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Using urban pasts to speak to urban presents in the Anthropocene

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With more people now living in urban areas than outside of them, urbanism is becoming an increasingly important socioeconomic and ecological arena for our species in the twenty-first century. Understanding historical and regional variation in urban trajectories and land use has the potential to provide long-term perspectives on pressing contemporary challenges. Here we review how novel methods and approaches are enabling archeology to shed new light on the past 5,500 years of urban life. From exploring urban variability in 'extreme' environments to studying the interaction of urbanism and the Earth system, we argue that the past provides a critical, growing reservoir of knowledge for contemporary urban scientists and planners.

Urbanism is a key element of human land use and social, economic and political organization in the twenty-first century. Over half of the world's population now lives in urban areas or cities, a number that is expected to rise to 66% by 2050[1–3]. Cities also form a central part of the ~30-trillion-ton technosphere—that is, all human made and/or modified environments—and are a hallmark of the Anthropocene[4]. Urbanism is quite literally bearing down on the Earth system, with cities being key contributors to climate change[5,6] and acting as critical frontiers of human interaction with the planet with consequences for sustainability, the evolution of plants and animals[7], and ecosystem vulnerability[8,9]. It is in cities, for example, where growing proportions of the world's human population are having to deal with new adaptive challenges, including the impacts of climate change on water availability and sea-level changes[10]. Cities can also accelerate innovation, drive economic productivity[11], shape social networks and perpetuate inequalities[12]. This 'dual nature of cities'[13] makes them a major part of both local and global social systems that increasingly interplay with the Earth system[14]. Cities are, however, not a recent phenomenon. Archeological and historical evidence documents a rich, varied global urban history beginning as early as ~5,500 years ago[15]. This time depth and the global diversity of past urban forms afford the opportunity to study the long-term (defined here as centuries to millennia) co-evolutionary dynamics of urbanism, which will be crucial for charting sustainable futures in the coming century[3,16,17].

The past decade has seen the emergence of new theoretical frameworks and methodological advances in urban archeology (Fig. 1). Traditionally, urban archeology has centered on 'origin stories' (see refs. 18,19 for reviews), which perceive urbanism as a major turning point or 'revolution'[20] and seek out particular consistent features (for example, bureaucracy, craft specialization) to circumscribe its presence (for example, ref. 20). However, new, fluid, comparative theoretical approaches are moving beyond rigid, and often Eurocentric, perspectives to instead focus on the underlying dynamics, networks and varied manifestations that characterized urban experiences through time[21–23]. Methodologically, remote sensing has provided novel insights into the scale, form and infrastructure of past cities in

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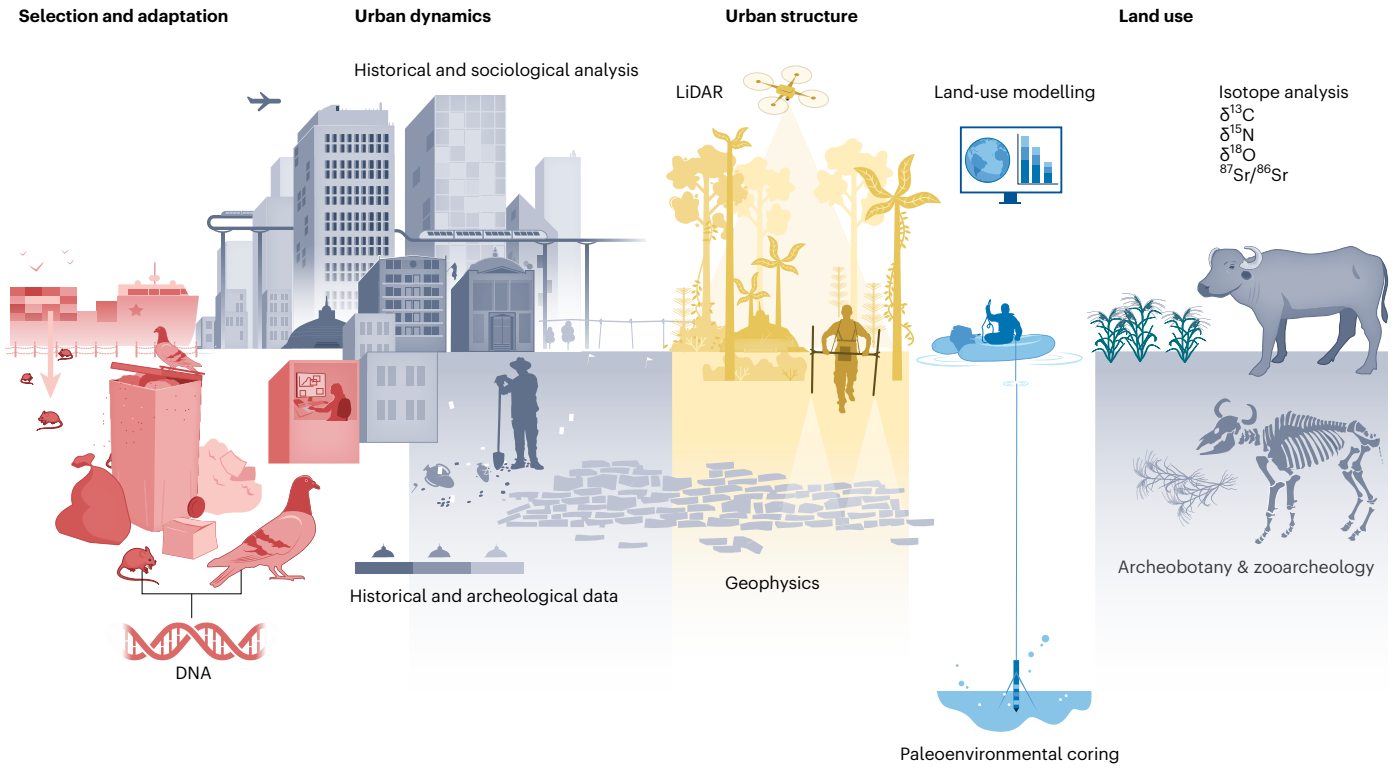

