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Urban heterogeneity and technological innovation in the Roman Empire

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Urban Heterogeneity and Technological Innovation in the Roman Empire

ABSTRACT This article explores the relation between imperial hegemony, social heterogeneity, and technological change. The abundance of archaeological and epigraphic evidence makes it possible to both reconstruct a historical geography of urban heterogeneity on the global scale, and to explore its impact at the level of individual regions and cities. This article argues that urban heterogeneity became unequally distributed over the Roman Empire, peaking in the core of the empire in central Italy. Emerging heterogeneity created ideal circumstances for technological innovation, and several key innovations from the Roman period can not only be associated with these extremely heterogeneous micro-regions, but also seem to be facilitated by their very heterogeneity. This perspective adds a new dimension to debates about technological innovation in the Roman Empire.

KEYWORDS Comparative urbanism; empire formation; heterogeneity; digital epigraphy; technological innovation; social change; globalization theory; Roman Empire; opportunity niches.

Urban Heterogeneity and Roman Imperial Hegemony

The Roman Empire presents an ideal environment for studying social heterogeneity in a complex, urbanized, and non-modern agrarian society: compared to all earlier and contemporary civilizations, the available evidence is both quantitatively and qualitatively outstanding, and there is, of course, an established and vast scholarly tradition in which both the urban history of the Roman Mediterranean, and the socio-economic and cultural

development of the Roman world play a central role (e.g. Zuiderhoek 2016; Scheidel 2012; more in general Bowman, Champlin, and Lintott 1996; Bowman, Garnsey, and Rathbone 2000). The word ‘heterogeneity’ itself may not have played a particularly central role in recent discourse on the Roman world, but some of the most intensive debates in Roman studies develop around closely related concepts. Indeed, Roman scholars tend to agree that the last centuries BC and first centuries AD brought increased levels of heterogeneity to the Mediterranean, both in a socio-economic and in a cultural sense. The redistribution of wealth and the allocation of social status through Rome’s imperial networks massively improved the socio-economic power of some local and imperial elites, while also creating new levels of social and economic deprivation in a range of other social groups, including, but not limited to enslaved people working in the large households of Roman imperial elite. Social and economic differences in the Roman Mediterranean of the imperial period became substantially bigger than they had been in the same region in the Hellenistic period, before Roman imperial expansion (Zuiderhoek 2009; Scheidel 2012, 13; Milanovic, Lindert, and Williamson 2011), and processes of specialization in the urban economy also created diversity in knowledge and skills (Ruffing 2016; von Petrikovits 1981). At the same time, imperial hegemony appears to have strengthened processes of cultural interaction, as people from divergent ethnic and cultural backgrounds were brought into direct contact through imperial networks of movement and exchange and through migration (Versluys 2014; Pitts and Versluys 2015; Pitts 2021). While Roman scholars tend to use different words — such as inequality or cultural diversity — when they refer to existing or emerging differences within

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communities, the basic idea that there was substantial ‘heterogeneity’ in the Roman Empire cannot be controversial, and one is unlikely to raise a lot of eyebrows if one claims that heterogeneity increased over time, as the empire grew and flourished.

Following from the points made in the introduction to this issue, this article explores the question of what this emerging heterogeneity meant for processes of technological innovation in the Roman world. Did the growth of heterogeneity in the Roman Mediterranean create something resembling the ‘opportunity niches’ that Arthur (2009, 18) envisaged to facilitate ‘combinatorial evolution’ (cf. Raja and Sindbæk 2023, in this volume), and if so, could this, then, add a new dimension to the vexed debate about the extent to which the Roman Empire stimulated or constrained technological development? This could be refreshing: after an enormous upsurge of interest in the 1990s and 2000s, scholarly discourse on ancient technology appears to have entered a kind of stalemate: the traditional, mid-twentieth-century idea that the Greek and Roman Mediterranean were characterized by technological stagnation (Finley 1965; Pleket 1973) has been definitively abandoned (Greene 2000; Wilson 2002), but the tension between optimists — who believe in a high level of sustained technological innovation — and pessimists — who are more sceptical about the extent and impact of technological progress — has not been fully resolved; in recent years, those who believe that innovation in the Roman world was relatively compromised and constrained seem to have had a slight upper hand (esp. Terpstra 2020; cf. Erdkamp 2020). They argue that the unification of the Mediterranean under Roman rule led to a one-off cross-fertilization, but not to sustained technological development. This paper will argue that analysing innovation in the Roman Empire through the lens of heterogeneity suggests that this position may be unduly sceptical. In fact, it will be proposed that the urban heterogeneity that emerged under Roman imperial hegemony created circumstances that could facilitate sustained technological innovation.

