

Communication, Computation, and Governance: A Multiscalar Vantage on the Prehispanic Mesoamerican World

Gary M. Feinman* and David M. Carballo

Abstract: Writing has often been put forth as one indicator of civilization. This correspondence dovetails with the even broader cross-species expectation that the degrees of social complexity and levels of computational communication should closely correlate. Although in a general sense across human cooperative arrangements, a basic relationship between these variables undoubtedly exists, more detailed and fine-grained analyses indicate important axes of variability. Here, our focus is on prehispanic Mesoamerica and the means of computation and communication employed over more than three millennia (ca. 1500 BCE–1520 CE). We take a multiscalar and diachronic analytical frame, in which we look at 30 central places, six macroregions, and Mesoamerica as whole. By unraveling elements of “social complexity”, and decoupling computation from communication, we illustrate that institutional differences in governance had a marked effect on the specific modes and technologies through which prehispanic Mesoamerican peoples communicated across time and space. Demographic and spatial scale, though relevant, do not alone determine time/space diversity in media of computational communication. This article is part of the theme issue “Evolution of Collective Computational Abilities of (Pre)Historic Societies”.

Key words: Mesoamerica; archaeology; communication; computation; writing; polity scale; calendrics; Maya; Aztec

1 Introduction: Research Question

Across the social and behavioral sciences, a close relationship between complexity of human social organizations and highly developed systems of communication and computation has long been presumed^[1]. For example, almost 75 years ago in a classic paper, Childe^[2] listed writing as one of the ten characteristics that defined emergent urban societies. The link between social complexity and developed modes of communication has even been extended to the

animal kingdom more generally^[3]. Nevertheless, the general relationship between human social relations and modes of communication has rarely been explicitly probed. Clearly, increases in organizational size or scale, and the geometric rise in interactions, have ramifications for means of interpersonal connectivity. But are population size and related scalar indices the principal determinant of modes of communication^[4]? Historically, how did communication systems vary across human social networks as their scale and organizational forms shifted? Was there a predictable sequence of stepped change^[5], or were the processes of innovation in computational and communicational systems somewhat more historically intricate, affected by differences in the configurations of institutions and governance, rather than a function of scale alone?

The organizers of this special section requested that we evaluate the evolution of computation and communication technologies in prehispanic

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Mesoamerica, a region where we both have conducted research for decades. More specifically, our initial charge was to assess two empirically based and cross-cultural models^[4, 5], both of which propose a strong relationship between dimensions of human organizational scale and technologies of computational communication. The two models are reliant on data accumulated by the Seshat Project^[6], which examines diachronic findings from 30 global regions. In the spirit of transparency, the authors of this paper contributed to (and were advisors during) the collection of data by the Seshat team, and Gary M. Feinman is among the 53 authors on the paper by Turchin et al.^[4]

The key point of debate between these two papers^[4, 5] concerns sequences of change. Whereas Turchin et al.^[4] saw a generally linear relationship between demographic/scalar variables and shifts in computational technologies, Shin et al.^[5] applied a finer-grain temporal lens. The latter team proposed a multistep process in which the relationship between scalar factors (population) and the technologies of computational communication shift at different rates relative to each other. From this analytical perspective, population initially increases more rapidly than computational technologies. Later in the sequence, means of computational communication develop at a faster tempo than demographic growth. Ultimately, in a third step, population again grows faster than informational factors. Yet the regionally based data collected and analyzed by Seshat are not perfectly suited to ground the proposed stepped relationship advanced by Shin et al.^[5]. A principal limitation is the scale-shifting embedded in the Seshat record. For several cases in that sample, the computational increases during the second stage of the three-step process were not a function of strictly regional-scale processes (specific local ties between scale and communication technologies), but the outcome of episodes of incorporation in which the study regions were engulfed into much larger polities whose heartlands, where the key changes in informational technologies occurred, were far removed from the regional cases. In the Seshat coding scheme, these changes in computational communication reflect imperial incorporation.

Because scalar variables are at the core of the research problem under investigation, we endeavor to be both flexible and clear in looking at the diachronic relationship between computational communication

technologies and scale in prehispanic Mesoamerica. For that reason, we explicitly examine these relationships across three principal scales, the Mesoamerican world as a whole, the six principal macroregions or cultural regions (Central Mexico, West Mexico, the Gulf Coast, Oaxaca, the Pacific Coast, and the Maya region), which generally are seen to make up wider Mesoamerica, and 30 relatively well-studied central places, which were at the core of significant polities at some point during the prehispanic sequence. Through this multiscale approach, we aim to more explicitly unravel the importance of differences in governance, institutions, and leadership as key considerations that mediate the relationship between scale and technologies of communication.

2 Conceptual Decoupling and Definition

Evans^[7] asked “How do the principles underlying computing and sociality fit together?” To assess this question requires explicit definitions, both for computational communication and social complexity, so that the conceptual underpinnings of our approach are transparent. We begin with the former. By definition, computational communication is recognized to have two phases or steps, information accumulation and information processing/analysis/storage^[8]. Both phases involve communication, but only the latter is computational. Thus, as Cover and Thomas^[9] made clear, communication and computation are intertwined but not equivalent. The computation of information generally requires or implies communication, but not all communication includes computation. For example, oral communication can convey information without necessarily spurring innovations in either the material or technological means to store or process that information^[10]. Oral communication is an effective way to convey information that can be enhanced or reinforced through ritual and other practices. To understand when writing, numeration, and other computational technologies, such as calendrics, were elaborated, we agree that the scale of social affiliations and aggregations is one key factor^[11], but so are the different ways in which social groupings were interconnected, organized, and governed^[12, 13]. With variance in governance, it becomes important to take into account the kinds of information that is/was conveyed, through which channels (mostly top down, bidirectional, etc.), and who

was communicating to whom (the nature of audiences/receptors).

Likewise, as perspectives on social complexity and governance shift from rigid adherence to unilinear models^[14–17], the decoupling of different dimensions of “social complexity” enables the assessment of relationships between scale, the nature and organization of governance, and different modes of connectivity and communication^[14]. Scale refers to the sizes of human social units, such as settlements or polities. It also includes the geographic extent of a polity, although that is difficult to ascertain archaeologically^[18]. Complexity encompasses several dimensions, including the relative concentration of power and decision making within an organization (the degree of centralization), as well as the hierarchical structure of decision making^[14]. Institutional clout may be highly centralized in a specific individual or it can be distributed across gently stepped or overlapping offices and institutions. In governance, highly concentrated power tends to characterize autocratic regimes, whereas distributed power and shared, collaborative, or pluralistic decision making are associated with more collective forms of organization.

Variation along the autocratic-collective dimension has different implications for the use of public space^[19] and the character of community ritual^[12, 13]. Networks of communication and interaction also vary with the ways in which power is wielded, legitimized, and reproduced. Are there mechanisms to gauge the voices of commoners? Do leaders communicate mostly with their immediate subordinates (secondary elite) or to larger gatherings of subalterns?

As in many regions of the globe, the sizes of prehispanic Mesoamerican polities expanded and contracted over time, although there was a general trend toward growth. But, as with the structures of other institutions^[20], political organizational expansions could entail either the linkages of similar peer polities (the scaffolding of like components) or more organic integrations in which incorporated territories did not simply mirror the structure of the core but were more fully interconnected into larger politico-economic entities that were systemically intertwined^[21]. The channels, flows, and nature of communications would differ in these contexts. As we examine temporal and spatial variation in prehispanic Mesoamerican modes of computational communication, we focus on scalar

dimensions but also diversity in governance and its impacts on modes of information transfer.

3 Prehispanic Mesoamerica

Before turning to the focal research questions, we geographically delimit prehispanic Mesoamerica, define its key, relevant parameters, outline traditional temporal segments applied to the region’s past, describe pertinent diachronic trends, and introduce our analytical sample. Prehispanic Mesoamerica long has been recognized as a cultural region or a “world” in the sense of a world as it was known to the people who lived in it^[22, 23]. Mesoamerica includes the southern two-thirds of what is today Mexico, in addition to Guatemala, Belize, and the western parts of Honduras and El Salvador. The limits of the Mesoamerica world were neither entirely static nor tightly bounded. To the north were the arid lands of northern Mexico, which were occupied by mobile peoples who generally lived at lower densities than prehispanic Mesoamericans. To the south, the divide with the Central American Intermediate Area was largely defined culturally as opposed to environmentally.

Environmental variation in the Mesoamerican world reflected altitude more than latitude. Rugged mountain ranges, which run mostly north-south, carve the Mesoamerican landscape into mountains, highland valleys, and expansive lowlands. For the purposes of our investigation, we focus on six macroregions (Fig. 1), three of which are principally highlands (Central Mexico, Oaxaca, and West Mexico) and three of which include extensive lowlands (the Gulf Coast, the Maya region, and the Pacific Coast). Despite marked elevational gradients, an absence of beasts of burden, and limited opportunities for water-borne transport, long-distance movements of people, goods, and information were anything but rare in prehispanic Mesoamerica. Foot trails traversed the terrain, and commodities moved readily and regularly on people’s backs. But in the mountainous highlands and forested lowlands of Mesoamerica, the movement of large armies or supply chains faced significant challenges.

Traditionally, the 3000-year era in which Mesoamerican peoples transitioned from widespread sedentary communities through the rises and falls of states and empires to the Spanish invasion is divided into three broad chronological periods: Preclassic or Formative (ca. 1500 BCE–200 CE), Classic (200–800



Fig. 1 Mesoamerica map with six macroregions.

CE), and Postclassic (800–1520 CE). Although, in general, the sizes of prehispanic polities increased across these periods, the sequences of political change in specific regions and macroregions were neither consistent nor linear. As with the size of political units, regional populations and the scale of central places tended to become somewhat larger across Mesoamerica over time. Nevertheless, there was marked variation region to region and at all spatial scales; demographic change varied in tempo and directionality across time. Besides the six macroregions, we also focus our analysis on 30 central places (Fig. 2). This sample represents large and well-studied Mesoamerican archaeological sites that have been described by their investigators as capitals or centers of their respective regions for an expressed time^[24]. Collectively, these 30 central places represent the three temporal periods, and they are spatially distributed across the Mesoamerican world.

