Complex societies precede moralizing gods throughout world history

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The origins of both religion and complex societies represent evolutionary puzzles[1–8]. The moralizing gods hypothesis offers a solution to both puzzles by proposing that belief in morally concerned supernatural agents culturally evolved to facilitate cooperation among strangers in large-scale societies[9–13]. While previous research has suggested an association between presence of moralizing gods and social complexity[3,6,7,9–18], the relationship between the two is disputed[9,10,13,19,20,23,24], and attempts to establish causality have been hampered by limitations in the availability of detailed global longitudinal data. To overcome these limitations, we systematically coded records for 414 societies spanning the last 10,000 years from 30 regions around the world, based on 51 measures of social complexity and four measures of supernatural enforcement of morality. Our analyses confirm the association between moralizing gods and social complexity but reveal that moralizing gods follow, rather than precede, large increases in social complexity. Contrary to previous predictions[9,12,16,18], powerful moralizing "big gods", *and* prosocial supernatural punishment more generally, tend to appear only after the emergence of "megasocieties" with populations of greater than around a million. Although moralizing gods are not a prerequisite for the evolution of social complexity, they may help to sustain and expand complex multiethnic empires after they have become established. In contrast, rituals facilitating the standardization of religious traditions across large populations[25,26] generally precede the appearance of moralizing gods. This suggests that ritual practices were more important than the particular content of religious belief to the initial rise of social complexity.

Supernatural agents that punish direct affronts to themselves (e.g. failure to perform sacrifices or observe taboos) are commonly represented in global history, but rarely are such deities believed to punish moral violations in interactions between humans[2]. Recent

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millennia, however, have seen the rise and spread of several "prosocial religions" postulating either powerful "moralizing high gods" (MHG; e.g. the Abrahamic God), or more general "broad supernatural punishment" (BSP) of moral transgressions (e.g. *karma* in Buddhism)[9,12,16–18]. Such moralizing gods may have provided a crucial mechanism for overcoming the classic "free-rider problem" in large-scale societies[11]. The association between moralizing gods and complex societies has been supported by two forms of evidence: psychological experiments[3,6,27,28] and cross-cultural comparative analyses [7,11,14–18,20].

The contributions of theistic beliefs to cooperation, as well as the historical question of whether moralizing gods precede or follow the establishment of large-scale cooperation, have been much debated[9,10,12,23,24]. Three recent studies that explicitly model temporal causality have come to contrasting conclusions. One applying phylogenetic comparative methods to infer historical changes in Austronesian religions reported that moralizing gods (specifically, BSP but not MHG) preceded the evolution of complex societies[16]. The same conclusion was reached through an analysis of historical and archaeological data from Viking-age Scandinavia[18]. But another study of Eurasian empires reported that moralizing gods followed, rather than preceded, the rise of complex, affluent societies[20]. All these studies, however, are restricted in geographic scope and use proxies for social complexity that the authors themselves concede are "very crude"[20] (e.g. binary classification of societies as either "high" or "low" complexity).

To overcome these limitations, we utilized *Seshat: Global History Databank*[29] – a vast repository of standardized data on social structure, religion, and other domains for hundreds of societies throughout world history. Unlike other databases that attempt to model history using contemporary ethnographic data, Seshat directly samples over time as well as space. Seshat also includes estimates of expert disagreement and uncertainty, and uses more detailed variables than many databases.

To test the moralizing god hypothesis, we coded data on 55 variables from 414 polities (independent political units) that occupied 30 geographic regions from the beginning of the Neolithic to the beginning of Industrial/Colonial periods (Fig. 1; Supplementary Dataset). We used a recently developed and validated measure of social complexity condensing 51 social complexity variables (Extended Data Table 5) into a single principal component capturing three quarters of the observed variation, dubbed "Social Complexity" (SC)[8]. The remaining four variables were selected to test the MHG and BSP sub-types of the moralizing gods hypothesis. One variable, MHG, was coded following the "moralizing high gods" variable standardly used in the literature on this topic[11,14–17,30], requiring that a high god who created and/or governs the cosmos actively enforces human morality. Because "morality" is complex, multidimensional, and in some respects culturally relative, and because not all moralizing gods are "high gods", we also coded three different variables related to BSP that are specifically relevant to prosocial cooperation: 1) reciprocity, 2) fairness, and 3) in-group loyalty. For analysis, these three variables were combined into a single BSP variable. See Methods, Supplementary Information, and http://seshatdatabank.info/methods/codebook for further methodological details, definitions, and justifications, including discussion of the relationship between MHG, BSP, and "Big Gods".

Figure 1 and Extended Data Table 1 show the temporal and geographical distribution of the appearance of moralizing gods in our sample. Although societies in all 30 regions possessed beliefs about appeasing supernatural agents through ritual performance, in 10 out of the 30

regions (light grey circles) there was no evidence for moralizing gods prior to their introduction by colonial powers. The remaining 20 regions displayed a diverse range of 15 different systems of belief in moralizing gods: in some the first evidence of moralizing gods came in the form of MHG and in others it came in the form of BSP (Extended Data Table 1). The first appearance of moralizing gods in our sample was in Egypt, where the concept of supernatural enforcement of *Maat* ("order") is attested by the 2nd Dynasty c. 2800BCE. This was followed by sporadic appearances in local religions throughout Eurasia (Mesopotamia c. 2200BCE, Anatolia c. 1500BCE, China c. 1000BCE) before the wider spread of transnational religions began during the 1st millennium BCE with Zoroastrianism and Buddhism, followed later by Christianity and Islam. Although Christianity and Islam would eventually become the most widespread religions, local forms of moralizing gods were present well before they arrived in most regions (e.g. Roman gods were believed to punish oath-breaking from as early as 500BCE, almost a millennium before Christianity was adopted as the official Roman religion). The diverse range of religious systems represented in our global sample makes it possible to draw more general conclusions about religion than have previously been possible.

