65] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 256.
[66] Turner, "The Accomplishment of Many Years: Three Notes towards a History of the Sand-Glass," 164.
[67] Joseph Sternfeld, "Hour Glasses," *Supplement to the Bulletin of the National Association of Watch and Clock Collectors*, 1953, 8.
[68] Rachel Doggett, ed., *Time: The Greatest Innovator: Timekeeping and Time Consciousness in Early Modern Europe* (Folger Shakespeare Library, 1987), 57–58.
[69] Guye and Michel, *Time & Space: Measuring Instruments from the 15th to the 19th Century*, 80, 85.

it takes to say these prayers, *Miserere* being a name for Psalm 51) and a "pissing wyle."[70]

The limitations of early clocks are particular apparent in the medieval cookbook, a genre which emerged in Christian Europe in the late fourteenth century.[71] Food preparation frequently requires keeping track of short periods of time; often a stage of cooking will last only a matter of minutes. At this scale, most clocks were still of little use; as a result, many cookbooks continued to use non-conventional time units. Thus, a mixture might be allowed to sit "a forlongwey or to [two]" (i.e. the time it takes to walk a furlong or two, a furlong being around 200 meters). Some units are more utilitarian; thus, a batter might be beaten "long enough to weary one person or two." Most interesting of all is the widespread use of prayers to describe short times; since these prayers would have been recited frequently at a more-or-less regular pace, a cookbook might usefully indicate that a mixture should be boiled "in water for the length of time of a *Miserere*," or the length of time it takes to pray a rosary.[72]

Small units are also used to describe other phenomena of short duration; thus, a workman might be barred from pausing from his labors for more than "ye tyme of a mileway,"[73] a formulation precisely parallel to the *shiʿur mil*, discussed below. In short, the advent of mechanical clocks did not eliminate the need for non-conventional time measurements.

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[70] Thompson, "Time, Work-Discipline, and Industrial Capitalism," 58.

[71] The following examples are taken from Bridget Ann Henisch, *Fast and Feast: Food in Medieval Society* (Pennsylvania State University Press, 1976), 144; and Ria Jansen-Sieben and Johanna Maria Van Winter, *De Keuken van de Late Middeleeuwen: Een Kookboek Uit de Lage Landen* (Netherlands, 1998), 23–25.

[72] Matthew S. Champion, *The Fullness of Time: Temporalities of the Fifteenth-Century Low Countries* (University of Chicago Press, 2017), 59. Muslims seem to have referred to recitation of segments of the Qur'ān in a similar manner; see, for example, Faḍlān, *Mission to the Volga*, para. 49.

[73] Mooney, "The Cock and the Clock: Telling Time in Chaucer's Day," n. 37.

II. The Jewish Reception of the Mechanical Clock

Methodological considerations and the Christian character of public clocks

The attempt to locate early awareness of the mechanical clock in Jewish timekeeping brings with it two methodological problems. The first, discussed in the previous chapter, is that the rise of the mechanical clock coincides with an influx of Arabic scientific knowledge into Christian Europe, through direct access to the texts in translation and through the writings of Jews living in Muslim lands, the most notable being Maimonides. These new sources of information included a well-developed timekeeping vocabulary and an awareness of the distinction between seasonal and equinoctial hours. For this reason, the presence of refined timekeeping terminology does not, on its own, demonstrate the influence of the mechanical clock.

To give an example: in the previous chapter, we noted that Menaḥem Meiri uses the concept of seasonal hours and uses hour approximations for short durations,[74] but these features of his writing need not indicate an awareness of mechanical timekeeping, even though it is conceivable that the devices had made their way to southern France by the time of his death in 1306.

Second, there is the far more difficult problem of determining whether the new "public" clocks were perceived as public by Jews in urban centers. While it is certainly true that Jews came to change the way in which they spoke about time in much the same way as their Christian counterparts, the clock did not cause Jewish minority status to melt away. The little evidence we have suggests that the Jewish relationship to the clock was more complicated than that of the Christian population.

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[74] See above, page 204.

First, as noted above, financing of clocks was a task that was sometimes taken up by a city's populace. In most cases there is no record of any role that Jews played in this process. In Dijon, however, records indicate that the lion's share of the cost was paid by the duke, while Jews and merchants were required to pay a smaller portion.[75] In this financial situation, Jews were situated somewhere between the Christian populace and the local ruler, a familiar position for Jews in medieval Europe.[76] A second, more remarkable record concerns the Jews of Pressburg who evidently refused to pay for the local tower clock; in response, the clock was built with only three faces, so that the Jewish neighborhood might not benefit from its construction.[77] While the reason for their refusal is not clear, it suggests that the Jews of the city were clearly operating in a manner distinct from the "public."

Beyond this, even the ostensibly "secularized" public clock continued to be perceived as having Christian associations. Though it no longer rang out seasonal hours, the bell, now linked to its escapement, remained a fundamentally Christian symbol; indeed, in many places, the clock was physically located in a monastery or on church grounds. The first public bell specifically intended for Jewish use—built on Prague's Jewish Town Hall, adjacent to the Altneuschul—was not constructed until 1586.[78] This famous clock, whose face features Hebrew letters rather than Roman numerals, and

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[75] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 136.
[76] On the many ways in which Jews were involved in medieval Christian building projects, see Shatzmiller, *Cultural Exchange: Jews, Christians, and Art in the Medieval Marketplace*, chap. 3.
[77] Karl Fischer, "Die Uhrmacher in Der Slowakei," *Bohemia-Jahrbuch Des Collegium Carolinum*, 1969, 406.
[78] Barry L. Stiefel, *Jews and the Renaissance of Synagogue Architecture, 1450–1730* (Pickering & Chatto, 2014), 73–76. Stiefel understands it to be significant that the bell was used for meetings and not to announce prayers. I do not think this is quite so significant; the original story, which has been cited and re-cited for more than 150 years, simply says that Jews were allowed to use the bell in order to announce meetings; it does not say who designated the bell thus or whether announcing prayer times would have been an option, nor does it say whether Jews or the government designated it thus. See Zacharias Frankel, "Die Erste Judenglocke," *Monatsschrift Für Geschichte Und Wissenschaft Des Judentums* 10 (1861): 280.

which was designed to run counterclockwise, was not built until 1764, making it one of only four Jewish exterior clocks built before 1800.[79] In some places the bell may have had particularly negative associations for Jews; in fourteenth- and early fifteenth-century Lisbon, it is noteworthy that the ringing of the evening bell marked the nightly closure of the Jewish quarter, and any Jew found outside the quarter could be fined, whipped, or subject to property seizure.[80]

The perception of the bell as a Christian object would also have been suggested by the bell's dominance in the European soundscape and by the absence (or suppression) of Jewish and Muslim sounds of comparable magnitude. Even before the mechanical clock, Jews in Christian Europe had eschewed the use of church bells to summon people to prayer, making due with a *schulklopfer*, a person who roused Jews for morning prayers by banging on their doors with a wooden mallet; this practice continued up until through the twentieth century.[81] Jewish awareness that it was important not to impinge too much on the Christian soundscape is also suggested by a fifteenth century Hebrew source, which says that Jews customarily deferred the sounding the *shofar* until late in the Rosh Hashanah morning serving because once, when it had been sounded early in the service, Christians interpreted the sound as the cue for a Jewish revolt.[82]

The clock's lingering associations with Christianity may also explain a curious disparity between Jewish and Christian illustrated manuscripts: whereas fifteenth- and sixteenth-century Christian manuscripts regularly depict clock towers in even the

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[79] See the survey of exterior clocks in the next chapter.
[80] David Philipson, *Old European Jewries* (Philadelphia: Jewish Publication Society of America, 1894), 25–26.
[81] See, for example, Israel of Krems, *Hagahot Asheri*, Beitzah ch. 5; Moshe Isserles' gloss on *Shulḥan ʿArukh* O.Ḥ. 338:1; see also *Beit Yosef* 338:1.
[82] See Sidney Steinman, *Custom and Survival: A Study of the Life and Work of Rabbi Jacob Molin* (New York: Bloch Publishing, 1963), 115, who cites Moritz Güdemann, *Geschichte Des Erziehungswesens Und Der Cultur Der Abendländischen Juden Während Des Mittelalters Und Der Neueren Zeit* (Vienna: Holder, 1888), 153, who cites an unidentified Berlin manuscript of the Maharil's laws regarding the *shofar*.

crudest and smallest drawings, Jewish manuscripts do not include clock towers in their depictions of cityscapes at all, just as they do not depict crosses on steeples. It seems that Jews did not share in the pride that other town members took in the installation of a new city clock.[83]

None of this information suggests that medieval or early modern Jews shunned clocks; the first strong critique of synagogue bells as Gentile trappings only arrives in the nineteenth century in response to the nascent Reform movement.[84] Still, these facts complicate Jacques Le Goff's notion that the clock marked a transition between "church time" and "merchant time."[85] While the introduction of the clock undoubtedly popularized and democratized timekeeping, the significance of its sounds was still dependent on the listener. In this sense, the clock's "public" nature remained moored in the same interreligious dynamics that had prevailed in Europe for centuries.[86]

Did Jews manufacture mechanical clocks?

In attempting to understand how quickly Jews might have gained exposure to timekeeping devices, we must also ask whether Jews were involved in the construction of the devices themselves. The answer is almost definitely no; there does not appear to be

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[83] For many examples, see Thérèse Metzger and Mendel Metzger, *Jewish Life in the Middle Ages: Illuminated Hebrew Manuscripts of the Thirteenth to the Sixteenth Centuries* (Alpine Fine Arts, 1982), 44–57. Of course, this result is complicated by the fact that many Jewish manuscripts were illustrated by Christians and occasionally contain Christian imagery as a result. See Shatzmiller, *Cultural Exchange: Jews, Christians, and Art in the Medieval Marketplace*, 122.

[84] Zvi Hirsch Chajes, "Minḥat Qena'ot," in *Kol Sifre Maharits Ḥayut, Volume 2* (Jerusalem, 1958), 991. Chajes ascribed this position to Abraham ben David (Ra'avad, d. 1198) and David Halevi Segal (Taz, d. 1667); see their respective comments on *Mishneh Torah*, Foreign Worship and Customs of the Nations, 11:1, and *Shulḥan ʿArukh*, Y.D. 178:1. In fact, neither source mentions anything about bells and both profess that they do not fully understand the text upon which they are commenting.

[85] Le Goff, *Time, Work, and Culture in the Middle Ages*, pt. 29ff.

[86] It is worth noting that whatever associations Jews had with bells did not prevent Jews in Islamic lands from becoming bell makers (*jalājilī*), although these bells were probably relatively small; see Shatzmiller, *Labour in the Medieval Islamic World*, 114.

any evidence that Jews played any significant role in clock manufacture, even thought they were involved in the development and manufacture of other emergent technologies, firearms being the most notable example.[87] The most important reason for this was systematic bias: Jews were barred from the clockmaking guilds that began forming in the sixteenth century, just as they were barred from other craft guilds.[88] (By the nineteenth century Jews had established themselves as watchmakers in Germany, America, and England; in the latter, their craftsmanship was the target of various anti-Semitic barbs.[89]) Had early clocks been smaller they might have made their way into Jewish hands when lent by Christian borrowers as securities for debts; their immense size and weight, however, would have made them impractical for this purpose.[90]

The one place where we might have expected Jewish clock manufacturing is Spain. As noted in the last chapter, Spanish Jews singlehandedly introduced advanced time-

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[87] Daniel Jütte, "Trading in Secrets: Jews and the Early Modern Quest for Clandestine Knowledge," *Isis* 103, no. 4 (2012): 69–79.

[88] On the religious composition of Augsburg's clockmaking guild, see Eva Groiss, "The Augusburg Clockmakers' Craft," in *The Clockwork Universe: German Clocks and Automata 1550–1650* (Neale Watson Academic Publications, 1980), 65. In his scholarship on Jewish guilds, Mark Wischnitzer several times makes reference to Polish Jews being pushed into watchmaking, as well as other crafts, from the beginning of the sixteenth century. (See Wischnitzer, *A History of Jewish Crafts and Guilds*, 212 and 307 n. 5; *Istoriya Evreev v Rossii* (Moscow, 1914), 291–2; Mark Wischnitzer, "Origins of the Jewish Artisan Class in Bohemia and Moravia, 1500–1648," *Jewish Social Studies* 16, no. 4 (1954): 335–350.) However, he provides little evidence to support this claim, and watchmaking guilds are mentioned neither by Jonathan Israel nor by Gershon Hundert in their discussions of Jewish crafts in Eastern Europe. See Jonathan I. Israel, *European Jewry in the Age of Mercantilism, 1550-1750* (Littman Library of Jewish Civilization, 1998), 149; Gershon David Hundert, *Jews in Poland-Lithuania in the Eighteenth Century: A Genealogy of Modernity* (University of California Press, 2004), 54. If late medieval or early modern Jewish clockmaking guilds did exist, further research is needed to clarify their nature.

[89] On Swiss watchmaking, see Stefanie Mahrer, "Les Russes — The Images of East European Jews in La Chaux-de-Fonds and Zurich: A Discourse of Power and Fear," in *Eastern European Jews in Switzerland* (De Gruyter, 2013), 18. On anti-Semitic tropes in London, see Todd M. Endelman, *The Jews of Georgian England, 1714–1830: Tradition and Jews in a Liberal Society* (University of Michigan Press, 1999), 205; Landes, *Revolution in Time: Clocks and the Making of the Modern World*, 297–298.

[90] On the practice of using sacred objects as pawns, see Joseph Shatzmiller, "Church Articles: Pawns in the Hands of Jewish Moneylenders," in *Wirtschaftgeschichte Der Mittelalterichen Juden* (Munich, 2008), 93–102; Shatzmiller, *Cultural Exchange: Jews, Christians, and Art in the Medieval Marketplace*, chap. 3. More recently, see Birgit Wiedl, "Sacred Objects in Jewish Hands: Two Case Studies," in *Jewish and Christians in Medieval Europe: The Historiographical Legacy of Bernhard Blumenkranz*, ed. Philippe Buc, Martha Keil, and John Tolan (Brepols, 2015), 57–77.

keeping ideas into Spain, and they remained central in both writing about and manufacturing scientific instruments of all kinds up until the massacres and mass conversions of 1391.[91] Despite their presence in this field, Spanish Jewish dominance does not appear to have extended from scientific instruments to the new mechanical clocks; instead, these were designed by a small number of itinerant artisans—initially mostly from Italy—whose work was disconnected from the older timekeeping traditions. Thus, for example, the mechanical clock commissioned by the court of Aragon in 1356 was not built by Aragon's Jewish astrologers and makers of non-mechanical clocks; instead, one Antonio Bovelli was hired to head the project.[92] Of the several hundred people listed as having contributed labor, only two are identified as Jews: one a trader, the other a woodturner.[93]

The bifurcation between involvement in the manufacturer of scientific instruments and mechanical clocks helps us understand a figure like Gersonides (d. 1344), whose location in Provence, period of activity, and intellectual profile all suggest that he could have known of, or been involved with, the clock's early development. Beyond his theoretical astronomical work, Gersonides was intimately involved in constructing and explaining new instruments.[94] References to both the astrolabe and the quadrant in his Bible commentary indicate that he was not interested in segregating his scientific and

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[91] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 184. See also the references to Jews in Jeanne Vielliard, "Horloges et Horlogers Catalans a La Fin Du Moyen Age," *Bulletin Hispanique* 63, no. 3–4 (1961): 161–168. Translated into English in Charles K. Aked, "Catalan Clocks & Clockmakers to the End of the Middle Ages," *Antiquarian Horology and the Proceedings of the Antiquarian Horological Society* 10 (1978): 722–727.

[92] Dohrn-van Rossum, "Migration Technischer Experten Im Spätmittelalter: Das Beispiel Der Uhrmacher," 298, 300. The construction of this particular clock is extremely well documented; see C.F.C. Beeson, "Perpignan 1356 and the Earliest Clocks," *Antiquarian Horology and the Proceedings of the Antiquarian Horological Society* 7 (1970): 408–414.

[93] See C.F.C. Beeson, *Perpignan 1356: The Making of a Tower Clock and Bell for the King's Castle* (London: Antiquariun Horological Society, 1982), fols. 24r, 54r, 60r.

[94] Bernard R. Goldstein, "Levi Ben Gerson and the Cross Staff Revisited," *Aleph* 11, no. 2 (2011): 365–383.

scriptural knowledge.[95] Along the lines of statements made by Shlomo ben Aderet and others, Gersonides specifies that the phrase "the glimmerings of dawn" (Job 41:10) defines the time between dawn and sunrise as "around an hour and a fifth," and on another occasion he makes a passing reference to "half an hour."[96] Ultimately, mechanical clocks do not appear anywhere in Gersonides' corpus, nor is his understanding of timekeeping distinguishable from that of older Christian European scholars. Whatever his knowledge, Gersonides does not appear to have been included in the new cadre of clockmakers.

To summarize: Spanish Jews' reception of the new devices was not appreciably different from that of any other Jewish community; by the time those other communities did acknowledge the clock, in the last decade of the fourteenth century, Spanish Jewry was in a state of crisis following the violence of 1391. As a result, there is not much of a Spanish Jewish reception to speak of, and no time during the first several centuries of their development in which Jews interacted with mechanical clocks as anything other than passive consumers and partial financiers.

Did Jewish astronomers take advantage of mechanical clocks?

The approximately one hundred years between the introduction of Islamic astronomical knowledge to Christian Europe and the mass erection of tower clocks resembles the situation in Islamic lands, described in Chapter 3, in which Jews with astronomical knowledge had an excellent understanding of timekeeping and a rich terminology, little of which trickled down to non-specialists.

[95] Gersonides, comment on Joshua 10:13.
[96] Gersonides, *Wars of the Lord*, I:14.

This situation is best exemplified in the writings of Isaac Israeli (d. ca. 1322), a scholar from Toledo whose 1310 encyclopedia, *Yesod ʿOlam* ("The Foundation of the World"), covers all scientific and mathematical knowledge relevant to the determination of the Jewish calendar.[97] In one chapter, Israeli describes in careful detail the concept of equinoctial hours (*shaʿot shavot*) and seasonal hours (*shaʿot meʿuvatot*), and the relationship of each to the motion of the Earth and the shifting of the seasons. He further describes and defends using the *ḥeleq* unit to subdivide the hour, as well as the Ptolemaic system of dividing the hour into sixty "moments" (*regaʿim*), each moment into sixty "seconds" (*sheniyyim*), each second into sixty "thirds," (*shelishiyyim*), and so on, up to division into "tenths" ($1/60^{10}$ hour). In addition, Israeli explains that the distinction between seasonal and equinoctial hours does not prevail on the equator itself, but rather pertains only to the climes (*aqlimim*).[98]

Throughout the chapter, Israeli portrays both equinoctial and seasonal hours as part of the astronomer's toolset; he does not say anything about whether and how they are used in everyday life or in rabbinic texts. More significantly, Israeli is skeptical that even those who constructed the calendar in the past understood the difference clearly. He writes:

> And now we have found that those who perform intercalations did not consider [this] in any of the calculations they performed for *moladot* (lunar conjunctions) or *tequfot* (seasons) of the sun; they did not heed the changing of the length of the hours, nor the changing of the lengths of the day and of the night in relation to one another in the climes (as opposed to on the equator) with the change in the portion (i.e. time) of the year. They did not pay attention to this alteration

[97] Ilana Wartenberg, "The Discovery of a Fragment of Isaac Ha-Israeli's Yesod Olam in the Cairo Genizah," *Zutot* 9 (2012): 52.
[98] For the theory of climes, see above, page 155.

> in their calculations; rather, *they acted as though the days and nights of the year were equal in length to one another, meaning that each one constituted twelve equal hours* (shaʿot shavot).[99]

Israeli's complaint is important for two reasons. First, it provides further corroboration for the argument made in chapters 2 and 3: namely, that seasonal and equinoctial hours were enigmatic concepts for most Jews, with the concept of seasonal hours proving especially difficult. Second, Israeli's treatment of the terms as being the province of specialists constitutes strong evidence that he was not yet aware of the public clock and equinoctial-hour timekeeping.[100]

At first, it may appear surprising that Jewish astronomers would not have availed themselves of the new clocks; after all, many of the earliest and most celebrated clocks were built with faces displaying the movements of heavenly bodies. Yet, as mentioned above, these clocks lacked precision and were therefore of little use to the scientists; indeed, there seems to have been a disconnect between these showpieces and the work of actual astronomers who do not appear to have utilized clocks until the early fifteenth century.[101]

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[99] Emphasis mine.

[100] Another exemplum is *Sefer Kaftor va-Feraḥ* ("Book of Calyx and Petals"), a work on the geography of the Land of Israel written by Eshtor ha-Parḥi in 1322. The author was born in France; after the 1306 expulsion he left for Spain, Egypt, and ultimately Palestine. Ha-Parḥi was clearly familiar with Ptolemy, who is cited in the work. Chapters 6 and 7 refer to equinoctial hours (*yesharot*), seasonal hours (*zemaniyyot*), and minutes (*rishonim*), all in the service of describing the clime in which the Land of Israel is situated. Both Israeli and ha-Parḥi died before the first definitive evidence of mechanical clocks, so it is always possible that he was simply never exposed to them. This cannot be said of Immanuel Bonfils (fl. 1350), inventor of decimal fractions and author of *Shesh Kenafayim*, a popular work on eclipses translated into both Latin and Greek. Not all of Bonfils' work has been published and he has not been well studied, so it cannot be said conclusively that he does not acknowledge the clock; nonetheless, clocks are absent from his discussion of arc hours, arc minutes, and degrees; see Bernard R. Goldstein, "The Introduction to Immanuel Ben Jacob Bonfils' Tables for 1340," *Aleph* 17, no. 1 (2017): 167–176. See also José Chabás, "The Astronomical Tables of Jacob Ben David Bonjorn," *Archive for History of Exact Sciences* 42, no. 2 (1991): 279–314.

[101] Álvarez, "The Role of the Mechanical Clock in Medieval Science," 65–66. On the slow march to precision, see William J. H. Andrewes, "Clocks and Watches: The Leap to Precision," in *Encyclopedia of Time* (Garland Publishing, 1994).

III. Five Receptions: An Overview

In 1290, King Edward I formally expelled all Jews from England; in 1306, King Philip IV did the same to the Jews of France; his territory did not include Provence. These expulsions meant that there were few or no Jews present in these territories to witness the mechanical clock's adoption and development. Evidence from Avignon at the end of the fourteenth century, where Jews continued to reside, is both thin and questionable. The same is true for Spain and Portugal, about which even less is known.

Clearer pictures can be painted for three other regions. In Germany, Austria, and Poland—what I will call Ashkenaz for simplicity—the primary effect was in the legal sphere. There, the presence of clocks created new expectations for punctuality and the equinoctial hour was transformed from an astronomical curiosity into a meaningful timekeeping standard. Within Ashkenaz a further division can be made between Poland, which employed "Italian" hours, and Germany/Austria, which used the "French" and "Nuremberg" systems. In Italy, by contrast, the introduction of clocks led to an increased interest in time registrations: that is, in marking events in terms of the precise hour at which they occurred. Clock time was also incorporated into Italian Jewish scientific works, and hour metrics were used in providing estimates of temporal duration. None of these developments appear to have made much of an impact on Italian Jewish legal literature, and the legal status of the timepieces themselves arose only rarely, perhaps because clocks were primarily being encountered in the public square and not in residential settings. Finally, the response to the mechanical clock among the Jews of the Ottoman Empire most closely resembles that of Ashkenazi Jews. In that region, as a result of the clock's late arrival and the persisting interest in private rather than public clocks, the reaction began later and was relatively weak.

IV. Avignon, Spain, and Portugal

Avignon

Two pieces of evidence suggest Jews in and around Avignon were familiar with clocks that followed the "French" hour system. The first is the colophon of a Hebrew book on astronomy, which indicates that it was completed "in Avignon, [5]155 (=1395 CE), 4 Adar Bet, Thursday, after midday, which is the 25th of February in solar months."[102] The mention of "after midday" is a new and relatively rare feature in colophons; this designation suggests—but does not prove—the use of "French" clock hours.

A second piece of evidence is a set of astronomical calculations. One of these documents seeks to determine astral influences for an event (a birth?) which took place on "Sunday, 23 Marḥeshvan, 5156 (=November 7, 1395), four hours and forty minutes (*daqim*) after midday."[103] Based on another treatise contained within the same bound manuscript, this work has been likely associated with Samuel d'Escola, an astronomer and Avignon native.[104]

As both of these pieces of evidence are associated with astronomy, which used midday as a reference point and employed *daqim* to refer to minutes.[105] As a result, neither constitutes strong testimony to the use of clocks in daily life.

Spain and Portugal

The mechanical clock's first boom in popularity coincides almost exactly with a rise

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[102] MS Kaufman A 505, col.
[103] RSL Ms. Guenzburg 1080, 46a. See also 36a, which performs a similar calculation for, "Tammuz[?] [5]203, which is 12 June, Wednesday, 2 hours, 33 minutes."
[104] Henri Gross, *Gallia Judaica* (Paris, 1897), 146–147.
[105] For another example, see NLI Ms. Heb. 8°1947.

in anti-Jewish violence. This likely accounts for the dearth of relevant texts in this region. Nonetheless, a few ambiguous texts may bear witness to the mechanical clock's presence.