Archaeologists have identified or inferred eight institutions that were widespread in Mesoamerica from the Formative period until Spanish conquest: states, cities, neighborhoods or districts, rural communities, marketplaces, temples, households, and water management collectives^[25]. These institutions took highly varied forms and sizes across time and space, but how they were manifested and interconnected had a major effect on organizational and governance differences in prehispanic Mesoamerica. In this world, beyond the lack of beasts of burden and the rarity of any domesticated animal species (only the dog, the turkey,

muscovy duck, and the honey bee were domesticated), the use of metal as tools was very rare, and no metal at all was present prior to 700 CE. Marketplace exchanges were a highly significant means of economic transfer in Mesoamerica, which reached a peak with the Aztec marketplace at Tenochtitlan-Tlatelolco, the size of which (and diversity of goods in) deeply impressed the sixteenth century invaders. Nevertheless, almost all Mesoamerican production for exchange occurred in domestic (not nonresidential workshop) contexts^[26, 27], and so both agrarian production and craftwork would have been nearly impossible to control centrally.

4 Mesoamerican Writing, Numeration, and Calendar

In Mesoamerica, recurrent symbolic representations were carved on polished stone celts, ceramic vessels, seals, and other media^[28] dating back to early in the Formative period (ca. 1500–1000 BCE). Yet the earliest Mesoamerican writing and numeration do not date until later in that period (ca. 650 to 250 BCE), when four notational systems have been recognized in which symbols were employed as representations of spoken languages. These four writing systems—Olmec (the Gulf Coast), Zoquean (Isthmus of Tehuantepec), Mayan (Pacific Coast of Guatemala and the Petén district of Guatemala), and Zapotec (Valley of Oaxaca)^[29, 30]—share a few conventions and signs (such as the logogram for being seated), but the contexts in which the scripts were used and the suite of glyphic

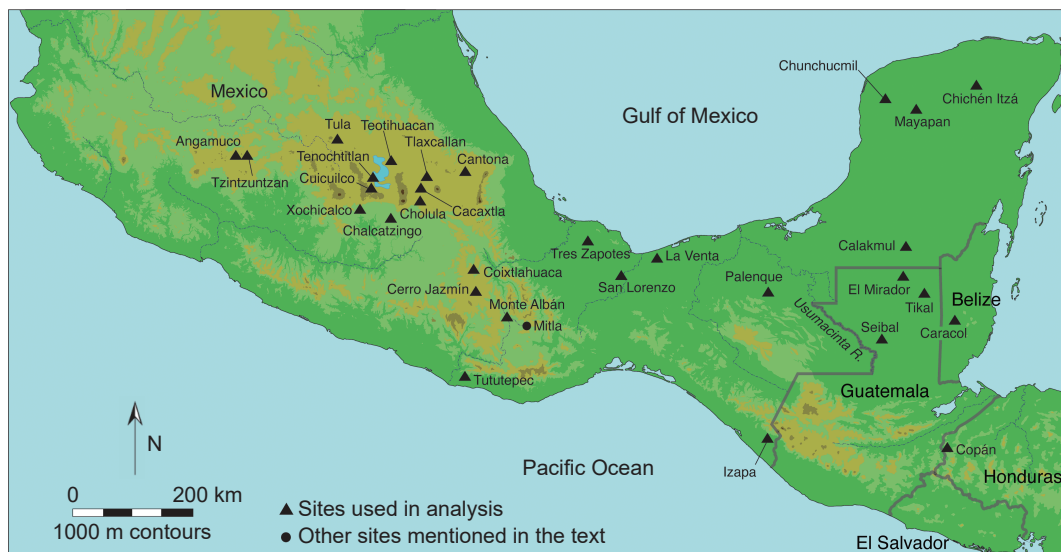


Fig. 2 Mesoamerica map with 30 central places in analytical sample and other sites mentioned.

components associated with each reflect regional differences.

During the Formative period, a small number of signs were abstract, but most were depictive. Texts were uniformly brief, generally carved on stone. In most cases, the short texts accompanied representational images of people^[31], a pattern that was continued later in the prehispanic era. Some early texts included individuals who appear to be “tagged”, or named, rulers for the Gulf Coast Olmec and captives in Oaxaca. The advent of writing systems coincided with evidence of calendric systems and the bar-dot convention of numeration, which was broadly followed across Mesoamerica. Dots represent single units; the bar represents five.

The earliest evidence of Mesoamerican calendrics was “the count of days” or the 260-day cycle, which dates back to the sixth century BCE in Oaxaca^[32]. Throughout most of Mesoamerica, the 260-day calendar was combined with a 365-day calendar, which was made up of 18 months of 20 days with five unlucky days at the end of the year. Juxtaposition of these two calendric cycles returned to the same suite of day names every 52 years, which is known as the “Calendar Round”. Despite time-space variation in the names of specific elements, the basic 260-day count was one of the most widespread cultural markers during later Formative, Classic, and Postclassic periods in Mesoamerica^[33, 34], perhaps, second only to the consumption of maize. Late in the Postclassic period, we know its use was even pervasive among commoners^[33].

The earliest known Long Count dates, a calendric system that enables temporal registry at millennial scales^[32], pertain to the last century BCE in Chiapas, Mexico, and along the Pacific Coast of Guatemala^[31]. Subsequently, the Long Count, which tracks time in a series of cycles, was employed almost exclusively by the Maya between the first centuries CE until just after 1000 CE. After that date, the Long Count was no longer recorded, and it likely dropped from use. Between 600–900 CE, hundreds of Long Count dates were carved on Maya stone stelae and recorded on other media, including polychrome vases. Placement of these dates almost always served to bracket and document the life crisis events of royals and their close associates^[35].

In the Maya area, the thousands of written texts^[36] dated to the period between 600–900 CE (the Late Classic) also differed markedly from both earlier and later Mesoamerican texts along a number of important dimensions. In general, texts were longer, they included a larger corpus of distinctive glyphs, a greater number of signs referenced specific localities, and more individuals and titles were named^[35, 37]. Classic Maya texts allowed for a true representation of spoken language, with the longest mean utterance of any pre-Columbian writing system. Furthermore, Classic Maya texts included statements of ownership (“his cacao vessel”); authorship is rarely if ever found elsewhere in Mesoamerica. Like the Mesoamerican world’s most precise calendric system, many of these other features of the Classic Maya writing system dropped from (or

greatly diminished in) use with the fall of the Maya centers of that era. Calendrical and astronomical information did not disappear from the Postclassic Maya world, but it was no longer used as directly to frame and legitimize dynastic histories. Rather, the focus shifted to divinatory almanacs read by specialists.

In highland Mesoamerica (specifically Central Mexico and Oaxaca), Formative and Classic period writing and texts were far shorter, found at fewer sites, and are much less abundant in quantity compared to the Classic Maya. In part because of the sparsity of texts and their brevity, the small number of recorded glyphs and representations at the highland cities of Teotihuacan (Central Mexico) and Monte Albán (Oaxaca) remain only partially deciphered. At Teotihuacan, the largest Classic period center in Mesoamerica, much of what we know includes numerals and refers to Calendar Round cycles^[38]. Such glyphs often were embedded in representational mural art, and not transcribed as discrete texts.

At Teotihuacan, fragmentary pieces of a polychrome mural in Early Classic Maya style, including Maya glyphs, have been recovered^[39, 40], but at the Central Mexican metropolis, not only was the indigenous writing system different but the uses were as well. Whereas at Classic Maya centers, stone stelae were often installed in restricted plazas adjacent to palaces and temples, most Teotihuacan writing was incorporated in murals painted in domestic contexts^[41]. Written referents were made to insignia of offices^[42] but not to named individuals as was the Classic Maya practice. Nevertheless, monuments displaying elements of Teotihuacan style and symbolism that were erected in both the Maya region^[43] and Guerrero^[44] did include named persons. Teotihuacan glyphs tended to be large, and iconographic, not easily recognizable as scriptural accounts^[38]. In contrast, Classic Maya glyphs carved in stone tended to be small and packed close together in lengthy texts. The longest array of Teotihuacan glyphs was not compiled in a discrete transcript, but rather was painted in a horizontal arrangement dispersed on a plaza floor in the La Ventilla residential compound, where these 42 glyphs are thought to have been used for teaching or ritual instruction^[45].

During the three to four centuries that followed the partial destruction and abandonment of the great metropolis of Teotihuacan (ca. 550–600 CE), networks

of interaction and uses of technologies of communication shifted across Mesoamerica. In that period, referred to as the Late Classic and Epiclassic periods, conventions of mural painting and illustrative mean that integrated texts and images into historical narratives (*mapas*), which were employed by the Late Classic Maya, gained greater prominence in the highlands^[46]. During the Postclassic, international styles of iconography, communication, and narrative that drew on customs and conventions of communication from both highlands and lowlands were shared across Mesoamerica. Historical narratives of origin and legitimacy took a range of forms, which were preserved in both prehispanic codices and through colonial period documents commissioned by the Spanish but written by indigenous scribes. At the time of the late prehispanic Aztec empire (1325–1520 CE), many earlier means of writing and communication were emulated and employed^[47].

5 Writing Index and Time/Space Variation in Mesoamerican Writing Systems

Overall, prehispanic Mesoamerican peoples and polities employed a diversity of writing and computational practices that recorded and disseminated a broad suite of information. These included records of the two different calendar systems, the widespread Calendar Round and the more spatially and temporally delimited Long Count. Beyond the calendars, information recorded in at least one Mesoamerican writing system included settlement toponyms, specific named buildings, office titles, representations of conquest/political subordination, tax and tribute records, ownership, authorship, and the use of maps (*mapas*) to relate historical narratives^[35, 37]. For the Classic Maya, scribal arts reached a degree of accomplishment and complexity that was not matched elsewhere in Mesoamerica^[36].

To facilitate comparisons over time and across space, we noted the presence/absence of ten written expressions/representations (Table 1) for all macroregions and at each of the 30 central places during their apogee or period of maximal size and importance (Table 2). We termed the summary scores for the presence/absence of these ten classes of written information as the “writing index”, which varied from 0 to 10. Although we fully recognize that an index to measure the degree of elaboration in a system of writing

Table 1 Categories of writing.

Calendar Round (ritual + solar)
Long Count calendar
Settlement toponyms
Building names
Titles of office
Conquest/political subordination
Tax/tribute
Ownership
Authorship
Map/migration

could be calculated in many ways, we selected these ten criteria as they are present in at least one Mesoamerican system of writing. Furthermore, the writing index scores

that we measured broadly correspond to what has been previously and widely recognized regarding the relative sophistication (compared to elsewhere in prehispanic Mesoamerica) of Classic Maya writing, and also corresponds with variation in the number and length of texts. Whereas all ten written criteria were present in the corpus of Classic Maya writing (for a score of 10), other Mesoamerica sites and regions scored 0 as textual records are absent, for example in West Mexico.