The discussion in this article will develop in three steps. First, I will offer a rough sketch of the relation between urbanization and heterogeneity on the macro-scale, on the basis of a big-data study of Latin inscriptions from the western half of the Roman Empire. This will not only illustrate how some of the regions around the western basin of the Mediterranean became excessively densely urbanized, but also how there were substantial differences in the nature and the extent of heterogeneity between these regions. Central Italy will particularly emerge as a hot spot of heterogeneity. Secondly, I will discuss

the development of heterogeneity on the micro-level of urban communities within this region, focusing on the Bay of Naples and the Roman metropolis. It will be argued that the socio-economic and cultural transformation of these densely urbanized regions created ideal circumstances for the emergence of Arthur’s ‘opportunity niches’. The third step of the argument will address the actual relation between heterogeneity and innovation, and suggest that, at least in central Italy, it is possible to see a clustering of technological innovations in environments that became particularly heterogeneous, and that, on top of that, social heterogeneity seems to have played a direct role in the emergence of some of these. In other words: this article will propose that we should see the technological history of the Roman world as structurally affected by the geography of urban heterogeneity brought about by Rome’s imperial hegemony. The claim in this article is not, of course, that urban heterogeneity was the only, or even the main, driving force for technological innovation in the Roman world. Nevertheless, if heterogeneity became a structural feature of densely urbanized regions like Latium and Campania, it can be seen as a factor that could contribute to a continuing cycle of innovation *beyond* the one-off cross-fertilization event that as some scholars have suggested followed the emergence of Roman imperial hegemony.

The approach in what follows is profoundly influenced by the ways in which Roman scholars in recent years have engaged with globalization theory (esp. Versluys 2014 and responses; Pitts and Versluys 2015; Pitts 2021), and particularly by the way in which they have explored the relation between larger-scale (‘global’) developments and local change. Rome, of course, emerged as an empire in a world that was already fairly well integrated and, to some extent, ‘globalizing’. Imperial hegemony intensified and partially redirected these processes, but it must be seen to resemble globalization in that it affected different localities in different ways at different moments: at the local level, empire formation will produce sharply divergent outcomes, and the way in which specific communities develop under the influence of imperial hegemony depends on their position in imperial political and economic networks, and their pre-imperial history (see e.g. the papers in Düring and Stek 2018). Thus, if the general picture of increasing socio-economic and cultural heterogeneity at the level of the Roman world as a whole is uncontroversial, what happened in regions and cities within the Roman world, and what that meant for processes of technological innovation is much less straightforward: heterogeneity on the level of the empire as a whole is no reliable proxy for the *lived* heterogeneity

ity at the level of human cognition and interaction within urban communities, and, of course, it is precisely this cognition and interaction on the micro-scale that, in the end, shapes opportunity niches for combinatorial evolution. In practice, thus, imperial heterogeneity can only be meaningfully approached as a *glocal* phenomenon (cf. González 2021, 96–101): there may have been sharp increases in socio-economic and cultural heterogeneity in some places, while other places remained mostly unaffected, or actually became more homogeneous. The key issue at stake, therefore, is not whether the Roman Empire generated social heterogeneity (or how much of it), but rather how this heterogeneity became situated in the Roman world, and how that, subsequently, came to feed into Roman geographies of innovation.