Fig. 1 | Schematic of multidisciplinary methodological approaches to urban archeology and history. Novel approaches can be used to explore urban selection, urban dynamics, urban structure and land use across space and time.

different regions[24–28], while biomolecular, paleoecological and historical ecology studies yield detailed information about urban–environment interactions and the urban conditions experienced by different species and human societies[29–31]. Growth in the amount, types and quality of data, alongside the forefronting of comparative perspectives, is allowing studies of the past to make active contributions to urban sciences and policy[16,32]. For example, analysis of material and construction choices in monumental buildings in Katmandu has revealed the existence of adaptive architectural pathways for 1,000 years in an earthquake-prone region[33]. Similarly, interdisciplinary combination of archeology, history and traditional knowledge in Punjab, India, has facilitated comparison of past and present water management strategies, leading to proposals for interventions to increase surface water availability in a region impacted by climate change[34]. Growing engagement with computational methods also means that such advances are not just qualitative. Instead, the archeological record can now also be interrogated for quantitiative insights into urban land use, resilience, breakdown, demography, infrastructure, innovation, environmental impact and economic output (see refs. 16,22,35–37).

Here we seek to demonstrate, to a multidisciplinary academic audience interested in urbanism, how archeology, alongside historical ecology and paleoecology, is better-placed than ever to contribute to urban studies more broadly. We explore new theoretical approaches to urban archeology and examine how recent multidisciplinary methodological advances enable exploration of several key themes: (1) variability in past urban forms between different environments, (2) selection pressures and co-evolutionary dynamics imposed by urbanism on different biota, including ourselves, (3) the different ways in which urbanism can impact land use, and (4) the social and economic dynamics underpinning urban organization and networks. We highlight the ways in which these new avenues of research facilitate the use of the unique time depth of urban history to speak to research and perspectives on an increasingly dominant form of human activity and life in the present[38]. In particular, we argue that contemporary urban studies can benefit from having a larger, more varied, diachronic database with which to make policy-relevant predictions on sustainability (defined here broadly as a balance between societal perseverance and environmental health over a prolonged time) and socio-environmental dynamics. Meanwhile, Earth-system sciences, such as geoanthropology[39], can explore long-term tendencies in urban dynamics and how they contribute to determining the drivers and limits of global urban growth and developing an appropriate co-evolutionary framework (that is, the reciprocal interaction and causal influences between urban, socioeconomic, land use and Earth-system dynamics) for understanding its interaction with our planet.

Defining cities in archeology

A desire to find the earliest 'origins' of urbanism in the past has seen much attention in urban archeology given to the definition of a city and its applicability to particular case studies, with Eurocentric perspectives often leading to biases in terms of what has been considered 'urban'[40]. Common definitions of the city in archeology fall into two major categories[41] (Fig. 2). As Smith[41] notes, formal, sociological definitions focus on the presence of "a large, dense, permanent settlement of people who are socially heterogeneous" (page 8 in ref. 42). However, such an approach excludes many early centers from the category of 'urban'[41], and archeological estimates of population density can be heavily disputed. The second category is functional (Fig. 2). Functional definitions tend to highlight the role of a city in relation to a 'hinterland' (page 577 in ref. 43), to the social and economic lives of its populace, or to political and ideological projection in a given region[44]. Scholars have defined certain material 'checklists' (for example, area size, fortifications, palaces, craft specialization) that can be identified to compare and contrast early cities and their function. Yet, demarcated hinterlands related to a particular city are often not clear, even in the twenty-first century (for example, urban sprawl[45]). Moreover, the 'checklists' used

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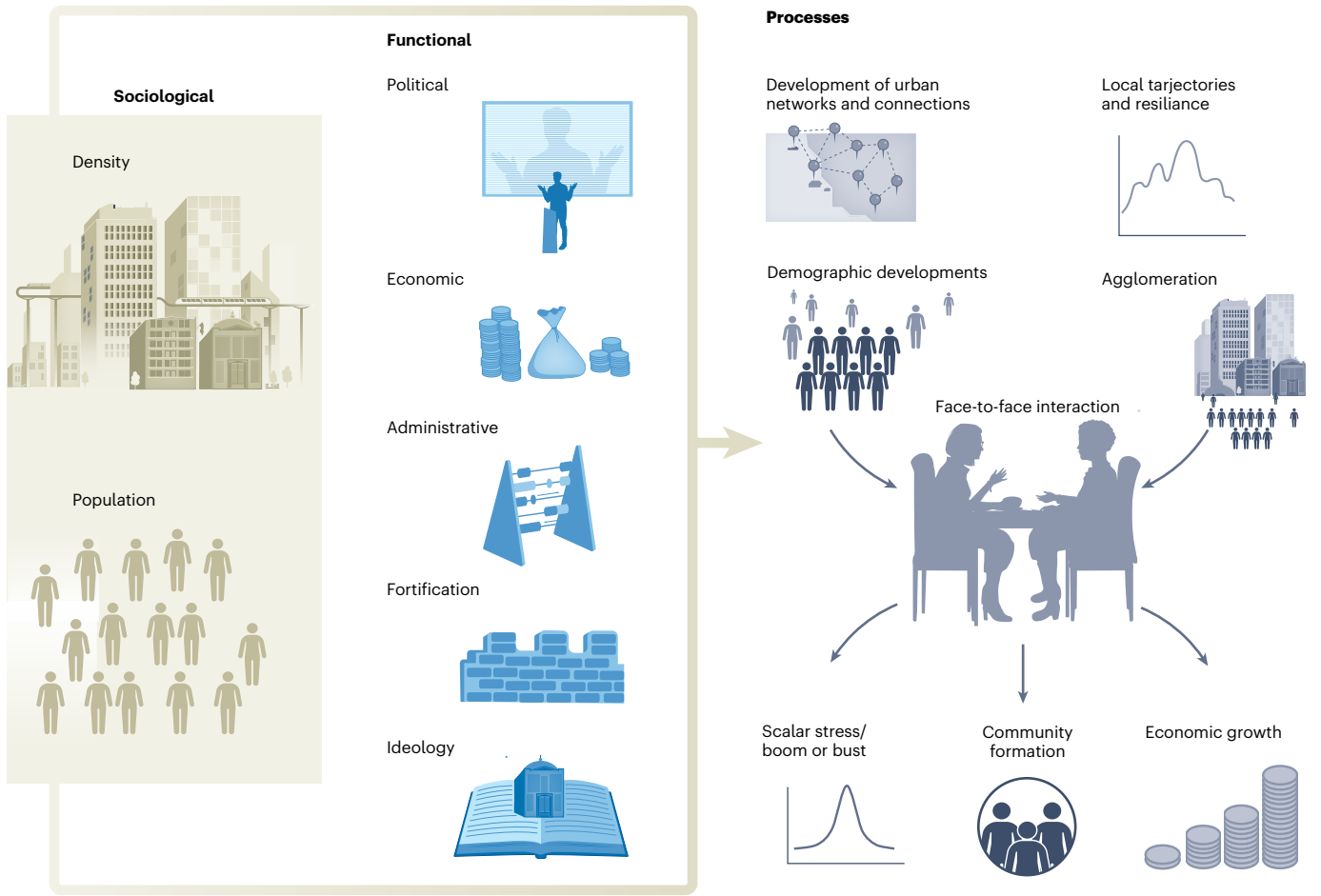