Drawing on the interpretations of the investigators who researched each of the 30 central places, we also recorded estimated apical population sizes as well as available estimates on the territorial hegemony of each center at their peak extent (Table 2). Twenty-six of the

Table 2 Thirty central places included in the analysis.

Region	Site	Period	Population	Writing index	Collectivity score	Polity size (km ²)
West Mexico	Angamuco	Postclassic	40 000	0	2.5	–
Central Mexico	Cacaxtla	Epi/Late Classic	15 000	6	1.0	–
Maya	Calakmul	Epi/Late Classic	50 000	10	0.5	8000
Central Mexico	Cantona	Epi/Late Classic	60 000	0	2.5	11 000
Maya	Caracol	Epi/Late Classic	100 000	10	2.0	–
Oaxaca	Cerro Jazmín	Postclassic	32 000	0	0.5	71
Central Mexico	Chalcatzingo	Preclassic	1000	0	2.0	–
Maya	Chichén Itzá	Epi/Late Classic	24 500	8	2.0	–
Central Mexico	Cholula	Postclassic	40 000	7	2.5	–
Maya	Chunchucmil	Classic	38 500	0	2.5	–
Oaxaca	Coixtlahuaca	Postclassic	54 000	6	0.5	47
Maya	Copán	Epi/Late Classic	10 000	10	0.0	–
Central Mexico	Cuicuilco	Preclassic	20 000	0	3.0	–
Maya	El Mirador	Preclassic	50 000	3	2.0	–
Pacific	Izapa	Preclassic	5725	4	2.0	450
Gulf of Mexico	La Venta	Preclassic	3000	2	0.0	–
Maya	Mayapan	Postclassic	17 500	7	2.5	45 000
Oaxaca	Monte Albán	Classic	25 000	6	2.5	16 000
Maya	Palenque	Epi/Late Classic	7500	10	0	–
Gulf of Mexico	San Lorenzo	Preclassic	10 400	0	0	8000
Maya	Seibal	Epi/Late Classic	7500	10	0	–
Central Mexico	Tenochtitlan	Postclassic	212 500	7	2.0	168 000
Central Mexico	Teotihuacan	Classic	100 000	5	3.0	62 500
Maya	Tikal	Epi/Late Classic	55 000	10	0.5	20 000
Central Mexico	Tlaxcallan	Postclassic	35 000	7	3.0	2000
Gulf of Mexico	Tres Zapotes	Preclassic	3000	5	2.5	–
Central Mexico	Tula	Postclassic	50 000	6	2.5	13 000
Oaxaca	Tututepec	Postclassic	16 000	7	0.5	25 000
West Mexico	Tzintzuntzan	Postclassic	35 000	0	1.0	75 000
Central Mexico	Xochicalco	Epi/Late Classic	12 000	7	2.5	10 000

Note: Data were compiled from Table 3 in Ref. [24].

30 central places in this sample were compared in a previous study (Table 3 in Ref. [24]), where the specific sources referenced are reported. We have added information on estimated polity sizes for Calakmul^[48] and Caraco^[49], which were not reported in our earlier paper. For the four central places that augment the present sample, we drew on the following sources: Angamuco^[50–52], Coixtlahuaca^[53, 54], Izapa^[55, 56], and Tzintzuntzan^[57–59].

In prehispanic Mesoamerica, the populations of the region’s major central places as well as the sizes of the territories associated with them gradually grew over time (Figs. 3a and 3c). But this increase in center or polity size was neither uniform nor linear. What most stands out in these graphs is the marked scalar difference for the Aztec imperial realm and its capital (Tenochtitlan) during the Late Postclassic period, compared to the size of any other polity or center earlier in the sequence. The writing index (Fig. 3b), the array of uses of writing, also increased over time, although there is marked variation in the index at all times. The highest writing indices occur in the Maya region during the Late Classic period, so they do not temporally or spatially correlate with the largest polity territory or settlement size (Aztec empire, Tenochtitlan).

Across macroregion to macroregion, we also found little consistent correspondence between polity size and the breadth of uses for writing (Fig. 4). For most of the Mesoamerican macroregions, the multistep expectations of Shin et al.^[5] were not met. For example, in the Maya region, the burst of writing innovations during the Classic period^[60], including the longest texts and the calendar able to track the longest temporal episodes, was followed by a time of lower macroregional, polity, and center size populations during the Postclassic period. In West Mexico, even when center sizes grew large during the Postclassic period, there was no evidence of writing. Only at the scale of Mesoamerica as a whole and in the Central Mexican macroregion, where the Aztec empire ultimately was centered, do the sequential expectations of Shin et al.^[5] generally fit the historical sequence.

In Central Mexico, the rise and fall of Teotihuacan^[61] were followed by advances in computational communication that were timed with slow (or no) demographic growth, and then by rising populations, which were associated with the foundation of prehispanic Mesoamerica’s largest city (Tenochtitlan) and polity (the Aztec empire). Thus, there is a degree of conformance with stepped model^[5]. At the scale of Mesoamerica as a whole, we also see a sequence of

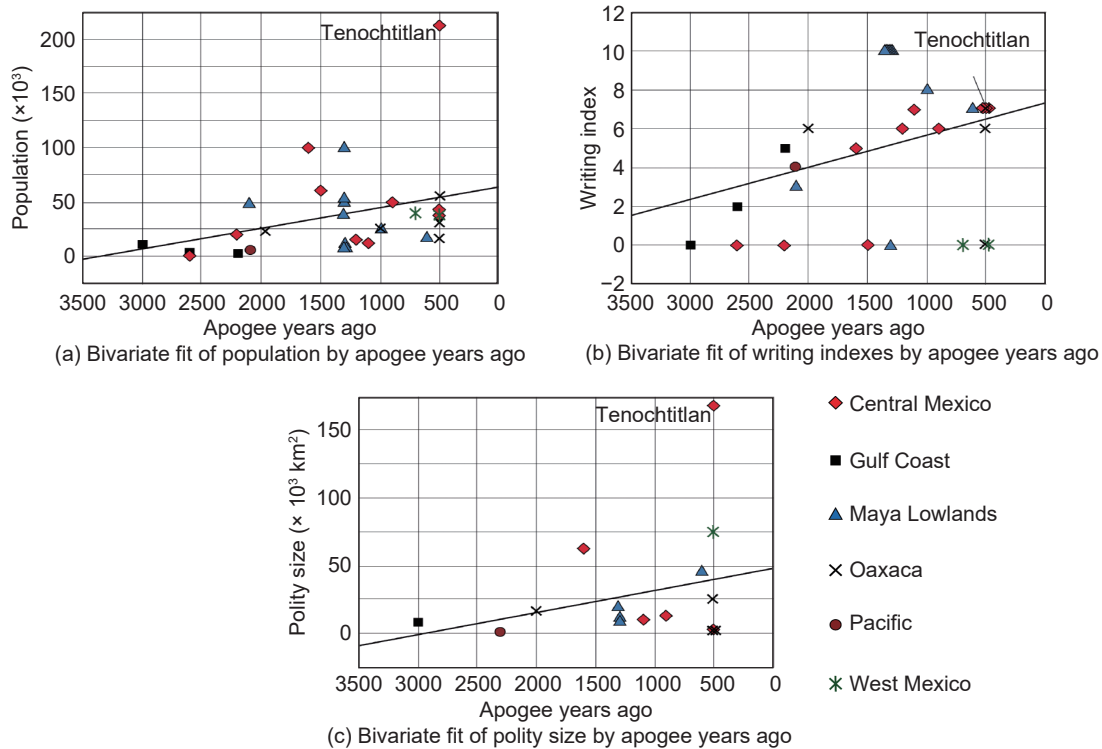


Fig. 3 Prehispanic Mesoamerica: Temporal trends in settlement population, territory, and writing.

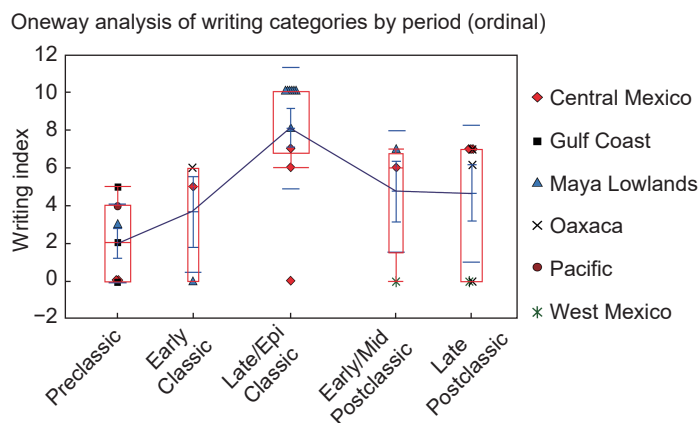


Fig. 4 Uses of Mesoamerican writing over time.

change that aligns with the predictions of Shin and colleagues^[5]. High Classic period populations and center sizes across much of the Mesoamerican world were followed by political breakdowns, population dispersals, relative demographic stasis, and decreases in center sizes during the Late Classic (in certain regions), Epiclassic, and Early Postclassic periods (ca. 700–1200 CE). Following the rise of new centers and the reorganization of long-distance networks across Mesoamerica^[62], populations increased in many regions across Mesoamerica (especially highland regions), so that the population of the Mesoamerican world was higher at the time of the Spanish invasion than at any time earlier^[63, 64].

For both the Central Mexican macroregion and Mesoamerica as a whole, it is the growth in scale and computational communication technologies during the Aztec empire that fosters a general conformance with the expectations of the stepped model in which populations did not increase as rapidly as the pace of innovations in computational communication, and then a more pronounced demographic increase follows^[5]. As evidenced at the scale of Mesoamerican centers and polities, there are only the weakest relationships between the functions and applications of writing (as measured by the writing index) and the scale of centers and polities (Table 2; Figs. 5c and 5d). The relationship between center size and the writing index is only weakly positive ($r = 0.14, p = 0.47$) and basically random if Tenochtitlan is removed. On the other hand, polity size and the writing index are negatively related in this sample ($r = -0.02, p = 0.95$) whether or not Tenochtitlan is included.

