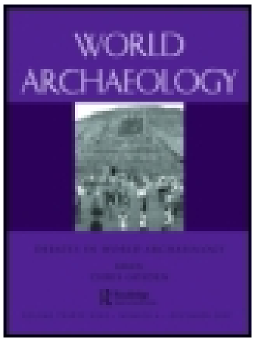

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The process of complex societies: dynamic models beyond site-size hierarchies

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The process of complex societies: dynamic models beyond site-size hierarchies

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ABSTRACT
The site-size hierarchy concept enables researchers to transform archaeological survey data into political classifications. Yet everything about the site-size rubric is worth re-thinking, from the reliability of surface-survey data to the recognition that sites of all sizes act autonomously within territorial configurations. New ways can visualize and analyze the *process* whereby complex societies (chiefdoms and states) emerge through the materialized energies of constituent parts (cities, towns, resource zones, fortifications, frontiers) that ebb and flow through connections of trade, warfare, alliances, and migration characterized by multiple and overlapping dynamisms among human and non-human elements, and in which historical trajectories form the basis of memory and action. Five alternative ways of mapping and analyzing relationships among sites are offered, derived from biological models of individual and collective interaction: reticulated hierarchies, logic gates, cellular automata, recurrent connectivity, and firefly synchronicity.

KEYWORDS
Landscapes; hierarchy; complexity; state-formation

Introduction

The state, as a philosophical and territorial concept, constitutes the largest sociopolitical unit of both the modern and the ancient world. Yet the origins of the state are obscure, occurring before the widespread use of writing; even when texts survive, they describe only a portion of any ancient polity's landscape, legal system, political genealogy, economic interactions, and administrative strategies. By contrast, archaeological sites and artifacts are widespread, and in their diversity of form and function provide a holistic opportunity to understand the push-and-pull of emergent sociopolitical complexity. To date, however, the depiction and analysis of the relationships among sites have been relatively static, carried out through settlement pattern surveys interpreted through concepts of linear hierarchies of control. Gosden and Malafouris (2015, 701), in their exhortation to analyze social transformations as a process in which archaeological theory explores 'becoming rather than being,' enable us to envision and analyze the development of ancient states beyond site-size hierarchies and other traditional interpretations.

The site-size hierarchy concept, used to describe the origin and development of ancient states and chiefdoms, was born of a marriage between research interests in the emergence of complex societies and the mid-twentieth-century development of regional archaeological surveys. Prior to the mid-1950s the primary survey rationale was to locate sites for excavation; after the 1950s,

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surveys were designed to elicit information for a holistic approach that included the classification of regional political characteristics (e.g. Adams 1965; Willey 1953; McDonald and Rapp 1972). Researchers subsequently used survey data to address questions of cultural cohesion, ancient territorial integration, and the origins of the state with the assumption that large sites constituted the most 'important' loci for territorial social complexity and that administrative authority devolved along a linear gradient of progressively smaller settlements.

The site-size hierarchy concept has been so frequently used to describe the level of socio-political complexity of a given region that its referent often is uncited; indeed, the exact genealogy of the concept is somewhat difficult to elicit from the published record. Kent Flannery (1972) first called attention to the descriptive potential of the site-size rubric, noting that 'Wright (1969) has suggested that the appearance of a three-tiered administrative hierarchy with trimodal site sizes (city, town, and village) may be one indicator of state organization, taken in conjunction with other phenomena.'[1] Flannery's mention of Wright's 1969 work focused on three site-size brackets (as did Johnson 1973, 15); Wright's own subsequent discussion of the concept indicates less stringent parameters, articulating the phrase 'three or more' in the definition of the state (Wright 1977, 389; see also Wright and Johnson 1975, 267); a decade later, this was augmented to specify not only site sizes but also a variety of qualitative criteria including administrative technology, public architecture, and iconography that signaled up to five tiers of control hierarchy (Wright 1986, 333–334). The general rule of thumb subsequently has infused the discussion of archaeological chiefdoms and states (e.g. Isbell and Schreiber 1978; Marcus and Feinman 1998, 6; Spencer 2003; Duffy 2015; Stanish 2020; Li et al. 2021).