Fig. 2 | Theoretical approaches to definitions of urbanism in archeology. There is increasingly a growing movement away from traditional sociological and functional approaches and towards the study of urban processes, networks and land use. Figure inspired by Smith[16].

by different archeologists can vary substantially, and some 'functional' features (for example, fortifications, churches) also appear in contexts that would not otherwise be considered urban (for example, an outpost or a village)[16].

More recently, archeologists and urban historians, like geographers, have suggested looking at urbanism in the past as a process or practice, rather than fitting sites into pre-defined boxes[16,46]. For example, Smith[41] sees 'settlements' as the basic unit of analysis. They can be compared along a series of dimensions including size, function, aspects of communal life (households, neighborhoods), economics (prosperity, poverty), form (layout), urban meaning (role in religion) and urban growth (economic, physical)[41]. These dimensions can be assessed by observation of different 'traits' (Fig. 2). Here, archeological features (for example, markets, palaces, formal public spaces, imports) are not parts of 'checklists' used to justify an 'urban' label. Instead, they are indicators of certain dimensions that can be qualitatively, as well as quantitatively, compared to explore the characteristics of a given settlement, and the urban processes underpinning its dynamics, impacts on peoples' lives, resilience and interaction with other centers and the surrounding landscape. Smith[16] has also introduced the concept of 'energized crowding' to highlight how urbanism, as a more abstract concept rather than a physical fact, simultaneously forms, and is generated by, its inhabitants and their social lives. Relatedly, some scholars have shifted from looking at individual centers to examining urban 'networks'[47], urban 'landscapes'[18,48] and urban 'societies'[16] (Fig. 2).

Together, these novel approaches have a series of benefits in rendering urban studies global and comparative while removing underlying, Eurocentric narratives. First, they facilitate a broader perspective of settlements and urban dynamics emerging in different environments and time periods. Second, instead of being typological tick boxes, material and historical insights into urbanism can be explored and modeled as data representative of different urban practices and expressions, facilitating spatial and temporal comparison. Third, these definitions allow for, and even promote, focus on the non-urban, pre-urban and on ruptures in urbanism, with urbanism being just one potential outcome rather than a desired destination. In other words, the process and the underlying social, economic and political forces driving different settlement trajectories and the relationship of different settlements to each other is just as interesting, if not more interesting, than simply being 'urban'[16,41]. This allows us to compare contemporary and ancient cities, which may look very different on the surface, producing insights that can ultimately benefit our understanding of both. A focus on urban dynamics has also led scholars to draw on concepts used to describe biological systems (organisms or ecosystems) when considering the co-evolutionary interaction of urbanism and social and environmental systems[22,49]. Here, methods, ranging from foodweb analysis to phylogenetics, can be used to study the tempo and nature of urban growth, the co-evolution of urbanism and environmental impacts, and the role of urbanism in homogenizing or diversifying land use and social systems (for example, ref. 22).

Documenting diversity

More open perspectives on urbanism in archeology, alongside new methodological toolkits, have resulted in a more diverse comparative

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Fig. 3 | Artistic representations of different case studies of past urbanism in diverse environmental contexts. a, Ancient urbanism in Mesopotamia ~3500 BCE. **b**, A 'garden city' in the Xingu River region of Amazonia[55]. **c**, 'Steppe urbanism' such as that seen at the historical capital of the Mongolian Empire, Kharakorum (based on geophysics work by ref. 57). Note that the representations are not meant to be exact likenesses. Nor are they supposed to represent the only, or even most important, urban 'models'. Rather, they have been chosen to highlight the diversity of environmental settings, urban forms and structures, and land use associated with past urbanism in these different parts of the world. Credit: Nabil Nezzar, under a CC-BY license.

dataset of past urban examples and socio-ecological contexts. Traditionally, interest in urban origins in archeology focused on the fertile river valleys of the semi-arid and arid Near East, particularly Mesopotamia. This is the region of Iran, Syria and Iraq between the Tigris and Euphrates rivers, where walled, dense, urban settlements emerged at sites such as Uruk and Tell Brak in the context of a bureaucratic system of royal and religious control ~5,500 years ago, providing a 'template' for understanding ancient urbanism elsewhere[19,50] (Fig. 3). Here, the Tigris and Euphrates water courses surrounded by drylands were seen as the ideal context for condensing populations and the emergence of structures of control and organization of resources[51]. Nevertheless, even within this classic region of urban 'origins', environmental variability in urban dynamics is visible. Wilkinson et al.[52], for example, showed how early Late Chalcolithic urbanism, with dense rural settlement, shifted to large, walled ramparted sites that underwent cycles of growth and collapse. By the late third millennium BCE, larger centers expanded in the drier agro-pastoral zone of Syria. Utilizing zooarcheological and archeobotanical data, Wilkinson et al. highlight the ways in which the relative focus on staple food production in river-fed lowlands versus higher-risk animal husbandry in climatically marginal regions shaped divergent urban pathways (see also Ur[53]).