6 Conundrums and Questions to Probe

Several further observations raise issues and questions

that require more in-depth historical probing. Although the writing index for Tenochtitlan was as high or higher than it was for most of the cases in the 30-center Mesoamerican sample, it was lower than for Classic Maya centers, which were smaller in size (the spatial and demographic scales of their associated polities also were much less extensive than the Aztec empire). Furthermore, no major breakthrough in communication or computation either occurred within a century or two before or is directly associated with the foundation of Tenochtitlan (ca. 1325 CE) and subsequent expansion of the Aztec empire. Nevertheless, the writing index for Tenochtitlan was higher than for prior highland (non-Maya) Mesoamerican centers.

Any consideration of communication/computation technologies in prehispanic Mesoamerica also must address why the Classic Maya writing system, which was used most voluminously, was associated with the longest prehispanic Mesoamerican texts, and was employed to convey a diversity of informational messages (hence the high writing indices), was no longer employed anywhere in Mesoamerica after the early tenth century CE. Likewise, the calendrical system that could most accurately track extended cycles of time, the Long Count calendar, also dropped from use with the fall of Classic Maya polities. Other representational means of communication that were employed by the Classic Maya, including *mapas* (the geographically situated historical narratives) and styles and conventions of polychrome mural painting, were conveyed from the Maya region to the highlands during the Epiclassic period^[46, 65]. So why weren't the Long Count and the Classic Maya writing system similarly transferred to other regions in Mesoamerica, or used at Postclassic centers in the Maya

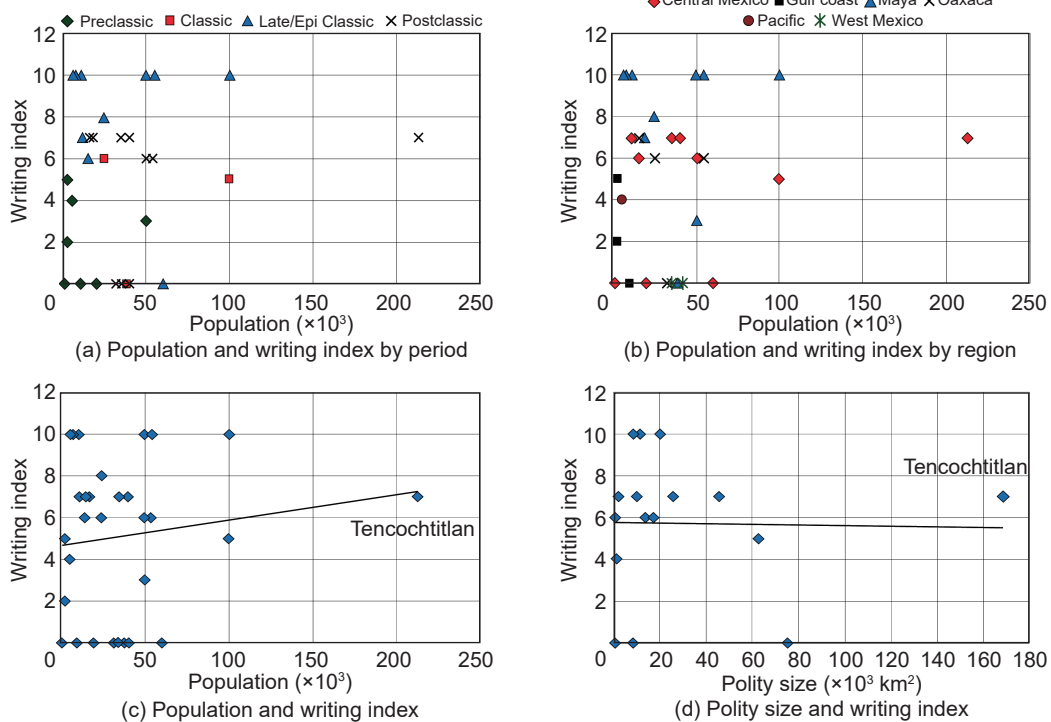


Fig. 5 Population, polity size, and writing index.

region, such as Mayapan? As Stuart^[66] has clarified, the Classic Maya had more than one system of numeration. The Long Count was able to track big numbers and long epochs of time in calendric cycles. But other means of counting also were employed, and these systems of numeration endured into the Maya Postclassic.

To address these broad questions and others concerning variability in prehispanic writing systems, we have to look a bit deeper into the contextual differences in the uses of writing and other computational systems across space and over time in Mesoamerica. As Trigger^[67] has argued in his global comparative study of early writing, efficiencies alone are not sufficient to explain the diversity and transference of writing systems. Rather, to address the variability, we have to consider the principal situations^[68, 69] in which writing was employed. What were the main communication channels? Who were the main intended audiences?

In prehispanic Mesoamerica, the act of writing or producing texts tended to be associated with high status and political principals^[70]. Nevertheless, because prehispanic Mesoamerican governance was not organized in a uniform way^[15, 24, 71], the situational contexts and the audiences for communication, writing,

and calendrics were variable. In some contexts, most written communications were long, intricate, and aimed largely at small, literate audiences (readers) of fellow elites^[36]. In other contexts, texts were short, specific, embedded in representational images^[38, 72], and, perhaps, not directed mainly toward a narrow status cohort. In this regard, it is also necessary to restate that modes of computational communication, including writing, are not the sole means to convey information to large groupings and that oral communications and public rituals, sometimes in concert, can convey and bidirectionally transfer messages^[10].

With a focus on governance, and variance in channels of communications between principals and subalterns, we narrow our focus to four more-specific questions concerning Mesoamerican systems of computational communication. (1) Why were they so variable in time and space throughout most of the prehispanic sequence, despite a narrow range of variability in the size of centers and polities? (2) Why were both writing and calendrics developed to such an elaborate degree at Classic Maya centers? (3) Why did so many aspects of Maya hieroglyphics and the Long Count calendar diminish or cease after the tenth century CE? (4) The Aztec empire reached unprecedented levels in the size of its capital and

polity; what were the accompanying shifts in systems of computational communication, if any? Before addressing these questions more directly, we offer brief perspectives on governance and its variability in prehispanic Mesoamerica.

7 Variance in Governance and Associated Technologies of Communication

Our approach to variation in governance looks mainly at the continuous axis that runs from highly distributed (collective) to highly personalized (autocratic and despotic) power relations (Table 3). As writing and associated technologies were principally associated with leadership and governing principals in Mesoamerica, how messages were communicated and to whom fosters certain modes of communication and computation and, perhaps, constrains others. Specifically, in comparing Mesoamerican political organization, we draw from collective action theory^[73] and an analytical framework focused on the fiscal financing of collective action^[17, 21, 74, 75].

From this empirically grounded perspective, based on 30 premodern cases^[21, 74], the funding of premodern governance is closely tied to both the distribution of power and the way government is organized. When the fiscal finances of governance are mainly derived from internal resources (e.g., local taxes, local labor drafts, and market participation taxes), the local government is likely to be both more responsive to its citizens and more concerned with their well-being. For that reason, high degrees of governmental dependence on internal resources tend to be associated with more robust

dispersals of public goods and services. Since the provisioning of such goods and services as well as the collection of tax revenues require personnel allotments to implement, reliance on internal resources tends to be linked to greater bureaucratic and infrastructural investments. Likewise, governmental dependence on internal resources, which fosters a concern with local well-being and trust, tends to dampen the hoarding and flaunting of wealth and power. In these settings, governance tends to be organized more collectively, with shared power, institutional checks and balances, and fewer wealth disparities (Figs. 6 and 7).

Alternatively, when governance is economically reliant on external resources, defined as sources of revenue not exacted from the local tax-payers/citizenry (e.g., control of trade routes, hoarding of spot resources, or the holding of slave estates), it tends to be structured more autocratically with fewer checks on the concentration of individualized power^[21, 75]. Principals who rely on external resources are less dependent on the exaction of labor and taxes from the local population, and so they are less inclined to negotiate with the local population or to provide ample public goods and services to their subaltern subjects. Likewise, they are less likely to expend resources to gauge and foster the well-being of their citizens. In autocracies, transactional, interpersonal alliances and patron-client relationships tend to define the active workings of governance in lieu of bureaucracy (Figs. 6 and 7).

In prehispanic Mesoamerica, more collectively organized governments tended to be associated with large, open public spaces (e.g., plazas) and broad

Table 3 Axes of collectivity for premodern complex societies.

More collective	Less collective
Shared or distributed power	Individualized power
Internal revenues: regularized taxation, a focus on staple finance and regional goods	External revenues: long-distance trade, importance of portable wealth, spoils of war, and control of spot resources
More communally owned or managed land	Less communally owned or managed land
Fewer disparities of wealth in life and death	Greater disparities of wealth in life and death
Political ideology emphasizes abstract principles of offices and strength of the polity, cosmology, and fertility	Political ideology emphasizes lineal descent systems for succession and legitimation, divine kingship and royal patron deities
Not centered on palaces	Centrality of palaces
Monumental architecture fosters access (e.g., open plazas, wide accessways, and community temples)	Monumental architecture fosters exclusivity (e.g., elite tombs and memorials, dynastic temples)
Greater expenditures on public goods	Smaller expenditures on public goods

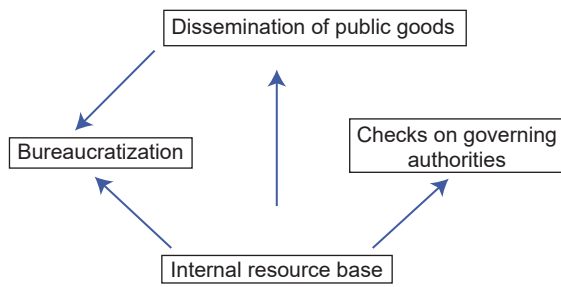


Fig. 6 Processes of collective governance.

Governance:	Less collective	More collective
	←————→	
Variable:		
Bureaucratization	Low	High
Control over principals	Low	High
Public goods	Low	High
Revenue source	External	Internal

Fig. 7 Variability in governance.

thoroughfares^[19, 24]. Such spaces facilitated public interchange and interaction, while providing opportunities to gauge citizen voice and to deliver ritual and other messages from principals to the broader population. Such large public spaces are much rarer in prehispanic Mesoamerican centers that were governed more autocratically. In general, with autocratic governance, plazas were smaller, more restricted, with limited access. The venues and audiences for statecraft and political communications seemingly varied between collective and autocratic governments. Whereas the former fostered communications between principals and subalterns at large spatial scales, autocratic governance involved more targeted interpersonal communications between small, high-status networks of allied equals or rulers with their subordinates.