An important responsum by the fifteenth-century Majorcan rabbinic scholar Tzemaḥ Duran may offer indirect evidence of the use of clock hours. In answering a question about whether it is true that there are "big hours and little hours," Duran gives one of rabbinic literature's most succinct and lucid explanations of equinoctial hours (*shaʿot shavot*) and seasonal hours (*shaʿot zemaniyyot*).[106] It is possible that Duran, like Shlomo ibn Aderet more than a century earlier, was simply responding to conceptual ideas which had spread from Maimonides and other Jewish astronomers in Islamic lands. Nonetheless, Duran's explanation that seasonal hours are used "to make your work easier" could be read as a defense of the seasonal hour among a population growing accustomed to the clock hour.

A similar motivation may be behind Rabbi David Abudarham's statement that "[the sages] agreed" that calendrical calculations be performed with seasonal hours (*shaʿot meʿuvatot*[107]), which may relate to the conversation in Germany and Poland, discussed above; however, the statement may simply emerge from his background in astronomy.[108] Similarly, the Spanish astronomer Abraham Zacuto (d. 1515) makes an offhand remark in his Jewish historiography, *Sefer Yuḥasin*, that, in England, a long day is "seventeen hours." It is not clear whether this indicates that equinoctial hours were now the default, or whether it simply reflects the mindset of an astronomer.[109]

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[106] *Shut Tashbetz*, 1:109; see also 3:216 for an additional reference to equinoctial hours.
[107] Literally "crooked hours." On the origins of this term, see above, page 133.
[108] *Sefer Abudurham*, Seder ha-ʿIbbur ha-Moladot veha-Shanim.
[109] *Sefer Yuḥasin*, ch. 6.

Another problematic prooftext is a passing reference in the philosophical commentary of Rabbi Isaac Arama (d. 1494), who speaks of "watermills and timekeeping instruments (*klei ha-shaʿot*) and the like" as metaphors for the world.[110] Both watermills and clocks are common tropes in medieval philosophical and theological literature; still, Arama's term is ambiguous, so it is unclear what kind of clock he has in mind.

Finally, a report by Rabbi Jacob Mitril, a Jerusalemite scholar active around 1500, attests to the use of a sandglass for purposes of timekeeping: "I heard a reliable report that in Lisbon, which was 'an enormous city' (Jonah 3:3), that they would place [sandglasses] on the ark before the preacher."[111] This report seems plausible, as the practice was quite common in churches.

To summarize: As in Avignon, a number of Hebrew writings from Spain suggest an awareness of mechanical clocks, but each may simply be an extension of the kind of astronomical knowledge displayed in fourteenth-century texts.

[110] *Akeiqat Yitzḥaq*, Genesis, sermon 5; cf. the reference to watermills in sermon 89, Israel Bettan, "The Sermons of Isaac Arama," *Hebrew Union College Annual* 12/13 (1937): 618.
[111] *Sefer Ḥidushei Dinim Le-Rabanei Yerushalayim Ha-Qadmonim* (Jerusalem, 1914), para. 31. This text discussed again in the Ottoman section below.

V. Ashkenaz

The earliest evidence for any Jewish awareness of mechanical clocks in Ashkenaz is found in the writings of a cluster of late fourteenth- and early fifteenth-century Austrian rabbinic scholars. The first of these is Rabbi Shalom ben Isaac, whose biography will be discussed below. Though most of Shalom's scholarship has been lost, one collection of anecdotes about his activities records the following incident:

> During the wedding of the sage Rabbi Yonah, the son of our teacher Rabbi Shalom, which was on the Thursday before [the fast of] the 17th of [the month of] Tammuz (it being on the following Sunday), the beadle called [the community] to come to the synagogue for prayer at the ringing of four hours after noon. The rabbi and congregation prayed the afternoon and evening prayers, after which was the *ḥuppah* (marriage ceremony, lit. "wedding canopy") and feast.[112]

This text contains three significant pieces of information. First, this represents the earliest documented rabbinic use of a public bell to schedule events. Second, the ringing of "four hours" positively identifies the presence of the new striking mechanism, probably, though not necessarily, facilitated by a verge-and-foliot escapement. Finally, the phrase "four hours *after noon*," indicates that the clock operated in accordance with

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[112] *Minhagei Maharash me-Noyshtat* §409. This story also appears in Maharil, *Minhagim*, Laws of Marriage §1. The significance of the date of the wedding is not clear. In a footnote, Israel Ta-Shma suggests that coordination using bells was important because, based on a previous anecdote (§406), both families had committed themselves to hefty fines if the marriage did not take place before Shabbat Naḥamu, i.e. the Shabbat immediately following the 9th of Av. Since it was customary not to perform weddings between the 17th of Tammuz and the 9th of Av, it was important that the wedding be held on that Thursday, and so the bells were a convenient way to summon the community; see Ta-Shma, "The Measurement of Time as Reflected in Medieval Rabbinic Literature [Hebrew]," n. 30. This interpretation explains why the anecdote states the exact date on which the wedding was held, but it suggests that the use of the clock was a kind of emergency measure, when there is nothing in the text to support this idea; there is no reason to believe that the bride and groom's parents procrastinated on their commitments until the last possible moment. Furthermore, it was not the bell itself which called the community together, but rather the beadle responding to the bell. Thus, we need only assert that Shalom considered the bell to be a useful organizational tool. On the custom of conducting weddings on Thursdays, see Daniel Sperber, "Wedding Dates," in *The Jewish Life Cycle: Custom, Lore and Iconography* (Oxford University Press, 2008), 171–182.

the "French" system; it is exactly equivalent to "4 P.M."[113]

Does this recognition of the clock—the first in Ashkenazi writings—indicate that it had only recently been erected, or does it simply mean that no previous scholars had found it worthy of mention? Answering this question requires us to reconstruct both the time and location of Rabbi Yonah's wedding, as well as the history of tower clocks in late fourteenth- and early fifteenth-century Austria.

Nothing in the anecdote itself indicates when Yonah's wedding might have been held, but we can approximate based on what is known of Shalom and his relatives.[114] Shalom ben Isaac was born in Wiener Neustadt in the middle of the fourteenth century into a distinguished rabbinic family; he died a martyr in 1413.[115] Early in his career, Shalom presided over Vienna; when he returned to Wiener Neustadt is not clear.[116] References to Shalom's brother, also named Yonah, suggest that the latter was older than he,[117] and that this was still alive in 1375. If Shalom followed Ashkenaz custom, his son would not have been given his brother's name unless the latter was no longer living.[118]

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[113] For the editor of this work, of course, it is probable that none of these things were notable. Instead, the anecdote is useful because it indicates protocol for when to pray on a long summer day with an afternoon wedding scheduled. As such, it is yet another example of northern European Jews attempting to reconcile the law with considerable seasonal fluctuations in daylight.

[114] It is difficult to pinpoint precisely when and where this incident occurred based on the text itself, as no location is given and the Tammuz fast frequently falls on Sunday. In fact, the fast falls on Sunday in a plurality of instances, because the fast is also held on Sunday if the 17^{th} of Tammuz falls on the preceding Saturday, since fasting is prohibited on Shabbat. In these instances the fast is still called "the 17^{th} of Tammuz," even when, in reality, it takes places on the 18^{th} of Tammuz.

[115] Shlomo Spitzer, *Halakhot U-Minhagei Rabbeinu Shalom Me-Noyshtat (Derashot Maharash)*, Second (Jerusalem, 1997), 18.

[116] Spitzer, 13–14.

[117] *Minhagei Maharash me-Noyshtat* §450. Shalom had two brothers, both rabbis, named Yonah and Yudel. He had two sons, also rabbis, with the same names. On Yonah the brother, see *Minhagei Maharash* §§144, 400, 438, 455. On Yonah the son, see *Minhagei Maharash* §§12, 118, 263, 290, 311, 345, 409, 417, 532. Shalom's exact birth date is unknown, though a tombstone bearing his father's name suggests it may have been as late as 1349, if he was indeed the youngest child; see Spitzer, *Halakhot U-Minhagei Rabbeinu Shalom Me-Noyshtat (Derashot Maharash)*.

[118] Spitzer. On the naming practice, see Lilach Assaf, "The Language of Names: Jewish Onomastics in Late Medieval Germany, Identity and Acculturation," in *Spätmittelalterlich Praktiken Der Namengebung Im Europäischen Vergleich*, ed. Christof Rolker and Gabriela Signori (Konstanz, 2011), 154–155.

On the basis of this information, we can construct speculative range. If the younger Yonah was born immediately after the death of his uncle and if he married in his early teens (as was common) the wedding could have taken place as early as the late 1380s.[119] If, on the other hand, Yonah was not *born* until the 1380s and married, atypically, only in his twenties, the wedding could have been as late as 1410, i.e. shortly before Shalom's death. Given this data, the most we can say is that Yonah's wedding very likely took place within a decade of 1400, with Ashkenaz's tradition of teenage weddings making the first half of this range more likely.

With regard to the location, the wedding would be taken place in either Vienna or Wiener Neustadt, depending on where Shalom was presiding at the time.[120] Having established the location options and likely chronological range for this anecdote, the next step is to determine whether our Hebrew sources accord with what we know about the early use of striking mechanisms and/or clocks in these two cities.

Tower clocks came to Austria at a relatively late date. The first, in Tulln (less than 30 kilometers from Vienna) was not built until 1372.[121] Wiener Neustadt's first clock with a striking mechanism could plausibly have been built in 1379, the year Leopold III (1351–1386) began erecting his imperial castle in the town. While the castle had a bell tower on its east side, the original structure was replaced in the early fifteenth century by Corpus Christi Chapel; as a result, we can only speculate about whether the original bell tower contained a clocks.[122] Given the boom in mechanical clock production and

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[119] On the age of marriage, see Steiman, *Custom and Survival: A Study of the Life and Work of Rabbi Jacob Molin*, 46; see also Avraham Grossman, *Pious and Rebellious: Jewish Women in Medieval Europe* (Brandeis University Press, 2004), 37ff.
[120] If Yonah's bride was from a third city, that information has been lost to us.
[121] Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 158.
[122] Sebastian Brunner, *Wiener-Neustadt in Bezug Auf Geschichte , Topographie, Kunst Und Alterthum* (Vienna: Mayer, 1842), 45–46.

the growing interest in sounding bells according to the equinoctial hours, it is possible that the wedding could have been held here, but no evidence from Wiener Neustadt itself corroborates this.

Such corroboration is available for Vienna. As was the case in Wiener Neustadt, Viennese interest in striking the equinoctial hours appears to have preceded the installation of a mechanical tower clock; this did not occur until 1417.[123] As early as 1377, local records refer to a certain Hannmann/Hanemann as a "*magister orloyorum*."[124] Financial records for the year 1380 indicate that the watchman of St. Stephen's Cathedral was now being paid "to beat the hours" (*pro pulsu horae*).[125] This suggests that Vienna, like other towns, was manually emulating the sounds of the new clocks, a testimony to their prestige and in anticipation of one day installing such a device.[126]

As is the case with the Hebrew anecdote, early fifteenth century evidence suggests that Vienna used the "French" hours system,[127] including a 1451 sundial located on the southern pillar of St. Stephen's cathedral, the oldest Viennese sundial still in existence. This dial, marks the hours from 6 until 6, with 12 as the midway point.[128]

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[123] Karl Uhlirz, "Beiträge Zur Culturgeschichte Und Geschictlichen Topographie Wiens, II. Zur Geschichte Der Uhren in Wien (1380–1699)," *Blätter Des Vereins Für Landeskunde von Niederösterreich* 25 (1891): 183. A private mechanical clock may have been present by 1380; see Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 391. (No citation is provided.)

[124] Franz Staub, *Quellen Zur Gesch. d. Stadt Wien 3. Abt., Bd. 1* (Vienna, 1898), sec. W. 1898, Nr. 937, 1133, S. 150, 185. I am deeply grateful to Dr. Dohrn-van Rossum for sharing with me his collected data on earliest Viennese clocks.

[125] The watchman had previously been located in the cathedral because its height would have allowed him to better surveil the city.

[126] Uhlirz, "Beiträge Zur Culturgeschichte Und Geschictlichen Topographie Wiens, II. Zur Geschichte Der Uhren in Wien (1380–1699)." Nuremberg's financial record indicate that they allocated funds for a similar purpose from 1388.

[127] Uhlirz.

[128] Peter Payer, "The City and the Clock: Public Time Perception in Vienna, from 1850 to 1914," n.d., 5.

Sundial on St. Stephen's Cathedral (1451). Note that the marks begin and end with "VI."

Based on this evidence, it is more likely that Yonah's wedding took place in Vienna—but regardless of location, the bells ringing the fourth hour heard by Shalom and his party would have been installed in the late 1370s. Given the date range for the wedding itself, this means that Ashkenaz's first clear acknowledgment of clock time took place between ten and thirty years after the clock had been introduced into the local environment. This is quite fast; indeed, with the exception of the printing press, no other pre-industrial technology receives such a fast response in Jewish sources.[129] Moreover (to return to the original question) it means that Shalom's teachers—including Israel of Krems, author of the *Hagahot Asheri*—betray no knowledge of the clock or clock time not because they did not consider these things important, but because the technology had not yet arrived. When the technology did arrive, it did not

[129] As an example: firearms appear in Europe from as early as the fourteenth century, but they do not appear in Jewish legal literature until the sixteenth century; see Moshe Isserles, *Shut Rema* §37.

take more than a generation for it to appear in the legal literature of Ashkenaz—not just in this one instance, but in other areas of law, as will be discussed below. This paints a picture of the clock as a powerful, transformative device.

At the same time, it is also possible that the sounding of the hours was not generated by an actual mechanical clock, but by a human being attempting to emulate a mechanical clock with a striking mechanism. One way or the other, it is clear that the Jewish encounter with mechanical clocks—unlike the encounter with all previous timepieces—began not with the physical objects, but only with their sound.

Direct engagement with mechanical clocks

Tower clocks were not under Jewish control; as a result, they do not feature in responsa literature. Small clocks, on the other hand, were luxury items. While a small number of identifiably Jewish silver timepieces from mid-sixteenth century German do exist, their magnificent craftsmanship suggests that they were exceptional.[130] It was only two generations after Shalom of Neustadt, with the emergence of small weight-driven clocks for residences and synagogues, that rabbinic positions regarding the legal status of clocks—specifically, the question of their permissibility on Shabbat—began to develop.

The first direct mention of clocks is in the work of Rabbi Jacob Weil (also known as Mahari Weil, d. before 1456), a student of Rabbi Jacob Moelin (also known as Maharil, d.

[130] A small spring-powered clock with a Roman numeral chapter ring (Germany, c. 1550) and a pendant watch (Nuremberg, ca. 1550), both finely etched with Stars of David, are catalogued in Vivian B. Mann and Richard I. Cohen, eds., *From Court Jews to the Rothschilds: Art, Patronage, and Power 1600–1800* (Prestel, 1996), 134. Another piece, inscribed with Hebrew initials, is dated to 1580; see *A Catalogue...Presented to the Worshipful Company of Clockmakers of the City of London*, Second (London: Blades, East & Blades, 1900), sec. 2. Finally, see several more examples in Klaus Maurice, *Die Deutsche Räderuhr* (Munich: C.H. Beck, 1976), figs. 568, 569, 571a, 574a.

1427), who was himself a student of Rabbi Shalom of Neustadt. When asked about the permissibility of winding or setting “a weight-driven instrument (*keli he-asui le-mishkalot*) for making noise according to the order of the hours,”[131] prior to Shabbat, in order that it run on Shabbat, Weil prohibits it.[132] As precedent, he cites the Late Antique rabbinic ban on pre-loading a watermill with grain before Shabbat, a ruling which the Talmud understands to be based on the noise such a watermill would make.[133]

Rabbi Judah Leib Landau, another student of Moelin, used similar terminology and the same prooftext to rule in the opposite direction. Asked whether a “weight-driven bell that rings the hours (*zog ha-mekashkesh le-shaʿot ʿasui ʿal yedei mishkalot*)” that can be “readied and set” prior to Shabbat is similar to a pre-loaded watermill, Landau responds that it is not. Whereas someone might suspect that a waterwheel grinding grain on Shabbat had been loaded that same day, “everyone knows that it is standard to ready clocks each day for the following day.”[134] A substantially similar position is cited in the name of Rabbi Israel Isserlein (d. 1460), a resident of Weiner Neustadt whose teacher, Rabbi Aaron Blumlein, studied with Shalom of Neustadt, as well.[135]

Although Landau indicates that his position accords with the people’s practice, the existence of opposing positions emerging among a close-knit group of scholars within a short time span suggests that the household clocks under discussion were a very new

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[131] On the meaning of *mishkalot*, see mKelim12:8.
[132] *Shut Mahari Vayl* §130. This text is discussed in Ta-Shma, “The Measurement of Time as Reflected in Medieval Rabbinic Literature [Hebrew],” 251.
[133] See tShabbat1:23 and bShabbat18a. Weil does not clarify whether his prohibition is dependent on the clock making noise or is about the act of setting up a device so that it operates on Shabbat. This ambiguity arose among later rabbis when silent clocks and watches began to appear.
[134] *Sefer he-Agur* §519. David Neustadter has suggested that the difference of opinion may have to do with Italian hour clocks being set before sunset and “French” hour clocks being set at noon. This does not adequately address the distinction, both because each rabbi lived in Germany (it was Judah’s son Jacob who moved to Italy) and because clocks of the area might have been wound and set more than once per day in any event as a result of their imprecision.
[135] *Leqet Yosher* I (O.Ḥ.) 48a.

phenomenon for which German and Austrian Jews had not yet adopted a uniform policy. That these positions were never reconciled suggests that the topic was not of major interest in the Jewish communities of Germany and Austria, for whom household clocks remained a rare luxury.

After this initial burst of interest, the legal conversation around mechanical clocks became dormant. Landau's position is reiterated by Rabbi Mordekhai Yoffe (d. 1612), and those of both Landau and Weil are discussed by Rabbi Moshe Isserles (d. 1572), but neither of these Polish scholars provided any additional commentary.[136] It was not until the appearance of cheap, widely used wall clocks and watches that rabbis again took interest in the topic.

Time registration

The practice of indicating the time of day when dating documents does not seem to have been especially prevalent in Ashkenaz. One book colophon contains a note from the owner stating that his wife had passed away "in the year [5]309 on the 4th of Sivan (=Friday, May 31, 1549) at two hours after noon...and she was buried in Neudenau."[137] According to an anecdote, Moelin and others were in a cemetery "around two hours before midday."[138] When the time is registered, "French" clock hours are not always used: Moelin's description of events that occurred at "around two hours at night" likely refers to seasonal hours (as opposed to "Italian" hours); he later talks about events

[136] *Levush* O.Ḥ. §338; *Darkhei Moshe ha-Qatzar* O.Ḥ. 252:7; *Shulḥan ʿArukh* O.Ḥ., 252:5.
[137] Hamburg Levy 32. Note that the copyist's colophon (199a) does not contain the hour.
[138] *Sefer Maharil* 84b.

"close to midnight."[139]

A rare use of the "Nuremberg" hour system—in which the clock is set to 12 at sunset and then again at sunrise—may be attested in the colophon of a German manuscript, which describes a severe and unseasonal thunderstorm in 1628 on the first day of the month of Shevat, "at eight hours of the day [*ḥ' shaʿot al ha-yom*], which is two hours after the *molad* [astronomical start of the new month]."[140] As the *molad* for that day was 12:21 P.M., it is possible that "Nuremberg" hours were intended. However, it is also possible that simple seasonal hours are in use.

In Poland, the use of the "Italian" hour system is attested from the sixteenth century. The colophon of a Krakow manuscript describes the copyist completing the work on "Thursday night, sixth hour, 13 Tishre, [5]317 (=September 17, 1556)."[141] On two occasions Rabbi Yoel Sirkes describes events taking place at "two hours of the night," as does Rabbi Moshe ben Yitzḥaq Yehudah Lima.[142] Rabbi Benjamin Aaron Slonik (d. 1620) describes events at "three hours at night."[143]

Sandglasses

Sandglasses and mechanical clocks appeared at almost exactly the same time in medieval Jewish sources, but Jews had access to the former more quickly by virtue of their simplicity and low cost. As a result, the legal discussion surrounding the use of

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139 *Shut Maharil* §92. See also Simha Assaf, *Meqorot Le-Toldot Ha-Ḥinukh Be-Yisrael*, 1953, I:58. Cf. Yosef ben Moshe, who notes that, "On [the holiday of] Purim, it is not the custom to say the evening prayer at the tenth [hour]," and later says that the Purim meal is concluded at "two or three hours of the night" (*Leqet Yosher* I, O.Ḥ., 159a).
140 NLI Ms. Heb. 8°3247, 1b. The unusual phrase "*shaʿot ʿal ha-yom*" may be a calque from another language.
141 RSL Ms. Guenzburg 283.
142 *Shut Baḥ ha-Ḥadashot* §31 and §32; *Ḥelqat Meḥoqeq* §17.
143 *Masat Binyamin* §106.

sandglasses is richer than that for mechanical clocks.

Evidence suggests that sandglasses were frequently employed to enforce existing legal and contractual obligations. The devices were common in German Jewish educational settings in order to time lessons. The second known depiction of a sandglass is located in a Hebrew Bible manuscript (1390–1396). The image features a student and teacher, with the sandglass there to track the length of the lesson.[144] German usage is reinforced in a responsum of the Regensburg authority Rabbi Israel Bruna (d. 1480), who notes that Rabbi Israel Isserlein (d. 1460) had thought it was the student's responsibility to supply a sandglass (*kli shaʿah*). Bruna dissented, arguing that a sandglass is as essential for a teacher's work as writing supplies are for a scribe.[145] Finally, Rabbi Moshe Isserles described an edict requiring that women use hour-length sandglasses ("an instrument called *shaʿah*, it being one of 24 parts of a complete day") when cleaning themselves in preparation for post-menstrual ritual immersion to ensure that they do this in haste.[146]

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[144] BL Add. 19776, fol. 72v. This image has been reproduced in many places, including Turner, "The Accomplishment of Many Years: Three Notes towards a History of the Sand-Glass," 163; Metzger and Metzger, *Jewish Life in the Middle Ages: Illuminated Hebrew Manuscripts of the Thirteenth to the Sixteenth Centuries*, 208. Similar depictions from elsewhere in Europe do not have a sandglass.

[145] *Shut Mahari mi-Bruna* §116; reprinted in Assaf, *Meqorot Le-Toldot Ha-Ḥinukh Be-Yisrael*, pt. 1:32. Dohrn-van Rossum suggests, unconvincingly, that Jews long had greater interest in setting times for educational lessons; Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, 253. This interpretation is based on A. Berliner, *Aus Dem Leben Der Deutschen Juden Im Mittelalter*, 1900, 8–9, who in turn cites bShabbat119b, a passage which does not concern timing.

[146] *Shut ha-Rema* §18; the same position is described in *Shut Maharshal* §6. Israel Ta-Shma sees this as an early testament to subdivisions of the hour; I do not see this in the text. See Ta-Shma, "The Measurement of Time as Reflected in Medieval Rabbinic Literature [Hebrew]," 256. On the use of the word *shaʿah* to refer to a sandglass, cf. Arabic *sāʿah* and German *Uhr* (Yiddish אוהר), both of which refer to the hour as well as a device which measures it.

British Library, Add. 19776 fol. 72v.

As with the mechanical clock, the use of the sandglasses on Shabbat was subject to debate. Jacob Moelin, who acknowledges the link between sandglasses and learning, indicates that he is inclined to prohibit their use, even though he can think of no clear reason for doing so. Tellingly, Moelin does not believe that the use of sandglasses falls under the Shabbat prohibition on "measuring;" instead, he writes, "even though measuring time is not technically 'measuring' (*ve-af ʿal gav de-lav medidah gemurah hi medidat ha-zeman*), it is nonetheless comparable."[147] Moelin's assumption that the legal definition of "measuring" includes weight and distance but not time underscores the novelty of precision timekeeping itself. Indeed, Yosef ben Moshe, a student of Israel Isserlein, argues that the sandglass does not *itself* measure, but rather *leads* to measurement if one counts how many times the glass has been flipped (*lahafokh ha-shaʿot*).[148]

Despite the professed baselessness of the prohibition, a prohibition does seem to have taken hold. In preparation for Shabbat, Israel Isserlein is reported to have cleaned the table upon which he studied each Friday, making sure to remove all objects which it would be forbidden to move on Shabbat (*muktzeh*), "not even letting the sandglass (*ha-shaʿah*) rest upon it."[149] In the sixteenth century, the German attitude towards the sandglass migrated to Poland, where both Moshe Isserles and Mordekhai Yoffe prohibited its use on Shabbat.[150] As will be discussed below, Jewish communities elsewhere had more permissive policies.

Legal literature

Apart from direct references to clocks and sandglasses, the appearance of new timekeeping devices impacted rabbinic legal discussions in other ways. Because tower clocks were now constantly signaling clock hours, Jewish sources began to incorporate this information into their legal positions. In Germany and Austria, this was done using

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[147] *Shut Maharil,* §200.
[148] *Leqet Yosher* I (O.Ḥ.), 64:4.
[149] *Leqet Yosher* I (O.Ḥ.), 49. The word is here spelled השע"ה; the purpose of the *gershayim* (quotation marks) is unclear to me, since a *gershayim* is normally reserved for acronyms or foreign words. See Ta-Shma, "The Measurement of Time as Reflected in Medieval Rabbinic Literature [Hebrew]," 252.
[150] *Shulḥan ʿArukh* O.Ḥ. 308:51; *Levush* O.Ḥ. 308:51. Separately, Yoffe permits carrying an astrolabe on Shabbat; see *Levush* O.Ḥ. 308:50.

the “French” hour system; in Poland, the “Italian” hour system was used. Meanwhile, both the tower clock and the sandglass simplified the task of determining multi-hour and sub-hour intervals, respectively. As a result, both kinds of intervals gained importance in Ashkenaz legal writings over the course of the fifteenth, sixteenth, and seventeenth centuries.