Interestingly, the site-size hierarchy concept appears to be applied only in selective global cases, and that too within large, contiguous continental landmasses. Yet a site-size hierarchy can exist without any implication of an emergent polity, as seen for example in the case of the Bronze Age Indus culture in what is today western India and Pakistan. With only four (or perhaps, five) genuine urban centers and a gradation of other site sizes (Possehl 2002, 49; R. Wright 2010, 107), the Indus may well represent a situation in which there is a clear site-size hierarchy of four or five tiers that otherwise bears little evidence of state-like political cohesion (for comparative cases in the Americas and Papua New Guinea, see Duffy 2015). By contrast, some well-known states – such as the Roman or Qin that have such a range of site sizes that they might be described as a 6, 8 or 12-tier site-size hierarchy – are never quantified through the site-size rubric, an observation that reveals that the principal purpose of the clustering exercise is to enable lesser-known political regions to be definitively pronounced to be 'states' as part of processual classifications and evolutionary comparisons. Other caveats about the site-size hierarchy concept have been offered, ranging from unease about the reliability of the data about site sizes (usually predicated on the distribution of ceramics; Spencer 2009, 144) to a recognition that state-formation is a dynamic process with significant edge effects (Feinman and Nicholas 1990, 216–217) to the ontological challenge of utilizing quantitative rubrics to assess qualitative, dynamic human interactions (what Adam T. Smith critiques as a 'mechanical spatial ontology,' Smith 2003, 42).

What is needed beyond the site-size hierarchy model is a way to understand the internal dynamics and the mechanisms of growth, integration and change among sites through ongoing political interactions. Archaeologists have long recognized that site sizes do not always directly correspond to site importance in a regional configuration; that sites of smaller sizes can represent special-purpose functions not duplicated at larger sites (Flannery 1976, 170–171); and that sites of all sizes are dynamically linked in different ways at different times (Feinman and Nicholas 1990; Duffy

2015). Interpretations of ancient political connections have expanded beyond the notion of hierarchy to encompass concepts of heterarchy (e.g. Crumley 2015), 'distributed political influence' (Harrower and D'Andrea 2014, 532) and cooperation (e.g. Carballo, Roscoe, and Feinman 2014), providing the impetus to develop more realistic analytic models. Intellectual pathways for archaeological research come from other disciplines focused on complex systems in which the effects of hierarchy have been scrutinized and critiqued and in which a multiplicity of overlapping dynamics are evident (e.g. Appley and Winder 1977 for corporate life; Larsen 2008 for geography; Padial and De la Riva 2020 for biology).

Dynamism in complex societies

A focus on 'becoming' (*sensu* Gosden and Malafouris 2015) as a process of ongoing, dynamic interactions brings to the study of the state an electric potentiality of interpretation. Understanding state integration and disaggregation as an ongoing process is significant beyond achieving a better set of maps or more clearly delineating the types of ancient societies that can be grouped together into comparative studies of chiefdoms and states. Through the modeling of the iterative minutiae of contact and communication, we can broaden the focus of state interpretation from its longstanding emphasis on elites to include the entire diversity of human and non-human occupants. We also can provide the theoretical apparatus to focus on the smallest, most ubiquitous units of political action: the households and individuals whose autonomous interactions result in multilayered social configurations materialized in artifacts and architecture.

Individuals within political and environmental groupings are 'self-conscious' in their actions (Wengrow and Graeber (2015, 606), and their 'daily face-to-face interaction … is the matrix in which the growth of larger social formations takes place' (Drennan and Peterson 2012, 72). The result can be seen in the entire range of human activities, from the moment-by-moment actions of craft-making (e.g. Gosden and Malafouris 2015) through the materialization of landscape-level efforts of infrastructure, warfare and migration (e.g. Erickson and Walker 2009; Smith and Mohanty 2018). A theoretical apparatus of recursive interactions also engages with the non-human elements of daily life, including sentient and non-sentient life forms, the (deleterious or enhancing) effects of sites upon their environments and the differential impacts of natural disjunctions such as storms, earthquakes and plagues.