To compare the 30 prehispanic Mesoamerican central places in our sample (Table 2) along the

collective–autocratic axis, we employed a three-criterion scale (Table 4). Each criterion— political economy, governance, and architecture— was scored nominally from 0–1 (less to more collective). The criteria were defined based on available data in the archaeological literature, and we relied on the reported findings^[24, 71] from the main investigations at each settlement both to assess each criterion and to derive population estimates for each site. In some instances when reported findings were equivocal, the cases were recorded as 0.5 for that attribute. The sum of the scores for the three criteria (the collectivity index) is presented in Table 2 for each central place, and they range from 0–3 (autocratic to collective). Twenty-two of the 30 cases in the sample have collectivity index values between 0–0.5 or 2.5–3.0, so in all but eight instances, the three criteria correspond in a manner that closely aligns with the theoretical expectations of the fiscal financing of the collective action framework^[21].

In prehispanic Mesoamerica, with no domesticated beasts of burden, limited uses of metal, and few navigable rivers, opportunities to monopolize trade routes or spot resources of value were rare. This may be one factor that underlies the Mesoamerican tendency toward more collective forms of governance. More than a third of the 30 central places in this sample have collectivity indices between 2.5–3.0, indicative of a high degree of collectivity in governance. This pattern seems to contrast with premodern Eurasia, where metal, wheeled transport, large-scale water-borne vessels, and horse travel (in nomadic empires) all had a far more significant historical role and served to underpin different processual linkages between polity scale, communication, and the concentration of wealth and power.

Table 4 Axes of collectivity[†] coded for Mesoamerican cases.

Variable/Score	1 – More collective	0 – Less collective
Political economy	Internal financing with greater focus on staple goods and market exchange; more muted socioeconomic differentiation	External financing with greater focus on prestige goods derived from long-distance exchange or control of spot resources; palace-centric production; more heightened socioeconomic differentiation
Governance	“Faceless” rulership; low mortuary differentiation; secular and bureaucratized political offices	Highly conspicuous rulers in burials and iconography; individualized rulers; divine kingship
Architecture	Emphasis on communal architecture over palaces, including temples, plazas, accessways; art emphasizing public goods	Palaces are more central and elaborate than communal architecture: art emphasizing exclusive access

Note: [†] Summed scores for each case range between 0 (least collective) and 3 (most collective).

We mention these differences because so many long-held expectations regarding early urban societies and links to the advent of systems of writing and communication were based mainly on Eurasia, where imperial expansions often involved episodes in which large swaths of territory were engulfed in brief temporal episodes of political consolidation^[76]. Likewise, the Seshat set of cases (and so the analytical samples in Turchin et al.^[4] and Shin et al.^[5]) are weighted rather heavily toward the Eastern Hemisphere. With animal and wheeled transport, conquest and supply were somewhat less costly despite the frictions of distance. As already outlined for Mesoamerica and in line with our discussion of further findings, we see only partial conformance with current preconceptions and models. This disjuncture may reflect that the conceptions of premodern society and governance that emphasize despotic power and state control of the economy^[77] are not, in general, a good fit for prehispanic Mesoamerica, or perhaps the precolonial Americas in general.

8 Mesoamerican Governance, Scale, and Writing

As we previously illustrated (Figs. 3 and 4), the size of Mesoamerican central places was not a good predictor of the writing index (the elaboration of writing). This lack of correspondence was apparent whether the data were organized by macroregion or time (Fig. 5). Likewise, polity size also did not closely correspond with the writing index (Fig. 5d). Rather, what stands out is the unprecedented size of the Aztec empire and its capital center (Tenochtitlan), which corresponded with a relatively high writing index, especially in relation to other non-Classic Maya centers, and the florescence of computational communication at Classic Maya centers basically without regard to their sizes.

At the same time, with the exception of Aztec Tenochtitlan, there was no temporal or linear trend in the elaboration of computational communication at prehispanic Mesoamerican central places. During all four periods represented, there was no evidence for writing at some central places in the sample (Fig. 5a). Central places with populations estimated at or below 60 000 people illustrated the full range of diversity in the elaboration of writing (Figs. 5a and 5b), with Cantona (approximately 60 000 people) having no evidence of writing at all.

For prehispanic Mesoamerican central places, population and polity size do align to a degree with more collective forms of governance (Fig. 8). In premodern contexts, the relationship between larger political units and more collective forms of governance is not historically unique to Mesoamerica^[11, 21, 78]. Nevertheless, what is perhaps somewhat surprising is the inverse correlation between the writing index and more collective forms of governance ($r = -0.23$, $p = 0.23$), which is one of the most negative correlations we encountered though not reaching the threshold of statistical significance at $p > 0.05$ (Fig. 9). If we re-ask the question, why doesn't the writing index correlate more closely with population for prehispanic Mesoamerican central places, it seems to us that variance in governance and what that means for statecraft and computational communication must be brought squarely into the discussion.

One thing to consider is that our coding of the writing index involved mostly top-down communication technologies. The main exception was the 260-day ritual calendar, which was used by a wide geographic cross-section of Mesoamerica's population, especially after the advent of the Common Era. But even where that calendar almost certainly was employed, it was not necessarily written down or recorded in ways that have endured. With these findings, it is necessary to take a more in-depth look at how statecraft and political interaction were enacted in prehispanic Mesoamerica and, more specifically, the differences between those interpersonal communications in contexts where governance was more collective in contrast to those where it was more autocratic.

9 Variability in Governance, Statecraft, and Associated Modes of Communication

One of the earliest^[28] and the most widespread glyphs that has been identified in prehispanic Mesoamerica, represented by many different writing systems, was the speech scroll or speech glyph. The ubiquity of this glyph and its frequent association with large, central personages or supernatural figures in positions (such as sitting and standing on elevated platforms where they could address associated assemblies) serve as evidence that speech and oratory were extremely significant dimensions of Mesoamerican political communication that were recorded for perpetuity. Oral story and myth

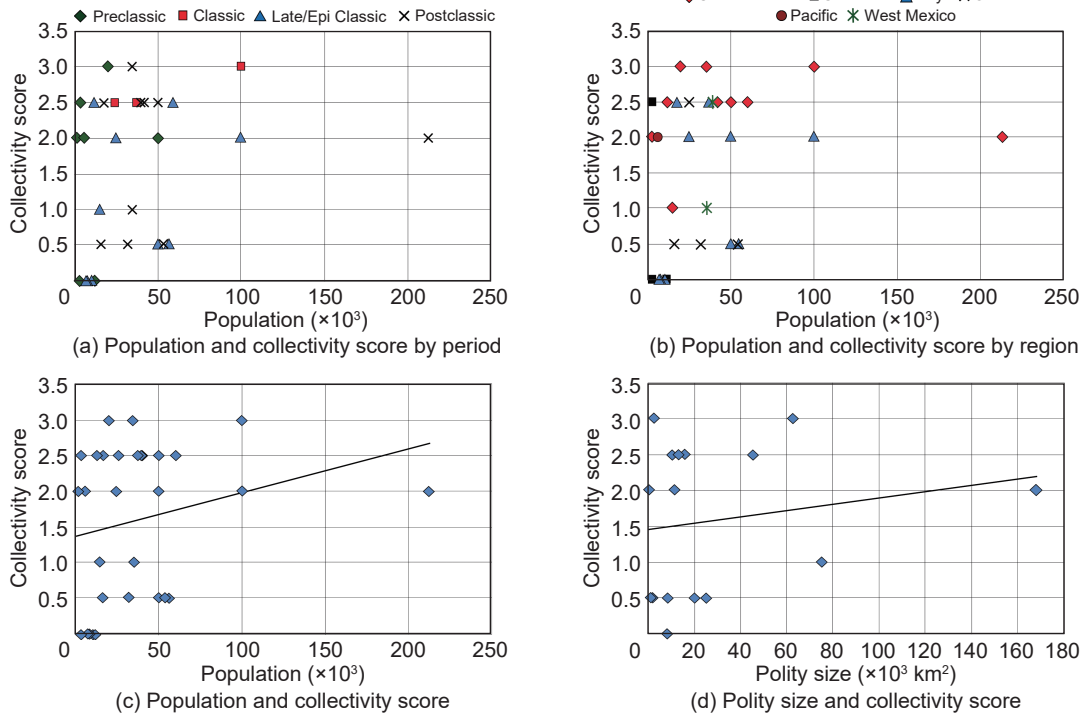


Fig. 8 Population, polity size, and governance.

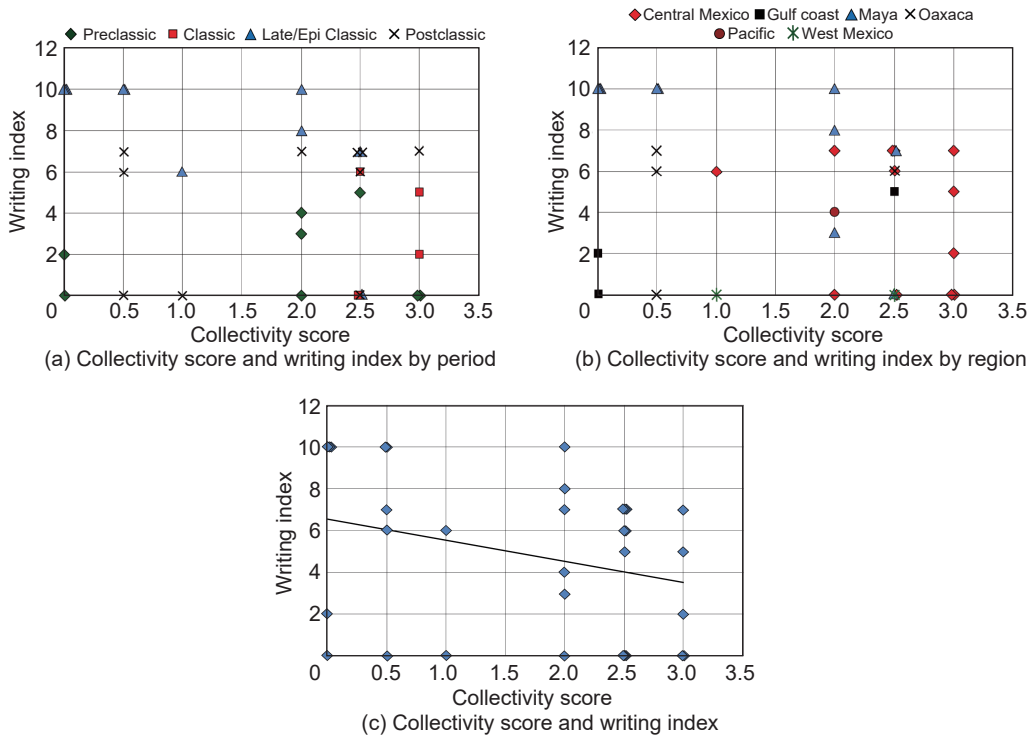


Fig. 9 Governance and writing index.

telling have a long human history, and such events can underpin social cohesion and cooperation^[79].