Moving away from traditional regions of focus in urban archeology, recent advances in remote sensing (for example, LiDAR (light detection and ranging)), supported by archeological ground-truthing, have revolutionized the exploration of urbanism in a variety of different environmental contexts[24–27], including in supposedly extreme habitats such as tropical forests or dry steppe-like regions once thought to be unattractive for substantial urban growth. For example, Greater Angkor (ninth to fifteenth centuries CE) in tropical Cambodia has now emerged as the largest pre-industrial center on record by area (~1,000 km^2)[24]. Following a 'low density' pattern of houses and fields interspersed with temple and palatial compounds, Angkor has been contrasted with traditional 'compact' ideas of urban layout and may reflect an adaptation to seasonally dry tropical landscapes[45,54]. LiDAR has stimulated similar discussions in the Classic Maya region of Mesoamerica, revealing apparently low-density settlement and palatial complexes connected by networks of causeways and hydraulic infrastructure[25]. Similar work has also expanded knowledge of Indigenous so-called garden cities (1250–1650 CE)[55], comprising a mosaic of fields, forest, road systems, monumental areas and settlement hierarchies, among the rainforests of the pre-Columbian Amazon[27] —environments once thought inhospitable to urbanism[56] (Fig. 3).

On the steppes of Mongolia[57], novel application of magnetic resonance survey techniques at Kharakorum, the thirteenth-century CE capital of the Mongol Empire, has revealed the extent, layout and organization of what is now being called 'steppe urbanism' in the dry grasslands of eastern Asia (Fig. 3). This work has documented emerging road networks, areas of variable occupation density and activity divisions across the landscape to explore the function of this city as a commercial hub and political center. The resulting data, alongside archival evidence, have led some to argue that this city formed in a very different manner to many other past urban examples, being a political and economic 'implant'[57]. Acknowledgment of these diverse examples highlights the variety of perspectives that urban planners and socio-ecological modelers can, and should, gain from the past. For example, reviewing the archeological record of urbanism in Africa, Chirikure[58] has argued for the development of 'Afro-centered' viewpoints when considering contemporary interventions, while work in the first-millennium BCE Middle Niger Basin has highlighted the different ways in which urban societies can structure and govern themselves (for example, in the form of a heterarchical rather than hierarchical systems)[59]. Not only that, but documentation of urbanism across very different environmental contexts in the past provides an important reference for contemporary urban societies attempting to navigate intensifying twenty-first-century climatic extremes.

Selection, adaptation and transformation in the city

As well as enriching the database of the urban past, new methodologies (Fig. 1) can also identify the long-term selection pressures and co-evolutionary dynamics that urban environments have introduced to the biology, genetics and behavior of humans and other species[60–62] (Fig. 4). Researchers have utilized island biogeography concepts to explore how contemporary urbanism creates novel selection pressures, isolates populations and facilitates species transfers[63]. For example, genetic studies of pigeons in Europe and Asia highlight lineage divergence between different urban areas[64]. Application of ancient DNA, zooarcheology and archeobotany can reveal further insights into the ways urbanism has shaped species through time. For example, urban networks seem to have been key to the rapid expansion of the black rat from southern India to Mesopotamia and into the Mediterranean[65]. Ancient microbial DNA extracted from human and animal remains has been used to study how urban networks and structures[66] may have encouraged or delayed the spread of disease[67], and human immunology has been shown to have been shaped by historic epidemics[66]—something of acute relevance to observations of the impacts of the COVID-19 pandemic and future pandemic potential. Given the capacity of urbanism to apply new pressures, and connect as well as isolate communities, assessing the possible impacts of urbanism on human mobility and genetic variability[68] using studies of strontium isotope analysis (for example, ref. 69) and ancient DNA in different urban contexts may be an interesting area for future research if ethical considerations can be appropriately taken into account.

Apart from applying selective pressures to individual organisms, cities, as novel environments, also place pressures on entire human societies. In the twenty-first century, rapid urbanization is making people more vulnerable to climate impacts[70]. Many megacities, such as Jakarta, Indonesia, are located directly on the coast, leaving them exposed to sea-level rise[10]. Meanwhile, the power of urban insolation leads to urban residents suffering more heat-related illnesses[6]. Urban networks also shape human food supply, so that local production problems in one region can be propagated across vast areas[71]. Archeology, alongside integrated paleoecological and paleoenvironmental research (for example, analysis of lake/swamp cores), can provide insights into the socio-ecological resilience of different urban societies in the past, enabling exploration of the degree to which different social systems, governance and ecological adaptations promoted persistence or change. For example, the dense packing of wooden structures in Medieval Europe made them particularly sensitive to fires, as seen in Warsaw in 1431[72]. Similarly, the 'low-density agrarian urbanism' of Greater Angkor has been argued to have been prone to political fission in the face of rainfall fluctuations as widely dispersed urban communities sought independent local solutions[45,54,73]. Archeology can also explore different scales of socio-ecological resilience within urban societies. For example, in the face of increasing drought strength and frequency Classic Maya (250–900 CE) centers and state structures moved away from the dry Central American lowlands towards more reliable water courses and highland areas[74]. However, smaller food-producing communities persisted across the region[75].