In the process archaeology envisioned by Gosden and Malafouris (2015), every human and non-human act is embodied in material expressions, and every action subsequently influences every subsequent action. The result is that archaeological sites are not merely discrete, bounded entities but are 'components of regional settlement systems characterized by distinctive site morphologies, land use strategies, and environmental relationships' (Casana 2007, 197). Site connections are sustained through physical and social pathways that shift and change as people establish new connections and abandon or avoid others (e.g. Carballo and Pluckhahn 2007; Hendrickson 2012). Pathways and their nodes are linked in many ways; while cities and other apex political centers may drive some types of political growth, they are not the exclusive locus of polity change and may not be the primary locus of political collapse (e.g. Feinman and Nicholas 1990, 237).

Three case studies: Siin West Africa, Angkor, Andean Moche culture

Three examples of the internal workings of complex societies illustrate the variability in social, economic, ritual and political configurations that necessitate recursive, dynamic models beyond site-size hierarchies.

The Siin region of West Africa in the mid-second millennium CE was characterized by a distribution of smaller and larger sites, but François Richard (2017, 211, 213) observes that these two-level site size hierarchies were nonetheless sophisticated beyond a village-and-hamlet binary because there were immaterial ways in which inhabitants expressed power, e.g. through people rather than monumental architecture, which means that we may not be able to see site 'sizes' or signs of visible labor investment in monuments as being the only yardstick of integrative iterations. He also suggests that due to the nature of cultivation and mobility, small settlements were short-lived (Richard 2017, 215), a factor that would overpopulate a map of site locations within broad chronological periods. Although seemingly simple, the two-tiered site size hierarchy in the Siin region supports the interpretive extrapolation of a variety of complex political configurations: a village-and-hamlet settlement configuration without any greater territorial political integration; a small chiefdom in the process of consolidating networks; a small chiefdom on the verge of collapse; a collapsed system with significant outside disruptions leading to settlement dispersal; and/or a steady and robust configuration characterized by bimodal site size distributions within distinct configurations of climate, agricultural production strategies, and transportation capacities.

Tegan Hall et al. (2016) provide an analysis of non-hierarchical dynamics in their analysis of the hinterlands of the second-millennium CE Angkor polity in Cambodia through a study of the site of Preah Khan, an iron-producing site located 100 km east of the political capital of Angkor. Evidence for Preah Khan's affiliation with the Angkorian polity is evidenced in the presence of temple complexes that closely follow the style and structure of royal architecture associated with the rulers Suryavarman II (1113–1150 CE) and Jayavarman VII (1182–1218 CE; Hall et al. 2016, 59), as well as the presence of a road network that linked Angkor with the site of Preah Khan (Hendrickson 2011). However, the differential timing of the temples, reservoir and iron production indicates that these were likely to have been sequential rather than simultaneous developments, and that the relationship between Preah Khan and Angkor was a dynamic one that changed over time. Even the 'collapse' of the Angkorian political realm was not a lockstep process with instantaneous effects on its surrounding network. Instead, researchers have found that there was a spike in charcoal at Preah Khan indicative of iron production in the waning days of Angkor, suggesting that the disarticulation of the polity was accompanied by resurgence in its hinterlands and that 'the apparent cessation of control by the political and economic elite based at Angkor appears to have occurred prior to the political abandonment of the capital in the early 15th century' (Hall et al. 2016, 62).

Edward Swenson's (2012) study of the Moche period (100–800 CE) incorporates excavation and survey data to show that population centers of the Jequetepeque Valley of Peru had differential investments in social and community activities as expressed in architecture and trash deposits. In particular, the 24-ha site of Huaca Colorada has evidence for very time-consuming ritual activities, including intentional burial and reconstruction of platforms and chambers. The intensity of ritual activities made Huaca Colorada prominent beyond the implications of its size, given that 'its spatial configuration, practices, and institutions seem to have diverged remarkably from other "centers" in the valley' (Swenson 2012, 22, citing Castillo, 2010). The investigator further concluded that 'the polycentric settlement system does not suggest a clear-cut hierarchy of sites and political institutions but points to alternative "constructions" of place and politics specific to Moche Jequetepeque' (Swenson 2012, 22). Just as Preah Khan was an important economic place that provided it with a special role, Huaca Colorada was an important ritual place with a special role in the Moche landscape; while each site was incorporated into a larger political configuration, it also had internal social dynamics and independent factors of change and stasis.