While our sampling scheme reduces non-independence, our polities still cannot be considered statistically independent due to historical relationships among them. We controlled for these using a logistic regression model to account for temporal, geographical, and cultural dependencies in the global distribution of moralizing gods (see Methods). This analysis revealed that SC was a stronger predictor of moralizing gods than temporal, geographical, or linguistic relationships, and remained highly significant even after controlling for these relationships ($z = 6.8$, d.f. = 800, $P < 10^{-11}$; Extended Data Table 2), conceptually replicating previous studies[7,11,14,15].

The moralizing gods hypothesis posits a "statistical causal relationship"[10] in which moralizing gods facilitate the evolution of complex societies[9,12,16–18]. This implies that, on average, social complexity should increase more rapidly following the appearance of moralizing gods. To test this prediction, we conducted time-series analyses of the 12 regions for which SC data were available both before and after the appearance of moralizing gods (Fig. 2, Extended Data Table 1 & Extended Data Fig. 1). Surprisingly, average rates of increase of SC were over five times greater *before* the appearance of moralizing gods, not after (paired $t = -6.6$, d.f. = 199, $P < 10^{-9}$; Fig. 2). This trend was significant both globally and individually for 10 out of the 12 regional time-series analyses (Extended Data Table 1 & Extended Data Fig. 1). None of these 12 regions displayed a significantly greater rate of increase in social complexity after the appearance of moralizing gods than before. Robustness analyses showed that our primary finding of higher rates of increasing social complexity before the appearance of moralizing gods was present regardless of the type of moralizing gods (MHG or BSP), the choice of variables used to estimate SC, uncertainty in the timing of appearance of moralizing gods, or the time-windows used to estimate rates of change in SC (Extended Data Table 4).

In sum, although our analyses confirm earlier studies showing an association between moralizing gods and complex societies[7,11,14–18,30] we find that moralizing gods usually follow, rather than precede, the rise of SC. Strikingly, most societies that exceeded a certain SC threshold developed a conception of moralizing gods. Specifically, in 10 out of the 12 regions analyzed, the transition to moralizing gods came within 100 years after exceeding an SC value of 0.6 (dubbed here a "megasociety", as it corresponds roughly to a population on the order of one million; Extended Data Fig. 1). Importantly, this "megasociety threshold" does not seem to correspond to the point at which societies develop writing, which might have

suggested that moralizing gods were present earlier but not preserved archaeologically. While we cannot rule out this possibility, the fact that written records preceded the development of moralizing gods in 9 out of the 12 regions analyzed (by an average period of 400 years; Table S2), combined with the fact that evidence for moralizing gods is lacking in the majority of non-literate societies,[2] suggests that such beliefs were not widespread before the invention of writing. Interestingly, the few small-scale societies that did display precolonial evidence of moralizing gods came from regions that had previously been used to support the claim that moralizing gods contributed to the rise of social complexity (Austronesia[16] and Iceland[18]), suggesting that such regions are the exception rather than the rule.

Conversely, of the societies in the 10 regions that did not develop precolonial moralizing gods, only one society exceeded (barely) the "megasociety threshold" (the short-lived Inca Empire, SC = 0.61). This suggests that, even if moralizing gods do not cause the evolution of complex societies, they may represent a cultural adaptation necessary to maintain cooperation in such societies once they have exceeded a certain size, perhaps due to the need to subject diverse populations in multiethnic empires to a common higher-level power[9]. This may explain why moralizing gods spread when large empires conquer smaller – but still complex – societies (e.g. the Spanish conquest of the Incas). In some cases, moralizing doctrines may have helped to stabilize empires, while also limiting further expansion – as when Emperor Ashoka adopted Buddhism and renounced war following his final bloody conquest of the Kalinga Kingdom that established the maximum extent of the Mauryan empire.

Although our results do not support the view that moralizing gods were necessary for the rise of complex societies, they also do not support a leading alternative hypothesis that moralizing gods only emerged as a byproduct of a sudden increase of affluence during a 1st millennium BCE "Axial Age"[19,20,21,22]. Instead, in three of our regions (Egypt, Mesopotamia, and Anatolia), moralizing gods appeared before 1500BCE. We propose that standardization of beliefs and practices via high-frequency repetition and enforcement by religious authorities enabled the unification of large populations for the first time, establishing common identities across states and empires[25,26]. Our data show that doctrinal rituals standardized via routinization (i.e. performed weekly or daily) or institutionalized policing (religions with multiple hierarchical levels) significantly predate moralizing gods, by an average of 1,100 years ($t = 2.8$, d.f. = 11, $P = .018$; Fig. 2a). Doctrinal rituals precede moralizing gods in 9 out of the 12 regions analyzed, and even precede written records in 6 of these cases (by as much as 4,000 years in the case of Çatalhöyük in Anatolia; see Table S2). While analyses of rates of change of SC before and after the appearance of doctrinal rituals do not offer conclusive support for the hypothesis that doctrinal rituals facilitate increasing SC (Extended Data Table 3), these data do at least suggest that doctrinal rituals led to the establishment of large-scale religious identities. In the future, higher-quality and higher-resolution archaeological data may allow for a more nuanced understanding of the timing and possible coevolution of the rise of doctrinal rituals and moralizing gods. Such data appear unlikely to affect our primary claim that complex societies preceded moralizing gods, but this is an empirical question open to future testing.