A particularly important theme of research that has emerged in discussions of the socio-ecological resilience of past cities is water security. For example, the aforementioned Classic Maya urban societies in the dry lowlands adapted to low surface water availability and dry season water scarcity by building extensive urban reservoir systems and constructed wetlands cleaned through the introduction of particular aquatic plants[76]. Similarly, at the early and mid-second-millennium CE site of Great Zimbabwe in sub-Saharan Africa, remote sensing and geoarcheology have revealed the centrality of large *dhaka* pits, dug into granite bedrock, to feed an integrated water system, which enabled urban communities to farm and persist through dry periods[77]. While the close integration of urban societies with these systems resulted in certain vulnerabilities, it also shaped new urban waterscapes that can still resonate with communities facing similar problems in those regions today. For example, Ochoa-Tocachi et al.[78] studied Inka water infiltration enhancement systems in the Andes dating to 1,400 years ago, showing how they would have enhanced the water yield and permanence of downslope natural springs. They argue that the re-use and extension of this system today could also enhance water security in the modern city of Lima. Meanwhile, the web of tanks and canals constructed in the ancient cities of Sri Lanka for over 2,000 years act as a 'living cultural heritage' for modern planning in the drier portions of the island[79].

Urban environments are not stable, meaning that the pressures acting on the organisms and societies that call them home, as well as the surrounding environment and settlements, are dynamic. At the most general level, the archeological record also provides a solid basis for extending a co-evolutionary framework, which can explore how changes in urbanism, land use and the Earth system have interacted, and reinforced or disrupted each other, through time[49]. Such a framework can explore external conditions (for example, environmental)

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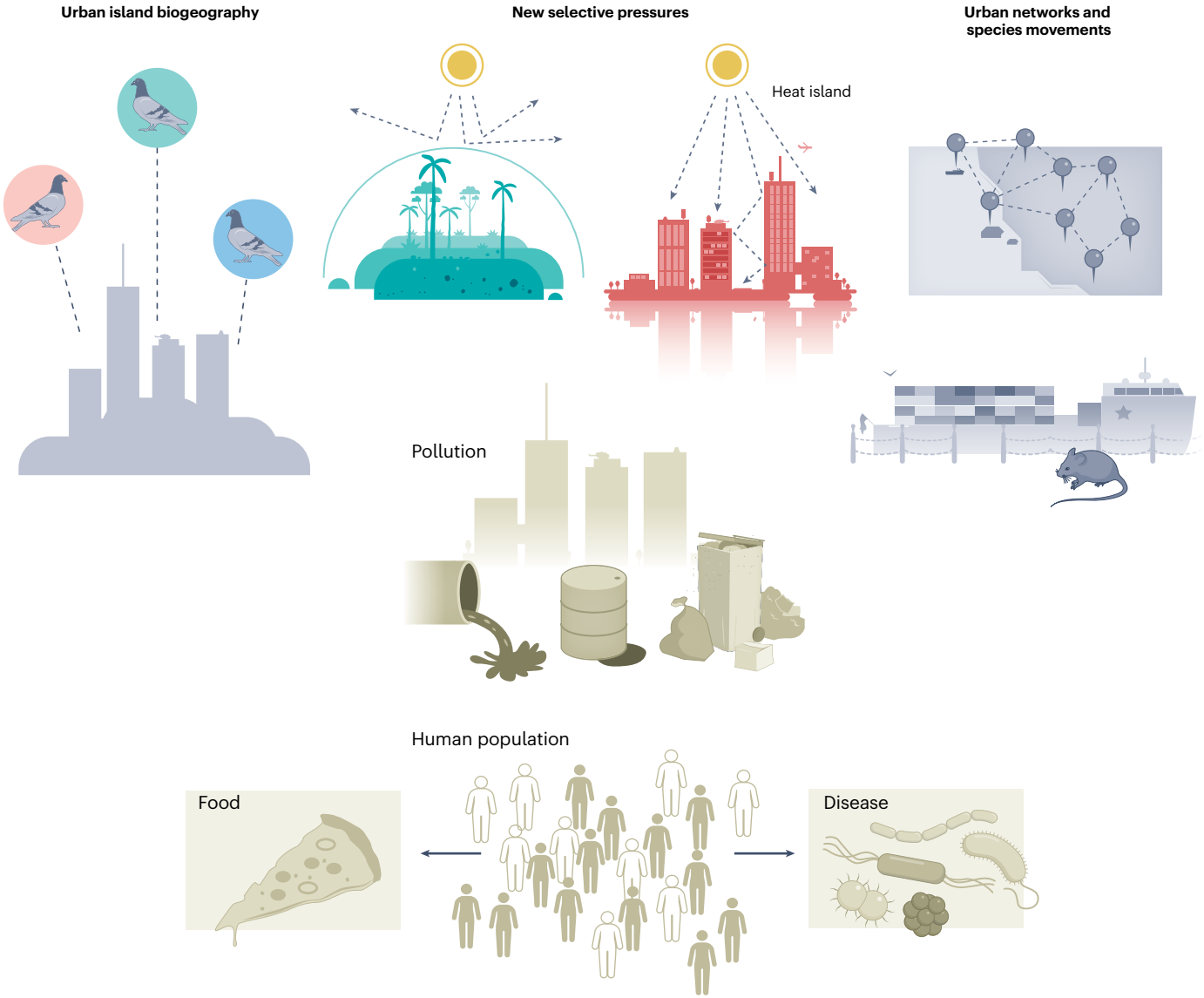

Fig. 4 | Demonstration of the ways in which urbanization can shape adaptation in plant and animal species. This includes: isolation through the urban 'island' effect; adaptation to new urban niches and selective pressures (for example, additional heat, pollution, waste and a density of human hosts for microbes); and homogenization and gene flow as a result of urban networks.

and internal mechanisms (for example, societal structures), as well as their interaction[14] (Fig. 5). It can also enable understanding of the ways in which urbanism, as a 'system', alters or shapes social and environmental path dependencies[22,80]. For example, Constantinople (now Istanbul), located at the intersection of Europe and Asia straddling the Bosphorus Strait, benefited from its geographical location to build an extensive supply system based on seaborne goods, investing considerably in granary and harbor infrastructure[81]. However, over time, repeated sieges, made more probable by its critical military and economic tactical position, led to ruptures in these supply chains, leaving the city highly vulnerable. This gradually resulted in more community-based approaches to food security, including investment in local fishing and the cultivation of food within the defensive walls[81]. In turn, this altered the city's relationship with environments on different scales.