Alternative models

Gosden and Malafouris (2015, 701) discuss the process of 'becoming' as one that is more dynamic and intense than any single moment of 'being.' Applied to the development of social complexity in the form of chiefdoms and states, their concept of process archaeology (P-Arch) compels researchers to recognize that any single moment of activity that is materialized in an archaeological site represents a slice of reality within a *longue durée* of continuity and that complex societies are dynamic before, during and after the cartographic depiction of their unique moment of maximal size (cf. M.L. Smith 2005; Gosden and Malafouris 2015, 704). Five models from biology, engineering and computational sciences are proposed to understand the workings and implications of locational autonomy within larger systems by identifying the recursive elements characteristic of the process of 'becoming':

1) *Reticulated hierarchies* blend local autonomy with hierarchical linkages (Winder and Winder 2014; Figure 1). The development of reticulated hierarchies is a nodal-agentive elaboration of evolutionary trajectories as a bush-like series of intersections rather than a dendritic, tree-like model (cf. Tehrani 2011). In reticulated hierarchies, each point of bifurcation contains the potential for directing the quantity, quality and directionality of subsequent lineage links. In nature, examples of reticulated hierarchies include the notion of 'ring species,' which are species with linear distributions that wrap around geographic features and that have minor genetic gradations throughout but in which the populations at the terminal end-points, even if they are geographically proximate, do not interbreed (Irwin et al. 2005). Other natural occurrences include polymorphisms under conditions of adaptive radiations in which diversifications proceed rapidly in contexts of 'instantaneous niche availability' (Suh, Smeds, and Ellegren 2015). Reticulated hierarchies can be seen in both time

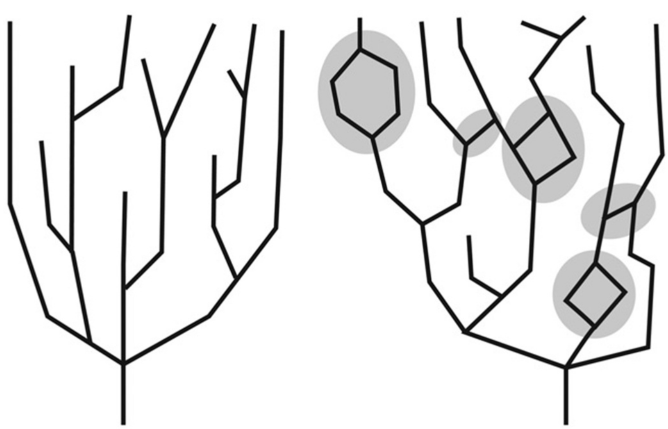

Figure 1. Regular hierarchy (left) and reticulated hierarchy (right; both images from Winder and Winder 2014, 301).

and space, in which there are divergences throughout landscapes as well as divergences in each specific location over time.

Applied to archaeological cases of complex societies, reticulated hierarchies are the result of any locale interacting with its proximate neighbors over space, in which the inhabitants of that locale also have a genealogical relationship to the prior and future inhabitants over time. For example, the simple two-tier site size distinctions of the Siin region can be viewed as a process of configuration and reconfiguration whereby locally powerful chiefs would connect their communities for a generation, leaving way for different configurations of power in subsequent generations. A reticulated hierarchy also illustrates the effect of local resurgences in economic growth after the collapse of a central node, as in the Angkorian case. Finally, a reticulated hierarchy describes the capacity of a religious node to enter into a one-to-one correspondence with both nearby and far-flung population centers through the phenomenon of pilgrimage, as was the case in Huaca Colorada.

2) *Logic gates* are nodal operations in which each node receives multiple inputs and in which the output is conditional upon the combination of the inputs within the node (Figure 2). The utility of a logic gate approach can be illustrated by an analogy to the difference between dendritic watershed systems and the more complex configurations of tidal zones in which simple downstream flows interact with incoming oceanic surges. Tidal zones are manifested in a variety of landforms (shorelines, estuaries and deltas) that each have differential properties depending on their size, topographic gradient and the volume and speed of landside drainage. Tidal zones have fluctuating, reversible energetics that support a diversity of lifeforms and a high biomass but also are subjected to physical changes such as erosion that have differential consequences depending on the timing and amplitude of inputs (including the variable day-to-day and year-to-year amplitude of tides [Vial 1993] and the magnified effects of high tides and storm surges when they co-occur [e.g.; Murty, Flather, and Henry 1986]).