This paper demonstrates how quantifying cultural characteristics of past societies can contribute to longstanding debates about the evolution of social complexity. Our results suggest that belief in moralizing gods was not the only or even the main factor enabling the expansion of human societies, but may have operated along with other features of ritual and religion to facilitate cooperation in increasingly complex social systems. In particular, an increase in ritual frequency and doctrinal control may have facilitated the establishment of

large-scale collective identities prior to the spread of beliefs in moralizing gods. Thus, when it comes to the initial rise of social complexity, *how* you worship may ultimately have been more important than *what* you worship.

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Author Contributions

H.W., P.F., and P.E.S. designed the study, with input from P.T., T.C., K.F., and R.M.R. E.C. and R.P. coded the religion/ritual data, with additional input from J.L., J.B., B.t.H, A.C., and other Seshat contributors. P.E.S. analyzed the data, with input from H.W., P.F., P.T., T.C., and R.M.R. P.E.S., H.W., and P.F. drafted the manuscript.

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FIGURE LEGENDS

Figure 1 | Locations of the 30 sampled regions on the world map, labeled according to precolonial evidence of moralizing gods. The area of each circle is proportional to social complexity (SC) of the earliest polity with moralizing gods to occupy the region, or the latest precolonial polity for regions without precolonial moralizing gods. For regions with precolonial moralizing gods, the date of earliest evidence of such beliefs is displayed in thousands of years ago (kya), coloured by type of moralizing gods. The three transnational religious systems representing the first appearance of moralizing gods in more than one region - Zoroastrianism, Abrahamic religions (Judaism, Islam, and Christianity), and Buddhism - are coloured red, orange, and blue respectively, while other local religious systems with beliefs in moralizing high gods (MHG) or broad supernatural punishment (BSP) are coloured yellow and purple, respectively. See Extended Data Table 1 for further details.

Figure 2 | Social complexity before and after the appearance of moralizing gods. a) Time-series showing mean social complexity over time for 2,000 years before and after the appearance of moralizing gods (n = 12 regions with pre-/post-moralizing gods SC data). Social complexity has been scaled so that the society with the highest SC (Qing Dynasty China c. 1900CE) has a value of 1 and that with the lowest SC (Early Woodland Illinois USA c. 400BCE) has a value of 0. Vertical bands represent the period in which moralizing gods and doctrinal rituals first appeared. All errors represent 95% confidence intervals, with the exception of the vertical bar for moralizing gods, which represents the mean duration of the polity in which moralizing gods appeared (because times are normalized to the time of first evidence of moralizing gods, and there is thus no variance in this parameter). b) Histogram of differences in rates of change in social complexity after minus before the appearance of moralizing gods (n = 200 time-windows from the 12 regions). The y-axis represents the number of time-windows out of 200. See Extended Data Fig. 1 for data for each of the 12 regions, and Extended Data Fig. 2 for a version extending beyond 2,000 years pre-/post-moralizing gods. These analyses treat either the presence of MHG or BSP as "moralizing gods" – see Extended Data Fig. 3 for an alternative analysis restricted only to the presence of MHG.

METHODS

Seshat: Global History Databank overview

Seshat: Global History Databank (http://seshatdatabank.info/) is a vast storehouse of information about global history from the end of the Paleolithic up to the Industrial Revolution. Eventually, it is intended that Seshat will cover the history of all past human societies but initially the goal has been to capture as much diversity in global history as possible. We therefore created a stratified sample of past societies by identifying 10 world regions distributed as widely as possible across the Earth's surface and within each of those regions designate three "natural geographic areas" (NGAs) with discrete ecological boundaries, on average about 10,000 km^2 in size, creating an initial sampling scheme of 30 such areas around the world. To maximise diversity in the sample, for each world region we chose one NGA in which social complexity was early emerging (e.g. Egypt), one where it arose relatively recently (e.g. Iceland), and one where is emerged somewhere in the middle of the range (e.g. Japan)[29]. The 30 regions and their selection rationale were published in 2015[29] prior to beginning data collection. Our aim was to maximize variability in our global sample while minimizing historical relationships between cultures.

Data on political systems ("polities") that emerged and persisted for at least a century in each of the NGAs was then gathered and inputted into Seshat in a continuous time series at 100-year intervals, going back as far into the history of that area as scholarly literature would allow (up to a maximum of roughly 10,000 years before present). In the case of NGAs that contain clusters of very small-scale polities that share a similar culture but are not under a

single system of jurisdictional control, we refer to these as "quasi-polities" and code information on all of them generically, unless information is available that would allow us to differentiate them.