Urban nodes and networks can also act as templates to be copied or implanted[39], they can provide resilient infrastructure and stimulate ideological and material exchange, and they can even create new niches or networks that impact future regulatory dynamics. It has been argued that urbanism was closely linked to the emergence and spread of writing, accounting, and legal, economic and political systems[39,82], of religions[83], and of technologies of warfare, construction, public health and economic extraction[84–87]. Cities such as Baghdad and Merv, for example, were critical to the extension and maintenance of the exchange network of the Silk Roads in the eighth and ninth centuries CE, which impacted cuisines, economies and social organization in far-flung areas of Eurasia[88]. Baghdad, the capital of the Abbasid Empire from the eighth century CE, not only benefited from this wider urban network by becoming a center of learning (for example, House of Wisdom) but also, in turn, helped maintain a wider system of knowledge across the Islamic world and beyond[89,90].The archeological record, when considered in these terms, can be used to explore the ways in which urbanism, or indeed other forms of settlement, in different parts of the globe have enhanced or ruptured environmental impacts, cultural and material homogenization or diversity, gene flow and connectivity, and the ways in which these observations provide insights into various trajectories that extend into the contemporary world.

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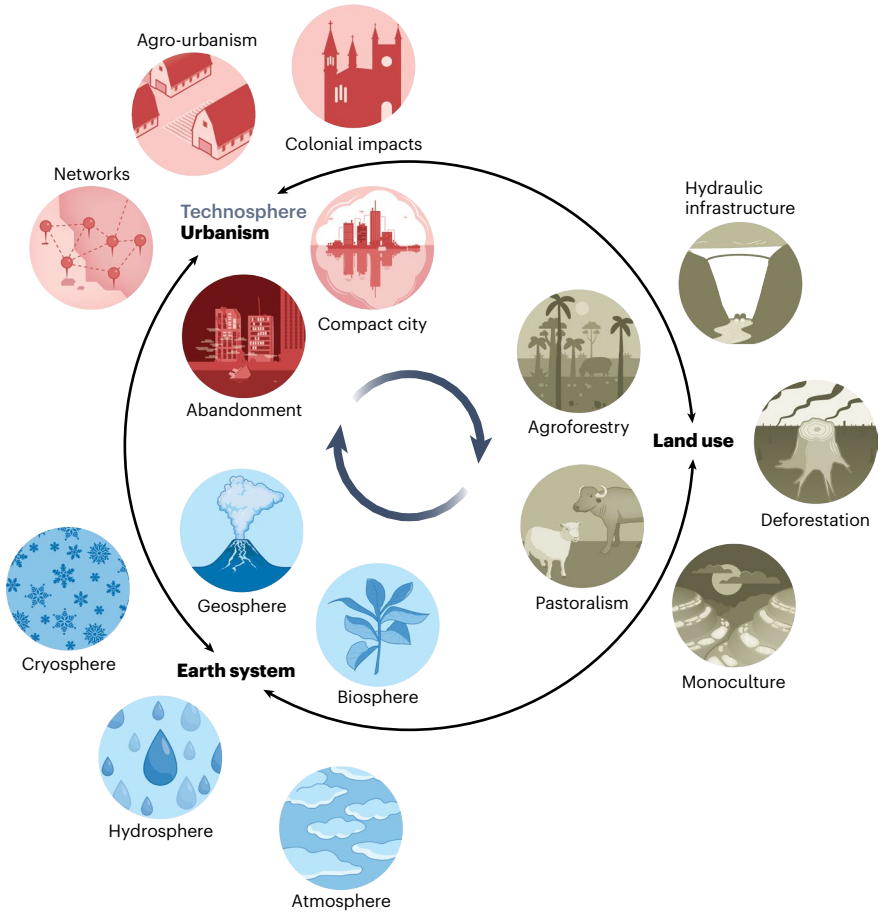

Fig. 5 | The intersection and co-evolution of urbanism, land use and the Earth system. Schematic showing the co-evolutionary interaction of elements of urbanism within the technosphere, types of land use and different parts of the Earth system.

Past urban land use and its Earth-system legacies

To properly understand the scale and nature of co-evolution of urbanism and the Earth system, it is important to explore the interaction of urbanism with land-use change, on both immediate and more distant spatial scales. Here, historical ecology, archeology and a diversity of scientific methods have contributed substantially to discussions of the nature of urban food bases. For example, isotope analyses of plants and animals preserved in urban contexts provide insights into the management of these species within the city and the surrounding landscape (Fig. 1). Styring et al.[30], for example, argue that increases in manuring, observed by performing stable nitrogen isotope analysis on crop remains found at urban sites, coincided with spreading urbanism in the Bronze Age Near East, suggesting urban growth and agricultural intensification were intertwined in this instance. By contrast, in the case of the Classic Maya, Greater Angkor and Amazonian examples[27,55] of low-density forms of urbanism, food production has been argued to have occurred within the urban area as part of agro-urban landscapes or peri-urban agricultural systems[91]. These forms of 'low-density, agrarian-based' urbanism[92], including urban gardens[93], agroforestry[55,75] and, depending on the environmental context, wetland raised fields[94], intermingled with causeways, monumental buildings and dwellings, have been seen as adaptive responses to seasonal and tropical environments that enhanced urban resilience in the past[91].