Applying these observations to ancient political systems, we can propose that the localized effects of decision-making in population centers of any size (such as proclamations of war and demands for food or raw materials) were likely to have been mitigated by conditions both at the locus of decision-making and in the adjacent regions that served as the source of people, energy and raw materials. These factors included the strength of local leadership and social configurations ranging from kinship obligations to perceptions of ownership and control exercised through investments in landesque capital (for the latter, see Erickson and Walker 2009). In the Siin region,

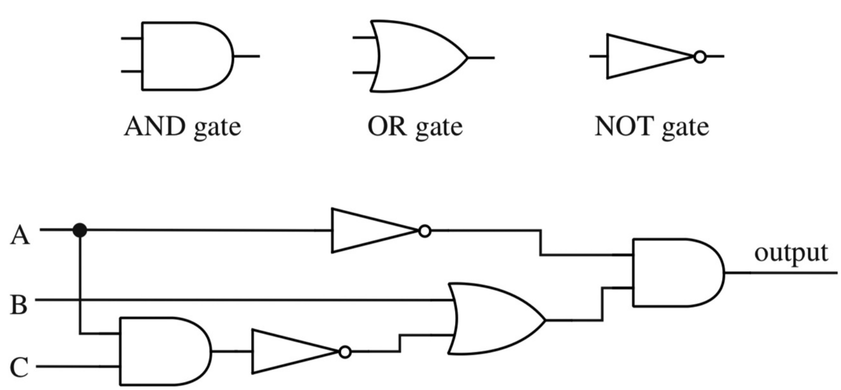

Figure 2. Logic gates. (Critchlow and Eck 2011, 17).

any site's relative proximity to the coast or hinterland provided distinct opportunities and constraints as neighboring groups pressed local groups into service, while the presence or absence of both human-made and natural niches of escape (cf. Monroe 2015) factored into the decisions of individuals as they mitigated or escaped warfare, capture and enslavement. In the Angkorian case, the collapse, failure or obsolescence of one portion of the network did not necessarily result in the demise of all parts of the economic, social or ritual network of connectivity among sites; as Hall et al. (2016) observe, some portions of a network may experience resurgence precisely because a previously powerful locality no longer is able to control or inhibit interactions with others.

3) *Neural plasticity* characterizes the links that are developed and maintained on the local level and that can be reconnected in novel ways to compensate for system-level changes (Figure 3). Neural networks are hierarchical, but research on brain functions has illustrated that damage to one physical area of the brain can be overcome through a re-wiring process in which 'structures comprise a dynamic flexible … microcircuit capable of compensation' (Zelikowsky et al. 2013, 9942). Neural networks also have peer-to-peer capacities, as shown in Figure 3. Through a combination of redundancy, rewiring and repurposing, the overall functionality of the brain is sustained despite shocks to the system. The process mirrors the ways in which states and other complex societies sustain landscape-wide interactions through the reallocation of resources (including the movement of population) along pathways that already exist or that are created anew in response to constraints.

Interactions within population centers and among sites of all sizes require decision-making capacities by real people (cf. Wright 1969; see also M.L. Smith 2010; Duru 2018), resulting in social interactions with a plasticity of economic, social, ritual, and political networks. Agents and locales cycle between latent and active connectivity depending on factors such as political pressure for or against engagement with a particular place (e.g. Golden 2003; Grave et al. 2016), natural variability such as annual fluctuations in precipitation (e.g. Smith and Mohanty 2018), or occasional cataclysmic natural interruptions (e.g. Mordechai and Pickett 2018). With regard to the above regional cases, Siin region traders, merchants, farmers and craft-makers engaged in a constant re-evaluation of sources of agricultural products, raw materials, labor and finished products that enabled up-to-the minute substitutions of both suppliers and consumers. In Angkor and at Huaca Colorada, the reverse seems