All the variables on which data has been gathered and entered into Seshat are derived from a Seshat Codebook that can be accesses and downloaded online (http://seshatdatabank.info/methods/codebook). The Codebook was designed by, and is continually updated and extended in consultation with, a large network of professional historians, archaeologists and other specialists whom we refer to as "Seshat Experts". Most variables in Seshat require the data to take the form of a number or numerical range or they specify a feature that can be coded as either absent, present, or unknown (also coding items as "inferred present/absent" where the evidence permits). The first step in data entry is for trained Research Assistants (RAs) to gather and input easily acquired data and, while doing so, compile lists of data that present more difficulty to interpret, requiring input from Seshat Experts. Especially during the early phases of data entry, variables in the codebook are revised and improved through a continual back and forth between Research Assistants and Seshat Experts. All data are linked to scholarly sources, including peer reviewed publications but also personal communications from established authorities. On occasions when Seshat Experts disagree on a particular coding, we keep a record of disagreements so that analyses can be run that take into account contrasting interpretations. Once used for the purposes of data analysis and publication, that version of the dataset is "frozen" so that it can be inspected by others and used for the purposes of replication. Nevertheless, the data in Seshat continually evolves, for example as new sources are discovered and as new Seshat Experts contribute additional layers of interpretation.

The data analyzed in the present paper focus on those sectors of the Seshat Codebook concerned with social complexity, religion, and ritual. A full account of the social complexity variables has been published elsewhere,[8] using 51 variables (Extended Data Table 5) associated with population size, hierarchy, territory, governance, bureaucracy, infrastructure, record keeping, economic development, and other domains that were previously identified as potentially relevant measures of social complexity. This required engagement with a wide-ranging body of literature on social complexity. Since previous researchers disagreed about which dimensions of social complexity were the most important to emphasize (e.g. number of jurisdictional levels versus more hierarchical or horizontal forms of complexity; autocracy versus democracy; diversity of specialist roles versus centralized coordination) we included proxies for all potentially relevant measures of social complexity that had been identified in the literature. This inclusive strategy was designed to allow us to investigate whether these different characteristics exhibited strong relationships with each other and whether a single principal component captures most of the observed variation. Our analyses confirmed that both are indeed the case and, furthermore, we found that different characteristics of social complexity are highly predictable across different world regions[8].

Whereas previous research has proposed an association between the rise of moralizing gods and the evolution of social complexity, measures used in the past to capture the latter have been comparatively crude. Variable selection and inclusion for moralizing gods was informed by existing literature on so-called "big gods", "moralizing high gods", and "broad supernatural punishment", as well as psychological and cross-cultural comparative research on the hypothesized link between belief in moralizing gods and large-scale cooperation.

Data collection for the religion and ritual variables involved matching each fully trained RA with one or more Seshat Experts. Seshat Experts provided guidance on how to delineate the temporal and geographical boundaries of the polity, assembled an initial reading list and, where necessary, helped to interpret some of the key historiographical debates associated with the variables. RAs then populated the variables with data and presented this to Seshat Experts for review. The comments and suggestions made by the experts were then implemented by the RAs. The next stage required a second team of fully trained RAs to go over the gathered data and to conduct a series of quality checks, including vetting of the footnotes and the use of correct syntax for the machine-readable part of the data. Finally, this checked dataset was offered to the Seshat Experts for review. The coding of religion and ritual data required the input of experts every step of the way, given the frequent need for complex and nuanced interpretation of the evidence. By contrast, the data required for the social complexity variables frequently consisted of facts that RAs could procure with less supervision, allowing expert input and review to occur at a later stage of the process.

Data coding

Social Complexity (SC): The 51 variables used to construct the overall social complexity measure are shown in Extended Data Table 5. These variables were chosen because they reflect common features associated with social complexity and can be grouped into 9 complexity characteristics (Polity population size, Capital population size, Polity Territory size, Hierarchy, Infrastructure, Government, Information systems, Texts, Money). Details of coding definitions for these variables have previously been published[8,29].

Moralizing High Gods (MHG):
For consistency with previous studies that have generally used the "Moralizing High Gods" variable from the *Ethnographic Atlas*, the presence of MHG was coded as a binary variable based on this original definition:

As outlined by Murdock[30] (1967:52), a high god follows the definition of Guy Swanson[31] (1960: chapter III and appendix 1) as "a spiritual being who is believed to have created all reality and/or to be its ultimate governor, even though his sole act was to create other spirits who, in turn, created or control the natural world"... (1) "Absent or not reported," (2) "Present but not active in human affairs," (3) "Present and active in human affairs but not supportive of human morality" and (4) "Present, active, and specifically supportive of human morality."[11,32]

Thus, a coding of high gods "present, active, and specifically supportive of human morality" was coded as MHG being present, while all other types were coded as absent.

Broad Supernatural Punishment (BSP):

The terms "big gods" and "moralizing high gods" are sometimes used interchangeably[17], but can have different connotations. The term "moralizing high gods" (MHG) was developed and defined by Swanson[31], who proposed that high gods were associated with social complexity (regardless of their moral concern). Swanson's MHG variable was incorporated into Murdock's *Ethnographic Atlas*[30], resulting in it being widely used in cross-cultural research. Swanson's ideas were extended by Johnson in his "supernatural punishment hypothesis"[11,12,33], where he focused on the mechanism of morality enforcement rather than high gods, but used Swanson's MHG variable for testing due to the availability of previous research using

this definition. Johnson's ideas have been further developed by Norenzayan and colleagues[9, 10, 27,34] to include various additional mechanisms, most notably invoking cultural group selection to explain the rapid spread of moralizing gods without accompanying genetic changes.