Paleoecological and paleoenvironmental records can be used to study the complex relationship between urban demands for water, fuel, food and resources, and the surrounding environment. For example, strontium isotope analysis of the geological origins of animal food resources have documented changing urban catchments in Medieval Spain[95]. Geoarcheological assessment in Central America[96] and on the Loess Plateau in China[97] has revealed the role of urbanism, and its associated landuse practices, in stimulating soil erosion, something frequently observed in contemporary urban settings[98]. Various degrees of deforestation linked to urban expansion, as well as mitigation and management strategies, have also been observed through paleoenvironmental, archeological and historical research in third-millennium BCE Mesopotamia[99], city states in Classical Greece, the High Andes of the Inka Empire, ancient China, Medieval Europe[100], and the vicinity of some Classic Maya centers[101] as part of a tense relationship between urbanism and forests that continues today[102]. Furthermore, in the Amazon Basin, multidisciplinary geoarcheological research has shown how urban networks both stimulated, and were reliant on, the formation of anthropogenic dark earths (with their production intensifying 2,000 to 1,000 years ago)[103], which still dictate the location of agroforestry and farming settlements along the banks of the Amazon and its tributaries today[104].

At the broadest level, there is a growing drive to use archeological and historical data to produce better-informed land-use and land-cover models and maps[105] to study how past human societies, including urban forms, have influenced land use and land cover across wider, regional scales. For example, Kay and Kaplan[106] used estimates of resource needs and their productivity to compare the land use of a city in an Ethiopian/Late Nilotic kingdom, a Swahili coastal trading urban center and an Atlantic coast kingdom. Notably, such models can be factored into Earth-system modeling—Cook et al.[107] argued that estimated Classic Maya urban and agricultural land use may have reduced precipitation in Central America by up to 15%. Historical and archeological research

has an important role to play in complexifying land-use models and determining which portions of urban society had the greatest land-use impacts[108] and in assessing the ways in which different, historical factors may have shaped urban land use through time. For example, the Manila earthquake of 1863 has been argued to have initiated commercial logging in the Philippines as different portions of society sought to rapidly rebuild houses and other structures using wood from a wider area across Luzon[109]. Meanwhile, the impacts of European colonialism on towns and cities in different environments[110] have been argued to represent a major transition in the co-evolution of urbanism and land use in different parts of the world.

Modeling social, economic and ideological urban dynamics

Insights into past urban scale, infrastructure, population, land use and environmental impacts can also be fed into the expanding world of computational archeology. Here, urban variation can be compared, not just in an anecdotal sense, but also in terms of quantifiable parameters that can be measured. In this context, material and archival observations of different facets of urbanism (for example, road extents, frequency of certain buildings, population, area) can be treated as numerical data to explore different correlations between different elements of urbanism. Although the culturally variable experiences of urbanism across space and time should not be forgotten in such exercises, these datasets can also be used to explore trends across space and time, from pre-urban contexts through to a variety of different urban contexts, to study ongoing processes rather than identify 'cut-offs' for urban emergence. For example, Crawford et al.[111] developed quantitative estimates of urban persistence (for example, settlement continuity in a region), population and prosperity (for example, craft output, household quality of life) to determine the different factors behind urban 'success' and 'failure' in the past[112]. In preliminarily application of these estimates to some case studies, they highlight that 'success' was particularly contingent on long-term adaptation and response to environmental, institutional and political 'shocks'[111].

A further prominent example of computational archeology is the application of settlement scaling theory to past urban case studies[35,36]. This theory explains and predicts socioeconomic outcomes in urban centers as a function of fundamental principles of human social interaction[11,113], with settlement area, infrastructure extent, economic output and innovation scaling predictably with population size[11,113]. Archeology can be used to test whether these scaling 'laws' are unique to particular industrial urban phenomena in the twenty-first century, or whether there are general characteristics of urban social metabolisms that extend back in time and across different geographical and cultural contexts. When these methodologies have been applied to past examples, patterns consistent with the theory have been identified, albeit with some interesting variability[114]. For example, development and analysis of the Roman Cities Database[36,115] has shown a clear relationship between Roman urban site and infrastructural area for Roman cities between 50 BCE and 300 CE, suggesting a scaling that aligns with expectations of organic growth[115]. This supports arguments that Roman imperialism applied Roman ideals within existing urban logics. Interestingly, analysis of monument variability relative to city area reveals different functions and statuses for different urban sites. For example, Pompeii had greater monument variability than would be expected, perhaps indicating a wealthier status[115].

Moving to the other side of the world, settlement scaling theory has been applied to show that areas of sites in the Valley of Mexico, dating from the pre-colonial period to recent history, scale with proxies for economic production[32]. These studies support the suggestion that urban size and population has a primary role in shaping the social and economic worlds of urban areas[16,114]. However, such approaches are yet to be applied to the growing dataset of urban forms in very different socio-ecological settings. For example, it has yet to be extensively tested whether relationships between population, area, infrastructure and economic output proposed by settlement scaling theory hold in the case of low-density or agro-urban instances (though see ref. 116). Such quantitative approaches may also be applied to other aspects of urban life, such as waste production, management and re-use, symbolic architecture, the development of communities or social belonging, and the intensity of urban land use within and beyond the immediate city. Nevertheless, this growing body of work, highlights the ways in which archeological data can be used in quantitative approaches to exploring varied regulatory structures of social, cultural and economic life in different urban forms, and how they change with expansion and growth, providing rich comparative data for studying urban dynamics in the twenty-first century and developing future urban projections[11].