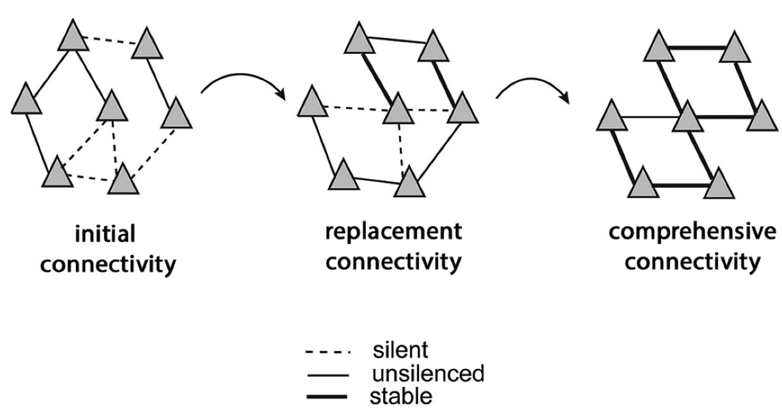

Figure 3. Neural plasticity (adapted from Xu, Löwel, and Schlüter 2020, Figure 1).

to have occurred: raw material supplies and the locus of ritual authority were firmly anchored in place, but customers and pathways shifted.

4) *Cellular automata* are defined by the reactions of units or loci in a grid to the condition of neighboring elements (Wolfram 1984; Manukyani et al. 2017, 173; Figure 4). Any change in a locality results in the potential for the adjacent cell to also change depending on the rules of engagement, but relationships among adjacent cells are articulated only at the local level and not in regard to larger-scale interactions. Analytically, however, the sum total of local interactions results in a large-scale pattern that can be viewed across a computer screen or across a landscape in ways that provide insights on both the details and the summation of landscape events that often have multiple inputs. Researchers have used the cellular automata approach to analyze forest fires in which ignition within any grid point is affected by static factors such as vegetation and topography, by situational factors such as proximity to a fire source, and by dynamic and fluctuating external factors such as weather, wind direction and wind speed (e.g. Freire and DaCamara 2019).

Applied to social systems, each 'cell' or unit reaction to its neighbor describes relationships at all scales of measurement, from the household scale (e.g. the interactions of sharing and storage described by Michelle Hegmon 1991) to the aggregate relationships sustained across entire landscapes in which village, town and city interactions are conditioned by the activities of neighboring settlements (e.g. Hassan 1993; Grave et al. 2016). As in the case of the use of cellular automata for modeling fire behavior, rules for modeling sociopolitical changes could include environmental as well as sociopolitical variables (for example, environmental change such as flooding that triggers losses in one locality and corresponding increased demand in the neighbor, expressed in a variety of responses ranging from migration as an individual action to the redistribution of state resources to support affected communities).

At the landscape level of ancient complex societies, the 'respond-to-your-neighbor' principle of cellular automata would have been particularly strongly developed along linear connections such as trade routes or river systems where population centers were in regular contact with one another and reacted to their neighbors' collaborative or competitive intent expressed through economic, social, sportive, ethnic or other points of reference. In the Siin region, trade and ritual activities of households within villages would be linked to similar activities in neighboring settlements, in which

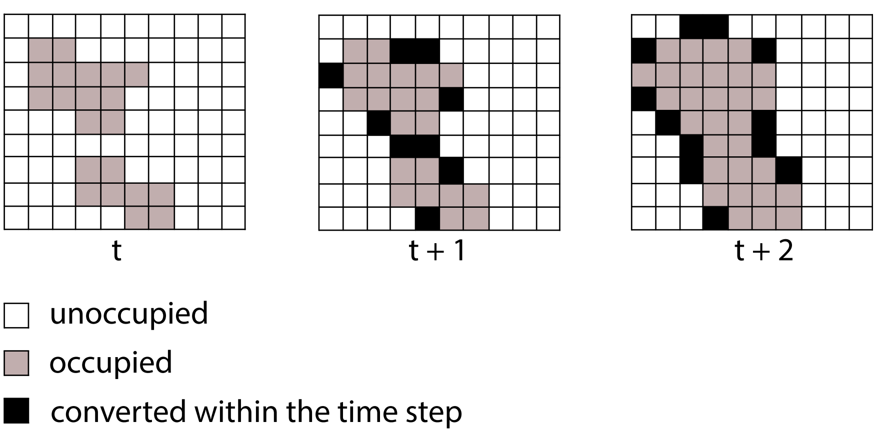

Figure 4. Example of the progression of cellular automata, under the rule in which at each time step *t*, for every cell that has three or more adjacent non-occupied cells, the cell is converted into 'occupied' (modified from Leao, Bishop and Evans 2004, 148).