Norenzayan originally chose the term "Big Gods" (defined as "powerful, omniscient, interventionist, morally concerned gods"[34]) as the title of his monograph describing this theory. Later, however, Norenzayan and colleagues relaxed this definition and emphasized that the term "Big Gods" was a rhetorical device intended to include a broad range of morally concerned supernatural agents, not only MHGs:
...powerful, all-knowing and morally concerned supernatural agents who are believed to monitor social interactions and to reward and sanction behaviors in ways that contribute to the cultural success of the group, including practices that effectively transmit the faith. Rhetorically, we call these "Big Gods," but we alert readers that we are referring to a multidimensional continuum of supernatural agents in which Big Gods occupy a particular corner of the space.[9]

Watts et al.[16] developed and coded a new variable they call "Broad Supernatural Punishment" which arguably more closely matches this relaxed definition of "Big Gods" than does the traditional "Moralizing High Gods" variable. Watts et al. define "Broad Supernatural Punishment" as follows:
For BSP to be coded as present in a culture there must be the concept of a supernatural agent or process that reliably monitors and punishes selfish actions, and this concept must (i) be widely advocated within the community, (ii) involve punishment of a broad range of selfish behaviours and (iii) apply to a wide range of community members.

Because "selfish actions" can occur in a variety of domains, Seshat subdivides the types of supernatural enforcement of morality based on nine proposed categories of morality[35,36]. For this study, we focused on three domains that are relevant to the establishment of large-scale cooperation: 1) fairness (sharing of resources; e.g. dividing disputed resources, bargaining, redistribution of wealth); 2) reciprocity (e.g. fulfilling contracts, returning gifts, repaying debts, upholding trust); and 3) in-group loyalty (the need to remain loyal to *unrelated* members of the same group; e.g. helping coreligionists, going to war for one's group). BSP was coded as present if at least one of these three sub-types of selfish actions was supernaturally enforced.

Our robustness analyses analyzing BSP and MHG separately (Methods, Extended Data Table 4) suggest that, rather than moralizing gods following a general pattern of evolution from "small" (BSP) to "big" (MHG), the presence or absence of "high gods" independent of their moralizing status has little functional relationship with social complexity, and instead appears largely contingent on history and geography. In regions such as Southern and Eastern Asia, BSP in the form of karmic religions (Buddhism, Hinduism) remains the dominant form of moralizing gods, whereas in regions such as Europe and Africa moralizing Abrahamic MHGs were commonly adopted or imposed wholesale without any intermediate evolution through a BSP stage.

Doctrinal rituals:

The "Modes of Religiosity" hypothesis focuses on two factors that facilitate standardization of a body of beliefs and practices. First, high frequency (e.g. daily or weekly) collective

rituals facilitate easy detection of deviations from the orthodox canon. Second, religious hierarchy enables enforcement of authorized belief and practice. Seshat codes five different types of rituals: the most frequent, most widespread, largest scale, most euphoric, and most dysphoric rituals. For each ritual, frequency is coded as daily, weekly, monthly, seasonally, yearly, generationally, or once-in-a-lifetime. Seshat also codes for levels of religious hierarchy. One represents no levels of religious hierarchy beyond the local priest/shaman, while higher numbers represent multiple levels of hierarchy (e.g. senior priests, High Druids).

Making inferences about prehistoric rituals requires using various measurable archaeological proxies. Previous research has established that both frequent rituals and multi-level religious hierarchies tend to co-occur with other features of doctrinal rituals (e.g., low arousal)[25,37,38,39]. Not all of these features can always be found in the archaeological record, so in this paper we use the appearance of either religious hierarchy *or* frequent rituals as proxies for the appearance of doctrinal rituals. Doctrinal rituals were thus coded as present if the most frequent ritual occurred weekly or daily, or if there was evidence of multiple levels of religious hierarchy.

Separate reanalyses were also conducted defining doctrinal rituals based only ritual frequency and only religious hierarchy. In both cases, doctrinal rituals still preceded moralizing gods by an average of over 200 years, although this difference only remained significant when using religious hierarchy as a proxy for doctrinal ritual (religious hierarchy: mean = 991 years, t = 2.4, d.f. = 11, $P = .035$; ritual frequency: mean = 210 years, t = 1.1, d.f. = 11, $P = .30$).

Note that we coded only aspects of ritual and religion associated with the official cult, and so the rituals of interest were not necessarily polity-wide but could be largely or wholly restricted to elite groups.

Data collation

The process of data collection for the MHG, BSP, and "doctrinal rituals" variables involved matching each fully trained research assistant (RA) with one or more experts (recognized authorities on the polity in question, typically holding a relevant doctorate and occupying a faculty position in a university). Experts provided guidance on how to delineate the temporal and geographical boundaries of the polity, assembled an initial reading list and, where necessary, helped to interpret some of the key historiographical debates associated with the variables. RAs then populated the variables with data and presented this to the experts for review. The comments and suggestions made by the experts were then implemented by the RAs. The next stage required a second team of fully trained RAs to conduct a series of quality checks, including vetting of the footnotes (which currently reference over 2,000 unique academic sources) and the use of correct syntax for the machine-readable part of the data. Finally, this checked dataset was offered to the experts for review. By contrast, the data required for the social complexity variables frequently consisted of facts that RAs could procure with less supervision, allowing expert input to occur at a later stage of the process. Data vetting in Seshat is a continuously ongoing dynamic process that includes incorporation of disagreement among experts within the project and input from external experts via our open-access interface.