From past data to urban predictions

Urbanism should certainly not be seen as the ultimate pinnacle of human settlement or social organization. Nor should non-urban societies be seen as any less complex or notable in their adaptations to different environmental, social or economic settings[116,117]. Urbanism is simply one set of human adaptations to living in communities, to organizing and projecting land use and economic dynamics, and to political and administrative organization that became increasingly prominent in different parts of the world from ~5,500 years ago. Larger proportions of the world's population will continue to be pulled into cities in the twenty-first century, yet the legacies and path dependencies of past urbanization processes for the contemporary world remain to be fully explored[16,17]. Cities bring together heterogeneous groups, often generating new forms of social and political stratification and inequality, but also giving rise to new forms of community and diversity beyond traditional social or ethnic differentiation[118,119]. Cities can also be centers of consumption, extraction and intensive land use[120,121]. Yet, it is also in cities where large populations have developed communal adaptations to climatic change, to natural hazards, and to sustainable water and land use[122]. In a world where heat and climatic unpredictability will represent increasingly prominent adaptive challenges[6], the past can act as a long-term reservoir of knowledge about urban socioeconomic and climatic interactions.

Indeed, the urban archeological record is already actively being used as a resource by urban planners and architects. For example, 'wind-catchers' documented in ancient Iran act as solar chimneys, drawing cooler air into the building and reducing temperatures by as much as 8–12 °C (ref. 123). These devices are still used in homes in Iran today and architects are using computer-aided tools to make use of this effective, electricity-free device[124]. At the level or urban organization, examples of agro-urban landscapes from the past have provided inspiration for urban planners focusing on the importance of 'green' areas in cities for buffering insolation changes and anchoring soils in the face of climatic challenges, as well as providing more local sources of food through peri-urban food production[91,125]. There are also ample examples from urban archeology that can be used to explore how new social dynamics and identities have been created within urban areas[118,119], how urban layouts and buildings have shaped phenomenological experiences of cities, and how gender, ethnic and regional identities have been negotiated[12,47,48,126]. Nevertheless, so far, the past has often remained something of an anecdotal, rather than practical, resource for contemporary urban studies and policies. In this Review, we hope to have shown how new theoretical and methodological approaches in archeology can facilitate new, more practical connections between the rich urban archeological record and twenty-first-century urban concerns.

"What's past is prologue" (Shakespeare, *The Tempest*), and archeology and history can be used within broader co-evolutionary frameworks of urban dynamics and land use to determine how we got to where we are. What are the factors, trends and tipping points that shape urban trajectories? How can they help inform important global initiatives such as the '100 Resilient Cities' program[127]? Archeology

and history can allow us to explore the gradual or rapid transitions in urban form and experience, and their legacies, in different parts of the world: from Roman to Medieval to post-nineteenth-century cities in Europe, from Indigenous (for example, Tenochtitlan) to colonial cities (Mexico City) in the tropics[128], from pre-industrial cities to twentieth-century megacity phenomena. Silva[129], for example, emphasizes the importance of identifying the impacts of European colonialism when understanding where current structures of African urban planning come from as well as their relative resilience. Using the theoretical and methodological toolkit at our disposal, we can determine the degree to which interplays between external conditions (for example, climate change, warfare, economic crisis) and internal dynamics shaped different urban centers and networks, their potential demise and the timescales over which this occurred[111]. We can also explore the ways in which co-evolution of urbanization and land use sheds light on the overall dynamics of the technosphere and the flows of information, energy, labor and resources that shape human lives around the planet today.

Within such a co-evolutionary approach, archeology, history and paleoenvironmental research can also be used to assess whether there are general mechanisms driving the expansion and resilience of sustainable urban models, a question of key importance as we come to terms with the Anthropocene. Do they vary between environments? Are well-honed local urban adaptations inevitably ruptured by the forces of globalization, or can they be empowered as global solutions? Harvey[1] has suggested that until the sixteenth and seventeenth centuries, urbanization was limited by a specific 'metabolic relation' between cities and a relatively confined hinterland, being sustainable "because they had to be" (page 17 in ref. 1). Subsequently, he argues, technological, economic and organizational changes, operating within imperial or global market frameworks, shaped new, extractive, planetary footprints of urbanization. Given acknowledgment of the notable role of urbanism in global climate change mitigation[130] and governance[131], testing such hypotheses and exploring the subtle and long-range effects that alternative forms of urbanization have had on human–Earth system interaction through time, is essential. To study such questions, it is clearly insufficient to just pursue isolated case studies of 'cities'. One rather needs an encompassing framework for studying the co-evolution of urbanization and land use. Only then can we study key transitions or pathways of this co-evolution and explore the ways in which different forms of traditional land use and collective urban life and governance can coexist, or push back against, more extractive models[132,133].

Undoubtedly, the major historical changes witnessed over the past 5,500 years, and particularly the past 500 years, mean that there are some limitations in the degree to which deep history perspectives can be directly, practically applied to the urban present. Middleton[134], for example, explored the trajectories of three different cities in Anatolia around ~1200 BCE, a time point often associated with climatic and economic upheaval, to highlight the very different responses that can occur as a result of human choice and unique historic and geographical contexts. There is also, of course, no guarantee that archeologists will always effectively identify the issues most pressing to urban planners and policymakers in the twenty-first century. Nevertheless, we hope to have shown how engagement across disciplinary divides, new theoretical frameworks, expanding and diversifying archeological datasets, and the application of quantitative and co-evolutionary models can provide important insights into long-term urban trajectories, dynamism and adaptations. Urbanism, which started out as a novel, rare way of life in human history, is now a key phenomenon structuring human lives, economies, politics, societies and even Earth-system dynamics across the planet in the twenty-first century. We believe that by exploring the rich urban archeological and historical record, we can gain a better understanding of where our contemporary urban challenges come from, as well as how we might begin to address them.

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Author contributions

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Competing interests

The authors declare no competing interests.

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