More specifically, beyond the pan-Mesoamerican representations of speech^[72], the Mayan word for king,

lord, or ruler (*ajaw*) and the Nahuatl (Aztec) word for ruler (*tlatoani*) both have their roots in words for speaking. Significantly, the Mayan word, *ajaw*, which literally means “person who shouts or cries out”^[80],

stems back to the Formative period^[81, 82] when Maya political organization was less autocratic than it was in the Classic period^[83]. In Nahuatl^[84], *tlatoani* means literally “he who speaks”. The association of leadership and power with oral communication in two prominent prehispanic languages would seem to point to the importance of orality in political action.

Likewise, for the Aztec, the same Nahuatl word was employed for “to write” and “to paint”^[85]. In comparative considerations of governance, statecraft, and associated communications, a broader vantage beyond written texts and scripts seems in order, as numerical and other messages were embedded in more representational mural art^[38]. Written texts were not the sole, or necessarily even a principal, means to transfer materialized information to large audiences, even when those messages were meant to be repeatedly conveyed.

With these caveats, we compare and contrast the dissemination and exchange of information in two well-studied Mesoamerican examples (Table 5), one with collective governance (Teotihuacan) and the other with autocratic rulership (the core Classic Maya central places, Copan, Palenque, and Tikal). Through a consideration of the contexts, intended audiences, and political communication networks that were manifest in these cases, we construct a foundation to account for why the population of central places and the writing index do not correlate more closely. Furthermore, we examine why computational communication reached the levels it did during the Maya Classic and why those technologies

did not endure, and what was the nature of the shifts that occurred in modes of communication in Aztec times as central place (Tenochtitlan) and polity sizes reached new heights. Teotihuacan and the Classic Maya centers cannot be seen as strictly representative of other Mesoamerican central places, but the stark communicational differences between the two cases help define patterned distinctions between collectively and autocratically organized central places in Mesoamerica^[86, 87].

Comparisons of written texts between the Classic Maya and Teotihuacan indicate major differences in contexts, intended audiences, and the kinds of messages transferred and recorded. At Teotihuacan, only a relatively small corpus of glyphs has been identified, but many of these are repeated or frequently represented^[88]. Texts are brief, and glyphs generally are presented as elements of (embedded in) larger representational murals that were painted on the walls of domestic contexts, and so access was not narrowly restricted. Teotihuacan glyphs do not have linguistic meaning, rather they represent or are associated with numbers, names of buildings, place names, or political offices/positions^[38, 41, 72, 89, 90]. Glyphs, whether integrated into murals or not, such as those recovered on the floor of the La Ventiila plaza^[45] and a recent carved stone glyph recovered at the Plaza of the Columns (Fig. 10), were both stand alone and relatively large.

In contrast, Classic Maya writing, which is found on a diversity of media, including carved stones,

Table 5 Differences between Teotihuacan and Classic Maya.

Integrative/ Communication technology	Teotihuacan	Core Classic Maya centers
Writing	Few glyphs/short texts, not linguistic, few texts	Many texts/diverse media /patrimonial/small glyphs (3–10 m viewing range), exclusive audience, linguistic (average longer length of text)
Mural/symbol	Domestic contexts, cosmological themes, no personal ownership	Restrictive spaces, portable goods in elite networks, individual ownership
Calendar	“Open-access” short-term cyclic calendars—fosters broad participation in calendric rituals, market rounds	Long Count—precise, restricted, scholarly
Public space	Large, more accessible	Small, restricted
Intra-settlement movement	Grid plan, wide thoroughfares	Spoke-wheel (all paths to center of community)
Education	Schools—qualified by class and ability	Elite versus commoners
Ritual	Processions, ritual activities involving coordinated movements	Dance-ruler spectacles, dance platforms for performances
Polychrome	Cosmological themes	Representations of courts, rulers

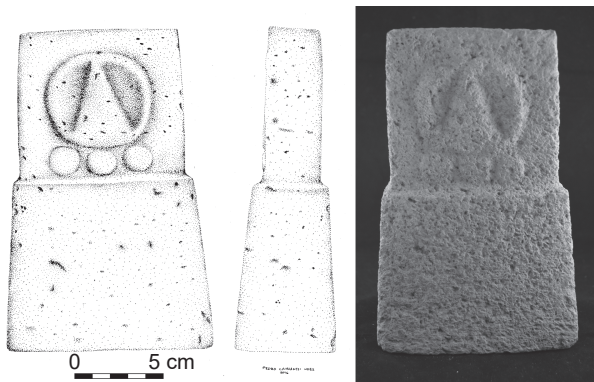


Fig. 10 Teotihuacan carved stone with glyph from Plaza of the Columns (Photograph by David M. Carballo, illustrations by Pedro Cahuantzi Hernández).

polychrome ceramics, and painted murals, generally was recorded in much longer texts^[60]. Including portable objects, there are estimated to be as many as 10 000 texts^[36], many times more than found for any other Mesoamerican writing system. Scholars have identified a greater number of Maya glyphs (650–700 CE) compared to any other Mesoamerican script^[91]. The accessibility of Classic Maya texts likely was highly variable. Some Maya may only have been able to recognize but not cognize the meaning of written glyphs, but they could have been guided in deciphering content by the scenic representations that generally accompanied texts^[92]. To a degree, Maya writing had a linguistic foundation^[93], so some practiced individuals may have been able to sound out sections of texts. Nevertheless, the full reading, and especially the preparation of written transcripts, required extensive training and likely was limited to a select few^[36, 94]. Although our knowledge of schooling and training is limited, Maya schools were seemingly class stratified^[95, 96] with high-status Maya segregated from others and instructed by specialists who conveyed special ritual knowledge. This seems to contrast with the more open Plaza of the Glyphs, which is thought to have been a context for pedagogy and is situated in the La Ventilla residential compound at Teotihuacan. Later Aztec schools also allowed for degrees of social mobility and were not entirely segregated by status^[96].

Classic Maya texts on stone tended to be situated in small, restricted contexts, including closed or limited-access plazas at the center of Maya cities, in association with elite burials, and in public buildings and palaces where only few could venture. Generally, Maya

glyphs carved in stone were small and had to be read within distances of three to ten meters. Maya murals^[97] also tended to be painted in elite-restricted contexts, while polychrome ceramic vessels often depicted courtly scenes, centered around powerful lords, and these highly crafted objects tended to be made for (and gifted between) the powerful^[98]. The scenes and messages painted on these portable vessels affirmed and reinforced relationships spelled out in greater detail on stone inscriptions^[99].

Thematically, Classic Maya writing was focused on the life-crisis events of divine kings^[100], their accessions, conquests, and diplomatic alliances^[35]. Much of the content has been interpreted as patrimonial rhetoric^[15, 35], focused on lordly legitimation and transactionally targeted (at least in terms of the detailed textual messages) at small numbers of fellow elite in the royal court and beyond^[101]. At the same time, the associated personalized, often self-aggrandizing, representations of rulers and lords that accompanied the texts clearly were aimed at broader audiences and meant to affirm rights to rule, links to divinity, and the personal role of lords in maintaining order in the universe^[35, 102, 103].

The Maya Long Count calendar was integrally linked to Classic Maya patrimonial rhetoric, which was deeply individualized, and for which the calendar served to order heroic biographies that included accessions, inscribed rituals, diplomatic visits, battles, successions, and the like into cyclic histories that interwove myth and history^[35]. At the local scale of specific central places, the calendar was employed to record dynastic successions and sequences, a foundation for legitimacy. The erection of standing stones, many of which included lengthy inscriptions in which the calendrical text consumed significant proportions of space, and associated rituals reenacted supernatural performances in the deep past and thereby constituted universal continuity and order^[35]. The tenets of this order, and the hieroglyphic writing and calendric systems that helped maintain it, extended across the Classic Maya world well beyond the territorial footprints of individual sites or polities.

In contrast to the Classic Maya pattern of situating lengthy texts in locations of restricted access, with the texts written by literate specialists primarily for a limited, status-selected audience, Teotihuacan murals and other

representations with glyphs tended to be placed in domestic and more public contexts, generally open to more socially diversified viewers. Thematically, mural art at Teotihuacan focused on cosmological themes with an emphasis on fertility^[104, 105]. Although a case can be made that Teotihuacan mural art may occasionally depict an individual ruler or officeholder^[106], these individuals are not named, nor are they contextualized with patrimonial rhetoric or listed in sequences of genealogical succession, all of which are prominent features in Classic Maya texts. Rather, the murals at Teotihuacan feature processions of masked figures in similar, fine attire^[72], thereby lacking the personalization so evident in Classic Maya representations. Recent studies have begun to decipher a cycle of rituals, which included processions and other communal events, and were tied to the Calendar Round^[38, 104].

Like the murals, elaborate ceramic vessels and censers featured oft-repeated cosmological symbols and fertility themes that echo the visual themes and communicated messages evident in Teotihuacan's murals. The supernatural entity Tlaloc, associated with storms, rain, and fertility, was ubiquitously represented in Teotihuacan^[105], a stark contrast with the Classic Maya where different dynasties were associated with their own patron deities^[107]. At Teotihuacan, the unifying themes of community fertility and prosperity were not directly tied to individual royals with claimed links to specific supernatural agents but were more generally associated with participation in and adherence to cycles of ritual that defined what it meant to be Teotihua^[105].