Whether these legal debates reflect changes in practice is difficult to determine. Certainly the improved ability to keep track of time led rabbis to assert more strongly how laws should be performed in practice, but at the same time, many of these cases highlight some type of normative divide. Sometimes the divide is between pious and regular observance; at other times it is between theoretical norms and folk practice. It was probably not until the eighteenth century that improvements in clock technology had a direct impact on normative practice.

Using clock hours

In the “French” hour system, the use of noon as a reference point and the division of the day into two twelve-hour cycles mean that there is a rough correspondence between “French” hours and rabbinic hours. Given the inaccuracy of early clocks, the chiming of the clock would have been a reasonable proxy for rabbinic hours, at least during the spring and fall. This did not go unnoticed by German and Austrian rabbis, who soon began translating rabbinic seasonal hours into “French” clock hours for the convenience of their readers.[151] One of Shalom’s students, Rabbi Isaac Tyrnau, describes the earliest time for saying the afternoon prayer as “half an hour after noon,” and by-

[151] Shalom himself uses the phrase “before midday,” in a ruling (*Minhagei Maharash me-Noyshtat*, 390:2), but this is similar to the language of older rabbis, since no specific number of hours before noon is indicated.

passes the standard formulation, "six and a half hours."[152] Such "translations" also feature in writings by Shalom's most important student, Rabbi Jacob Moelin, whose own city, Mainz, installed a striking clock in its St. Quentin church in 1369.[153] On two occasions, Moelin explained that the rabbinic obligation to eat one's third meal on Passover day after "the ninth hour" refers to "three hours after noon."[154] On another occasion he wrote that, on wedding days during the summer, it was the custom of the Jews of Mainz to pray the afternoon prayer at "three hours in the afternoon."[155]

References like this are less common in Poland, for reasons that will be explored below. However, Rabbi Solomon Luria does refer to a communal practice of praying "after 23 hours," reflecting the "Italian" hour system that had been adopted in Polish towns.[156]

Seasonal hours vs. clock hours

If the use of the clock as a proxy for rabbinic hours was sometimes useful, it also brought to the surface a long-dormant problem: the ambiguity in the rabbinic use of the word "hour." In chapter 2, we argued that the Late Antique rabbinic notion of the hour is "naïve," i.e. it is not internally consistent. In chapter 3, we described how the advent of Islamic scientific knowledge led some scientifically-minded rabbis to consider the distinction between seasonal and equinoctial hours for the first time. Armed with this knowledge, Maimonides injected an understanding of seasonal hours into the rabbinic corpus; still, neither Maimonides nor anyone else referred to a situation in which

[152] *Sefer Minhagim (Tyrnau)*, "Minhag Shel Yom Ḥol" and "Erev Pesaḥ." In the latter, Isaac does not translate "nine hours," as Moelin does.
[153] Bilfinger, *Die Mittelalterlichen Horen Und Die Modernen Stunden: Ein Beitrag Zur Kulturgeschichte*, 205.
[154] *Sefer Maharil* (Warsaw, 1875), 4a–b and 17b. Given the inaccuracy of the clocks of the day and the fact that Passover takes place around the equinox, we can ignore that this is also a translation of seasonal into equinoctial hours.
[155] *Sefer Maharil*, 64a–b.
[156] *Shut Maharshal* §13.

the distinction was important. The terms "seasonal hours" and "equal hours" did not gain popularity outside of scientific circles, and most Jews remained unreflective about their use of the hour system.

With the introduction of tower clocks ringing "French" hours, this long-standing ambiguity came to a head in the form of three legal controversies. All pertained to areas of the law in which precision was understood to be of great importance. It is in these controversies that the meaning of the Late Antique rabbinic hour finally began to be debated.

Example #1: calculating the tequfah. The first locus of conflict concerned a subject which lies at the intersection of Jewish astronomy and popular practice: the calculation of the "*tequfah*," which in this context refers to the transition point from one season to the next. As the Talmud describes it, each *tequfah* takes place exactly 91 days and 7½ hours after the last one: thus, if the spring *tequfah* started at the beginning of the night, the summer *tequfah* would start 7½ hours into the night. As discussed in a previous chapter, the Talmud's explanation of the length of the *tequfah* is not fully coherent, a problem noted by the Tosafists but never resolved.[157]

Despite this ambiguity, superstitions pertaining to the *tequfah*—most prominently the custom neither to drink water during the *tequfah* itself nor to drink water which had been uncovered during the *tequfah*—were taken seriously in Ashkenaz.[158] The origin of the superstitions is not clear, but the practice was likely reinforced by a similar

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[157] See above, page 195.

[158] On the history of the custom, see Ta-Shma, "The Danger of Drinking Water During the Tequfa: The History of an Idea."

Christian ritual called Quatember.[159]

Even before the appearance of the mechanical clock, the scholarly and folk conversations concerning the *tequfah* had parted ways. The medieval Jewish astronomers Abraham bar Ḥiyya and Isaac Israeli had stated that the Talmud's definition of the *tequfah* pertains to hours at the equator, which remain the same length all year,[160] yet neither showed interest in educating the public regarding a method for determining when the *tequfah* would occur on the basis of this definition; in other words, they do not indicate that the *tequfah* had any normative significance. Abraham ibn Ezra, the astronomer and exegete, uses this silence to critique popular superstitions around the *tequfah*, "for the astronomers who knew the true *tequfah* clearly never mentioned that eating and drinking at the time of the *tequfah* would be harmful."[161] By contrast, Rabbi Alexander Suslin ha-Kohen (d. 1349), who cited Tosafot instead of astronomy, left open the possibility of reckoning by seasonal hours—though he, too, reached no practical conclusion.[162]

With the arrival of the tower clock, it suddenly became feasible to use the astronomers' definition of the *tequfah* in normative practice; rather than instructing people to pay attention to the movement of the sun or the time that had elapsed at night, one could simply announce the hour during which the *tequfah* would occur. The first to take this idea seriously was Jacob Moelin. Asked whether *tequfah* calculations should be linked to the seasons, Moelin equivocates, responding that some areas of law do shift in accordance with the season, such as the latest time for the afternoon prayer and the

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[159] Carlebach, *Palaces of Time*, 166.
[160] Bar Ḥiyya, *Sefer ha-ʿIbbur*, 1:10; Isaac Israeli, *Yesod ha-ʿOlam*, 2:13. See, as well, *Shut Tashbetz*, 1:109.
[161] Carlebach, *Palaces of Time*, 165.
[162] *Ha-Agudah*, Eruvin ch. 5, 56a.

earliest time for beginning Shabbat on Friday afternoon. However, based on Tosafot's concerns, he remains undecided on whether the *tequfah* follows similar rules.[163]

Faced with this dilemma, Moelin hedged: when a *tequfah* was to occur at night, he calculated precisely when it would take place by reckoning from the beginning of the night, regardless of the season. (For example, a *tequfah* calculated as taking place at "1½ hours of the night" would begin 1½ hours after sunset.) At the same time, he "cushioned" this reckoning by adding three hours before and after the projected *tequfah* moment as a precaution.[164] Since it is a difficult task to reckon three hours—especially at night or near sunset—this practice would only have been possible in the presence of a mechanical clock. Moelin, apparently, was not willing to use the mechanical clock in order to create a practice that accorded with the astronomers' definition of the *tequfah*—but he *was* willing to use the mechanical clock in order to create a margin of error that covered both the popular and the astronomical calculation of the *tequfah*.

The clock also allowed Moelin to be the first scholar to put the astronomers' conception of the *tequfah* into normative practice. While Moelin's hedge did not take hold, the astronomers' *tequfah* did—but only among other scholars like Israel Isserlein, who is recorded as beginning dinner at 7½ hours after noon, precisely after the astronomers' *tequfah* would have concluded, without any hedging whatsoever.[165] The public, however, did not follow along. In this case, the spread of clocks did not lead to a change in practice; instead, it forced the rabbis to reconcile themselves to the fact that the populace was calculating the *tequfah* in a manner that was both incorrect and correctable.

The first person to note the problem with the populace's position was Mordekhai

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[163] *Shut Maharil* §152. Cf. *Maharaḥ Or Zarua*ʿ, §185.
[164] *Sefer Maharil*, 86b.
[165] *Leqet Yosher* I, (O.Ḥ.), 70a.

Yoffe. In an extended excursus on the *tequfah* written in 1579, Yoffe writes that it is inappropriate to use Poland's "Italian" hours for the purposes of this calculation:

> I must also pass on to you one of the secrets of calendrical computation which deserves to be spread to the public...it is understood by those who know a little of astronomy (*ḥokhmat ha-tekhunah*) and even those who only know the shape of the sphere. Namely: know that what is written in astronomical tables for *moladot* (lunar conjunctions) and *tequfot* is not determined with the hours that we count from the beginning of the night each day.[166]

For purposes of the *tequfah*, argues Yoffe, "night" and "day" are simply constructions: night begins six equinoctial hours after the sun passes directly overhead and ends twelve equinoctial hours later, irrespective of the season or whether it is light or dark. "1½ hours at night," then, is not 1½ hours after sunset, but 1½ hours after six hours after noon. Even though it is counterintuitive to ignore whether is *actually* day or night (what he called *ha-tequfah ha-amitit*), Yoffe insists that this must be the correct method:

> And although the *tequfah* is not [calculated on the basis of] real [seasonal hours], but rather equalized [hours], according to what we have received regarding the dangers of the [transition from the last] moment of a *tequfah* to the [next] *tequfah*, it nonetheless appears that it is *tequfot* of equalized [hours] which have been transmitted to us. One must be punctilious about this [method]; even though the world only cares about the number of hours from the beginning of the night,[167] it is essential to be precise regarding hours about which I have written, and "God protects the simple" (Psalms 116:6).[168]

Resigned to the fact that the populace will not follow him even though he is right,

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[166] *Levush* O.Ḥ., 428:8.
[167] Though it may just be a turn of phrase, Yoffe here seems to be assuming that "Italian" hours had been universally adopted.
[168] *Levush*, O.Ḥ., 428:8.

Yoffe closes with an assertion that God will nonetheless protect God's people from the effects of the *tequfah* should they accidentally violate its taboos. This position is affirmed and amplified by Menaḥem Mendel Krochmal (d. 1661), who asserts, with regards to the calculation of the *tequfah*, that popular custom (*minhag*) carries its own authority which can overturn law itself.[169]

Though the popular position did not ultimately change, the rabbis' consideration of the *tequfah* may be seen as reflecting the expectation that the public *could* have kept track of time differently if it had so chosen. While the tower clock did not effect a change in practice, its presence led to a discussion about the possibility of such a change and a confirmation of the public's practice.[170]

<u>*Example #2: The Fourth Hour on Passover Eve.*</u> The second significant conflict concerns Passover Eve; as discussed in previous chapters, this was a day on which precise scheduling was very important in order to avoid serious legal violations. The rabbis of Late Antiquity had permitted leavened bread (*ḥametz*) to be eaten on that day until the fourth hour which, at that time, corresponded to the conclusion of the first meal of the day.[171] Indeed, because "fourth hour" might have been code for "morning meal," it is possible that the "fourth hour" had a loose relationship with even the position of the sun in the sky.

In the medieval period, by contrast, the correspondence between the fourth hour

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[169] *Shut Tzemaḥ Tzedeq* §14.
[170] By the end of the nineteenth century, the popular custom had lost traction and Yoffe's position become normative. This took place at the same time as the superstition itself began to fade.
[171] mPesaḥim1:4–5.

and the morning meal no longer held.[172] As a result, some other method for determining the end of the fourth hour was necessary. Eliezer ben Joel ha-Levi's description of a primitive hand sundial, described and discussed in the previous chapter, was one such method; could the bells of the clock tower be another? On this question German and Austrian rabbis were split. For some, the rough correspondence between the rabbinic fourth hour and "two hours before midday"—i.e. the moment in the morning when the clock chimed ten—meant that the latter could be assigned legal significance. Other rabbis, however, contended that "four hours" meant four out of the twelve seasonal hours in any given day; consequently, one could not rely upon the clock's chimes.

It is not clear when this controversy began. In the previous chapter we noted that, because the public may not have understood what "four hours" meant, both the anonymous French *Sefer ha-Niyyar* and the Catalonian rabbi Menaḥem Meiri had clarified that one may not eat *ḥametz* on Passover Eve after a third of the day has passed. A similar claim was made by Shalom of Neustadt, who is quoted as saying, "'Four hours,' with respect to burning *ḥametz*, means a third of the day."[173] It is possible that Shalom's specification was simply to clarify the meaning of the phrase "four hours." However, given that Shalom's teachers did not feel the need to explain the meaning of the phrase,[174] it is more likely that Shalom's clarification was *also* an attempt to exclude the notion that "four hours" had anything to do with the chiming of the clock. This idea was given its strongest articulation by a younger scholar living in the same city, Rabbi Israel Isser-

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[172] P.W. Hammond, *Food and Feast in Medieval England* (Alan Sutton, 1993), 104–105.
[173] *Minhagei Maharash me-Noyshtat* §398:2; see also *Sefer Maharil* 8a. Cf. *Minhagei Maharash* §373.
[174] For example, compare Shalom's formulation to that of his teacher Abraham Kloyzner in the latter's *Sefer Minhagim* (Deva, Romania, 1929), 33b.

lein, although, as we shall see, there is reason to believe that the idea predated him.[175]

The possibility that clock hours might have legal significance is first broached in a question to Isserlein:

> Question: Like Rabbi Yehudah [at bPesaḥim12b], we maintain that we eat [*ḥametz*] until the fourth [hour] and not later. In a leap year[176] [i.e. when Passover, which usually falls around the equinox, is delayed by a month], when the day lengthens [*ma'arikh*] in our region, such that the end of the fourth [hour] is still around three hours until midday, until when is it permissible to eat *ḥametz*? Is it always until two hours before midday, or should we say that once four hours have elapsed from the beginning of the day it is always forbidden to eat *ḥametz*?[177]

Before getting to Isserlein's answer, we need to consider how the word *hour* is being used here, since the question does not provide clarification on this point. The motivation behind the question itself is undoubtedly the clock hour, since the assessment that, during leap years, there are three hours until midday after the fourth hour implies a day of approximately fourteen hours. (This is in fact the approximate length of the day on Passover Eve in a leap year near Wiener Neustadt.) Furthermore, the phrase "two hours before midday" must refer to clock hours, since it is strongly associated with the "French" hour system itself.

More significantly, the questioner must *also* be using clock hours in the phrase "four hours," even though this is a clear departure from meaning of the phrase as used in Late Antiquity. This reading is supported by the fact that the questioner does not at-

[175] Certainly, both Shalom of Neustadt and Jacob Moelin are later understood to be standing in opposition to Isserlein; see *Darkhei Moshe ha-Qatzar*, O.Ḥ. 443:1. On Isserlein's life, see Solomon B. Freehof, *The Responsa Literature* (Skokie, Illinois: Varda Books, 2001), 74–76.
[176] The Jewish calendar is primarily lunar, but in "leap years" an additional month is added in order to bring the calendar in line with the solar year over the course of a 19-year cycle. In each cycle, 7 of 19 years are leap years.
[177] *Terumat ha-Deshen* §121.

tempt to specify that these are seasonal hours, either explicitly, or by identifying "four hours" with "a third of the day," as Shalom had done. Furthermore, the math does not add up: in a fourteen-hour day, four seasonal hours are the equivalent of 4⅔ hours, leaving only 2⅓ hours until midday. This is hardly the three hours specified in the question and, at the time, would have been hardly distinguishable from two hours. In other words: by the time that this question had been posed, the concept of clock time had been so thoroughly absorbed that it had become the default understanding of the word "hour." Moreover, this meaning was being anachronistically read into texts which clearly could not have been using such clocks.

Isserlein's response[178] to this question is unambiguous: "It is always permissible to eat until two hours before midday." Like his questioner, Isserlein does not distinguish between seasonal and equinoctial hours in his response; indeed, evidence from elsewhere in his corpus of responsa suggests that Isserlein rarely used "hours" in their seasonal sense. A notable exception is his discussion of the local custom to recite the evening prayer before the accepted time; his careful definition of the concept in this case indicates that it was exceptional.[179] In responding to the question about the leap year, Isserlein *does* clarify that he is discussing, "four hours *from the beginning of the day*." This specification is only necessary because, in a "French" hour context, "four hours" normally means 4 A.M. or 4 P.M. At no point does a seasonal-hour interpretation of the rule get a hearing.

Isserlein's perspective was set forth more explicitly by his student Rabbi Yosef ben Moshe, who wrote that, on Passover Eve, "one needs to be careful to finish eating

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[178] It has sometimes been suggested that Isserlein composed his own questions and then answered them. For a definitive rebuttal of this theory, see *Sefer Leqet Yosher* (Berlin, 1904), xiv.

[179] *Terumat ha-Deshen* §1.

ḥametz...at the end of four hours [counting] from the beginning of the day at dawn, even in a leap year...*And these four hours are not reckoned as always being a third of the day* or always two hours before midday."[180] Rabbi Israel Bruna, another of Isserlein's students, seems to have accepted the clock-hour meaning of "four hours," as well; he, too, indicated that this should be normative practice.[181]

Isserlein and his questioner offer the strongest evidence for the acceptance of the clock hour into Jewish law. It is perhaps because clock hours easily mapped onto the "naïve" hours which appear in Late Antique rabbinic texts that they felt no need to explore the meaning of their terms using the vocabulary which had recently become available through Maimonides and other texts from Islamic lands. Neither Isserles nor any other Austrian rabbi of the fifteenth century speaks about a generalized distinction between seasonal and equal hours.[182]

This theoretical language only begins to emerge as the core of our debate as it shifts to Poland, whose "Italian" hour system could not be so easily mapped onto rabbinic hours. Moreover, the use of the phrase "seasonal hours" (*shaʿot zemaniyyot*) may have only come to popularity at the end of the century through the 1492 Naples printing of Judah al-Ḥarīzī's translation of Maimonides' Mishnah commentary.[183]

First to articulate Isserlein's conceptual position in full is the Polish scholar Rabbi Moshe Isserles (d. 1572).[184] For Isserles, Isserlein's argument was not about clocks, but

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[180] *Leqet Yosher* 1 (O.Ḥ.) 78b; emphasis mine.
[181] Bruna's position survives in *Darkhei Moshe ha-Qatzar*, O.Ḥ. 443:1.
[182] Isserlein's ambiguity led his remarks to become the subject of controversy among later rabbis; see below.
[183] *Mishnayot ʿim Peirush ha-Rambam* (J. Soncino and J. ibn Peso: Naples: 1492), fol. 11b. Notably, Ibn Ezra's straight/crooked terminology does not gain a following.
[184] On the sources of his knowledge, see Y. Tzvi Langermann, "The Astronomy of Rabbi Moses Isserles," in *Physics, Cosmology and Astronomy, 1300–1700: Tension and Accommodation*, ed. Sabetai Unguru (Kluwer Academic Publishers, 1991), 83–98.

about the use of equinoctial hours—and it is for this very reason that it cannot be correct:

> In *Terumat ha-Deshen*, it is written that, in leap years, when [Passover Eve] is lengthened such that at the end of four [hours] it is still three hours until midday, it is permitted to eat [*ḥametz*] beyond the fourth [hour], and in general, one may eat until two hours before midday. But Maimonides wrote…that all hours mentioned in the Talmud are seasonal hours [*zemaniyyot*]…so when it says, "until four hours," it is as though it had said, "until a third of the day." And thus ruled the Maharil (=Jacob Moelin) in the name of Shalom of Neustadt. And this is not in accordance with the responsa of Rabbi Israel Bruna, who forbade eating *ḥametz* after four hours in the day, even during a leap year.[185]

In the century that followed, Isserlein's position became a frequent topic of discussion among Polish rabbinic authorities, although few actually sided with him. Rabbi Joel Sirkes ruled against Isserlein, citing a desire for stringency;[186] Rabbi Tzvi Katz (b. 1590) posited that Isserlein's position could be relied upon *ex post facto*.[187] Rabbi David ha-Levi (d. 1667) ruled against Isserlein, as well, but in doing so he described the position as "two of our hours (*shaʿot shelanu*)" before noon, simultaneously rejecting the ruling and conceding that clock time had become internalized.[188] Similar language is used by Rabbi Mordekhai Yoffe, who refers to equinoctial hours as "unspecified hours" (*shaʿot setamiyot*).[189] Rabbi Joel Sirkes explicitly stated that reckoning according to equinoctial hours had become the norm, writing, "In their [Gentiles'] language, 'hour' only means

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[185] *Darkhei Moshe ha-Qatzar* O.Ḥ. 443:1.
[186] *Baḥ* O.Ḥ. 331:1.
[187] *Naḥalat Tzvi* 443:1. Katz describes a hypothetical day that is eighteen hours long; on such a day, he says, Isserlein would allow one to sell *ḥametz* until the "eighth hour," by which he presumably means one equinoctial hour before noon. Despite his rejection of Isserlein's position, this is an indication of clock hours—perhaps even the Nuremburg hour system, which begins at 12 each sunrise and continues for as many hours are necessary to arrive at sunset.
[188] *Taz* O.Ḥ. 443:3. Ha-Levi is one of the first to use "our hours" to describe clock time; the phrase is employed by several later scholars, as well.
[189] *Levush* O.Ḥ., §89. This phrase may have been added by a later editor.

one hour of the 24 hours of the day."[190] Growing Jewish comfortability with the clock hour is also manifest in unprompted clarifications that prayer times follow the (now no longer default) seasonal hours.[191]

As with the *tequfah* discussion, the proliferation of clock hours is visible behind this debate. Though Isserlein's ascription of legal significance to clock hours was ultimately ignored, the discussion of his claim resulted in one of the first clear articulations of the practical legal difference between seasonal and equinoctial hours.

<u>*Example #3: The meaning of "ʿonah."*</u> A final legal controversy concerns the reconsideration of an old argument about the duration of an ʿ*onah* (term), the interval during which Jewish law prohibits physical intimacy between a woman and her husband while anticipating the imminent start of her menstrual period. (The Talmudic definition of an ʿ*onah* and the subsequent debate have already been described in the previous chapter.[192]) By the end of the fourteenth century, there was almost complete consensus that an ʿ*onah* was either a day or a night (depending on whether the menstrual period was expected to commence in one or the other), irrespective of the time of year. The sole dissent came from Rabbi Eliezer ben Joel ha-Levi, who asserted that this definition applied only during the spring and fall; during the winter and summer, an ʿ*onah* was defined as "half of the day and half of the night," in line with a Talmudic position that all others had ignored.

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[190] *Shut Baḥ* §79.
[191] On the final time to say the *shema*ʿ and the morning prayers, see *Levush*, O.Ḥ. 58:1. On the time of the afternoon prayer, see *Levush*, O.Ḥ. 233 and 361:4; see also Isserles' gloss on *Shulḥan ʿArukh*, O.Ḥ. 233:1, which gives a formal explanation of seasonal hours and explains how the rabbis used them. On the time of a *pidyon ha-ben* ceremony, see *Baḥ*, O.Ḥ. §249.
[192] See above, page 179.

While Eliezer ben Joel ha-Levi's position had either been adopted or entertained and rejected by later rabbis, it was always taken at face value. It was not until the sixteenth century that his position was expanded into a conceptual argument about the use of "hours" in the applied context of family purity. In his legal commentary, Rabbi Yosef Caro speculated that Eliezer ben Joel ha-Levi was making a larger point: an *ʿonah* period is "twelve hours of those 'hours' of which there are 24 in a day and night."[193] However, says Caro, Eliezer ben Joel ha-Levi's position is incorrect, for the Talmud says nothing about "hours." (Ironically, a more straightforward reading of Eliezer ben Joel ha-Levi's position would have shown that his position is directly supported by the Talmud.)

Caro's position stirred further debate: Can a Talmudic discussion which never mentions hours actually have a concept of hours at its core? On this question, Rabbi Shabbetai ha-Kohen (d. 1662) answered an emphatic yes: "half a day and half a night" is just another way of speaking about an interest in resorting to seasonal hours.[194] Meanwhile, his colleague Rabbi David ha-Levi Segal (d. 1667) affirmed Caro's position, arguing that the Talmud's position would be impractical to implement were it to involve a certain number of hours, rather than a full day or full night.[195]

Where the debates around the reckoning of the *tequfah* and the consumption of *ḥametz* on Passover Eve had a direct impact on normative practice, this last discussion might be a called a meta-debate; it is not about the law, but simply about how the texts

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[193] *Beit Yosef* Y.D., 184:2.
[194] *Shakh*, Y.D., 184:7.
[195] *Taz,* Y.D., 184:2; see, as well, the example given in Y.D. 193.

in question should be read.[196] As we shall see in the next chapter, conceptual discussions like this became more common in the eighteenth and nineteenth centuries.

More precise durations

The use of hour approximations was not solely associated with technological development. As we have seen, such usage in Islamic lands did not correspond with any such advance. As Jewish texts written in Islamic lands began to appear in Christian Europe, hour approximations began appearing there, as well; by the invention of the clock and sandglass, it was no longer a new phenomenon. Despite this, the invention of the clock and sandglass are associated with an increase in hour approximations, a new comfortability with durations of time that are not linked to events in legal discourse, and, because of the sandglass, a new ability to be precise with sub-hour durations.