There is room for reasonable disagreement about the most effective way of gathering data about world history, particularly regarding the role of expert contributors[44,47]. An alternative approach would be to have every single data point signed off by a single recognized expert,

perhaps even without requiring further citations. We trialed such an expert-driven approach to data entry during initial phases of our project but found it took too long to source experts and have them enter the data required. Instead we found faster progress could be made using the approach described above and having multiple points at which the data were examined and vetted. To this end, we have made not only all our data but also all of the metadata and references supporting these data available for everyone to examine and comment on. Rather than relying on the single authority of one expert for each entry, Seshat involves regional experts to help guide data collection and assess the quality of our data and meta-data as one of several complementary components in our quality control approach – which also includes incorporating disagreement among multiple experts.

Analyses

To ensure consistency and comparability in our analyses, we sampled polities at 100-year intervals, sampling whichever polity happened to occupy a given region at 100BCE, 0CE, 100CE, etc., while not including polities that existed only between century boundaries[8] (see SI for details and examples regarding the temporal sampling procedure). All analyses were performed in R V3.4.1[42]. All *P*-values reported are two-tailed.

Quantifying social complexity:
In order to create an overall measure of social complexity (SC) we took a previously published approach based on principal component analysis (PCA)[8] and applied it to the latest available data from Seshat. This method aggregates the 51 social complexity variables (Extended Data Table 5) into nine "complexity characteristics" and then analyses them using PCA.

PCA is a commonly used tool for dimension reduction – in this case we have nine different aggregated variables that we want to reduce to a single variable that best captures social complexity. However, we obtain the same conclusions even without using PCA regardless of which of the nine complexity characteristics we choose as a proxy for social complexity (Extended Data Table 4).

As shown previously, these different complexity characteristics turn out to be highly correlated and all load heavily onto a single principal component that captures 76% of the variance in the individual complexity characteristic variables. Our approach utilizes multiple imputation[43] to account for missing data, uncertainty, and expert disagreement by imputing data based on a range of possible values and averaging the results over the course of 20 imputations. The results of this approach have proven highly robust to a number of different modelling assumptions (see ref. 8 and SI). Full details of this approach and justifications for selecting the social complexity variables can be found in the previous paper (ref. 8). We carried out a number of robustness checks in that paper including cross-validation analysis and bootstrap resampling to assess whether our PCA methods were robust to spatial/temporal autocorrelation. Specifically, k-fold cross-validation showed that our multiple imputation methods accurately predicted complexity characteristic values when each geographic region was systematically removed from the analysis, while bootstrapping showed that removing different geographic regions and time periods did not affect our PCA results (see ref. 8 and the "Robustness checks" section in the SI for full details).

Extensions of PCA (e.g. Generalized Low Rank Models [GLRM][44], spatio-temporal PCA [stPCA][45], singular spectrum analysis [SSA][46]) may be worth considering in future analyses

as alternative methods of accommodating binary variables and spatial/temporal autocorrelation. Note, however, that the subsequent regression analyses performed in this paper explicitly control for spatial, temporal and phylogenetic autocorrelation. More importantly, our current results consistently failed to support the temporal sequence of the moralizing gods hypothesis across all geographic regions (Extended Data Table 1 and Extended Data Fig. 1), and robustness analyses using each of the nine complexity characteristics independently without performing PCA also confirm our main findings (Extended Data Table 4). This confirms that our primary finding that complex societies precede moralizing gods cannot be an artefact of autocorrelation in our PCA methods.

Logistic regression:

In order to examine the association between moralizing gods and social complexity while controlling for non-independence in our data due to spatial/temporal autocorrelation and historical connections between cultures[47], we fitted a logistic regression model to the data. A detailed description of this model has previously been published along with extensive validation of its robustness when applied to Seshat data[48]. This approach stems from the field of nonlinear dynamical systems, and is similar in spirit to the concept of "Granger causality"[53,54] commonly used in economics, in that both employ linear models with time-lagged variables.

Our approach is similar to that adopted by Botero et al.[7], except that we use more fine-grained measures of geographical diffusion and linguistic similarity, and also incorporate temporal information, as follows:

$$Y_{i,t} = a + \sum_{\tau} b_{\tau} Y_{i,t-\tau} + c \sum_{i \neq j} \exp\left[-\frac{\delta_{i,j}}{d}\right] Y_{j,t-1} + h \sum_{i \neq j} w_{i,j}\, Y_{j,t-1} + \sum_{k} g_k\, X_{k,i,t-1} + \epsilon_{i,t}$$