Whereas the Classic Maya employed both the Long Count and the Calendar Round, only the latter was broadly utilized at Teotihuacan, though rare examples of painted Maya-style glyphs demonstrate Teotihua were aware of the Long Count^[39]. Comparative calendrics further illustrates the major distinctions in computational communication between these two governance regimes^[108]. For the Classic Maya, the Long Count was the nearly exclusive domain of priests and scribes, who themselves were elite and frequently titled^[35, 109]. They were direct dependents of royal dynasts, and their lives and livelihoods rose and fell with their superiors, whose exploits they were charged with promoting to those of comparable standing, to allies, and even to enemies of their lord^[35, 109, 110]. The precise Long

Count allowed for the linear tracking of historical events and personalized royal narratives, albeit embellished with myth and belief. Classic Maya histories were monopolized by the elite; commoners were rare, if not absent, in the large corpus of textual accounts^[110]. Classic Maya recorded histories, imbued with patrimonial rhetoric, were aimed principally at legitimation, the building of diplomatic alliances, and the maintenance and growth of personalized power.

In stark contrast, at Teotihuacan, the short-term Calendar Round was the primary means of reckoning time. It served to mark annual cycles of participatory rituals^[38, 104] and likely helped synchronize the timing of long-distance market exchange networks^[111]. Thus, reading the Calendar Round was by design both less restrictive and more "open-access" than the Long Count. At Teotihuacan, there were at least two means available to monitor the Calendar Round. One was reliant on building alignments^[112, 113] and so must have been established early in the city's history, whereas the other was dependent on the daily movement of pebbles through a sequence of small depressions that were carved into flat surfaces and arranged as a double circle "pecked cross"^[114–116]. During Teotihuacan's history as a great metropolis, both of these means of tracking the Calendar Round were emulated across much of Mesoamerica (Fig. 11)^[111, 117, 118]. Accordingly, while the Calendar Round was a chronological foundation to bring people together, both within and between settlements, through seasonally timed rituals, the Classic Maya Long Count, and the texts dated by them, were exclusive technologies and texts, understood by (and targeted to) a highly limited elite segment of the Classic Maya population.

A similar contrast between the Classic Maya and Teotihuacan also is evidenced in the layouts and venues where written communications were read or likely read out orally. For the Classic Maya, murals and stela often were positioned in circumscribed contexts, accessible only to a limited elite few. These contexts include interior spaces, associated with funerary rituals and ancestral veneration^[119]. Monuments with texts also were situated in more ample central plazas often adjacent to palatial courts and residences. The larger events in these venues are interpreted to have been spectacles, focused on the dances and performative enactments of kings with messages of ostentatious display and

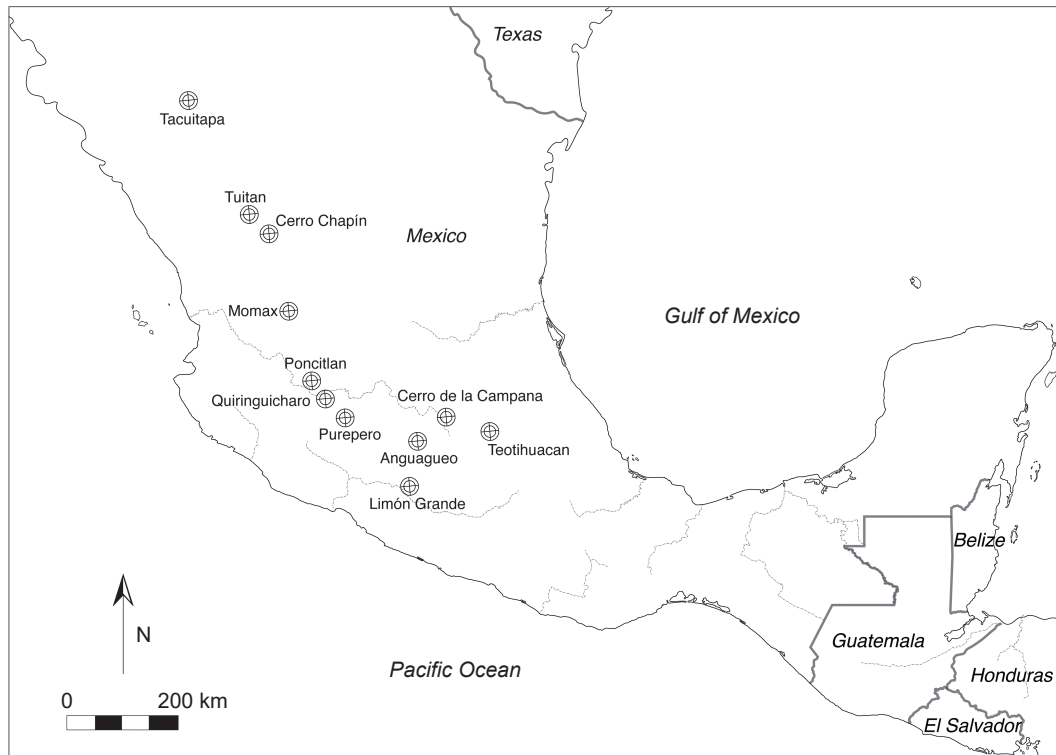


Fig. 11 Geographic distribution of pecked crosses in Mesoamerica.

aggrandizement communicated almost exclusively from the top down^[120–122]. At Teotihuacan, the city's wide thoroughfares and large, open public spaces likely were settings for processions and other large coordinated ritual activities that seemingly involved greater degrees of collective action and participation^[106].

Teotihuacan and the Classic Maya are at opposite poles in regard to the variances between more collective and more autocratic forms of prehispanic Mesoamerican governance. And yet, the patterns found through this contrast generally correspond across the larger sample of cases^[24, 71]. With this context, it begins to get far clearer why we encountered barely any correlation between the writing index and population across prehispanic Mesoamerican central places and why the degree of collectivity and the writing index were inversely correlated. In the autocratic world of the Classic Maya, written accounts were aimed solely at a small subset of the population, and the Long Count situated recorded historical events in ways intended to legitimate and consolidate power^[35]. At Teotihuacan, in contrast, access to and understanding of the technologies and computational communication were more open, inclusive calls to action for participatory rituals in which information flows were likely to have been somewhat

more bidirectional and not entirely from the top down.

These differences also provide a basis to account for why key practices associated with the Classic Maya writing system and the Long Count dropped from use with the collapse of the Classic Maya political system (ca. 950 CE). Why were these seemingly precise and efficient technologies not adopted by other Mesoamerican peoples? As Maya lords lost their political clout, and Maya populations dispersed during the last centuries of the first millennium CE, the royal patrons of these technologies could sustain neither their dependent entourages of priests and scribes nor the pedagogical (likely palatial/courtly) contexts through which these technologies were passed^[123]. The Maya writing system and the Long Count were so integrally intertwined with the top-down, courtly politics of the Classic Maya that the technologies—known and used by high-status scribes—were largely untransferable in a post-Classic Maya world in which populations had declined and most surviving polities were organized and governed more collectively.

10 Prehispanic Mesoamerican Temporal Overview

To this point, we have illustrated that in prehispanic

Mesoamerica, there was a relationship between modes of communication and computation and the scale of settlements and polities. Nevertheless, to make sense of this complex correspondence, analytical attention must be expanded beyond those communication technologies that leave an explicit computational referent and deliberation broadened to consider orality, representational art, and interpersonal rituals, all of which may convey important information that fosters affiliation, trust, information transfers, and interdependency. Although for prehispanic Mesoamerica these means of communication may not leave clear remnants like preserved texts and calendar dates, they may provide decipherable clues, including spatial layouts and architectural remains. Based on the comparison of the Classic Maya and Teotihuacan, we also have shown that the pathways to larger-scale human settlements and political affiliations were far from uniform in the prehispanic Mesoamerican world. To understand how the Aztec empire transcended the scalar constraints that were in place prior to its formation and growth, we draw on the above findings and place the Aztec empire in a longer temporal context.

The diachronic overview of pan-Mesoamerican change that follows is necessarily abbreviated (Table 6). As background, we restate that prehispanic Mesoamerican governance tended toward collective forms^[15, 24, 71]. This was especially the case prior to the beginnings of Classic Maya kingship during the last two centuries of the prior era^[35]. The only seeming exception at that time were the Gulf Coast Olmec centers of San Lorenzo and La Venta, where giant stone heads of important individuals were carved and erected^[124]. Yet, at their time, settlement and polity sizes were small compared to just centuries later.

From a pan-Mesoamerican world perspective there were four episodes when the scale of settlements and/or polities increased markedly. Each of these episodes was preceded by (or roughly coincided with) the establishment of new sociospatial contexts or the advent of novel computational technologies that facilitated or expanded the potential for interpersonal communication. The four periods of growth were: (1) around 1500 BCE by which time relatively permanent communities were established across Mesoamerica^[124, 125], (2) between 500 and 300 BCE when Mesoamerican central places grew beyond 10 000–20 000 people in size, (3) from 100–

500 CE when one city (Teotihuacan) expanded to 100 000 people and polity sizes were even larger^[61, 106, 126], and (4) 1300–1520 CE, which encompassed the foundation and rapid growth of Tenochtitlan and the Aztec empire^[127, 128]. Although not amenable to concrete measurement, each of these episodes seems to have co-occurred with overall demographic expansion in the prehispanic Mesoamerican world^[64].

Three thousand years ago, sedentary community formation in Mesoamerica was preceded by (or at least coincided with) the building of large platforms, likely ritual spaces^[129]. At the same time, some early Mesoamerican villages had open plaza spaces at or near the center of the settlement. In both cases, these open spaces provided grounds for interaction, oral communications, and ritual. One thousand years later, the establishment of the earliest cities in several macroregions, including Monte Albán, Cuicuilco, and El Mirador, were immediately preceded by the advent of writing systems and the Calendar Round. During the early centuries CE, the growth of cities and polities of even greater sizes were preceded by community layouts that facilitated traffic flows, such as grid plans^[130, 131], the growth of interregional market and exchange networks^[111, 132], and in the Maya region, the widespread adoption of the Long Count. Over the course of the first millennium CE, the sizes of centers and polities in Mesoamerica seemingly did not eclipse those of Teotihuacan and its political domain. Nevertheless, in the Maya region, central plazas reached their maximum prehispanic extent. To recapitulate a key point from the prior section, the suite of communication modes and the forms of governance at this time were diametrically different in the eastern (Maya) and western (Central and Southern Highlands) sectors of Mesoamerica.

The fourth episode of Mesoamerican population increase in the sizes of cities, polities, and population as a whole occurred during the final centuries of the prehispanic sequence. Tenochtitlan, the largest prehispanic city, was established and grew expansively. Both the Aztecs and the Tarascans constructed empires, and Mesoamerica's overall population reached unprecedented heights. In the realm of communication, perhaps the most significant shift was the transfer of an element of Classic Maya communication practice (*mapas*)—historical narratives grounded in specific geographic settings^[46]—into the highlands during the

Table 6 Temporal trends in Mesoamerica.