A few changes in locution are notable. In an anecdote, Israel Isserlein is described as having performed a section of prayer "for three parts of an hour," which Israel Ta-Shma understood to mean three quarters of an hour.[197] Isserlein also used the phrase "72 hours," instead of the normal rabbinic formulation, "three *me-ʿet le-ʿet*;" in Late Antique rabbinic literature, "me-*ʿet le-ʿet*" (lit. "from time to time") had been the predominant technical way of describing a 24-hour period.[198] Though novel, locutions of this sort remained a minor phenomenon.

Example #1: eating dairy after meat. The first important use of more precise dura-

[196] Shabbetai ha-Kohen provides this kind of meta-commentary elsewhere, as well. See *Shakh*, Y.D., 389:4 and 399:1.
[197] *Leqet Yosher* I (O.Ḥ.), 17, #4. Ta-Shma, "The Measurement of Time as Reflected in Medieval Rabbinic Literature [Hebrew]," 254.
[198] *Leqet Yosher* I (O.Ḥ.), 47, #2.

tions can be seen in rabbinic discussions of the prohibition on eating dairy too soon after eating meat. A statement in the Talmud suggests that one should not eat dairy until the next meal; by the twelfth century, it was agreed that the time between meals is approximately six hours. Growing use of the mechanical clock did not immediately change the norm around this law; rather, it transformed the phrase "six hours" from a shorthand for "the time between meals" into the rule itself, although this rule was initially only followed by pietists. In the process, it entirely detached the rule from its Talmudic origins.

The reliance on mechanical clocks in order to observe this law is already attested by Rabbi Jacob Moelin, who stated:

> But after meat—even fowl—one should not eat cheese until a different meal. The pious ones—both the first ones[199] and the ones now—wait for six hours. The custom is to wait for one hour.[200]

Moelin recognizes that the core of the law mandates waiting until the next meal, but observes that, in practice, both pious and regular people just count off a certain number of hours. Furthermore, Moelin does not draw a direct line between the legal standard ("until a different meal") and the pious and regular practices; his phrasing suggests that both are valid implementations. This is a departure from Maimonides, who did not recognize a one-hour wait time as valid practice.[201]

Like Moelin, Rabbi Israel Isserlein understood the six-hour wait to be a pious practice, but he goes further in understanding this waiting period as having been mandated

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[199] Perhaps referring the "first pietists;" see above, page 54.
[200] *Minhagei Maharil* 76a.
[201] Ironically, the Talmudic passage upon which this rule is based understood waiting until a different meal to be the *less* pious position; the more pious position was to wait until the next day. See bḤullin105a, quoted and discussed above, page 142.

by Maimonides:

> [Isserlein] practiced according to how Maimonides ruled: whether he ate meat or fowl, he would wait six hours from one meal to the next if he wanted to eat cheese next, but he did not object to others who were not punctilious in their actions. However, he did object to his son [being uncareful] as soon as he was a *bar mitzvah* (i.e. had turned thirteen).[202]

In this passage, Isserlein is presented as one of the "pious ones," whose piety is marked by keeping track of an interval. (Unlike Moelin, he does not indicate whether regular people kept track of a shorter interval.) More significantly, he understands "six hours" to be a Maimonidean "ruling," when in fact it was simply a rule of thumb. Whereas Maimonides understood the six-hour interval to be an *effect* of the time between meals, in Isserlein's practice it is the *reason* to wait this long between meals. Oddly, Isserlein understands Maimonides to be "ruling" for pietists, even though Maimonides does not distinguish between pietist and popular custom with regards to this law.

A further development in interpretation can be noted in the writings of the German expatriate Rabbi Jacob Judah Landau, who seems to have replaced the "between meals" ruling with something entirely different:

> One who ate animals, beasts, or fowl should not eat cheese until six hours later. Even after this period, if one has meat in one's teeth, one must remove it [before eating cheese]. Within this time [the six hours]: even if there isn't any meat between one's teeth [one cannot eat cheese], because meat emits grease and makes the taste endure for a long time...and Maimonides gave the reason for waiting as being the presence of meat between the teeth. According to his words, one is permitted to eat meat after waiting six hours, even if meat between the teeth remains. And one who chews up meat for a baby must wait [six

[202] *Leqet Yosher* I, O.Ḥ., 35, #3.

hours].[203]

Elsewhere, Landau asserts that waiting "around six hours" is the custom of the people of Ashkenaz, rather than simply a pious custom.[204] Landau is also aware that not all authorities required a waiting period, and even cites Rabbi Asher ben Yeḥiel (d. 1327) saying that one should wait "around the time between the morning meal and evening meal." Despite this awareness of the diversity of opinions around the law, Landau is clear that actual practice involves waiting a fixed number of hours. In his understanding, this was Maimonides' ruling; he does not mention that, for Maimonides, the six hours were only an approximation of the time between meals.

<u>*Example #2: The definition of "shiʿur mil."*</u> A second important development can be seen in discussions of the time it takes to walk a mile (*shiʿur mil*). This Talmudic metric is used to describe sub-hour intervals in several areas of law.[205] In chapter 3, we noted two previous attempts to define this term: a Genizah fragment which lent itself to the understanding of *shiʿur mil* as a third of an hour, and Maimonides' commentary on the Mishnah, which states that it is two-fifths of an equinoctial hour. Neither of these definitions received much attention: Maimonides' interpretation is even absent from his own *Mishneh Torah* legal code, and the *shiʿur mil* metric is invoked without comment by both Rabbi Shlomo ben Aderet and Rabbi Menaḥem Meiri, the two pre-mechanical-clock scholars most interested in carefully defined durations.[206] It was not until the first half of the fifteenth century that the *shiʿur mil* was suddenly subjected to renewed scru-

[203] *Sefer ha-Agur* §1240.
[204] *Sefer ha-Agur* §223.
[205] It is also used to describe the length of twilight; on this, see the next chapter.
[206] Maimonides, *Mishneh Torah*, Laws of Ḥametz and Matzah, 5:13.

tiny.[207]

The first to tackle the subject was Shalom of Neustadt, who in one report is said to have defined *shiʿur mil* as one half of an hour and in another report as one third of an hour.[208] Whichever report is accurate, Shalom is presumed to have innovated it himself.[209] Jacob Moelin indicates that it is "a little more than a third of an hour"—possibly emulating his teacher—although on another occasion he discusses the measure without translating it.[210]

A more precise definition was given by Rabbi Israel Isserlein. In discussing the laws of salting meat (a necessary preparatory step, since the consumption of blood is forbidden), Isserlein rules that salt must be left on the meat for an hour, but when there is a time pressure one may follow Maimonides, for whom "the period of salting is a *mil*'s distance, which is a third of an hour less a thirtieth of an hour, as we have proven from an average person's distance [covered while walking] being 10 *parsa'ot* on an average day, which is twelve hours."[211] This definition, which is confirmed in a second responsum,[212] relies on a variant of the triangulation of Talmudic passages we assumed Maimonides to have used. In both passages Isserlein alludes to having "proved" his position elsewhere, but no such text survives in his work.

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[207] Jacob ben Asher does further clarify the term, but not with regards to time; see *Tur*, O.Ḥ. §293.
[208] Half an hour is given in *Minhagei Maharash me-Noyshtat* §280. The one third of an hour rule appears in Isaac Tyrnau, *Hagahot ha-Minhagim*, Laws of Scouring and Kneading.
[209] There are around a dozen original rulings in Shalom's corpus. See Spitzer, *Halakhot U-Minhagei Rabbeinu Shalom Me-Noyshtat (Derashot Maharash)*, 21. In a similar vein, Moelin rules that Ḥanukkah candles should burn for half an hour (*Minhagei Maharil* 56b). This position also appears in a Genizah fragment, but the two rulings are probably unrelated.
[210] *Sefer Minhagim,* Hilkhot Afiyat ha-Matzot and *Shut Maharil he-Ḥadashot* §51.
[211] *Terumat ha-Deshen* §167. bPesaḥim93b records that a person can walk five *mil*s from dawn to sunrise, 30 from sunrise to sunset, and five from sunset to nightfall. Because Maimonides defines the day as beginning at sunrise and ending at sunset, a person can walk a *mil* in two-fifths of an hour (twelve hours per day divided by 30 *mil*). If one defines the day as beginning with dawn and ending with nightfall, the calculation yields three-tenths of an hour instead. Finally, note that, by defining an "average day" as twelve hours, Isserlein again demonstrates his use of the clock hours as a default.
[212] *Terumat ha-Deshen* §102.

Importantly, Isserlein does not seem to be aware that he is in conflict with Maimonides, whom he cites in support of his position. Since it is only in Maimonides' Mishnah commentary that the "two-fifths of an hour" interpretation appears, this is understandable; as we have already noted, lack of access to this commentary also explains why Isserlein and his Austrian colleagues did not speak about *shaʿot zemaniyyot* explicitly. While they disagree, both Moelin and Isserlein define *shiʿur mil* in terms of thirds of the hour. By contrast, both Jacob Weil and Yosef ben Moshe reformulated Isserlein's position and describe it as a quarter of an hour plus 1/20 of an hour.[213] All of these positions may reflect the use of sandglasses in the home; the difference between Moelin and Weil may even reflect the use of third-hour sandglasses, quarter-hour sandglasses, or clocks that chimed the quarter hour.

Isserlein's position was sufficiently well known that the editors of the 1519 Venice printed edition of his book inserted it in an unrelated context.[214] Despite this brief flurry of interest, however, none of these interpretations gained traction or replaced the phrase *shiʿur mil* itself, and Isserles ultimately did not codify any of the interpretations.[215] Such small units remained difficult to measure. It would not be until clocks improved that rabbis took up this topic again.

[213] *Shut Mahari Vayl* §193 and *Leqet Yosher* O.Ḥ., page 79, §3. With regard to the time it takes flour and water to leaven, Yosef specifies that the rule only applies to normal temperatures—an important caveat for those baking in the early spring in central Europe. See, as well, *Hagahot Asheri*, Pesaḥim, chapter 3.
[214] *Terumat ha-Deshen* (Venice, 1519), §123.
[215] Isserles is definitely aware of Isserlein's comments on salting; see *Shulḥan ʿArukh,* Y.Ḍ., 69:6. See, however, *Shakh*, Y.D. 69:25. A similar formulation can be found in *Baḥ*, Y.D. 69.

VI. Italy

Jews in Italy responded to the mechanical clock at almost exactly the same time as their Austrian counterparts; it is here that "Italian" hours first appear in Jewish texts. A strong early attestation to this practice appears in a letter by a Jewish tutor in Siena describing the daily learning regimen. I have italicized the relevant terms below:

> In the evening we study until *the fourth hour*. Then we go in to supper...While we are at table, three times a week one of the pupils speaks on a topic of Talmudic law, while his fellow students fire questions at him...This goes on for an hour and a half, sometimes two hours. After that, we go to bed and sleep until *the tenth hour*. We get up and, since it is not yet daylight, we devote ourselves for three hours to the study of the text of the Talmud. When it gets light, we go to the synagogue for morning prayers, after which we study another Talmudic text. Then we go and have breakfast. Then we proceed to the study of the glosses on the Talmud, until we have perfectly absorbed the text. At the *nineteenth hour*, we eat lunch, and after that we do not study again until evening. This is because I have left the afternoon open for the teaching of grammar (i.e., Latin), which is taught by a Christian instructor.[216]

As in Ashkenaz, pedagogic schedules frequently made use of strict timekeeping to demarcate responsibilities.[217] In a letter requesting back pay, the instructor Rabbi David ibn Yaḥya, who lived in Naples, wrote, "I was required not only to teach in the morning, but [to teach] in the morning, afternoon, and also in the evening until 6 hours."[218] The system of "Italian" hours appears in other narratives, as well. Elijah Capsali (d. 1555)

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[216] Translated in Robert Bonfil, *Jewish Life in Renaissance Italy* (University of California Press, 1994), 149. Original in Assaf, *Meqorot Le-Toldot Ha-Ḥinukh Be-Yisrael*, 4:20.
[217] I have not encountered references to sandglasses in Italian Jewish sources. For a possible depiction, see the sixteenth century manuscript, Vat.ebr. 395, 8v; the caption above reads *shaʿot.* The page also contains pictures of two people holding scientific instruments(?) towards the sun and a wheel with a dial marked *galgal ha-shaʿot* ("wheel of hours"). The wheel contains eight segments, each marked "thousands."
[218] Assaf, *Meqorot Le-Toldot Ha-Ḥinukh Be-Yisrael*, II, 114.

refers to a person dying on Shabbat "at three hours of the night."[219]

Legal and mystical texts

Generally speaking, Italian Jewish texts interest in mechanical clocks is not attested in discussions of legal matters. This may reflect the fact that "Italian" hours could not easily be mapped onto rabbinic hours. In addition, an analysis of the evidence below shows that "Italian" hours are *least* likely to be mentioned in connection with morning hours.[220] It was the use of clock hours in the morning that proved so controversial in Ashkenaz, where rabbis debated whether they could be used on Passover Eve as signals that the time to eat *ḥametz* had ended, as discussed above.

That Italian Jewish authorities did not use clock hours to describe legal rules is highlighted by an exception to the rule: Rabbi Jacob Judah Landau (d. 1493) stated that, on a Shabbat immediately preceding the Tisha B'Av fast, one must cease eating from "18 hours," instead of saying—as it appears in the source he is citing—"noon."[221] Though his legal compilation, *Sefer ha-Agur*, was written and published in Italy, Landau's early life and education took place in Germany; his father was a pupil of both Jacob Moelin and Jacob Weil. This influence may explain why Landau is the sole Italian scholar to use clock hours in a legal context.

A second exception also has a German connection. In an opinion cited by Yosef ben

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[219] Assaf, II, 108. A curious exception appears in a volume of correspondence by a certain Jacob ben Joseph. Writing in Venice in the second half the sixteenth century, he described himself as sleeping "until at least two hours of the day [*ʿal ha-yom*]," but this may not be a reference to clock hours; see JTS Ms. 3792. It is also possible that the "Nuremberg" system is being used here. For another use of this phrase, see above, note 140.

[220] In the material I analyzed, I found one reference each to hours 10, 14, 15, 17, 18, 21, and 23; two for 9, 16, 19, and 22; three for 3 and 4, and four for 6. The references to the sixth hour may be stand-ins for "midnight."

[221] *Sefer ha-Agur* §837. On the use of XVIII to indicate noon, see Stowasser, *The Day Begins At Sunset: Perceptions of Time in the Islamic World*, 164.

Moshe (*Leqet Yosher*), a Rabbi Phoebus Fortuna (ויפש פרטנא)—the in-law of Israel Isserlein—is described as having noted that, for the purpose of ritual bathing, Venetian Jewish women would use a body of water that did not become deep enough for immersion until "around midnight," presumably because of the tides.[222] Fortuna asks, "In light of this, are they therefore allowed to begin preparing themselves [for immersion] close to the time of their immersion, at 3 or 4 hours of the night?"[223] The premise of the question is that "3 or 4 hours of the night" is very close to midnight, which would leave women little time for their preparations.[224]

A final attestation to the use of "Italian" hours appears in a unique Italian seventeenth century manuscript that lists mystical words for each hour of the day, from 1 to 24.[225] The ascription of mystical significance to clock hours is a late but intriguing testimony to their penetration of Jewish life. It suggests a shift in thinking similar to the one that led Late Antique rabbis to consider Roman seasonal hours to be immutable and essential.[226]

Time registration

The largest number of Italian Jewish documents that bear evidence of the clock hour occur in the form of time registrations. While some appear in a handful of pub-

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[222] The assumption that tidal forces are at play in this responsum is shared by Elliott Horowitz, "Women, Water, and Wine: The Paradoxical Piety of Early Modern Jewry," in *The Cambridge History of Judaism: Volume 7, The Early Modern World, 1500–1815*, ed. Jonathan Karp and Adam Sutcliffe (Cambridge University Press, 2018), 687.

[223] *Leqet Yosher* II Y.D., 23a.

[224] As we saw above, Moshe Isserles expected preparations to take at least an hour. Seasonal fluctuations in the length of the night in Venice would have meant that "3 or 4 hours of the night" was not *always* close to midnight—but neither would high tide have always corresponded with midnight. One way or another, this question was not meant to address a problem that existed during every night of the year.

[225] JTS Ms. 1584 / ENA 838, 162a–169a. Cf. a fifteenth century manuscript (Paris heb. 765, 10a–12a) which lists the evil spirits that are present in each of the twelve hours of the night.

[226] See above, page 47.

lished works, they are most prominent in the colophons of Italian Hebrew manuscripts. The relationship between the use of "Italian" hours and the countries in which they were used—Italy and occasionally Poland—is so consistent that it can and should be used as a tool by historians attempting to identify the provenance of a given text.[227]

The first colophon with a time registration that I have been able to locate appears in a copy of Midrash Rabbah, whose copyist, Menaḥem ben Shmuel, indicates that he completed the work "on Sunday,[228] at 23 hours, 5 Elul, [5]178 (= August 7, 1418 CE)."[229] The copyist's script identifies the manuscript as being of Italian provenance, and this is confirmed by the phrase "23 hours," an unmistakable usage of the "Italian" system to refer to the penultimate equinoctial hour before sunset.

Many similar colophons exist across a wide variety of texts. Part of a compilation from Ferrara was completed "at 4 hours of the night, on Rosh Ḥodesh Marḥeshvan 5235, which is October 12 [1474]."[230] A copy of Judah Messer Leon's *Livnat ha-Sapir* was completed in the same city "on Friday at 19 hours, which is 11 Tammuz [5]235 (=1475), 16 June."[231] A colophon in a collection of medical texts states, "I finished it here in Florence on Tuesday night, 3 hours of the night, 4 Av, 5247 (=July 24, 1487)."[232] A compilation of laws pertaining to women was finished "on Tuesday, 21 hours, 27 Tammuz, 5356 (=July 23, 1596), here in Venice."[233] The scribe of a manuscript of Abraham Abulafia's *Or ha-Sekhel* concludes, "In the morning watch, after midnight, 9 hours, Tuesday, 25 Tishre

[227] All manuscripts cited below are hand-copied.
[228] For convenience, I have translated the Hebrew "Day One, Day Two, etc." as "Sunday, Monday." Transliterated day names do not appear in the material, while transliterated Christian month names do.
[229] Muenchen, Cod. hebr. 97, 365a. Note that Hebrew manuscripts frequently omit the thousands digit when indicating the year.
[230] Ambrosiana F 25 Sup., 211a.
[231] Schocken Ms. 14052, 166a.
[232] Firenze Panciat 86, 91b.
[233] Muenchen Cod. hebr. 475, 15a.

[5]422 (=October 18, 1661)."[234] In all these instances, the use of "Italian" hours aligns with other evidence of the manuscript's Italian provenance.

In addition to copyists' statements, colophons sometimes contain information about significant events in the life of the manuscript's owner, and some of these statements register the specific hour. The owner of a prayer book writes that his son Yitzḥaq was born "on Thursday night, at 6 hours, 15 Adar [Bet], [5]285 (=March 10, 1525), here in Padua."[235] The owner of another prayer book records the birth of a son "on Friday, Shabbat night, at 6 hours of the night, May 8, [5]316 (=1556), the 44th day of the ʿ*omer*."[236] A fourteenth-century Hebrew Bible records, "On Thursday, 12 Kislev 5298 (=November 15, 1537), there was born to me, Shabbetai ben Menaḥem *z"l*,[237] a son at 22 hours."[238] A book on the laws of ritual slaughter contains the inscription, "A blessed child was born to me today, Monday, 15 hours, 7 Tevet [5]322, 15 December [1561]."[239] A Pentateuch owned by Daniel Fassilio contains an Italian note with the birth dates and hours for sons born in 1552 and 1562.[240] A Hebrew Bible records the birth of a certain Shlomo Yehudah Nursia's firstborn son "on Monday night, at 6 hours, 18 Tishre [5]355

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[234] NLI Ms. Heb. 8°3009, 72a. On the use of the phrase "morning watch," see page 22.
[235] Kaufmann A 370, fol. 761.
[236] Casanatense 2721, end. The Bible describes an ʿ*omer* ("sheaf") offering, which was to be brought on the second day of Passover. The Bible further states that, from the day on which the ʿ*omer* is offered, one should count out seven weeks (=49 days); the holiday of Shavuot (literally "weeks") is celebrated at the end of that period (see Leviticus 23:9–21). In rabbinic law, the requirement to count outlived the ʿ*omer* offering itself and became ritualized as *sefirat ha-ʿomer*, "the counting of the ʿ*omer*." Thus, on the second day of Passover one recites, "Today is the first day of the ʿ*omer*," on the following day, "today is the second day of the ʿ*omer*," until the 49th day, with the 50th day being the Shavuot holiday. The 44th day of the ʿ*omer* always corresponds to 29 Iyar on the Hebrew calendar, but this writer—who was evidently aware of the Julian date and probably operating in the Julian framework on a day-to-day basis—may not have known the Hebrew date off the top of his head, whereas he *would* have been aware of the "day of the ʿ*omer*," because of his daily obligation to recite it.

The owner of the book is Yitzḥaq ben Menaḥem of Modigliana; it is unclear where he was living at the time of the birth.
[237] *Zekher livrakhah*, "may the memory be for a blessing," indicating that the owner's father was deceased.
[238] Firenze Magl. III. 44, 119v. The catalogue record incorrectly understands the year to be 5303.
[239] BL Or. 9152, 480a.
[240] Parma 2026 / De Rossi 1114, 270v.; see Benjamin Richler and Malachi Beit-Arié, eds., *Hebrew Manuscripts in the Biblioteca Palatina in Parma* (Jerusalem, 2001), 39–40.

(=1594), October 2."[241] A compilation of writings by Yedidiah ben Moshe Recanati begins with a note regarding that scholar's work as tutor for the future Talmudist Moshe ben Yitzḥaq Leoni, who was then thirteen years old; the latter's birthdate is recorded as "Shabbat, 14 and a half(!) hours, 18 Kislev, conclusion of November, [5]327 (=November 30, 1566)."[242] The owner of a collection of kabbalistic works recorded the birth of a son "in the year [5]387 (=1627), Monday, between 16 and 17 hours, 11 August, 6 Elul."[243]

In addition to births, the hour of death and the hour of a miraculous occurrence were occasionally recorded. The owner of a Hebrew Bible noted the death of Yaʿakov of Terracina "in the city of Sienna, [5]272 (=1512), 27 Tammuz, 11 July, at 16 hours."[244] In a work on the customs of Roman Jews, the manuscript's owner, Avraham ben David Provenzale, mentioned a miracle which occurred in Modena to Neḥemiah ben Moshe, who escaped a murder attempt "on Friday, 5 Av, [5]328 (=July 30, 1568), at around 22 hours."[245]

That hours are most commonly listed with regard to births likely reflects an interest in the hour's astrological significance. That clock hours could be useful for these determinations is attested in one fifteenth-century manuscript, which contains the personalized horoscope for David Kalonymous, born "28 March, 19 hours, 2 minutes, in the afternoon, in the year [1]458."[246] This same collection gives instructions on how to

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241 Private collection, NLI shelf number F 76338, fol. 237a. The identification of 18 Tishre with October 2 reflects the use of the Gregorian calendar, which had been introduced only twelve years earlier.
242 NLI Ms. Heb. 28°4001, 2b. On this colophon see David Kaufmann, "Jedidiah of Remini; or, Amadeo Di Moïse Di Recanati," *Jewish Quarterly Review* XI (1899): n. 6.
243 RSL Ms. Guenzburg 83, beginning.
244 Parma 2822, end. Cf. the interest in noting the hour of death on Roman graves, discussed in chapter 2.
245 Copenhagen Cod. Sim. Hebr. 70, 206a.
246 Parma 2637, 73a–79b. Note that "in the afternoon" means the 19th hour fell in the afternoon, not that the birth occurred nineteen hours after noon. Another example of such a horoscope can be found in RNL Evr. II A 2403.

build a sundial and another kind of timekeeping device.[247]

In addition to these inscriptions, two Italian rabbis register the time in their published writings. In three of his responsa, the northern Italian scholar Rabbi Joseph ben Solomon Colon (d. 1480) began answering a question by registering the time at which he received it; in each instance the registration of its arrival includes an hour.[248] Elijah Capsali of Candia (d. 1555) emphasized the importance of tracking time in an educational setting; in at least one case, he described an event as having occurred on Friday night "in the ninth hour."[249]

The well-attested incorporation of "Italian" hours into Italian manuscripts was sufficiently prevalent that Rabbi Azariah de Fano (d. 1620) found it remarkable when Jews of a certain place did *not* indicate the hour at which a contract was signed.[250] At the same time, usage is highly inconsistent. Of the manuscripts cited above, many contain additional colophons which identify themselves as having been written in Italy and yet make no mention of the hour. Many other Italian Hebrew manuscripts from this period make no mention of the hour whatsoever. The advent of the clock, it seems, gave Italian Jews access to the time, but its use—at least for event-marking—was far from compulsory.

Scientific literature

Awareness of equinoctial hours, as we have already seen, was evident among Jews with astronomical knowledge long before it became widespread. Nonetheless, Italian

[247] Parma 2637, 18a and 23b.
[248] *Shut Maharik* §27, §97, and §186. Beyond these registrations, Colon does not show any other interest in clock hours.
[249] Capsali, *Eliyahu Zuta* (1977 ed.) 2:246; Bonfil, *Jewish Life in Renaissance Italy*, 268.
[250] *Shut ha-Ramaʿ mi-Fano*, §54.

astronomical treatises written in Hebrew in the age of the clock began to include additional features that pertained directly to the new timekeeping conventions.