changes in practices or re-commitments to tradition might be sparked by the development of new ritual traditions or the production and adoption of new types of trade goods (cf. DeCorse 2001; Richard 2017; Gokee and Thiaw 2020). At Angkor, a recognition of neighbor-to-neighbor actions in material culture adoption and ritual traditions is made possible by a growing amount of research on ordinary households and the decisions sustained at the smallest levels that resulted in large-scale complexity (e.g. Carter et al. 2018). And in the Moche region, incremental investments in landscapes through practices such as irrigation canals (Goodbred et al. 2020) constituted a physical connectivity of respond-to-your-neighbor that provided the basis upon which settlements had the resources to emulate or react against other settlements.

5) *Firefly synchronicity* describes the process of phase oscillation whereby members of bioluminescent species (including *Luciola pupilla* and *Pteroptyx malaccae*) eventually, over the course of a night, space out the timing of their emissions of light until the entire group flashes in unison. The inception of any individual's oscillatory pulse emerges not as a simple presence/absence phenomenon, but encodes a multiplicity of meanings including defense, communication and reproductive availability within a context in which not every individual flashes continuously (Ramírez-Ávila, Kurths, and Deneubourg 2019, 133). Firefly synchronicity constitutes a self-organizing system and does not depend on the instigation of a leader; however, particularly germane to this concept's applicability to territorial political systems, a mass of bioluminescent individuals does not always synchronize and variable outcomes are possible including incoherence and total or partial oscillation death (Ariaratnam and Strogatz 2001; Figure 5).

The outcome of firefly synchronicity is incumbent on the participation of organisms whose pulses are necessarily spaced rather than constituting a continuous source of light, because moments of emission are balanced by moments of pause/absorption. Applied to human population centers, the notion of pulses corresponds to seasonal or generational energy outputs; for example, when a village or a town has its harvest committed for its own use and also is taxed by an external entity, it has expended its capacity to generate energy and must pause after every harvest to regenerate its agricultural products and other renewable resources. The length of the pause varies not only with the timing of the regeneration of agricultural products (largely a natural phenomenon) but also with

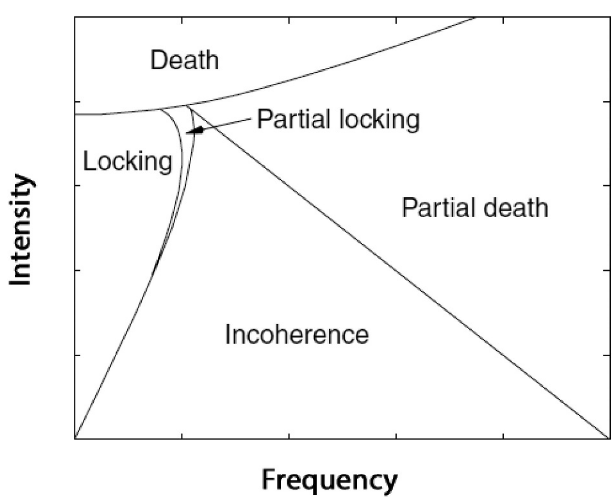

Figure 5. Outcomes of firefly synchronicity. Modified from (Ariaratnam and Strogatz 2001, 4280).

the timing of political inputs of taxation revenue rebates (such as famine relief, military protection or infrastructure development that is returned at a future time with the risk of system death, partial death, or incoherence in the interim).

Applied to the Siin case, the concept of firefly synchronization can be seen in the development of trade patterns in which emulation even in the most basic goods creates and affirms social status, leading to neighbors perceiving and often also adopting the item in question (cf. Miller 1985; M.L. Smith 2010). At Angkor, the existence of syncretic Buddhist and Hindu practices was 'broadcast' from the temples but was only effective if the signals were in turn accepted and rebroadcast at the scale of the self, the household and the local community. At Huaca Colorada, synchronicity in a belief system and the sustaining of a ritual locale was the result of agentive and collective practices of individuals and households across a landscape. At both Angkor and Huaca Colorada, ritual traditions would cease or be transformed at moments of prolonged incoherence, providing an insight into the ways in which changes in ritual systems can be identified in the archaeological record.