Here $Y_{i,t}$ is the binary variable coding presence of absence of moralizing gods in location i at time t. The time step $\Delta t = 100$ years. Starting from the first term on the right-hand side, a is the regression constant (intercept). The next term captures the influences of past history (autoregressive terms), with $\tau = 1, 2, \ldots$ indexing time-lagged values of Y (as time is measured in centuries, $Y_{i,t-1}$ refers to presence or absence of moralizing gods 100 years before t). The third term represents potential effects resulting from geographical diffusion[49,50]. We use a negative-exponential form to relate the distance between society i and society j, $\delta_{i,j}$, to the influence of j on i because, unlike with a linear kernel, negative-exponential does not become negative at very long $\delta_{i,j}$, instead approaching 0 smoothly. We avoid the problem of endogeneity by using time lagged $Y_{j,t-1}$. The third term, thus, is a weighted average of moralizing gods occurrence in the vicinity of society i at the previous time step, with weights falling off to 0 as distance from i increases. Parameter d measures how steeply the influence falls with distance, and was set to $d = 1000$km after optimizing the AIC value using 200km increments from 200-2000km ($d = 200, 400, 600, \ldots$ 2000km). Parameter c is a regression coefficient measuring the importance of geographical diffusion. Detecting autocorrelations due to shared cultural history (next term) is done analogously, except w now represents the weight due to linguistic similarity (set to 1 if societies i and j share the same language, 0.5 if they are in the same linguistic genus, 0.25 if they are in the same linguistic family, and 0 if they are in different linguistic families; linguistic genera and families were taken from Glottolog[51] and the World Atlas of Language Structures[52]). The rest of the right-hand side represents effects of predictor variables $X_{k,i,t-1}$ (time-lagged); g_k are regression coefficients, and $\varepsilon_{i,t}$ is the error term. This approach allows us to investigate the

effects of the predictor variable (social complexity [SC], calculated above via principal component analysis), while controlling for serial autocorrelations, spatial diffusion, and autocorrelations due to shared cultural history.
The regression results are detailed in Extended Data Table 2.

Pre-/post-moralizing gods comparison:
To more directly examine the direction of causality predicted by the moralizing gods hypothesis, we created time-series of SC over time for all 12 regions for which social complexity data were available both before and after the appearance of moralizing gods (Extended Data Fig. 1). We then compared rates of change in social complexity over time before and after moralizing gods using sliding time-windows. First, we compared rates of change using a 100-year window (i.e. comparing the rate for the 100 years before the appearance of moralizing gods with the rate for the 100 years after), then repeated this using a 200-year window, 300-year window, and so on up to a maximum of between 700- and 3,900-years windows depending on the region.

Different regions have different time-depths of data available for making these comparisons. The region with the shallowest time-depth was in Mali (±700 years before/after the appearance of Islam c. 1100CE [400CE-1800CE]), while the region with the deepest time-depth was in Iran (±3,900 years before/after evidence of the moralizing Mesopotamian sun god *Shamash* c. 2200BCE [6100BCE-1700CE]). If we used all available data (up to ±3,900 years), we risked weighting the analyses too heavily toward regions such as Iran with deep time-depths, while using only a consistent upper limit of a maximum of ±700 years risks throwing away too much data. As a compromise, we conducted analyses using an intermediate upper limit of a maximum of ±2,000 years (Fig. 2b), but also repeated the analyses using extreme upper limits of ±700 years and ±3,900 years (see robustness analyses below). All of these choices produced qualitatively identical results (Extended Data Table 4).

Note that these analyses do not attempt to construct a single "average rate of change before moralizing gods", a single "average rate of change after moralizing gods", and compare these average rates. We cannot assume such a constant rate of change, and indeed Fig. 2a shows that rates of change are clearly not constant. Instead, these analyses calculate a difference value for each time window (e.g. subtracting the rate of change for the 100-year period before moralizing gods from the rate of change for the 100-year period after, then doing the same for a ±200-year period, etc.). The key prediction of the moralizing gods hypothesis is that these difference values should tend to be positive (i.e. for a given time-window, the rate of change after moralizing gods should be greater than the rate before). However, Fig. 2b demonstrates that, in fact, the distribution of difference values was significantly negative (paired t-tests, $P < 10^{-9}$).

Robustness analyses:
To explore the robustness of our results to modeling assumptions, we ran the following robustness analyses:

To ensure that the analyses are not affected by the fact that religious hierarchy is included as one of social complexity variables in addition to being one of the variables used to define doctrinal mode, we re-ran the analyses after removing the religious hierarchy variable from the social complexity variables. We chose to do this for robustness analyses rather than the primary analysis in order to use the same 51 SC variables used in our previously published studies[8,48] for consistency.

To ensure that the observed plateauing of SC was not simply an artefact of a ceiling effect wherein polities "max out" certain variables, we re-ran the analyses twice after splitting the SC variables in two subsets. The "scale" subset (2a) contained only the subset of seven SC variables for which there was no theoretical maximum value (from the categories "Polity Population", "Polity Territory", "Capital Population", and "Hierarchy"). The "non-scale" subset (2b) contained the remaining 44 SC variables for which there was a theoretical maximum that could be attained once all our variables were present in a society (from the categories "Government", "Money", "Infrastructure", "Information Systems", and "Texts").

To examine whether our results were affected by the definition of "moralizing gods", we re-ran the analyses limiting the definition of moralizing gods exclusively to "moralizing high gods" (MHG), rather than the more inclusive definition of "broad supernatural punishment" (BSP) used in the primary analysis.

Our primary analysis treated moralizing gods as being present from the beginning of the polity in which they appeared. To ensure that our analyses were not affected by dating uncertainty, we re-ran the analyses randomly resampling to treat moralizing gods as appearing at some point from within the full date range of this polity (e.g. 2900-2700BCE for Egypt).