A figure worthy of study is Mordekhai Finzi (d. 1476), who was in direct contact with clockmakers. In a treatise on constructing an astrolabe, Finzi stated that he would explain "what I learned from the *mastro Bartolomeo degli orlogi*, who lives in the city of Mantua." This is likely Bartolomeo Manfredi, who built Mantua's clock tower in 1473.[251]

Finzi's most popular work was a list of tables for half-daylight (*luaḥ shaʿot ḥatzi ha-yom*, i.e. the length of the interval from morning until noon) for the latitude of 44°N; this work exists in at least eighteen manuscript copies. Both an autograph manuscript and several other copies include instructions on how to translate the time of the *molad*—an astronomical calculation expressed as some number of hours after noon—into "Italian" hours. Finzi calls the latter, "the hours of the *orlogi*, which are well-known to the general public [*he-hamon*]."[252]

Similar acts of cultural translation can be found in a Latin treatise describing a unique astrolabe ring created by Jacob ben Emanuel Provenzale, also known as Bonetus de Latis.[253] The treatise, dedicated to Pope Alexander VI, was completed in 1492/3, after de Latis had left France for Pisa. In addition to the usual chapters—on calculating the altitude of the sun, the hours since sunrise at different locations and different times, and so on—de Latis includes separate chapters on determining the time "according to the French method" and "according to the Italian method." These subjects do not ap-

[251] Roma Corsiniana Or. 259, p. 318. This work is described in Giancarlo Lacerenza, "A Rediscovered Autograph Manuscript by Mordekay Finzi," *Aleph* 3 (2003): 301–325. See also Y. Tzvi Langermann, "The Scientific Writings of Mordekhai Finzi," *Italia* 7, no. 1–2 (1988): 31.
[252] Bodleian Library MS Opp. Add. Qu. 37, 64v–66r. See Langermann, "The Scientific Writings of Mordekhai Finzi," 14.
[253] The full text and a translation of de Latis' treatise can be found in Josefina Rodríguez-Arribas, "The Astrolabe Finger Ring of Bonetus de Latis: Study, Latin Text, and English Translation with Commentary," *Medieval Encounters* 23, no. 1–5 (2017): 45–105.

pear in the only other Latin treatise on astrolabes, written by Ibn Ezra.[254]

As much Jewish astronomical literature remains in manuscript, these results are necessarily preliminary. Nonetheless, these texts are important because they offer us a sense of what it meant for astronomers—who already knew about equinoctial hours, seasonal hours, and minutes—to accommodate the newly-prominent mechanical clock. As more texts are published, examination of when and how clocks and hour-naming conventions appear will yield further information.[255]

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[254] Arribas, "Medieval Jews and Medieval Astrolabes: Where, Why, How, and What For?," 239.

[255] A final, minor literary genre in which mechanical clocks make an appearance is philosophy. As discussed in chapter 3, the idea of a complex and presumably self-powered device whose inner workings are not immediately clear had long captured the fancy of philosophers, who viewed these automata as useful metaphors for creation. Among such devices, the clock was of particular interest; in fact, many of the most impressive movements were not intended to tell time at all, but simply to show the revolutions of the celestial spheres. (See Doggett, *Time: The Greatest Innovator: Timekeeping and Time Consciousness in Early Modern Europe*, 17.) The comparison between the universe and a clock (or Christ as a clock, according to Heinrich Suso) already appeared in the first half of the fourteenth century, when clocks were rare and the technology in its infancy. (See Scattergood, "Writing the Clock: The Reconstruction of Time in the Late Middle Ages," 463.) It is not surprising that these ideas found their way into the works of Jewish thinkers, as well.

The most significant treatment of this type is by Abraham Yagel (d. 1623), a writer deeply influenced by the Italian Renaissance; his comments on the subject appear around the time that Descartes referred to humans as a kind of machine and somewhat before John Locke and Gottfried Wilhelm Leibniz brought the clock metaphor to prominence. (Jessica Riskin, *The Restless Clock: A History of the Centuries-Long Argument over What Makes Living Things Tick* (University of Chicago Press, 2016), 53. On Yagel's life, see David B. Ruderman, *Kabbalah, Magic, and Science : The Cultural Universe of a Sixteenth-Century Jewish Physician* (Cambridge, Massachusetts: Harvard University Press, 1988), chap. 1.) In his idiosyncratic *Bet Yaʿar ha-Levanon* ("Lebanon Forest House"), Yagel devotes a full chapter to an extended parable about a shepherd (our forefathers) who sees a city and sees a clock (God or God's creation). (Unfortunately, the conclusion of the chapter is not extant; this chapter is discussed in detail in Ruderman, 104.) Impressed by the device but not knowing how it could run "without the spirit of life in it," the shepherd attempted to recreate it in crude form. The king discovers this and praises the shepherd for using his intelligence to understand how the clock works. Yagel's point seems to be that Jews have a special talent for discerning God and therefore have no need for philosophy.

VII. Ottoman Empire

Despite the clock's proliferation among their contemporaries living under Christian rule, Jews in the Ottoman Empire did not begin acknowledging these devices until usage increased in their own territory, sometime in the middle of the sixteenth century. The earliest pieces of evidence I have found—in responsa by Rabbi Elijah Mizraḥi (d. 1525/6) and Rabbi Moses Alashkar (d. 1542), the latter dated to 1531—occur in stories retold as part of legal questions.[256] A third relevant responsum appears in an astronomical formulation by Rabbi Moshe ben Yosef Trani (d. 1580), who lived in Safed, Palestine.[257] All three responsa indicate use of the "Italian" hour system; *alaturka* hours—which are a modification of the "Italian" system—were apparently not yet in use.[258]

In all three sources, the system is identifiably Italian because daylight hours are described and the numbers used are between 13 and 24. With the introduction of *alaturka* hours, one might expect to see these daylight clock references be replaced by their twelve-hour-cycle equivalents: for example, the penultimate hour before sunset would by "11 hours" rather than "23 hours." In Jewish Ottoman texts, however, references to daylight hours simply disappear. In our sources, then, the *alaturka* system appears identical to the "Italian" system, but only at night.

Direct discussion of clocks and sandglasses

When Jews in the Ottoman Empire began discussing the new, imported clocks, they did so using imported language. In ruling on the permissibility of clocks on Shabbat,

[256] Respectively, *Shut Mayyimʿ Amuqim* 1:31 (see also 1:287) and *Shut Maharam Alashkar* §114.
[257] *Shut Mabit* 1:50. See also 1:287, a reference to entering a house "at around 4 hours of the night."
[258] In the Italian system, there is one 24-hour cycle, beginning at sunset. In the Ottoman system, that cycle is divided in two.

Rabbi Yosef Caro simply cites the position of Judah Leib Landau, discussed above,[259] and in ruling on sandglasses he cites Rabbi Jacob Moelin.[260] Though Caro's treatment of clocks does not betray any personal acquaintance with the devices, his term for the sandglass (*moreh ʿal ha-shaʿot*, "indicator of the hours"), his use of a colloquial term ("it is called *riluzo*," cognate of *horologium*), and his unwillingness to follow Moelin in prohibiting its use on Shabbat all suggest that Caro was personally familiar with these timepieces. A lenient position regarding use of the sandglass on Shabbat is also recorded in the name of Rabbi Jacob Mitril, who was active in Jerusalem around 1500.[261]

Other than Caro and Mitril, Ottoman rabbis do not appear to have discussed either timepiece much, perhaps because these remained relatively uncommon until a much later date.

Legal discussions

As was seen among their Polish counterparts, Ottoman rabbis sometimes specify that they are referring to seasonal hours; unlike Polish rabbis, they do not discuss legal problems related to the use of equinoctial instead of seasonal hours. Rabbi Levi ibn Ḥabib (d. 1545), a Spanish exile in Salonika, notes that seasonal hours are indicated in the Talmudic rule about a person erring up to two hours when reckoning the time; he does not seem to consider the alternative.[262] In another responsum, Ibn Ḥabib describes a method for calculating the *tequfah* that assumes the use of seasonal hours.[263] Similarly,

[259] *Beit Yosef* O.Ḥ. 338; *Shulḥan ʿArukh* O.Ḥ. 338:3.
[260] *Beit Yosef* O.Ḥ. 308; *Shulḥan ʿArukh* O.Ḥ. 308:51.
[261] *Sefer Ḥidushei Dinim Le-Rabanei Yerushalayim Ha-Qadmonim*, para. 31.On the identity of this figure, see Aryeh Leib Frumkin, *Sefer Even Shmu'el: Kolel Toldot Ḥakhmei Yerushalayim* (Vilna, 1874), 53.
[262] *Shut Maharalbaḥ* §136.
[263] *Shut Maharalbaḥ* §147.

Rabbi Isaiah Horowitz (d. 1630) affirms that the time for saying the morning *shemaʿ* prayer ends "after the first quarter of the day, whether the day is long or short, ten or nine hours or even less."[264]

A number of responsa ask questions about whether a short time interval has legal significance. Elijah Mizraḥi (d. 1526), the chief rabbi of the Ottoman Empire, describes a situation in which a marriage was contracted and then cancelled after "two or three hours."[265] In Safed, Rabbi Yom Tov ben Moses Tzahalon (d. 1638) was asked about a couple who wed, consummated the marriage, fought, separated "for three or four hours," then reconciled.[266] A number of stories concern babies who survived only a specific number hours after birth; such cases are described by Rabbi Yosef ben David ibn Lev (d. 1580),[267] Rabbi Shmuel ben Moses Kalei (d. ca. 1585)[268], and Rabbi Shlomo ben Avraham ha-Kohen (d. ca. 1601).[269] A variety of other intervals, from one hour to ten hours, are also mentioned.[270]

The reception of clocks by Ottoman Jews was most comprehensibly represented in the work of Yosef Caro, who preserved an understanding of seasonal hours and of timepieces, but was not immersed in clock culture to the same degree as his counterparts in Ashkenaz. Importantly, Caro was aware of the debate about when to stop eating *ḥametz* on Passover Eve, but he misread Isserlein as advocating for seasonal hours because Caro did not recognize that the locution "two hours before noon" referenced "French" clock hours. Missing this crucial element, Caro collapses the debate: "the sag-

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[264] *Shelah*, Tamid, Perek Ner Mitzvah. See also *Shut Radbaz*, IV:56.
[265] *Shut ha-Re'em* §69.
[266] *Shut Maharitatz (Yeshenot)* §67.
[267] *Shut Mahari Ben Lev*, IV:19.
[268] *Shut Mishpetei Shmuel*, §34.
[269] *Shut Maharshakh*, III:19.
[270] *Shut Mahari Ben Levi*, 1:57 and III:36; *Shut Maharashdam*, E.H. §196 and Ḥ.M. §430; *Shut Ranaḥ* §91.

es forbid it [to be eaten] from two hours beforehand, which is the beginning of the fifth hour."[271] Like Maimonides, he asserts that "the hours in the Mishnah are seasonal," but he does not deliberate on the implications of this assertion, as did his European counterparts.[272] Finally, Caro adds nothing regarding the meaning of *shiʿur mil* and in fact is inconsistent in his usage; in one place he defines it as "around a third of an hour," and elsewhere as "a quarter of an hour and a twentieth of an hour."[273]

To sum up: the Ottoman Jewish reception of the mechanical clock was both later and considerably less impactful on Ottoman Jews than the reception of the clock in Europe had been for European Jews. Notwithstanding awareness of timepieces and lip service to the concept of seasonal hours, the mechanical clock's arrival did not bring about any legal discussion of note. By the same token, Ottoman Jews did not put time registrations in their books with the same frequency as Italian Jews. This weak reception is most likely due to the lack of tower clocks in Ottoman cities, which elsewhere served both to popularize the clock hour and to set expectations for what the public would understand. This state of affairs did not change until the eighteenth century.

[271] *Beit Yosef*, O.Ḥ. 431; *Shulḥan ʿArukh* O.Ḥ., 443:1. Caro's misreading was recognized by Joel Sirkes; see *Baḥ* O.Ḥ., 431, cf. *Taz* O.Ḥ., §443.
[272] *Beit Yosef*, O.Ḥ. 58; *Shulḥan ʿArukh* O.H, 58:3, 58:6, 89:1.
[273] *Shulḥan ʿArukh* Y.D. 69:6 and O.Ḥ. 459:2.

VIII. "Jewish hours"

For Europeans Christian, the transition from seasonal hours to clock hours was uncomplicated, as the former had never been widely used outside of the church. European rabbis did not let go of seasonal hours so easily. In Italy, clock hours were not seen as having significance in matters of Jewish law. In Ashkenaz, grappling with clock hours actually led to a clarification and reaffirmation of the seasonal hour, and the concept retained its legal significance within rabbinic law. Ironically, the Jewish embrace of seasonal hours at precisely the moment that they were falling out of use elsewhere led to seasonal hours—which Jews had borrowed from Hellenistic culture, which had been widely used across cultures and religions for millennia, which the English had once called "common hours"—becoming specifically associated with Jews.[274]

The term "Jewish hours" was employed interchangeably with "planetary hours" and "old unequal hours" to describe a certain way of inscribing hour markings on a sundial. In this usage, "Jewish hours" were distinct from "Babylonian" hours (twenty-four equinoctial hours, beginning at sunrise) and "Italian" hours (twenty-four equinoctial hours, beginning at sunset).[275] "They are called *ancient* or *Jewish* hours," wrote one nineteenth century English scholar, "because [they were] used by the ancients, and still

[274] It is further possible that Jews maintained an interest in the seasonal hour *because* it was becoming a distinctively Jewish symbol; however, there does not appear to be evidence that Jews themselves saw the seasonal hour as being distinctively Jewish. On the phrase "common hours," see Mooney, "The Cock and the Clock: Telling Time in Chaucer's Day," 98.

[275] For examples of its usage, see William Leybourn, *A Supplement to Geometric Dialling* (London: Thomas Sawbridge, 1689), 13. See, as well, "Dialling," in *Encyclopaedia Britannica, Volume Seven*, 1854, 796. This is an important example of what I call "meaning via attrition," whereby an object or an idea gains significance within a particular culture not through any deliberate choice by that culture but simply because all neighboring cultures have relegated that object or idea to obsolescence. Examples within Jewish culture are the Purim *grogger*, the Ḥanukkah dreidel, particular modes of Ḥasidic dress, and the Torah scroll.

among the Jews."[276] The term was probably widespread; it appears in both French (*heures judaïques*) and German (*Jüdischen Stunden*) before the end of the seventeenth century, both times in similar explanatory texts, suggesting that the term had already long been in use.[277] The earliest instance I have encountered is in a 1560 Latin treatise on astronomy by the German polymath Jean Taisnier. In Taisnier's treatise, *horae iudaicae* are contrasted with "Italian" hours and "French" hours, rather than Babylonian hours; unlike later treatises which use the phrase, Taisnier was not primarily interested in making sundials.[278] It is unlikely that he coined the term, and thus quite probable that the concept of Jewish hours already existed in the first half of the sixteenth century. Still, it is likely the latest of the three terms, "Babylonian hours" already being in evidence from the fourteenth century.[279]

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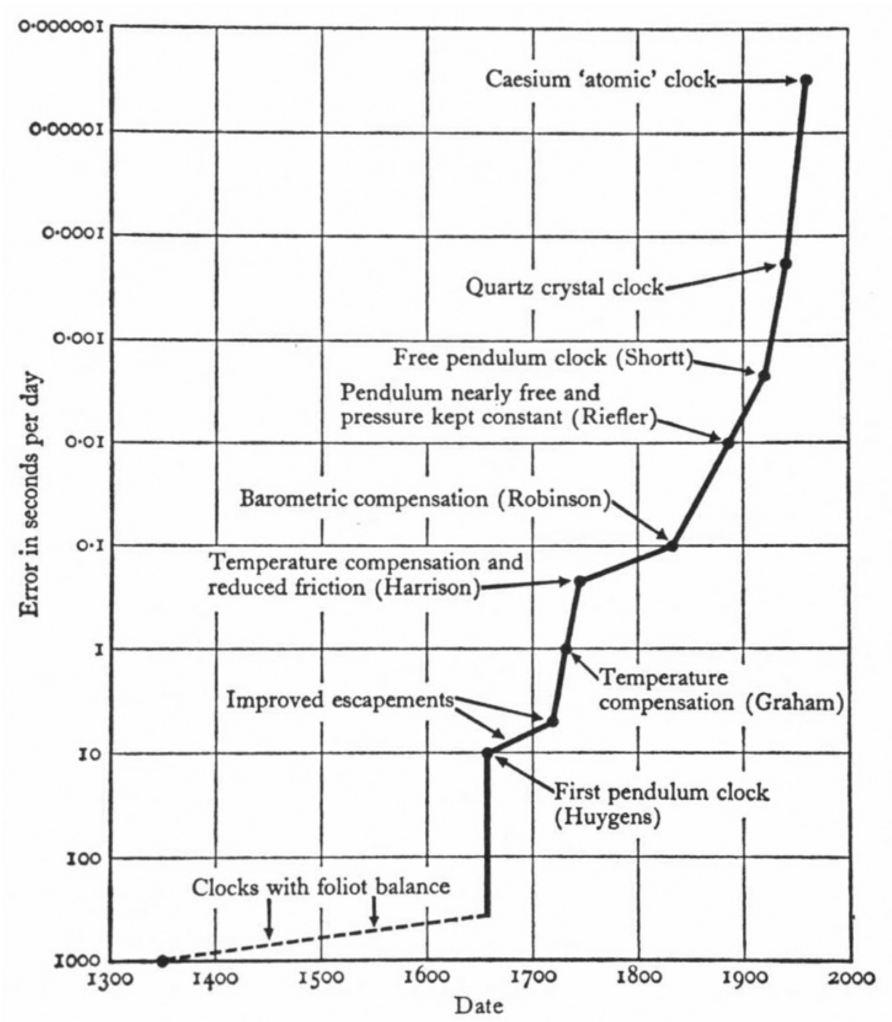
[276] Abraham Rees, "Hour," in *The Cyclopedia or Universal Dictionary of Arts, Sciences, and Literature, Volume 18*, 1819.
[277] Jacques Ozanam, *Cours de Mathématique* (Paris: Jean Jombert, 1693). The edition I consulted was printed in Amsterdam in 1697; see pages 6, 15, and 116. For German, see Hans Jacob Faesi, *Deliciae Astronomicae* (Zürich: Heinrich Bodmer, 1697), chap. 7.
[278] Jean Taisnier, *De Annuli Sphaerici Fabrica & Usu Libri* (Antwerp: Jean Richard, 1560), fols. 23–24. My thanks to Daniel Picus for his assistance with this source. Taisnier wrote works on both scientific subjects and chiromancy, though he was accused of having plagiarized some of these; see John Flood, *Poets Laureate in the Holy Roman Empire: A Bio-Bibliographical Handbook* (De Gruyter, 2011), 2050.
[279] Josefina Rodríguez-Arribas, "A Treatise on the Construction of Astrolabes by Jacob Ben Abi Abraham Isaac Al-Corsuno (Barcelona, 1378): Edition, Translation and Commentary," *Journal for the History of Astronomy* 49, no. 1 (2018): 49–52.

Chapter 6: Timekeeping from 1657 to the Early Twentieth Century



From Cipolla, Clocks and Culture, *59.*

Over its many centuries of development, the mechanical clock has had few major milestones but many minor ones.[1] By the beginning of the twentieth century, mechanical clocks had become so accurate that they could detect minor fluctuations in the

[1] A modern analog to the clock's development might be Moore's law, which is the observation that the number of transistors that can fit in a given area doubles every two years. Moore's law, originally proposed in 1965, has accurately tracked the progress of more than fifty years of research and development and an untold number of incremental breakthroughs (development phases are in fact calls "ticks" and "tocks"). As of 2019, transistor density is on the order of ten million times what it was when the law was first formulated. By pure coincidence, Shortt clocks—the most accurate mechanical clocks ever built—are on the order of ten million times more accurate than their thirteenth-century ancestors, but achieving this level of accuracy took more than six centuries, rather than five decades. See Pierre H. Boucheron, "Effects of the Gravitational Attractions of the Sun and Moon on the Period of a Pendulum," *Antiquarian Horology and the Proceedings of the Antiquarian Horological Society* 16, no. 1 (1986): 53–65.

Earth's rotation, for the first time exceeding the regularity of the celestial movements that they had originally been designed to mirror. Work on improving mechanical movements continues to this day, although they are no longer at the forefront of accuracy, having been supplanted first by quartz movements and then by cesium atomic clocks.

The existence of this long, unbroken history means that any ending to this study other than the present day cannot help but be artificial; nonetheless, extending this study into the world of atomic clocks would require a great deal more space than this study allows, as the amount of source material increases exponentially as the reliability of timepieces climbs and the cost of ownership plummets. Rather than end abruptly in the middle of the seventeenth century, I devote this final chapter to key aspects of the Jewish reception of timekeeping in the years between 1657 and the early twentieth century. Whereas in previous chapters I attempted to paint a complete picture, this chapter is not intended to be exhaustive; rather, it presents a combination of original research and suggestions for promising future avenues of study.

In the two-and-a-half centuries covered in this chapter, I identify two basic trends. One—the impact of improvements in accuracy and availability on Jewish legal sources—is simply an extension of what was discussed in each of the previous chapters: improved accuracy changes rabbinic expectations of accuracy both for Jews of their own time as well as their predecessors. At the same time, increased toleration of Jews across Europe and the emergence of Jewish clockmakers and watchmakers removed from these devices certain associations with Christianity and Christian worship; this resulted in new Jewish uses of timepieces in public, in private, and in literature.

I. Improvements in accuracy and increased availability after 1657

If the history of mechanical clocks were a story in two acts, it would look like this: in the first three centuries of its existence, clocks and watches became far more accessible, but they did not become much more accurate; in the next four centuries, the focus turned to accuracy and precision in increasingly adverse environments.

Beyond the immediate improvements it provided, the escapement mechanism also established a clear path by which timekeeping devices could be made more accurate. Since time units were now accumulations of small, regular ticks, increased accuracy meant making those ticks as uniform as possible. This was accomplished in three ways. First, clockmakers developed increasingly sophisticated escapement mechanisms in order to purge any lingering power fluctuations from the power source; this was especially important when the power source was almost exhausted, and crucial for watches, whose gears were constantly being jostled. Second, clockmaking itself improved as the craft matured into a profession and artisans began to specialize in different parts of the clock. As a result this professionalization and specialization, parts were more accurately produced and fitted, leading to ever-increasing improvements in precision.[2] Finally, the ticks themselves were made as small as possible, thereby mitigating the effects of any variations. This final factor explains why mechanical movements (usually fewer than ten oscillations per second) remain less accurate than quartz movements (32,768 per second), which are in turn less accurate than atomic clock (9,192,631,770 per second).[3]

For our purposes, understanding these improvements is crucial for contextualizing

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[2] Scattergood, "Writing the Clock: The Reconstruction of Time in the Late Middle Ages," 460.

[3] A full account of this entire process is given in Tony Jones, *Splitting the Second: The Story of Atomic Time* (Bristol and Philadelphia: Institute of Physics Publishing, 2000).

the development of Jewish thought on timekeeping. Unlike the era of the sundial and the clepsydra, which could be crude or well-crafted but always stayed within a certain range of accuracy, the mechanical clock (or watch) cannot be considered in abstract; rather, we always need to consider, to the best of our abilities, *which* mechanical time-keeper was being used and how widely it was being employed. In doing this it is possible to understand Jewish reception of the mechanical clock not as a single incident, but rather a series of developments which can be tracked over centuries.

Through the first half of the seventeenth century, almost all mechanical clocks employed the verge-and-foliot mechanism described in the previous chapter. Within this system the foliot (also known as a balance wheel) was always the weakest element, since, in reality, its oscillations were affected not just by its weights, but by almost every other part of the system. Heavy weights would make the foliot run faster, as would erosion of the escapement gear—an inevitability, since the method by which the gear stopped and started involved a series of high-energy collisions between the gear's teeth and the two pallets.[4] Any almost-exhausted power source, on the other hand, could make it slower. While better clock construction mitigated some of these flaws and a few pioneering clockmakers experimented with variations of the basic design, the fundamental design made precision very difficult to achieve.[5] By the early 1650s, it was still common for verge-and-foliot clocks to be off by up to fifteen minutes per day. In order for the clock to improve, a better, more independent replacement for the foliot was required.

The pendulum was just such a device. In the first decades of the seventeenth centu-

[4] H. von Bertele, "Precision Timekeeping in the Pre-Huygens Era," *Horological Journal* 95 (1953): 804.
[5] Bertele, 808.

ry, Galileo Galilei made an important discovery: the time it takes for a pendulum to complete one full swing was highly dependent on the pendulum's length but not at all dependent on its mass and largely independent of the size of its arc. This behavior, called isochronism, made the pendulum an ideal replacement for the foliot. Whereas previously the foliot had been bolted to the verge in order to function—thereby tying its accuracy to the accuracy of the rest of the clock's parts—a pendulum, once given momentum by the verge, could swing both freely and predictably.[6] Seeing the benefit for timekeeping, Galileo developed designs for the first pendulum clock but did not live to finish constructing a prototype. Galileo's designs inspired Christopher Huygens, who built such a clock in 1657. Despite his patent on the machine, the pendulum clock was swiftly copied by others.[7]

The pendulum verge clock was a vast improvement over its predecessor; nonetheless, it still had one important flaw. While a pendulum's period is *mostly* unrelated to how hard the pendulum is being pushed (i.e. amplitude), it is not entirely independent of this, and it is particularly susceptible when it is swinging through large angles; as a result, fluctuations in a clock's power source continued to be a source of inaccuracy. As it turns out, this problem was also solved in 1657, this time by Robert Hooke, through a redesign of both the verge and the escapement. By placing all movement on a single plane, the so-called anchor escapement simplified the manufacturing process; by requiring the pendulum to swing only a few degrees at a time, the design significantly minimized the problem of fluctuations from the power source.