Discussion

Models derived from dynamic biological and natural processes are more realistic for the analysis of the development of complex societies than the simple linear descriptors associated with site-size hierarchies. In each model identified above, each nodal entity has the capacity for peer-to-peer and hierarchical interactions that are expressed in both one-to-one and many-to-one relationships. These models still allow for directional and even teleological causal interpretation of the kind promulgated in historical texts and analyzed through the lens of singular actions (such as specific moments of warfare or short-duration, mass-onset events such as earthquakes, volcanic eruptions and tsunamis). But they also encompass the 'slow time' of incremental cultural and environmental change, and the subtle recursive augmentations, ameliorations and accretions of individual and household actions stretching back into the beginnings of Pleistocene-era social adaptations (e.g. Wengrow and Graeber 2015).

Interactions at a local scale result in local effects, but they also result in complexities beyond simple domino effects across a landscape. While each decision-making node (individual, household or settlement) may remain viable in its own environment, its interconnection with others and the resultant archaeological perception of a 'system' is the result of a constant process of interconnection with both cooperative and competitive pressures from other nodes and from the physical environment, resulting in the potential for 'paradigmatic nonlinear interactions' of the kind recognized by Manukyani et al. (2017, 173) for biology. The creation of multiple dynamic models for past political configurations enables us to address the growth of social complexity at the most granular level to understand not only the quantitative changes associated with the manifestation of chiefdoms and states, but also the qualitative and phenomenological shifts experienced at multiple scales (cf. M.L. Smith 2020).

The development of dynamic models for human communities enables researchers to supersede the limitations of linear, hierarchical models for complex systems. The five models identified above are not mutually exclusive, and can exist simultaneously. For example, the nodal configurations characterized by firefly synchronicity or cellular automata could describe the interactions within the reticulation points of reticulated hierarchies. Geographical and other logistical constraints consisting of real-world affordances of access (including those resulting from annual seasonality or long-term climate change) provide opportunities and constraints that can be described by logic gates of specific times of decision-making within systems whose overall configurations are characterized by neural plasticity. Within smaller local geographies characterized by limited connectivity (such as mountain valleys or island chains), the generation of synchronous interdependencies within a group might mesh well within the confines of a natural system, but mesh only intermittently with the synchronicities emerging elsewhere within any single linguistic, economic, or political system. Finally, multipurpose interactions among small settlements (or within neighborhoods of a larger settlement) might be characterized as that of cellular automata, overlain by occasional special-purpose interactions with political and ritual places.

Conclusion

Models for complex societies based on reticulated hierarchies, logic gates, neural plasticity, cellular automata, and firefly synchronization highlight the agentive contributions of individuals and collective network nodes of all sizes. Within and among groups, relational systems are embedded in long-term memories of collaboration and cooperation that counterbalance the effects of hierarchical, linear moments of competition (cf. Appley and Winder 1977). The resultant models emphasize not only the autonomy of each spatial locale within a complex configuration, but also incorporate past chronologies of memory and future chronologies of intent such that interactions within and among nodes are a process of ***'becoming'*** rather than static being (Gosden and Malafouris 2015, 701, emph. orig.). The process of 'becoming' is not merely accretionary or unidirectional, however, because both stasis and change encompass episodes of decline, stagnation and devolution as discerned in archaeological settlement research (e.g. Gokee and Thiaw 2020; Jing et al. 2020; see also Flannery 1972, 421).

Societies at all levels of complexity, but especially those in the process of becoming territorially integrated as chiefdoms and states, are dynamic entities in which political agents consolidate and manage territories through cooperating and competing with other territorially-organizing political groups. Each unit (individual, household, settlement) within a landscape-scale political group also has ongoing engagements marked by cooperation, competition and stasis. In the ancient period as well as in modern times, differential configurations of territorial interaction among the residents of population centers reflect heterarchical, collective and/or situational-network configurations in which the viability of sites changed over time as new technologies of communication and transportation were developed, and as populations exercised their capacities vis-à-vis the opportunities presented to them and that they made for themselves. Given the overwhelming impact of the state in our own times, an application of dynamic models to ancient time periods reveals the inflection points, fractures and recombinations that were first developed in the earliest expressions of socio-political complexity and that continue to operate today.

Note

1. The citation in Flannery's paper is listed as a mimeographed work entitled Early Urban Systems in Southwestern Iran, but this work does not appear to have been published or made widely available.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes on contributor

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