Our primary analysis used time-windows of up to 2,000 years before and after the appearance of moralizing gods, because 2,000 was intermediate between the maximum time-window for the region with the shallowest time-depth (±700 years for Mali) and the deepest time-depth (±3,900 years for Iran). To examine whether our results were affected by the depth of the time-window used, we re-ran analyses using consistent time-windows for each region of up to 700 years before/after moralizing gods (since ±700 was the maximum time-window possible for Mali; 5a), and also using the full time-window available for each region (i.e. as wide as 3,900 years for Iran; 5b).

In order to ensure that our results were not affected by possible autocorrelation in our use of PCA to extract a measurement of social complexity, we re-ran the analysis nine times using each of the nine individual "complexity characteristics" as a measure of social complexity without performing any PCA.

All of these robustness analyses (16 in total) produced qualitatively identical results in which the rate of increase of social complexity was significantly greater before the appearance of moralizing gods than afterwards (more than double in all cases; Extended Data Table 4), confirming that our primary conclusion that complex societies precede moralizing gods is highly robust.

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Code availability: Source code is available online at http://github.com/pesavage/moralizing-gods.

Data availability: The full machine-readable dataset is available as Supplementary Dataset 1, and at http://seshatdatabank.info/datasets. Full codings with detailed explanations and references are available at http://seshatdatabank.info/data, and are summarized in Table S2. The data include the coded levels of uncertainty and disagreement, the textual explanations, and the references for each of the variables for all polities used in our analysis. These webpages also make it possible to comment on each of our data points and suggest additions or corrections and thus provide an up-to-date and dynamic dataset undergoing continual improvement by members of the Seshat team and also external scholars. To maximize

transparency, we have tied each cluster of variables to the names of the research assistants who gathered the data and the names of the experts who reviewed the data.

Extended Data Legends

Extended Data Figure 1 | Social complexity time-series for individual regions. The 12 regions for which social complexity data are available both before and after the appearance of moralizing gods are shown. Vertical bands represent the period in which the first evidence of moralizing gods (red) and doctrinal rituals (blue) appeared. Grey shading represents 95% confidence intervals based on principal component analysis using multiple imputation[8].

Extended Data Figure 2 | Full time-series showing mean social complexity over time before and after the appearance of moralizing gods. n = 12 regions with pre-/post-moralizing gods SC data. Social complexity has been scaled so that the society with the highest SC (Qing Dynasty China c. 1900CE) has a value of 1 and that with the lowest SC (Early Woodland Illinois USA c. 400BCE) has a value of 0. Vertical bands represent the period in which moralizing gods and doctrinal rituals first appeared. All errors represent 95% confidence intervals, with the exception of the vertical bar for moralizing gods, which represents the mean duration of the polity in which moralizing gods appeared (because times are normalized to the time of first evidence of moralizing gods, and there is thus no variance in this parameter). Lack of confidence intervals indicates data from only a single region. This figure is identical to Fig. 2a, except that it also includes all available data pre-/post- moralizing gods, rather than restricting to a window of 2,000 years pre-/post-moralizing gods.

Extended Data Figure 3 | Social complexity before and after the appearance of moralizing high gods. This is a version of Fig. 2 in which analyses are restricted only to "moralizing high gods" (MHG) rather than the broader definition of "moralizing gods" used in Fig. 2 and elsewhere that includes "broad supernatural punishment" (BSP) as well as MHG. a) Time-series showing mean social complexity over time for 2,000 years before and after the appearance of moralizing high gods (n = 10 regions with pre-/post-moralizing high gods SC data). Social complexity has been scaled so that the society with the highest SC (Qing Dynasty China c. 1900CE) has a value of 1 and that with the lowest SC (Early Woodland Illinois USA c. 400BCE) has a value of 0. Vertical bands represent the period in which moralizing high gods and doctrinal rituals first appeared. All errors represent 95% confidence intervals, with the exception of the vertical bar for moralizing high gods, which represents the mean duration of the polity in which moralizing high gods appeared (because times are normalized to the time of first evidence of moralizing high gods, and there is thus no variance in this parameter). b) Histogram of differences in rates of change in social complexity after minus before the appearance of moralizing high gods (n = 158 time-windows from the 10 regions). The y-axis represents the number of time-windows out of 158.

Extended Data Table 1 | Rates of change in social complexity before and after the earliest precolonial evidence of moralizing gods for the 30 regions in Figure 1
For locations without precolonial concepts of moralizing gods, the polity represents the latest polity analyzed. See Table S2 and http://seshatdatabank.info/data for details and references. "MHG" = Moralizing high gods, "BSP" = Broad supernatural punishment. Rates of change before vs. rates after moralizing gods were compared using paired t-tests on up to 20 time-windows (100-2,000 years before/after the appearance of moralizing gods) for all 12 regions with social complexity data available both before and after the appearance of moralizing gods. Negative t-values represent higher rates of change before moralizing gods. *$P < .05$; **$P < .01$; ***$P < .001$

Extended Data Table 2 | Logistic regression results predicting moralizing gods
The model includes parameters for social complexity and for geographical, temporal, and cultural relationships, ordered by absolute z-value (see Methods for details).

Extended Data Table 3 | Analyses with doctrinal rituals instead of moralizing gods as the dependent variable
See Tables S3-S5 for full regression results

Extended Data Table 4 | Robustness analyses modifying modeling assumptions of the analyses
See Methods for details, and see Extended Data Table 2 and Tables S6-18 for full regression results

Extended Data Table 5 | List of the 51 social complexity variables analyzed
See ref. 8 and http://seshatdatabank.info/methods/codebook/ for full definitions and selection rationale