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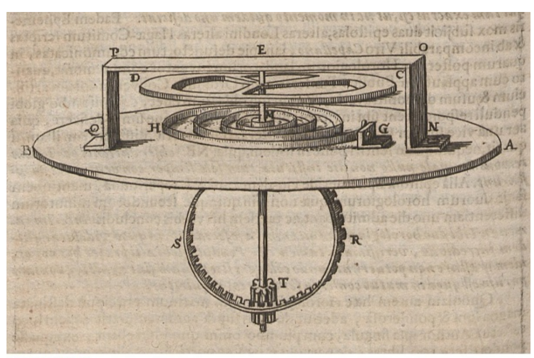
[6] In technical terms, the foliot was a non-harmonic oscillator, while the pendulum was the first harmonic oscillator.

[7] The development of the mechanical clock has been covered in many horological histories, though some of these explanations are quite opaque. For useful descriptions and diagrams of the various movements, see Ruxu Du and Longhan Xie, *The Mechanics of Mechanical Watches and Clocks* (Springer, 2013), 7–16.

With the pendulum and anchor escapement, clocks achieved an unprecedented level of precision. At the same time, mainspring-driven movements, used in portable clocks and watches, made a significant advance, as well. Mainsprings lost power as they unwound; despite the use of the stackfreed and fusee to compensate for this, accuracy always lagged well behind that of weight-driven clocks, with the former losing or gaining as much as half an hour per day.[8] Hooke rectified this situation with the invention of the balance wheel, which served a task very similar to the pendulum in stationary clocks. The balance spring was further developed by Huygens and was quickly adopted in all spring-driven movements.[9] In addition to the advances in accuracy that the balance spring provided, the abandonment of the necessarily-thick fusee allowed watches to become progressively thinner and more compact. This practice culminated in the end of the nineteenth century with significant price decreases for pocket watches, making it possible for many more individuals to carry a time indicator on their person.[10]



An early depiction of a balance spring by Huygens.

In the eighteenth century, precision timekeeping also became an interest of the

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[8] Landes, *Revolution in Time: Clocks and the Making of the Modern World*, 139.
[9] Usher, *A History of Mechanical Inventions: Revised Edition*, 321–22.
[10] Alexis McCrossen, *Marking Modern Times: A History of Clocks, Watches, and Other Timekeepers in American Life* (University of Chicago Press, 2013), 88. Statistics on adoption rates for pocket watches are not available.

state. A perpetual problem with sea travel had been the difficulty in determining one's longitude (that is, one's east-west position). Without this information, ships were at constant risk of going in the wrong direction and hitting land unintentionally; when they did stick to the few known "safe" routes, they could fall victim to the pirates who patrolled those routes. While it was in theory possible to determine longitude through celestial observations, a much simpler method involved noting the difference between the current time and the time at one's port of departure, but preserving the latter while at sea required timepieces which were both extremely precise and durable in rough conditions. Five such devices were designed by John Harrison (d. 1776) in response to a prize established by the British Parliament; the fourth of these, "H4," became the prototype of the chronometer.[11] Though chronometers remained specialty items, some of Harrison's techniques were widely incorporated into more popular timepieces.

With precision also came a renewed interest in the minute hand. While minute hands appear on clocks as early as the sixteenth century (initially on a separate dial), the imprecision of the devices meant that these hands served little purpose; it was only in the early eighteenth century that they became common and meaningful.[12]

The introduction of the minute hand also led to the clock becoming independent of the apparent motion of the sun, which—because the Earth is titled on its axis and its orbit around the Sun is not a perfect circle—fluctuates slightly over the course of the year. Since clocks were initially calibrated by sundials on a daily basis, this was not a

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[11] The search for a reliable way of measuring longitude and John Harrison's contributions is recounted memorably in Dava Sobel's popular work, *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time* (Penguin, 1995). Sobel's focus is not on the innovations themselves; these are covered in Jonathan Hird, Jonathan Betts, and Derek Pratt, "The Diamond Pallets of John Harrison's Fourth Longitude Timekeeper—H4," *Annals of Science* 65, no. 2 (2008): 171–200.
[12] Guye and Michel, *Time & Space: Measuring Instruments from the 15th to the 19th Century*, 80, 85.

problem at first. As such calibrations became unnecessary, however, the discrepancy between clock and apparent solar time—which could be as much as fifteen minutes—became difficult to ignore. Initially, efforts were made to solve this problem by distributing "watch papers," which indicated how to convert between clock and apparent solar time on each day of the year, but this method was cumbersome. Instead of performing this translation, cities began abandoning apparent solar time entirely, and adopted "local mean time," which corrected for these variations but did not correspond to the actual position of the sun in the sky. First adopted in Geneva in 1780, this system grew slowly in popularity until, in the late nineteenth century, the needs of the railroad industry led to the adoption of a *universal* mean time.[13]

New discussions about timepieces

By the seventeenth century, public clocks had become sufficiently common that their absence was more notable than their presence. A responsum by the Polish authority Rabbi Shmuel ha-Levi Segal (d. 1681) addresses a situation in which a small town's *minyan* (quorum for prayer) was imperiled during the time of the year when *seliḥot* (additional penitential prayers recited before and during the High Holy Days season) are said before the morning prayer. "Because there is no weighted device, known as a *zeiger*," people sometimes rose long before dawn, and *seliḥot* were sometimes said so early that the time for the morning prayers had not yet arrived by their conclusion. Rather than waiting for dawn, some community members simply went home, threatening the likelihood of meeting the requirement that at least ten individuals be present during

[13] The introduction of mean time is discussed in Samuel L. Macey, "Partitioning the Day," in *Encyclopedia of Time* (Garland Publishing, 1994).

the recitation of communal prayers.[14] The problem of rising too early is known in responsa literature from at least the fifteenth century; in those documents, however, it is not treated as exceptional.[15]

The propagation of cheap watches also resulted in greater interest in the legal status of the devices themselves, particularly with regard to whether their use violated the laws of Shabbat. Responsa on this question exist from the fifteenth century, but they are quite brief and are concerned with small residential clocks, rather than watches. Towards the end of the seventeenth century the subject again appears in responsa literature, this time concerning the new, personal timepieces carried on one's person or worn on the body.

Some rabbinic positions, reinforcing and acknowledging existing communal practice rather than creating new norms. The Venetian rabbi Shmuel Aboab (d. 1694) writes that carrying a watch on Shabbat is prohibited, for "even though there is a clear prohibition neither from the Talmud nor from previous decisors, the custom to prohibit has already become widespread."[16] This position is criticized by Rabbi Jacob ben Joseph Reischer (d. 1733).[17] Interestingly, the Eastern European authority Rabbi Meir Eisenstadt drew a highly subjective distinction between sundials and sandglasses on the one hand and clocks on the other: the former violate the Shabbat prohibition on "measuring" (*medidah*) because *interpreting their state* involves measurement, whereas a clock

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[14] *Sefer Naḥalat Shivʿah*, §6.
[15] *Minhagei Maharil* 36a, 54a. Cf. Ta-Shma, "The Measurement of Time as Reflected in Medieval Rabbinic Literature [Hebrew]," pt. 251. See, as well *Mordekhai*, Shabbat 2, §297, which describes how people during the time of Sherira Gaon (d. 1006) began Shabbat early on cloudy days in order to prevent accidental transgressions.
[16] *Davar Shmuel* §334.
[17] *Shut Shev Yaʿakov*, III:26.

requires no interpretation and is thus permitted.[18] That Eisenstadt did not see glancing at a clock face as an interpretive act—despite the fact that interpreting a clock face requires more training that interpreting a sandglass—suggests a deep societal familiarity with the technology. Furthermore, both Eistenstadt and Rabbi Jacob Emden (d. 1776) list the specific actions one might perform on a clock or watch: carrying, pulling a chain, winding, etc.[19] The Galician rabbi Joseph ben Meir Teomim (d. 1792) went further, differentiating between clocks that chime and those that are silent and discussing whether it is permissible to ask a Gentile to wind one's clock on Shabbat.[20]

New legal issues

Just as the proliferation of crude clocks had opened up a number of legal questions (mostly regarding the distinction between equinoctial and seasonal hours and the method for calculating the latter), the proliferation of precision timepieces brought to the surface a wide variety of new legal questions, all premised on the advanced and widespread ability to track time. Each of these new discussions deserves extensive analysis; here I wish simply to enumerate the major topics.[21]

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[18] *Shut Panim Me'irot* §122.
[19] *Mor u-Qetzi'ah*, §338, §431, §443.
[20] *Mishbetzot Zahav*,§252 and §338. Additional authorities who weigh in are listed in David Neustadter, "Winding Clocks on Shabbat: An Example of the Parallel Development of Technology and Halakha," *Tradition* 51, no. 1 (2019): 45–47.
[21] In addition to the influence of the clock, some of these trends were furthered by the effort of the eighteenth century "Brody *kloyz*," a tight-knit group of scholars in a Ukrainian town, who, among other things, devoted energy towards more firmly quantifying the various metrics which appear in Jewish law, including those which relate to time. On this topic, see Maoz Kahana, "Changing the World's Measures – Rabbi Zeev Olesker and the Revolutionary Scholars Circle in Brody Kloyz [Hebrew]," *AJS Review* 37, no. 1 (2013): כט-נג.

Putting seasonal hours on the clock

In its original usage, the rabbinic “naïve hour” was reckoned by determining the position of the sun in the sky. As the concept of seasonal hours became more common, however, the rabbis began positing that references to hours in legal texts were not just statements about the position of the sun, but statements about the passage of quantifiable amounts of time. With regard to seasonal hours, this meant that the length of each seasonal hour varied based on the total length of the day. In practice, this understanding remained secondary to direct observation; thus, for example, Rabbi Israel Isserlein’s deliberation about when one should stop eating *ḥametz* on Passover Eve[22] is essentially a deliberation over whether clock time or observation of the sun should be used. Since the imprecision of clocks meant that sundials continued to proliferate available in order to serve as calibrating mechanisms, both metrics would have been available.

As the clock became more precise, however, the relationship between clock time and solar time became strained, eventually breaking altogether with the introduction of mean time, which did not correspond to the position of the sun. As familiarity with solar time and sundials faded, so did the understanding of the seasonal hour as something determined by direct observation. The result of this transformation was a reimagining of seasonal hours *in terms of* clock hours, with each seasonal hour corresponding to a certain number of minutes depending on the length of the day. By putting seasonal hours on the clock, this system also became subject to whatever level of precision the clock possessed, which in turn resurfaced older conversations about the seasonal hour’s precise definition. Since a seasonal hour is one twelfth of a day, the def-

[22] See page 246, above.

inition of “a day” became a matter of debate, with some arguing that the day began at dawn and ended at dusk, and others—Rabbi Elijah of Vilna (d. 1797) foremost among them—contending that it began with sunrise and ended with sunset.[23] The practical significance of these debates was then reified with the printing of tables listing prayer times, discussed below.

How long does it take to walk a mil?

The time it takes to walk a *mil* has been discussed in previous chapters. While medieval Jewish authorities offered several definitions—two fifths of an hour, a quarter of an hour plus a twentieth of an hour, or simply half an hour—these definitions were functionally identical in the absence of clocks with minute hands, and as a result little effort was made to reconcile them. This state of affairs began to change in the seventeenth century as legal authorities first sought to ground the conflict with prooftexts and then attempted to determine which should be followed in practice.[24] In the eighteenth century, this discussion took a further turn when these fractions of hours were reframed in terms of minutes (generally called *minuten*), a unit which had previously appeared only in Jewish texts in astrological contexts (generally called *daq/daqim*).[25]

Short durations: seasonal or equinoctial? In chapter 2, I noted that one characteristic of the rabbinic “naïve hour” is the implication that twilight (both dawn to sunrise and sunset to nightfall) has a fixed length throughout the year.[26] This is not correct, but since twilight is not very long in the first place the topic went unexplored even at northerly latitudes. Beginning in the seventeenth century, a number of scholars began to

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[23] For a summary of positions, see Benish, *Sefer Ha-Zemanim Ba-Halakhah*, 112.
[24] *Magen Avraham* O.Ḥ. 459:2; *Tosafot Yom Tov*, Pesaḥim ch. 3 and Berakhot ch. 1; *Kanfei Yonah* §69.
[25] Samuel Loew Kelin (d. 1806), *Maḥatzit ha-Shekel*, O.Ḥ. 261.
[26] See Ibn Ezra’s commentary on Ecclesiastes 12:2 and Maimonides’s commentary on mBerakhot1:1.

argue, correctly, that these cannot be fixed durations and that the Talmud had only intended to specify the durations for the equinoxes.[27] This discussion was frequently tied to the previous one, since twilight's duration was originally formulated in terms of *mil* units.

This interest in greater specificity also resulted in a discussion of whether the rabbinic rule that one must wait six hours before consuming dairy after consuming meat—itself originally a shorthand for "wait until the next meal"—referred to six *seasonal* or *equinoctial* hours.[28] Given that the six-hour interval only became the core normative practice after the invention of the clock, the emergence of this new discussion suggests that the origins of the rule had been obscured; reimagined as rule from Late Antiquity, it became reasonable to wonder whether it, like other early rabbinic intervals, was covered by Maimonides' claim that the early rabbis had been using seasonal hours.

Defining the beginning and end of the day

Debates about the length of twilight had important practical implications, since they coincided with the widespread circulation of calendrical tables, some of which listed prayer times for each day rounded to the nearest minute. For purposes of standardized practice, the time between dawn and sunrise was collapsed into one of three positions: 72 minutes, 90 minutes, and 120 minutes. Different municipalities adopted different positions, and some cities continued to retain a local custom.[29]

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[27] Benish, *Sefer Ha-Zemanim Ba-Halakhah*, 158–160. See also *Shut Maharif*, §47.
[28] *Shut Peraḥ Shoshan*, Y.D. 1:1.
[29] Benish, *Sefer Ha-Zemanim Ba-Halakhah*, 190.

Specification of candle lighting times

Printed tables listing the start and end times for Shabbat began to appear in the early nineteenth century.[30] While these tables were not always precise—some rounded to the nearest half hour—and were sometimes miscalculated, their existence meant that consensus needed to be reached on matters that, up until to that point, had previously been left vague. In the process of performing these quantifications, it emerged that most communities began Shabbat slightly before sunset itself, though precisely how long beforehand varied between cities, from around fifteen minutes to around 40 minutes before sunset. At the beginning of the twentieth century, attempts were made to understand the reasons for this variation and prooftexts were retroactively assigned to provide textual backing. These prooftexts, in turn, likely solidified the various customs.[31]

Defining midnight (ḥatzot)

As discussed in chapter 2, the concept of midnight in the Bible was a vague concept; in Late Antiquity, it slowly gained precision, ultimately being transformed into a moment in time so precise that only God could reliably locate it. Because midnight has legal significance in various contexts—the ideal end time for reciting the evening prayer, the time by which the last foods of the Passover *seder* must be consumed, and the time at which the mystical nighttime *tiqqun ḥatzot* prayer was to be said—calculating when it would occur should have been a priority. Nonetheless, it was not until the seventeenth century that efforts were made to provide a precise method for calculating midnight;

[30] For some early examples, see Geoffrey Cantor, *Quakers, Jews, and Science: Religious Responses to Modernity and the Sciences in Britain, 1650–1900* (Oxford University Press, 2005), 290ff.
[31] Yechiel Michel Tucazinsky, *Bein Ha-Shmashot* (Jerusalem, 1929), chap. 6.

indeed, there was some debate about whether midnight is twelve equinoctial hours after midday (i.e. approximately 12 A.M.) or, following a reading of the Zohar, six *equinoctial* hours from the onset of night.[32] The latter position is associated with a passage in the Zohar which states that day and night always have twelve hours each; from the seventeenth century, this position is sometimes interpreted to mean twelve *equinoctial* hours.[33]

Prayer times in polar regions

Beginning in the seventeenth century, a number of scholars began discussing how one might observe Shabbat or conduct prayer at latitudes where day and night last six months each. Because it is difficult to entertain the notion that one would only need to pray three times a year or keep Shabbat once every seven years, solutions to this problem normally required that one keep track of time according to some non-polar reference point. This required the assistance of a reliable clock or watch, since no calibration via direct observation was possible.[34]

Programmatic treatments of the different meanings of "hour"

Attempts to read seasonal and equinoctial hours into rabbinic texts began with Maimonides. These discussions become a source of controversy in fifteenth century

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[32] *Shut Shev Ya'akov*, I:1; see also *Magen Avraham* O.Ḥ. 1:4; Judah Leib Pukhovitzer, *Derekh Ḥokhmah* (Padua, 1683), 44b; *Mor u-Qetziʿah*, §1. While some older authorities seem to be providing similar definitions (*Shut Tashbetz*, 1:109; *Levush*, O.Ḥ. 428), they are making observations about astronomical calculations rather than station a legal position; it is only much later than the Zohar's position is understood to have legal significance.

[33] *Zohar*, Vayakhel 195b and Vayeḥi 231b. See, for example, Elijah Spira (d. 1712), *Eliyahu Rabbah*, §1; *Peri Megadim*, O.Ḥ. 1.

[34] See, for example *Tiferet Yisrael*, Berakhot ch. 1 and *Mor u-Qetziʿah* §344. Muslims had to deal with the same problem, but I have seen no evidence that they did so before the twentieth century; see Meziane and Guessoum, "The Determination of Islamic Fasting and Prayer Times at High-Latitude Locations: Historical Review and New Astronomical Solutions."

Austria and then again in sixteenth century Poland in response to specific legal problems. In the eighteenth and nineteenth century, the understanding of hours was treated again, but this time in a more abstract form.[35] Of particular interest is a responsum of Rabbi Moshe Schreiber (also known as Ḥatam Sofer, d. 1839), who correctly noted that rabbinic literature employs the word "hour" in three senses: (1) seasonal; (2) equinoctial; and (3) to refer to a short amount of time. Notably, Schreiber states that "the undefined 'hours' used in reference to time-bound obligations [in Late Antique rabbinic literature] refers to seasonal hours, but the undefined term 'hour' mentioned by legal authorities is equinoctial most of the time, because people are accustomed to it."[36] Rabbi Jacob Emden, too, believed that the meaning of "hour" was overdue for reanalysis, stating, "In all the generations until today, the true explanation of whether they are seasonal or equinoctial was never made clear;" though Maimonides and others had given their positions on the topic, they were never given proper justification.[37]

II. New attitudes toward clocks and watches

The clock was the first timekeeping device to have a particular religious valence; as discussed in the previous chapter, Jews were not involved in its development or manufacture. In private contexts, Jews and Christians used the devices in much the same way; in the public square, however, clocks were never associated with Jews or Jewish institutions.

In the eighteenth century, Jews began to warm towards public-facing clocks, most likely as a result of Jewish emancipation in various parts of Europe. In the following, I

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[35] See, for example, *Shut Shevut Ya'akov*, II:6.
[36] *Shut Ḥatam Sofer*, I (O.Ḥ.), §199; see also III (E.H.) §92.
[37] *Mor u-Qetziʿah*, introduction. See also *Peri Megadim*, O.Ḥ. 58.

examine new trends in Jews' relationship to clocks and watches. Each of these areas is worthy of much greater study and a complete search of the material evidence is a desideratum.

Jewish clockmakers and watchmakers

As restrictions on Jewish participation in craft guilds subsided, Jewish clockmakers began to emerge across Western Europe. In Hamburg, a now-destroyed headstone engraved with the word *Uhrmacher* suggests their presence in that city from the early eighteenth century.[38] A clockmaker is numbered among the Jewish notables in an 1806 delegation summoned to Paris by Napoleon.[39] Jewish watchmakers lived in Baltimore and Philadelphia from the beginning of the nineteenth century, making them some of the first Americans to participate in this field.[40]

The most important center of Jewish activity was London which, alongside Zurich, emerged in the eighteenth century as the most important center for clockmaking and watchmaking. Jewish clock and watchmakers were admitted to guilds beginning in the 1730s. Though initially admitted only in small numbers, Jews quickly flocked to the profession; a study of Jewish trade cards (a kind of early business card) from the second half of the eighteenth century reveals that watchmaking is one of the most frequently recorded professions.[41] A survey of London Jews from the last decade of the nineteenth

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[38] M. Grunwald, *Hamburgs Deutsche Juden Bis Zur Auflösung Der Dreigemeinden 1811* (Hamburg: Alfred Janssen, 1904), 243.
[39] Abrahams, *Jewish Life in the Middle Ages*, fol. 249.
[40] Robert P. Swierenga, *The Forerunners: Dutch Jewry in the North American Diaspora* (Wayne State University Press, 1994), chap. 6.
[41] Alfred Rubens, "Portrait of Anglo-Jewry 1656–1836," *Transactions (Jewish Historical Society of England)* 19 (1955): 19.

century counted twelve clockmakers and 57 watchmakers in the city.[42]

Cartoon of a man examining a watch purchased from a Jew (London, 1828).[43]

In early nineteenth-century London society, Jewish watchmakers were sometimes scapegoated for passing off cheap, unreliable pocket watches as top quality, or for en-

[42] Joseph Jacobs, *Studies in Jewish Statistics* (London, 1891), 37. Jewish clock and watchmakers lived in other English cities, as well; see Helen P. Fry, "The Jews of Barnstaple and Bideford," *European Judaism* 34, no. 2 (2001): 9.
[43] United States Holocaust Memorial Museum, Accession Number 2016.184.166.

gaging in a variety of scams around the sale of watches. Such frauds were, in fact, common, although there is no evidence that Jews participated in them disproportionately.[44] Still, one Londoner proposed that watchmakers be required to sign their works, because "there are very few gentlemen would buy watches with the names of Moses or Levi on them."[45] Some visual caricatures of this stereotype exist.

Clocks in Jewish portraiture

Clocks feature prominently in European portraiture from as early as the sixteenth century; they continued to be popular with the advent of photography, and both portrait artists and photographers regularly carried clocks to use as props in their images. Motivating its depiction was the clock's status as both a *memento mori* and a signifier of wealth; those with the means to purchase their own clocks were regularly depicted holding their assets.[46] While not yet systematically studied, my survey of the existing literature shows that depictions of Jews largely eschew this trend. (Jews regularly chose more scholarly props like a book in the hand, often with a finger left inside to mark the place.[47]) The clock's absence is particularly notable given that many of these portraits were painted by Christian artists in their studios, in which clocks would likely have been available.[48]

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[44] Landes, *Revolution in Time: Clocks and the Making of the Modern World*, 297.
[45] Landes, 297.
[46] Christina Juliet Faraday, "Tudor Time Machines: Clocks and Watches in English Portraits c.1530-c.1630," *Renaissance Studies* (October 15, 2018): 60–85.
[47] For a study of Jewish portraiture, see Richard I. Cohen, *Jewish Icons: Art and Society in Modern Europe* (University of California Press, 1998), chap. 3. Another important collection of images is Alfred Rubens, *A Jewish Iconography* (London: Nonpareil, 1981). An unexamined repository of German portraits is given in Grunwald, *Hamburgs Deutsche Juden Bis Zur Auflösung Der Dreigemeinden 1811*, 143ff. See also Peter Freimark, "Porträts von Rabbinern Der Dreigemeinde Altona-Hamburg-Wandsbek Aus Dem 18. Jahrhundert," in *Juden in Deutschland: Emanzipation, Integration, Verfolgung Und Vernichtung*, ed. Peter Freimark, Alice Jankowski, and Ina S. Lorenz (Hamburg: Hans Christian Verlag, 1991), 36–57.
[48] Cohen, *Jewish Icons: Art and Society in Modern Europe*, 118–119.

Portrait of Samuel Oppenheimer (1630–1703)

There are exceptions, however. The first Jew to be portrayed in a manner emphasizing material accomplishments over scholarship was the German banker Samuel Oppenheimer (d. 1703); his portrait features a table clock in the background, serving as a signifier of wealth and status.[49] At least one of the more than twenty depictions of Rabbi Jonathan Eybeschütz (d. 1764) featured the rabbi sitting in front of a bookcase topped

[49] Mann and Cohen, *From Court Jews to the Rothschilds: Art, Patronage, and Power 1600–1800*, 99.

by a small clock, but the more popular depictions do not. Furthermore, this portrait was only created in the mid-nineteenth century; the earliest ones were made during his lifetime.[50] A portrait of the Hasidic rabbi David Twersky of Talne (d. 1882) also features a large wall-mounted pendulum clock.[51]

Nineteenth century portrait of Rabbi Jonathan Eybeschütz.

The most interesting case pertains to portraits of Elijah of Vilna, commonly known as the Vilna Gaon. As the most prominent Talmud scholar of his day, the Vilna Gaon's

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[50] Rubens, *A Jewish Iconography*, fig. 1242. On Eybeschütz's portraits, see Cohen, *Jewish Icons: Art and Society in Modern Europe*, 124; Freimark, "Porträts von Rabbinern Der Dreigemeinde Altona-Hamburg-Wandsbek Aus Dem 18. Jahrhundert," 40–41.
[51] A small facsimile of this portrait can be found in Benzion Eisenstadt, *Otzar Temunot* (New York, 1915), 9.

portraits were widely disseminated; as with Eybeschütz, a few of these—all created after the Vilna Gaon's death—contain wall clocks.[52] The oldest such depiction, an undated, anonymous lithograph from the first half of the nineteenth century, features a wall clock in a position typical for such portraits.[53] In all variants of this illustration, the Vilna Gaon's figure is framed by drapes, with a cartel clock—a rather ornate, French design—in the corner.