Region	>2000 BCE	2000–1500 BCE	1500–1000 BCE	1000–500 BCE	500–1 BCE	1–500 CE	500–1000 CE	1000–1520 CE
Central Mexico			Plaza, symbolic communications		<i>Synchronization of markets</i> (Teotihuacan)	<i>Grid-planned city, pecked cross ("open source" 260-day ritual calendar)</i> (Teotihuacan)	<i>Cosmological mapas (stone and murals)</i> (Cantona)	<i>Metal currency, cosmological mapas on paper (codices)</i> (Tenochtitlan)
Oaxaca	Dance ground		Plaza, symbolic communications	Glyphs, 260-day calendar on stone	260 + 365-day calendar, marketplace exchange, market synchronization, temples (Monte Albán)			Personalized mapas on paper (codices)
Gulf Coast			<i>Plaza, symbolic communications, calendar, day-ruler portraits</i> (San Lorenzo)	<i>Ritual names, glyphic numerals, ruler name glyph on seal</i> (La Venta)	Glyphs on stone			
Isthmus/Pacific Coast		<i>Ballcourt</i> (Paso de la Amada)	Plaza, monumental symbolic communication					
Maya			E-groups	Gridded community plan (1 site)	Long Count, divine kingship, synchronization of markets (El Mirador)	Leaders portrayed on stelae, portable objects with legitimating texts (Tikal)	Personalized mapas (stone, murals), long texts on stone, ceramics with legitimation scenes/texts, specific political titles/roles (Tikal)	
West Mexico								Metal currency and tools

Note: Bold text denotes periods with pulsations in growth in the size of centers. Italicized text denotes the location of the largest center for each temporal block. Largest site in each region listed in parentheses.

Epiclassic period (900–1100 CE) and their eventual repurposing in Central Mexico.

Throughout the prehispanic sequence, the transfer of communication and computational technologies (*mapas*, the Calendar Round, and even the Long Count early in its history) indicates that these technologies could be adopted in regions and cultural settings beyond where they were first employed. But whether they actually were diffused and adopted depended in part on the modes of governance and computational communication in the regions outside their points of use.

Mapas were a key dimension of Classic Maya communication^[35, 46]. Narrative histories focused on dynasts, dynasties, their dependents, and allies, centered in geographic space and time, were prominent in the corpus of known Maya texts, with accounts represented in sequences of carved stone monuments and other architectural elements as well as polychrome murals. It seems likely that literate scribes may have documented these accounts in books, which facilitated their serving as ambassadors or enforcers, but we have no direct proof for such records. Nevertheless, it is clear that the

information in the *mapas* and associated texts^[35, 37, 133] has left us a record beyond individualized histories that documents political alliances, expansions, contractions, emissarial visits, and conquests. The oscillations in the sizes and extents of Maya polities, and the ebbs and flows in monumental construction and stela erection, are reflected in these shifting interpersonal networks and their links with specific palatial courts and dynastic fortunes. Maya polities grew through interpersonal networking and scaffolding, the linking together of similar, small, center-focused polities. The fragility of these interpersonal top-down “scaffolds”, which were not underpinned by more integrative socioeconomic interconnections, is evidenced in the frequently shifting political landscape of this epoch.

Following the fall of many of the core Maya centers by the tenth century CE, and the dispersal of populations from the Petén and adjacent regions, key elements of Classic Maya communication were transported to the highlands as pan-Mesoamerican networks of interaction were reconfigured^[62]. These elements included *mapas*^[46], polychrome mural art^[65], and specific aspects of calendrical knowledge^[134]. Initially, *mapas* were employed in the highlands to record individualized narratives as at Cacaxtla^[65]. A century or two later, in the Valley of Oaxaca following the decline of Monte Albán and an episode of political fragmentation into small city-states that were organized autocratically^[135], a historical narrative focused on royals was recorded on palatial lintels at the site of Mitla^[136]. Similar-style *mapas* were the thematic basis for the Mixtec codices^[137], which documented royal histories, marriages, conquests, and alliances in a manner that parallels the texts of the Classic Maya but lacks the precise dating (of the Long Count) and lengthy associated inscriptions. As seen for the Classic Maya, the elite-driven alliances and scaffolded courts that knit together confederations of Postclassic Mixtec/Zapotec city-states (in Puebla and Oaxaca), which in some instances were recorded in the codices, tended to oscillate in their spatial extents and have limited durability^[138].

Aztec imperial expansion was a centuries-long, multistep process, which involved both the politico-economic consolidation of small city-states in Central Mexico under the Aztec Triple Alliance and the hegemonic conquest and expansion of the empire over a large swath of Mesoamerica^[139, 140]. In service of the

former process, *mapas*^[46, 141, 142] were repurposed in Postclassic Central Mexico, from their prior themes focused on individualized dynasts, their legitimacy, kin, allies, and histories to origin and migration accounts that wove together the coming and shared “rags-to-riches” successes of the peoples at the core of the Aztec polity^[140]. These historical narratives grounded and expounded the joint identity and the victories of what clearly was a multiethnic populace. Because of their significant pictorial content, these texts are reasoned to have been readable by the speakers of different languages who were integrated into the Aztec empire^[143]. At the same time, some of these mythic histories outlined a kind of social contract that was not entirely top down, patrimonial, or exclusive to a single ethnic or language group. These documents (and their oral analogues) legitimized distributions of power, recorded historical alliances, and chronologically linked sequences of events that were not tied to a specific person or a lineage; instead, they were explicitly centered geographically at the core of the empire, its capital^[141]. Nevertheless, adherence to legal coda was not necessarily uniform across geographic space or degrees of political power^[144].

From the standpoint of communication, the practices of the Aztec empire were not distinguished by a single technological breakthrough, but rather saw the utilization of a wide repertoire of communication and computation modes. Some of these previously tended to be associated with more collectively organized central places, such as seasonal/calendric cycles of participatory rituals and processions^[145, 146], and others parallel the practices generally associated with more autocratic polities. The latter include the tracking and presentation of a sequence of dynastic successions, as represented by a conquest monument known as the Tizoc stone^[147, 148], and the forging of tactical elite/marriage alliances^[149]. On the other hand, the Aztec also employed computational systems that recorded imperial tributes, as well as written registries of tax records and censuses on household landholdings^[150]. The latter records provided a critical basis to establish equitable modes of taxation based on potential agrarian productivity, a form of information storage and communication underpinning a system of internal exaction that would not be typically present in a highly autocratic polity^[21].

In building empire, the Aztec employed a diverse mix

of cosmological, bureaucratic, and patrimonial messaging and communication (to a far greater degree than in prior eras); the governing practices of the empire likewise were intermediate between collective and autocratic^[24, 71]. At the core of the Aztec empire, political and economic integration was more organic and interconnected^[20, 21], so that the prior organizations of previously autonomous city-states were broken down and reconfigured^[151]. At the same time, in distant provinces, local rulers were left in place. In general, these outlying defeated states were not deeply transformed or reconfigured politically or economically; rather they were scaffolded into the imperial core, through transactional alliances and marriage ties that also required the payment of taxes and tribute to Tenochtitlan^[139].

11 Synthetic and Speculative Thoughts

In line with previous research^[4, 5], we have documented empirically that the scale of prehispanic Mesoamerican central places and polities had a weak, though perhaps less robust than expected, correspondence with the degree of elaboration in systems of communication and computation. We have shown that a fuller understanding of this relationship is gained when the analytical scale is expanded to the Mesoamerican world as a whole, since systems of communication are amenable to transfer under certain conditions. We also suggest that in premodern worlds, oral communication and participatory rituals were important bases for the dissemination of key information and for building social cooperation and cohesion, especially in those instances where power was more distributed and governance was not explicitly top down. A key finding from this analysis is how distinctive systems of communication and computation were in those cases where governance was collective as opposed to those where governance was autocratic.

In prehispanic Mesoamerica, highly autocratic, top-down governance, most demonstrably for the Classic Maya, tended to correlate with more elaborate writing and computation systems. Alternatively, at central places where governance was more collective, systems of writing were less heavily used, left a far sparser material record, and were less capable of conveying detailed or precise information. This distinction is provocative and raises important questions concerning

the key differences in the nature of writing and communication systems in the Americas versus Eurasia during premodern times. The Classic Maya illustrates that peoples in the indigenous Americas were fully capable of devising highly elaborated systems of writing, numeration, and calendrics, so why weren't similar technologies more prevalent and widespread in the pre-colonial Western Hemisphere? What does this tell us about hemispheric differences and tendencies in modes of governance? Did more available pack animals, greater potentials for water-borne transport, and a larger role for metal and coinage have impacts on polity sizes and governance and, therefore, affect prevalent modes of computation and communication?

At the same time, the sociospatial context of the Classic Maya—with numerous autocratically organized polities that shared a suite of elite traditions and practices, and where competition between the leaders of the polities was rampant—seems to be one in which pre-alphabetic systems of writing were subject to episodes of elaboration. Writing first was developed in more collectively organized polities, such as in the Indus Valley^[152] and in more autocratic polities, such as in ancient Egypt. Yet globally, early episodes in which conventions of writing were rapidly expanded in use and elaborated in application roughly parallel the Classic Maya, where the primary intended audience for texts that were promoted by principals was elite allies, dependents, and enemies. These include Early Dynastic Mesopotamia^[153], Mycenaean Greece^[154], Shang China^[155], and early Egypt^[156].

Finally, going forward, it is worthwhile to think in a comparative vein about thresholds. It merits noting that the distinction in communication patterns between collectively and autocratically governed central places became less apparent with Tenochtitlan and the Aztec empire when previous scalar limits in the sizes of Mesoamerican cities and polities were roundly eclipsed and a fuller repertoire of communication means were employed. Just before the Spanish incursion, one probable phonetic element was employed in Aztec writing, the only simple phonetic usage outside the Maya area^[157]. The broad scalar expanse of the Aztec empire was a relatively recent phenomenon at the time the Spanish invaded^[140], a similar temporal circumstance for the even larger scale of the Andean empire of the Inca. In both cases, extant political fissures were exploited by

the European invaders. If this collision of worlds had been delayed but a century or two, one can only speculate on what kinds of sources and records may have met the Europeans on arrival.

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