One of the earliest portraits of Rabbi Elijah of Vilna to feature a clock.

[52] An (exhaustive?) list of depictions is presented in Yeshayahu Vinograd, *Otsar Sifre Ha-Gera* (Jerusalem: Kerem Eliyahu, 2003), 301–312. See, as well, Rachel Schnold, *The Gaon of Vilna: The Man and His Legacy* (Tel Aviv: Beit Hatefutsoth, 1998). Schnold claims that wall clocks were "not an unusual item in portraits of sages and depictions of the Jewish home." I agree that this true with regards to the Jewish home, but it does not appear to be true with regard to sages.

[53] Schnold, *The Gaon of Vilna: The Man and His Legacy*, 57.

This portrayal apparently inspired an extremely popular, much finer lithograph commissioned by Mordecai Katzenellenbogen in 1898 for the centennial of the Vilna Gaon's death. In this depiction, an effort was made to emphasize the Vilna Gaon's scholarship: the background between the drapes was filled in with rows of books, and the ornate cartel clock was replaced with a simple clock face hanging in mid-air.[54]

Mordecai Katzenellenbogen's depiction of the Vilna Gaon (1898)

[54] Here the clock reads 9:03. Viewed together with Elijah's *tefillin*, this time may allude to Elijah's legal opinion about the latest time at which one can recite the morning *shema*ʿ prayer, which was defined in Late Antiquity as "the third hour." Elijah's interpretation of "the third hour" is later than that of his colleagues; my thanks to Shlomo Zuckier for this suggestion. In an email exchange, Christina Faraday suggested to me that the position of the clock hands likely does have significance; in Christian portraiture, the displayed time is often just before or after 12:00, the moment what the twelve-hour cycle begins and ends, signaling both death and resurrection.

Since the Vilna Gaon was famously jealous of his study time above all else, Eliyahu Stern has hypothesized that the clock was supposed to remind people to use their time well.[55] It is also possible—especially given that both versions of the portrait feature the Vilna Gaon wearing *tefillin*, holding a book and putting quill to paper—that these depictions bear some relationship to the portrait of Jonathan Eybeschütz, who is depicted in an identical pose and whose wearing of *tefillin* in the portrait is similarly exceptional.[56] The direction of the relationship is unclear to me, as neither the Eybeschütz nor the early portrait of the Vilna Gaon have been precisely dated.

Joos van Cleve, Jerome in His Study *(ca. 1485). Note the elaborate clock in the top right corner.*

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[55] Eliyahu Stern, *The Genius* (Yale University Press, 2014), 159.
[56] The affinity between the portraits is pointed out here: https://lifeofthesynagogue.library.cofc.edu/?page_id=277. Yisrael of Kozienice (known as the Magid Mesharim) is also depicted wearing *tefillin* in more than one early-nineteenth-century portrait, although none features a clock; see Schnold, *The Gaon of Vilna: The Man and His Legacy*, 51. Wearing *tefillin* all day was itself considered a sign of piety.

Whatever the relationship between the portraits, both were likely inspired by depictions of saints—particularly Jerome, translator of the Bible into Latin, who was typically painted at work in his study, hunched over a book, sometimes with a quill in hand, a sandglass or clock in the background as an admonition against wasting time (a skull is also often present for the same reason).[57]

Despite these exceptions, the portrayal of clocks in portraits of both rabbis and laity remained quite rare. While the taboo on depicting clocks in Jewish portraits may have been lifted, most rabbis (and their followers) did not rush to make a change. Jews no longer shunned the use of the clock in public-facing contexts, but neither did they wholeheartedly embrace it.[58]

Exterior clocks on European Jewish buildings

One of the most important developments in the eighteenth century was the construction—albeit in only a handful of instances—of Jewish buildings featuring clocks as part of their exterior architecture. The manufacture of such clocks required the consent of local government, interest from the local Jewish community, and the allocation of local resources. As a result of the tower clock's long association with the church, few

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[57] Doggett, *Time: The Greatest Innovator: Timekeeping and Time Consciousness in Early Modern Europe*, 28. See, for example, El Greco, *Saint Jerome* (c. 1600); Jan van Eyck, *Saint Jerome in His Study* (ca. 1435); Albrecht Dürer, *Saint Jerome in his Study* (1514); Antonio de Fabriano, *Saint Jerome in his Study* (1451). It is even possible that the *tefillin* worn on the heads of both the Vilna Gaon and Eybeschütz is a play on Jerome's tonsure.

[58] A small number of portraits of Jewish scientists have the figure holding a scientific instrument. Most prominent among these is the portrait of the Polish physician and author Tobias Cohen (d. 1729), who holds a book in his right hand and an armillary sphere in his left. See, as well, NLI Ms Heb 8°3931, fol 4b–5a, which depicts an astrolabe hanging around the neck of Abraham Ibn Ezra, and Maimonides holding some kind of circular timekeeping instrument.

synagogues opted to build them.[59] Still, the total number of exterior clocks is not insignificant, even if they represent a small minority of synagogues. What follows is, I believe, an exhaustive list of all known exterior Jewish clocks, though further research may uncover additional examples. All clocks listed below—including those which have now been destroyed—survive in photographs.

First to feature a clock was likely the Boompjes synagogue in Rotterdam; this was completed in 1725 and destroyed by a German bombing in 1940. In constructing a new location for the city's burgeoning Ashkenazi population, community leaders hired the Swiss Protestant architect Titus Favre; it is almost certainly due to Favre's experience designing churches that the synagogue ended up with a clock, bell, and weathervane.[60] In an effort to de-Christianize the clock face, all X's on the chapter ring (the part of the clock face containing numbers and letters) were replaced with P's: thus, IP P PI PII instead of IX X XI XII. This subtle modification, not found on other synagogue clocks, speaks to the device's lingering Christian character in Jewish minds.[61]

A second clock was constructed on the exterior of a synagogue for the Bohemian town Sobědruhy (now part of Teplice, Czech Republic).[62] The building was destroyed in 1957, although the clock itself apparently still exists.[63] The clock and clock tower were built in 1750 by Empress Maria Theresa on the occasion of a royal hunt, although it is unclear why; in the early twentieth century, local Jewish lore had it that officials were

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[59] Saskia Coenen Snyder, *Building a Public Judaism: Synagogues and Jewish Identity in Nineteenth-Century Europe* (Harvard University Press, 2013), 3–4. In 1873, church bells rang on the inauguration of the East London synagogue; see page 145.
[60] Timothy De Paepe, "Among the Most Beautiful Synagogues of Western Europe": A Virtual Reconstruction of the Rotterdam Synagogue of the Boompjes (1725–1940)," *Digital Applications in Archaeology and Cultural Heritage* 1 (2014): 23.
[61] De Paepe, 24. I do not know why the letter P was chosen.
[62] Stiefel, *Jews and the Renaissance of Synagogue Architecture, 1450–1730*, 76.
[63] Jan Herman, "Sobedruhy," Encyclopedia Judaica, n.d.

told to find the first church in town and happened upon a synagogue by accident.[64] Regardless of the veracity of this tale, its circulation suggests that the town's residents themselves found the synagogue clock to be out of place.

The most famous and oldest extant Jewish clock is that found on Prague's Jewish Town Hall, built in 1764. The clock face features Hebrew letters instead of Roman numerals and the mechanism runs counterclockwise.[65] Like the Boompjes clock, the Prague clock was designed by a Gentile clockmaker, although its addition is perhaps less unlikely given the building's already-unusual use of bells. As with the Boompjes and Sobědruhy clocks, it is unclear whether these special elements were requested by Jews or bestowed by the Gentile builders. Finally, a tiny sundial—much like the crude dials on medieval English churches—can be found on the façade of the synagogue in Kazimierz Dolny, Poland, built before 1800.[66]

The synagogue clocks manufactured in the nineteenth century are more common but still eclectic. The most impressive pair are installed in the towers of Budapest's Central Synagogue, completed in 1859; these are intact but no longer run. The clock towers themselves bear a strong resemblance to the towers of Munich's Frauenkirche, which also contain clocks.[67] The synagogue of Pécs, Budapest, built in 1869, also features a clock on its façade; both it and the interior of the Budapest sanctuary were de-

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[64] Hugo Gold, *Die Juden Und Judengemeinden Boehmens in Vergangenheit Und Gegenwart* (Brno-Prague, 1934), 602.

[65] The Prague Jewish Town Hall (*Židovská radnice*) was destroyed and rebuilt several times, most recently between 1763 and 1765. The building also features a regular clock; both clocks apparently run on a single mechanism. See A. Seifung, *Prag Und Umgebungen* (Berlin: Albert Goldschmidt, 1873), pts. 109–110; Philipson, *Old European Jewries*, pts. 102–103. On the identity of the clockmaker, Sebastian Landesperger, see Karl Fischer, "Die Uhrmacher in Böhmen Und Mähren 1630–1850," *Bohemia* 9 (1968): sec. 90. While basic information about the clock has been repeated often, I have not seen primary documentation regarding the clock's construction.

[66] The dial can be seen here: http://cja.huji.ac.il/browser.php?mode=set&id=8017.

[67] Rudolf Klein, "Oriental-Style Synagogues in Austria-Hungary: Philosophy and Historical Significance," *Ars Judaica* 2 (2006): 126. Manhattan's Central Synagogue is a replica of the Budapest structure, but its towers lack clocks.

signed by Frigyes Feszl, a Gentile architect.[68] The façade of the 1855 synagogue in Nová Cerekev, Czech Republic, features a clock, as well. In addition to these I am aware of a now-destroyed clock on a synagogue in Košice, Slovakia.[69]

England's oldest synagogue clock, built in 1833, sits above the Montefiore Synagogue in Ramsgate, Kent, surrounded by the words, "Time Flies; Virtue Alone Remains," a clear adoption of the clock as a *memento mori*.[70] In London, the Bevis Marks synagogue, completed in 1701, features a clock on its façade inscribed with the year of its construction according to both the Jewish and Christian calendars, 5618/1858.[71] No other synagogues in the British Isles have exterior clocks, although the Spitalfields Great Synagogue—built as a Huguenot chapel in 1743 and converted into the Brick Lane Mosque in 1976—features a sundial on its façade.[72]

A group of synagogues in and around Alsace-Lorraine feature clocks, as well. The synagogue in Ingwiller features a bell tower containing a clock with a Hebrew chapter ring; the building was constructed on the remains of a castle in 1822, but the clock itself may only have been built during renovations in 1870 or 1903.[73] In the nearby town of Belfort, a synagogue built in 1857 features a clock constructed sometime in the 1860s.[74] There is also a small clock over the doorway of the Moorish-style synagogue of Bensançon, France; it can be seen in postcards from the early twentieth century but is

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[68] József Sisa, ed., *Motherland and Progress: Hungarian Architecture and Design 1800–1900* (Basel: Birkhäuser, 2016), 333.
[69] See the dissertation by Maroš Borský, "Synagogue Architecture in Slovakia: A Memorial Landscape of a Lost Community" (Heidelberg, 2005), 63, 125.
[70] Sharman Kadish, "Constructing Identity: Anglo-Jewry and Synagogue Architecture," *Architectural History* 45, no. 2002 (2007): 390. See also Sharman Kadish, *The Synagogues of Britain and Ireland: An Architectural and Social History* (Yale University Press, 2011), 37–38.
[71] On the creation of this synagogue, see Sharman Kadish, ed., *Building Jerusalem: Jewish Architecture in Britain* (Vallentine Mitchell, 1996), 19–20. Its designer, Joseph Avis, was Christian.
[72] Kadish, 96–97. My thanks to Sharman Kadish for her expertise in this area.
[73] http://judaisme.sdv.fr/synagog/basrhin/g-p/ingwill.htm.
[74] http://judaisme.sdv.fr/synagog/fcomte/belfort/syn-belfort.htm.

probably older.[75] The synagogue of Colmar, inaugurated in 1843, has not only a clock on its façade but a small bell tower, as well.[76] Finally, one Parisian synagogue, on Rue Notre-Dame-de-Nazareth (1852), features a clock on its façade; at some point its chapter ring was replaced with the twelve zodiac symbols, a unique feature.[77] There is no clock on the much larger Grand Synagogue of Paris—the successor to this synagogue—even though the latter was one of the most lavish and cost-intensive synagogues that had been built in Europe up to that point.[78] This suggests that exterior clocks were not seen as a major marker of prestige.

In the Netherlands, the only synagogue clock other than the one on the Boompjes synagogue was built into the Boas diamond factory on Nieuwe Uilenburgerstraat (1878). This rather large building contained a very small synagogue for its workers; the building itself has a small clock on its façade, together with a small bell.[79]

There are no synagogues in America—or indeed anywhere in the Western Hemisphere—which incorporate clocks into their architecture.[80] This is surprising for a number of reasons. First, the religious liberties afforded to American Jews would have made the use of clocks more acceptable. Second, many early American synagogues were converted from churches; it seems plausible that a synagogue might have ac-

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[75] Two old, undated postcards of the synagogue also show the clock. A photograph may be seen here: https://upload.wikimedia.org/wikipedia/commons/c/c9/Besan%C3%A7on_Synagogue_62.JPG.
[76] http://judaisme.sdv.fr/histoire/villes/colmar/syncolm.htm. My thanks to Jean Daltroff for this reference.
[77] Coenen Snyder, *Building a Public Judaism: Synagogues and Jewish Identity in Nineteenth-Century Europe*, 240–241. A picture of the façade in its original form can be found there, as well. The hands of the clock came off during a 1999 windstorm.
[78] Coenen Snyder, 242.
[79] Coenen Snyder, 173.
[80] My thanks to Samuel Gruber, Jonathan Sarna, and Barry Stiefel for their expertise on the subject of American synagogues.

quired a church clock simply by chance,[81] and Americans in the eighteenth and nineteenth century were in fact *more* reliant on public clocks than their European counterparts.[82] Third, responsa literature discussing the permissibility of using former church spaces does not show any concern for the building's architecture.[83] Fourth, American synagogues were not designed by Jews until the 1840s; it seems plausible that, as in Europe, a Gentile architect might have included a clock as part of the design.[84]

Finally, the lack of clocks is particularly interesting in the case of American synagogues that were consciously modelled on churches for the express purpose of presenting Judaism as consonant with American life. For example, Kahal Kadosh Beth Elohim, built in Charleston, South Carolina, in 1794 (and consumed in a city fire in 1838), had a spire closely resembling one found in the larger St. Michael's Episcopal Church, yet unlike that church's spire it lacked a clock.[85] Congregation Mickve Israel in Savannah, Georgia (1878), is a rare Gothic-style synagogue that features a prominent bell tower, but this tower contains neither bell nor clock. Given that conditions for American synagogue clocks matched or exceeded those for European synagogue clocks, the absence of the former may be significant; further research in this area may be fruitful. At present, I do not have any plausible theories that explain the absence.

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[81] Rachel Wischnitzer, *Synagogue Architecture in the United States* (Philadelphia: Jewish Publication Society of America, 1955), 61–62.

[82] An exhaustive catalogue of 54 clocks is given in Frederick Shelley, *Early American Tower Clocks: Surviving American Tower Clocks from 1726 to 1870* (Columbia, Pennsylvania: National Association of Watch and Clock Collectors, 1999).

[83] Freehof, *The Responsa Literature*, 144–145. Converted churches are not quite an exclusively American phenomenon (witness the Spitalfields Synagogue described above), but it is only in America that churches were converted with some regularity.

[84] Wischnitzer, *Synagogue Architecture in the United States*, 5.

[85] Daniel Kurt Ackermann, "The 1794 Synagogue of Kahal Kadosh Beth Elohim of Charleston: Reconstructed and Reconsidered," *American Jewish History* 93, no. 2 (2007): 166.

Exterior clocks in Judaica and imagery

Related to clocks on actual buildings is the *depiction* of buildings with clocks on ritual objects and in manuscripts. One relevant item is a unique set of Torah finials (*rimmonim*) fashioned by Johannes Beekman Hayens around 1800; these are modelled on the town of Emden's church and town hall. While Western European finials had long born a strong resemblance to church towers—a result of both Christian craftsmanship and the influence of Christian aesthetics—this pair is distinct in its representation of the towers' clocks, as well, although only the faces and moveable hands are duplicated; there is no actual clockwork behind them.[86] A second ritual item is a nineteenth-century Polish spice box in the shape of a tower with a very crude clock face at its base. The clock face also serves as an opening for inserting spices, with the hand serving as a latch.[87] Spice boxes in the style of church spires are not unusual, but the representation of a clock is.[88] As with their larger, architectural counterparts, however, these objects seem to be anomalies.[89]

In the previous chapter, we noted that clocks are absent from Jewish depictions of cityscapes, even while they had become commonplace in Christian manuscripts; in this period, there are a few exceptions to this rule. The earliest is a depiction of a clock on a tower in an eclectic manuscript illustrating various industrial processes; since the same image depicts King David with a *globus cruciger* ("orb and cross," a common piece of

[86] The finials can be seen here: http://www.sothebys.com/en/auctions/ecatalogue/2018/important-judaica-n09955/lot.16.html.
[87] See http://cja.huji.ac.il/browser.php?mode=set&id=18383. The clock face has no numbers and, oddly, seventeen marks on the chapter ring.
[88] Shatzmiller, *Cultural Exchange: Jews, Christians, and Art in the Medieval Marketplace*, 120–122.
[89] For a possible depiction of a clock on a generic synagogue, see the 1737 Haggadah of Joseph ben David Leipnik; the image is replicated in Mann and Cohen, *From Court Jews to the Rothschilds: Art, Patronage, and Power 1600–1800*, 69.

monarchical regalia) on a table before him, it is possible that the illustrations were done by a Christian artist.[90] The manuscript is dated to the late seventeenth or early eighteenth century and the clock tower seems to serve a purely decorative function. A second clock tower appears in a cityscape on the cover of a 1781 Hebrew grammar written in Judaeo-Italian. Though the cityscape is labelled "Jerusalem," it bears little resemblance to the actual city; the artist may have drawn inspiration from another city or simply created a generic-looking town.[91] Finally, a very intricate Prague synagogue plaque from the second half of the nineteenth century features a clock tower on top of a building, though the reasons for this are not clear to me.[92]

Exterior clocks on Indian Jewish buildings

While synagogue clocks are extremely rare and idiosyncratic as a rule in most Jewish communities in the world, in India exterior clocks were somewhat more common. I counted nine Jewish-sponsored clocks (five on synagogues, four on secular structures) between three Indian cities against fifteen for all of Europe (fourteen on synagogues, one on a secular structure). The disproportionate number of Indian clocks has several possible explanations, including Indian synagogues' general affinity to church architecture, the wealth and status of the Sassoon merchant family, which resided in India, and the lack of height or size restrictions in the construction of synagogues in India which limited their European counterparts.[93]

The oldest of the Indian clocks (and the only one built in the eighteenth century) is

[90] NLI Ms Yah Heb 148, fol. 24a.
[91] British Library, Add. 26936, f. 1v.
[92] Eva Kosáková, ed., *100 Předmětů Ze Židovského Muzea v Praze*, 2006, fol. 72.
[93] On Indian synagogue architecture, see Kenneth X. Robbins and Pushkar Sohoni, *Jewish Heritage of the Deccan: Mumbai, The Northern Konkan, Pune* (Jaico Publishing, 2017), 30–31.

the Paradesi Synagogue clock of Cochin, a 1761 tower built next to a sixteenth century synagogue, the oldest in India. Constructed by Ezekiel Rahabi (d. 1771), a representative of the Dutch East India Company and a leader of the local Jewish community, this clock is distinguished by its three (possibly four) faces, each of which employs a different numeral system: Roman (facing Synagogue Lane), Hebrew (facing the synagogue), Malayalam (facing the harbor), and possibly Arabic (facing the Arabian Sea).[94] The clock tower also contained a bell, which has been restored.[95]

Four other synagogues with clocks were built in the nineteenth century, all by India's Baghdadi Jewish community. Kolkata's Beth El Synagogue was completed in 1856 by the merchants David Joseph Ezra (d. 1882) and Ezekiel Judah.[96] Kolkata's Magen David Synagogue, an extremely large building constructed by the Sassoon family in 1884, features a clock mounted on a prominent steeple.[97] Another Magen David Synagogue constructed by the Sassoon family, this one in Mumbai, features a clock on a steeple and was completed in 1861.[98] The building's architectural inspiration is not hard to determine, as it bears a very close resemblance to Christ Church (completed 1833), located only 300 meters away.[99] Finally, the Ohel David Synagogue in Pune (called *Lal Dewal*, "Red Temple"), also sponsored by the Sassoons and completed in 1867, features a London-imported clock on a large clock tower; outside of Israel, it one of the largest syna-

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[94] Nathan Katz, *Who Are the Jews of India?* (University of California Press, 2000), 46. The Arabic-Hindu numeral chapter ring is no longer present and has been hypothesized; it is possible that the clock only ever had three faces.
[95] See https://www.wmf.org/project/paradesi-synagogue.
[96] Isaac S. Abraham, *Origin and History of the Calcutta Jews* (Calcutta, 1969), 31.
[97] Abraham, 32–33.
[98] Peter Stansky, *Sassoon: The Worlds of Philip and Sybil* (Yale University Press, 2003), 7.
[99] For an image, see https://mumbaimirror.indiatimes.com/others/leisure/time-for-a-revival/articleshow/67922253.cms. I am grateful to Kenneth X. Robbins for pointing out this similarity.

gogues in Asia and a major municipal landmark.[100]

In addition to synagogues, David Sassoon donated the standalone clock tower in Mumbai's Victoria Gardens (1864) and Albert Sassoon donated the clock tower at the Sassoon Docks. These are the only two clock towers in the world exclusively financed by Jews.[101] Albert was also responsible for the David Sassoon Mechanics' Institute (now the David Sassoon Library and Reading Hall), whose façade also features a clock (1870).[102] David financed the construction of Sassoon General Hospital in Pune (1867), which has a tower clock on its southwest corner.[103]

The presence of these large Indian clocks is anomalous within the context of nineteenth century synagogue construction; they are, in their own way, no less idiosyncratic than their European counterparts. Still, it is only in India that we can speak of a Jewish tower clock "style;" in all likelihood, its existence was enabled by the diminishment of the clock's association with Christendom in a location where Christianity was not the dominant cultural influence.

Interior clocks for synagogue use

Timekeeping devices on the inside of synagogues were probably more common than clocks on the outside of synagogues, but it is difficult to determine precisely how common, as they are less commonly photographed and illustrated. As was the case with the sandglass, the initial purpose of the interior synagogue clock was to aid the sermon-giver in timing his speech; as a result, the standard location for the interior clock

[100] Katz, *Who Are the Jews of India?*, 126.
[101] Stansky, *Sassoon: The Worlds of Philip and Sybil*, 7; Robbins and Sohoni, *Jewish Heritage of the Deccan: Mumbai, The Northern Konkan, Pune*, 39–40.
[102] Robbins and Sohoni, *Jewish Heritage of the Deccan: Mumbai, The Northern Konkan, Pune*, 41–43.
[103] Robbins and Sohoni, 106–108.

is high up on the back wall, so that it can be seen easily from the pulpit.[104]

One early example of an interior synagogue clock is found in a depiction of the synagogue in Braunschweig, Germany; here a small clock is set above the ark.[105] In Plzeň, Czech Republic, a small clock hangs above the synagogue's back wall.[106] Two nineteenth-century London synagogues—in Princes Road and St. Petersburgh Place—feature interior clocks, both designed by George Audsley and both resembling the synagogue ark.[107] The Bensançon synagogue has such a clock, as does the Rue Notre-Dame-de-Nazareth synagogue in Paris.[108]

Clock above the ark in the Princes Road synagogue.

In the nineteenth century, an interest in defining prayer times more precisely led to the invention of special plaques composed of multiple clock faces, depicting the

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[104] Private correspondence, David Kaufman, February 19, 2019. For British churches, see Kadish, *The Synagogues of Britain and Ireland: An Architectural and Social History*, 25.
[105] Reproduced in Mann and Cohen, *From Court Jews to the Rothschilds: Art, Patronage, and Power 1600–1800*, 63.
[106] Images of the synagogue's interior can be seen here: https://www.10hvezd.cz/en/object/plzen/.
[107] Sharman Kadish, "The 'Cathedral Synagogues' of England," *Jewish Historical Studies* 39 (2004): 64. See also Kadish, *The Synagogues of Britain and Ireland: An Architectural and Social History*, 107.
[108] See https://commons.wikimedia.org/wiki/File:Synagogue_de_Besan%C3%A7on_-_orgue.jpg. For the latter, see the photograph in Dominique Jarrassé, "Synagogues Françaises Du Moyen Âge à 1939," *Monuments Historiques* 191 (1994): 58.

times at which the synagogue would meet for morning prayers, evening prayers, Shabbat prayers, and so on.[109] The clock faces typically have both an hour and a minute hand and the number of dials can vary. In some plaques, a functioning clock is integrated into the design. The history of these plaques awaits further study.

Interior clocks for secular use

Though they did not feature prominently in Jewish architecture or portraiture, by the nineteenth century the wall and mantle clocks were a regular fixture of Jewish homes and workplaces, as can been seen in many illustrations. In 1780, Prague's Jewish burial society (*ḥevrah qadishah*) commissioned more than a dozen paintings for its hall; each painting depicts a stage of the burial process, and some of these paintings include a mantle clock as an ornament inside the workroom.[110] Louis Katzenstein's 1861 painting *Beim Schachspiel* ("At Chess") features Gotthold Lessing (d. 1781) and Johann Lavater (d. 1801) arguing with Moses Mendelssohn (d. 1786) and depicts a mantle clock in the background.[111] Wall clocks can also be found in Alphonse Lévy's fin-de-siècle painting of a Hebrew lesson, a setting in which timekeeping devices were long understood to be crucial.[112] In houses of mourning in some parts of Germany, it was apparently customary to cover not only mirrors but clocks, as well; this custom was also prevalent in some

[109] For one example, see Abraham Pavian, "A Decorative Synagogue Plaque Indicating the Times of Prayer, Hermannstadt (Sibiu, Romania), 1878," 1878, http://www.sothebys.com/en/auctions/ecatalogue/2013/a-treasured-legacy-steinhardt-n08961/lot.13.lotnum.html. Another specimen can be found in David Altshuler, ed., *The Precious Legacy: Judaic Treasures from the Czechoslovak State Collections* (Summit Books, 1983), fig. 93; Kosáková, *100 Předmětů Ze Židovského Muzea v Praze*, fol. 75.
[110] Altshuler, *The Precious Legacy: Judaic Treasures from the Czechoslovak State Collections*, figs. 138–139; Kosáková, *100 Předmětů Ze Židovského Muzea v Praze*, fol. 53.
[111] My thanks to Richard Cohen for pointing out this image.
[112] Alphonse Lévy, "Scènes Familiales Juives" (1902), fig. 1.

Christian communities.[113] Finally, a series of late nineteenth century postcards depicting scenes in German Jewish domestic life regularly show wall and mantle clocks in either the dining room or parlor.[114] Further exploration in this area will undoubtedly reveal more examples.

In addition to these depictions, a considerable number of mantle clocks were created specifically for the Jewish market. Though clocks designed for wealthy Jewish clients have existed since at least the sixteenth century, the number of these items increases in the eighteenth century and the quality diminishes, suggesting that the clocks were becoming more common. The Jewish Museum in New York holds more than a dozen small clocks and pocket watches—mostly from the nineteenth century—with identifiable Jewish features: depictions of Moshe and the Ten Commandments, Hebrew numerals in place of Roman numerals (all running clockwise), and the Star of David in some combination.[115] The Israel Museum hold a German mantle clock with a Hebrew chapter ring from the eighteenth century.[116] I have also encountered two eighteenth century Eastern European Ḥanukkah menorahs which have small clocks embedded in their design; one of these menorahs is in the shape of a building, mimicking prevailing building styles in much the same way as the Torah finials described above.[117] Finally, there is at least one French pocket-sized mechanical perpetual Hebrew calendar; while it is not a clock, its size and calculation ability mirror the capabilities of some of the more ad-

[113] A. P. Bender, "Beliefs, Rites, and Customs of the Jews, Connected with Death, Burial, and Mourning. (As Illustrated by the Bible and Later Jewish Literature) IV," *Jewish Quarterly Review* 7, no. 1 (1894): 117. On the custom of covering clocks, see James Frazer, *The Golden Bough* (New York, 1900), 1:294.
[114] Wolfgang Krebs, *Der Jüdische Lebenslauf Und Seine Feste* (Kleve am Niederrhein: Pagina, 2016).
[115] See, as well, W. Barclay Stephens, "'Next Year in Jerusalem:' A Hebrew Clock and Watch," *Bulletin of the National Association of Watch & Clock Collectors*, 1959, 667–670.
[116] Israel Museum, accession number B13.0629 199/092.
[117] Israel Museum, accession number B83.0887 118/528; the building-shaped menorah is located in the Jewish Museum, accession number JM 3-53.

vanced mechanical timepieces.[118] A more thorough analysis will provide a better picture of how these clocks developed and their relationship to Jewish clockmakers, but the trend appears to be the result of a taboo being erased, rather than a new and specifically Jewish interest in such artifacts.

Clocks as holy objects

As seen in the last chapter, Jews did not shy away from the clock's utility as a metaphor, and they continued to use it in this period, as well. In his *De La Divina Providencia*, David Nieto (d. 1728), chief rabbi of the Spanish-Portuguese community in London, defends the idea that the stars can *appear* to exert influence on the world by comparing them to the elements of a clock. A person examining a clock may believe that the hands, gears, or weights in the clock are what make it operate—and while all of these are true, they do not exclude the necessity of a clockmaker. Similarly, the stars may be a kind of "gearing" for the world, but that does not override the need for God's role.[119]

Nieto's use of the clock is not particularly innovative. By contrast, some tales of the Ḥasidic masters finally embrace the clock's longstanding association with both the unceasing movement towards death and, conversely, the constant repetitive motions that constitute human life. In this context the clock becomes not only a *memento mori*, but a holy artifact in and of itself.

One story revolves around the clock of the Seer of Lublin (Yaʿakov Yitzḥaq, d. 1815), which was bequeathed to his son, Rabbi Yosef of Torczyn, together with a set of silk

[118] Jewish Museum, accession number F 3808.
[119] Jakob Josef Petuchowski, *The Theology of Haham David Nieto, an Eighteenth-Century Defense of the Jewish Tradition.* (Ktav, 1970), 58.

Shabbat clothes and belt. Stuck at an inn without money, Yosef gave the clock to an innkeeper, who used it to know when to milk his cows. (This suggests that he did not have any other clocks.)[120] In this version, the clock is called a "holy object," its holiness acquired through its constant presence in the Seer's room. Years after the clock was given to the innkeeper, a student of the Seer, Rebbe Yisoschor Ber Baron of Radoshits (d. 1843), rented a room but was joyously awake all night. In the morning, he remarked, "When I heard the ticking of the clock, I understood immediately that it was from our teacher, the Seer of Lublin, for in all clocks the chiming indicates to its owners that the time of death is an hour closer...but the clock of the Rebbe of Lublin emits a sound of happiness and rejoicing, indicating that it is an hour closer to the coming of the messiah."[121] This story constitutes a rare acknowledgment of the clock's status as a *memento mori*; the purpose of invoking the trope, of course, is to subvert it.

Other stories echo the common narrative trope of a clock stopping at the time of its owner's death.[122] In a detailed narrative of the death of the Ba'al Shem Tov (d. 1760), the Ḥasidic master indicated to his students that his house's two clocks would stop at the time of his death; one stopped at the beginning of the death process, the other at the end.[123] A similar story is told regarding Rabbi Shmuel Schneersohn (d. 1882), who sup-

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[120] These stories were initially spread orally; as such, determining their origins is unfortunately quite difficult. This version of the story is recounted in Shlomo Yosef Zevin, *Sippurei Ḥasidim* (Tel Aviv, 1957); see the Moadim volume, §319, 335ff.

[121] Compare this to an early seventeenth Christian century depiction of the clock face with its hand perilously clock to 12, signifying the coming eschaton; Daniel Rosenberg and Anthony Grafton, *Cartographies of Time* (Princeton Architectural Press, 2010), 59. See also Doggett, *Time: The Greatest Innovator: Timekeeping and Time Consciousness in Early Modern Europe*, 40–41.

[122] See, for example, the song "Grandfather's Clock" (1876), written by Henry Clay Work: "Ninety years without slumbering / (tick, tock, tick, tock) / His life's seconds numbering, / (tick, tock, tick, tock), / It stopped short never to go again when the old man died." The spontaneous stopping of clocks appears to be relative to a Western European mourning practice of manually stopping watches and clocks at the time of death. This practice has continued in various forms, especially as part of national memorials.

[123] Dan Ben-Amos and Jerome R. Mintz, eds., *In Praise of the Baal Shem Tov: The Earliest Collection of Legends About the Founder of Hasidism* (Rowman & Littlefield, 2004), 257. See also Martin Buber, *Tales of the Hasidim*

posedly set the hands of his clock at the time of his death and then jammed the hands with bits of paper, indicating that he would die at that time.[124]

Sandglasses in Jewish art

As we have already seen, Jews were early adopters of the sandglass as a pedagogic accessory, and the sandglass appears quite early in Jewish artwork. Sandglass use does not seem to have abated; indeed, in 1676 the town of Nikolsburg decreed that no teacher of small children could work without one.[125]

Still, it is only in the seventeenth century that the sandglass becomes a regular feature in Jewish artwork. Whereas in Christian artwork the sandglass represented temperance, in Jewish artwork it was used in calendrical contexts.[126] In her work on the Jewish calendar, Elisheva Carlebach has noted that the sandglass features regularly in Hebrew calendrical works (*sifrei ʿevronot*), where a person—sometimes labelled Issachar, a minor biblical character—is depicted on a ladder connecting the earth and heavens, a sandglass in his hand or on the ground nearby.[127] Carlebach argues that this is an allusion to the first half of 1 Chronicles 12:33, "The Issacharites, who had knowledge of the times (*yodʿei vinah la-ʿittim*)," and that the ladder, already depicted as a link between the heaven and earth in Genesis 28:10–19, represents Jews carrying calendrical knowledge

(Schocken Books, 1947), Vol. 1, pp. 83–84. The length of the death process is not indicated, but the narrative suggests it was an hour or two at most.

[124] *Torat Menaḥem* 5712, 4:1, §26.

[125] Assaf, *Meqorot Le-Toldot Ha-Ḥinukh Be-Yisrael*, 1:32, 1:88, 1:139.

[126] Balmer, "The Invention of the Sand Clock," 118.

[127] Carlebach lists New York, Columbia University, ms. X893 Se36, fol. 4r (reproduced in Elisheva Carlebach, "Palaces of Time: Illustration of Sifre Evronot," *Images* 2, no. 1 (2009): 28.); Oxford, Bodleian Library, ms. Opp. 701, fol. 4v; Berlin, Preussische Staatsbibliotek, ms. or. oct. 3150, fol. 7r; and Klau Library, Hebrew Union College, ms. 901, fol. 2b (reproduced on the cover of *Palaces of Time*). In addition, see the two depictions in the Braginsky Collection, #247, reproduced in Evelyn M Cohen, Sharon Liberman Mintz, and Emile G L Schrjiver, *A Journey through Jewish Worlds: Highlights from the Braginsky Collection of Hebrew Manuscripts and Printed Book* (Amsterdam, 2009), 98–99.

down from the heavens.[128] This interpretation accords well with a midrash discussed in Chapter 2, in which God's ceding control of the calendar to man is represented as a king transferring a timepiece (*orlogin*) to his son.[129] An 1863 commemorative plaque of Queen Esther and King Ahasuerus that depicts a sandglass sitting on a table next to the king may relay a similar idea.[130] It is also possible that Issachar is supposed to be making some sort of fine astronomical observation.

The abovementioned depictions are all located in German calendrical manuscripts from the seventeenth or eighteenth centuries. Why they did not appear earlier is a question that awaits further study; it is possible that it is related to the hourglass being depicted more regularly in Christian art generally.

Ottoman clock towers in Palestine and the Jewish afterlife of *alaturka* hours

A final area ripe for study is the influence of Ottoman timekeeping practices on the Jews of Palestine, both during and after Ottoman rule. While Jews throughout the Ottoman Empire used the *alaturka* system, a unique set of circumstances gave that system a particular staying power in Palestine, making this location particularly worthy of study.

As noted in the previous chapter, Jews in Ottoman lands appear to have used *alaturka* hours, beginning a cycle of twelve equinoctial hours each sunset, followed by a second set of twelve hours.[131] For Muslims, the system had the obvious benefit of being

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[128] Notably, depictions of Jacob's ladder do not contain sandglasses.
[129] Pesiqta de-Rav Kahana 5:13; see page 34, above.
[130] Kosáková, *100 Předmětů Ze Židovského Muzea v Praze*, fol. 74.
[131] In this system, the final hour of the day is always either cut short (because the clock has been reset to 12) or runs a few minutes long. The *alaturka* system is sometimes incorrectly described as using seasonal hours, when in fact it simply required setting the hands of a "normal" clock to 12 at a different time.

synchronized with the nightly call of the muezzin. Jews, both in Palestine and elsewhere in the Ottoman Empire, comfortably relied on this call, as well, although they sometimes specified that the Jewish sunset began some number of minutes before or after the signal.[132] This system continued until the Republic of Turkey adopted European timekeeping in December 1925. Moreover, Ottoman timekeeping continues to serve a minor function in some Ḥaredi communities, as will be discussed below, making Israel the sole remaining location in which this system continues to be used.

Belated Ottoman interest in clock tower construction resulted in the production of a small number of public timepieces, all constructed in the nineteenth century and beginning of the twentieth century as Muslim Ottomans—like Jews—became more comfortable with the use of public bells.[133] Though mechanically identical to European clocks, the chapter rings of Ottoman dials used a highly stylized version of the Arabic-Hindu numerals. Although they were never used exclusively, evidence of these chapter ring numerals dates as far back as the seventeenth century.[134] While their history and usage has not yet been studied, it is likely that they were designed to provide a superficial resemblance to Roman numerals.

Ottoman clock tower construction began in earnest in the nineteenth century; from the middle of that century all clock towers displayed both *alaturka* and *alafranga* (i.e. "French") hours, in deference to the latter system's status as an international standard, and because mean time had decoupled the clock from the actual position of the sun,

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[132] Benish, *Sefer Ha-Zemanim Ba-Halakhah*, 1:90–92.

[133] Uluengin, "Secularizing Anatolia Tick by Tick: Clock Towers in the Ottoman Empire and the Turkish Republic," 22.

[134] For a survey of relevant clock faces, see Fanny Davis, "The Clocks and Watches of the Topkapı Museum," *Journal of Turkish Studies* 8 (1984): 41–51. In addition, the clock tower in Berat, Albania, reportedly rang twelve times at noon; see Klaus Kreiser, "Ottoman Clock Towers: A Preliminary Survey and Some General Remarks on Construction Dates, Sponsors, Locations and Functions," in *Essays in Honour of Ekmeleddin İhsanoğlu*, vol. 1 (Istanbul, 2006), 549–550.

making it difficult to translate between the two.[135] The need to track both *alaturka* and *alafranga* hours is also demonstrated in double-sided Ottoman pocket watches and in published conversion tables.[136]

In Ottoman Palestine, the use of the dual system is attested by clock towers that were built with municipal or imperial Muslim funds in the first decade of the twentieth century in honor of Sultan Abdul Hamid II. With Palestine already full of public clocks attached to Christian churches and schools, the Ottoman clocks were built for the explicit purpose of creating both a visual and auditory symbol of Muslim control.[137] Each of these towers—in Jaffa (1903), Nablus (1906), Acre (1906), Haifa, Nazareth, Safed, and Jerusalem's Jaffa Gate (1907)—has four faces, two for each system.[138] The political and cultural significance of the clocks was not lost on the British. While the first six remain in their original locations, the Jaffa Gate clock was dismantled by the British in 1922; they installed it in a new, simpler tower, replaced its faces with Arabic numeral chapter rings and set all of them according to the European system.[139]

In Palestine, the *alaturka* system, sometimes called the Arab system, fell out of official use with the transition from Ottoman to British rule; however, this did not spell the end of its use in practice. Despite the fact that Turkey itself switched to European hours in 1925, the *alaturka* system enjoyed an afterlife in Mandate Palestine and later in the

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[135] Wishnitzer, *Reading Clocks, Alla Turca: Time and Society in the Late Ottoman Empire*, 180.
[136] Wishnitzer, 180.
[137] Wishnitzer, 181–182. The Lutheran Talitha Kumi school, established in 1851, featured a clock above its façade; while the original building is no longer extant, a portion of the façade, including its clock, has been preserved on King George Street.
[138] The construction of some these clocks is not well documented. For Haifa, Nazareth, and Acre, see Kreiser, "Ottoman Clock Towers: A Preliminary Survey and Some General Remarks on Construction Dates, Sponsors, Locations and Functions."
[139] Simon Goldhill, *Jerusalem: City of Longing* (Belknap Press, 2008), 146–147. This tower, too, has since been demolished; the movement itself currently resides in the British Museum.

State of Israel as a protest against the state on the part of certain Ḥaredi (ultra-Orthodox) communities, who apparently associated European timekeeping with governmental sovereignty. In this system, the Ottoman system is relabeled *shaʿon eretz yisrael* ("Land of Israel clock," often abbreviated in documents as לשא"י), or sometimes *shaʿon eretz ha-qodesh* ("Holy Land clock"), ironically appropriating for Jewish culture what had simply been the cultural construction of a previous government.[140] These are contrasted with the "Europe clock" (*shaʿon eiropa*).[141]

The *shaʿon eretz yisrael* system has not been studied, although I have been able to determine the subject's broad contours. The use of the term is recorded as far back as the early British Mandate; in earlier calendars no term was necessary, as no other system was in use.[142] Yechiel Michel Tucazinsky (d. 1955), the author of several works on timekeeping and the calendar and the creator of a popular calendar (*luaḥ*), refers to the "Arab clock" (*shaʿon ʿaravi*) in both his writing and in his calendar (which lists both *alaturka* and European hours), but he uses "Land of Israel clock" on occasion, as well.[143] The same terminology is used by Rafael Aharon Ben-Shimon (d. 1928), a chief rabbi of Cairo who eventually emigrated to Tel Aviv.[144]

Ideological Ḥaredi interest in the system dates at least as far back as the British mandate; a 1925 edition of the weekly *Kol Yisrael* newspaper comes to the defense of the *shaʿon eretz yisrael* against the newcomers who ridiculed it, improbably arguing that the

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[140] The word *shaʿon* ("clock") was coined by Yechiel Michel Pines (d. 1913) and first appear in print in 1885. It was initially used interchangeably with a variety of other terms: *mad zeman*, *kli shaʿah*, *moreh shaʿot*, and *orlogin*.
[141] Separately, but for similar reasons, some Ḥaredi communities ignore Israel's imposition of daylight saving time. (Daniël Meijers, *Ascetic Hasidism in Jerusalem: The Guardians-of-the-Faithful Community of Mea Shearim* (Brill, 1992), 69.)
[142] See, for example, the image in Benish, *Sefer Ha-Zemanim Ba-Halakhah*, 192.
[143] Tucazinsky, *Bein Ha-Shmashot*, 99ff.
[144] *Nehar Mitzrayim*, 67b–68a.

former was the very same system used by both King Aḥaz and the early rabbis, since, like the Jewish day, the system begins at nightfall.[145] At the same time, *Kol Yisrael* itself attests to the fact that several systems were simultaneously in use: in a different 1925 issue, the time for lighting Shabbat candles was indicated in both solar time (*shaʿon ha-shimshi*) and mean time (*shaʿon ha-do'ar*, lit. "clock of the post office"), while an invitation to a wedding and an advertisement for a lecture used the "Arab" system (*ʿaravit*).[146]

Over time, the status and labelling of the *alaturka* system began to change. In the 1930s, an advertisement for an upcoming class listed the *shaʿon eretz yisrael* time in brackets; by the 1950s, it is European time which appeared in brackets.[147] By the time the state of Israel was founded, the system had become obscure to most Israelis; secular newspapers reporting on Ḥaredi neighborhoods in 1950s explain the system in a way that suggests the rest of the public had lost familiarity with it.[148] The system is also well documented in *pashkevil* documents, the public notices which plaster the walls of Jerusalem's Meah Shearim neighborhood and other Ḥaredi neighborhoods in Israel. A preliminary survey of these documents indicates that *shaʿon eretz yisrael* is always given together with European hours, the latter appearing in brackets. This suggests that marking time with reference to *shaʿon eretz yisrael* serves a symbolic rather than a practical role. Further study should examine whether the term *shaʿon eretz yisrael* was created as a response to Zionism or was simply co-opted by anti-Zionist groups; it should also ex-

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[145] *Kol Yisrael*, May 25, 1925. A facsimile of this article can be found in Benish, *Sefer Ha-Zemanim Ba-Halakhah*, 1:91.
[146] Benish, 93.
[147] "Jerusalem," *Hamashkif*, December 13, 1939; Yehoshua Bitzur, "The War Has Gone to the Bulletin Boards," *Ma'ariv*, December 14, 1954.
[148] See "Sabbath Observers Go To The 'Bastille,'" *Ma'ariv*, April 21, 1952; Yitzḥak Yerushalmi, "Neighborhoods in Jerusalem: The 'Box Shut Tight,'" *Ḥerut*, May 3, 1953. The latter article explains the system as differing from European system by six hours, which is roughly correct. The use of the phrase is contextual; in many instances, *shaʿon eretz yisrael* simply refers to the time zone in which Israel is located.

amine how the system is employed across different Ḥaredi communities in Israel.

Conclusion

The Zoharei Ḥamah synagogue as it appeared in the 1920s.

Leave Jerusalem's Machane Yehuda market on the Yaffa Street side, look up, and you'll see it: a four-story building, now rendered inconspicuous by the busy street and the adjacent buildings, the façade of its top floor adorned by a giant half-arc sundial, each end dotted by a large clock, one for European and the other for *alaturka* time, the whole thing giving the effect of a giant smile. This is the Zoharei Ḥamah synagogue, built atop a one-story house by the American tailor Samuel Levy between 1908 and 1917 so that the residents of the area might be able to pray at the earliest possible time.[1] Three different timekeeping systems are represented on the façade: one based on the sun, one based on machinery, and one based on both. All three testify to the enduring influence of Greco-Roman timekeeping and, behind that, the Mesopotamian and ancient Egyptian frameworks from which it drew.

A single monument cannot capture the entirety of the Jewish discourse on timekeeping, but the façade of this synagogue at least alludes to it, bearing witness to Judaism's complex relationship to the subject as it developed across a changing cultural and technological landscape. Jewish culture ultimately absorbed elements of every timekeeping system and technology it encountered, along the way reconciling new frameworks with ones that had previously been absorbed. Fundamental vocabulary was acquired from Hellenistic culture, although the Hellenistic system's sophistication far surpassed the quotidian needs of the average person. Timepieces themselves were used, but rarely and in specialized circumstances. The longstanding association of timepieces with royalty—an association that begins with the biblical Dial of Aḥaz—held firm.

Meanwhile, astronomical knowledge evaded the rabbis, whose unreflective use of the term "hour" was not fully clarified until the rise of Islam, when a few scholars

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[1] Dovid Rossoff, *Where Heaven Touches Earth: Jewish Life in Jerusalem from Medieval Times to the Present* (Jerusalem: Guardian Press, 1998), 392–393. An article on its construction can be found in the July 4, 1906 edition of the newspaper *Hashkafah*. It is also discussed in Tucazinsky, *Bein Ha-Shmashot*, 103.

versed in scientific knowledge imported the distinction between the seasonal and equinoctial varieties. This new awareness, however, was not accompanied by cheaper or more precise timekeeping instruments, and so it did not gain purchase outside of a few specialized circles. Rabbanites retained their usage of the Hellenistic twelve-hour day, despite Islam's de-emphasis of this system; Karaites did not. Whereas Late Antique rabbis used unconventional terms, like "the time it takes to walk a *mil*," to describe short durations, Jews under Islam show a greater interest in describing these durations using hours, although the reasons for this are not entirely clear.

Lacking the astronomical knowledge of their counterparts in Islamic lands, the rabbis of Christian Europe spent little time expanding timekeeping discourse beyond what they had inherited from Late Antique sources. With clocks and bells rare outside of churches and monasteries, Jewish access to timekeeping devices reached a low ebb, although crude makeshift sundials were probably used on occasion. Even without the theoretical tools, however, their northerly location forced the rabbis to reckon with seasonal fluctuations in the length of the day in ways that neither their Rabbanite nor their Late Antique counterparts had done. In the thirteenth century, this timekeeping discourse changed again as Jews in the region gained access to the scholarly output of their counterparts in Islamic lands.

Though the mechanical clock was invented in the late thirteenth or early fourteenth century, Jews—who were not involved in its development and were barred from its associated guilds—did not take them up until the end of the fourteenth century, following quickly on the heels of the first explosion in clock construction in the 1370s. The reception took different forms in different regions. In Italy, Jews did not see the clock as having much legal significance, but its presence is well attested in time-registered documents. In Ashkenaz, by contrast, the presence of public clocks resulted in a number of new conversations around both the legal significance of clock hours and the legal status of the clocks themselves. In the Ottoman Empire, the Jewish response only began with the appearance of imported European pieces in the sixteenth century; because most devices were private, their impact seems to have been relatively minor. The sandglass, invented almost simultaneously, is woven into this history, as well; both it and the clock led to increased use of the hour (and fractions thereof) in measuring short durations.

In the seventeenth century, advances in timekeeping precision and the growing availability of portable devices led to a second wave of legal conversations around timekeeping. In the eighteenth century, the lingering Christian associations of the mechanical clock began to fade, and Jews became increasingly comfortable with using them more prominently, both in synagogue architecture and in some Jewish literature. Finally, in the twentieth century, some Jewish groups in Palestine took ownership in an unprecedented manner over one particular timekeeping system—the Ottoman *alaturka* hours—by transforming it into the "Land of Israel clock," in protest against the European system used first by the British and then by the Israeli government.

Looking up at the façade of the Zoharei Ḥamah synagogue, one can see certain elements of this long history, but they appear in flattened form, their origins lost. The full story of the Jewish relationship to timekeeping, this investigation has demonstrated, cannot be glimpsed in a single era of Jewish history or a single region of Jewish settlement; the relevant scientific and technological developments played out over millennia, not centuries. This study, I hope, has shown the value of performing historical analysis over such a long period.

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