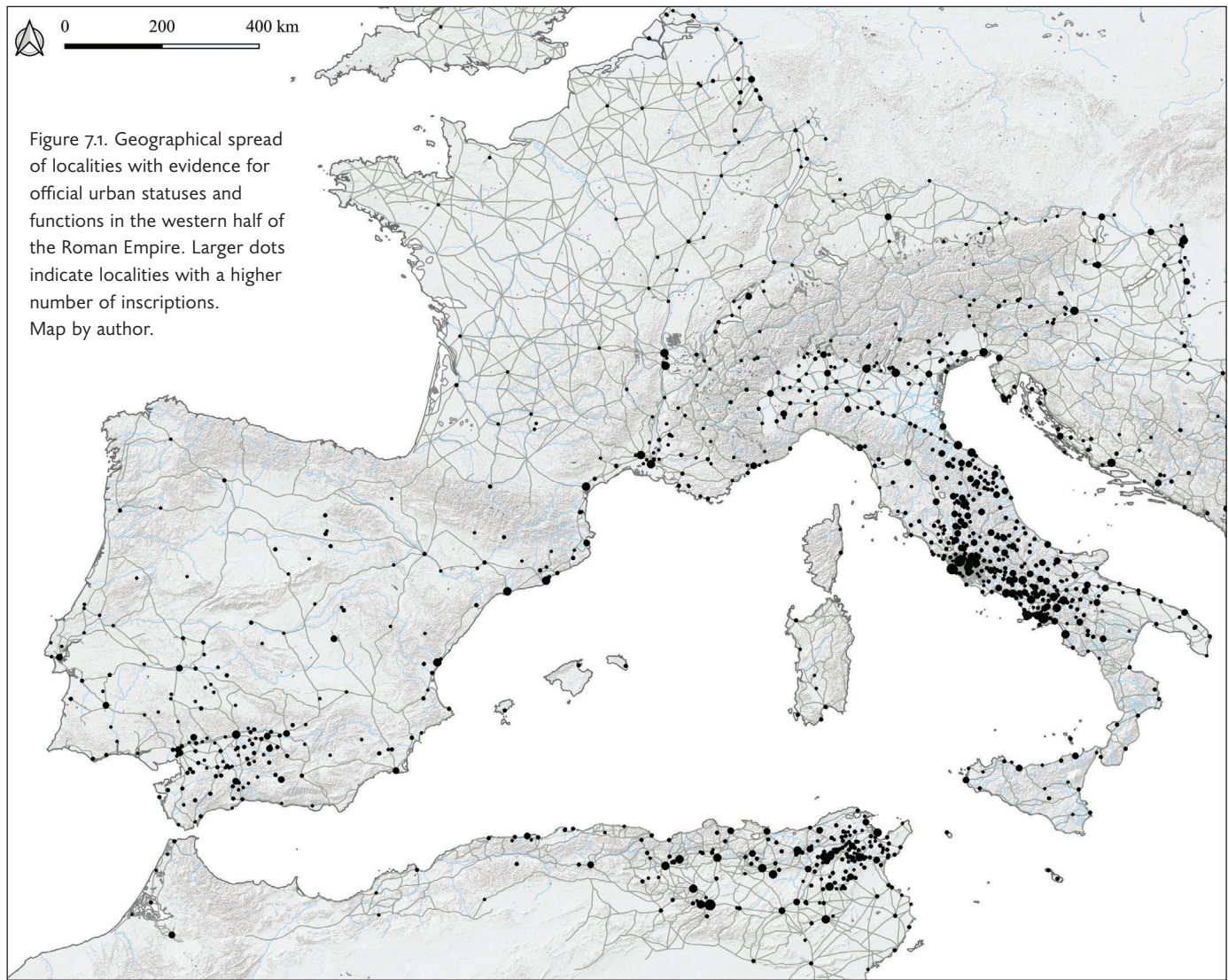
Digital Epigraphy and Urban Heterogeneity in the Roman Mediterranean

Past scholarship has not explicitly addressed the geography of heterogeneity, but it offers some starting points for hypothesizing the ways in which empire formation may have affected the development of social heterogeneity at the local level. It may be suggested that heterogeneity will often tend to follow both the movement of people and the accumulation of capital: socio-economic heterogeneity is able to become more pronounced in places that accumulate a lot of wealth, simply because more wealth means that there is more room for socio-economic differentiation (the ‘inequality possibility frontier’ increases) (cf. Milanovic, Lindert, and Williamson 2011). Conversely, in places from which wealth is being extracted, heterogeneity is bound to remain more constrained: in poorer regions, socio-economic differences will have remained more limited. Similarly, cultural heterogeneity is likely to become more pronounced in places where people from diverse origins flock together, while it is likely to have been less well developed in places that remained outside the leading patterns of social, political, and economic mobility. In practice, this means that well-connected localities and regions in the core networks of an empire could more easily become heterogeneous than places in more peripheral regions. In the context of the Roman Empire, this would mean that the region with the highest potential for developing both cultural and socio-economic heterogeneity would have been the Italian Peninsula and, particularly, the imperial heartland of Rome and the surrounding regions of Latium and Campania. Here, imperial hegemony facilitated the accumulation

of both people and capital from the last centuries BC onwards (Temin 2013, 252–57; cf. Hopkins 1978, 1–98). Conversely, imperial peripheries like Egypt, Dacia, and Britain, which paid for rather than profited from imperial hegemony, and which were, generally, less obvious destinations for travellers or migrants, excepting the Roman army, are likely to have developed heterogeneity to a much more limited extent; regions in the Mediterranean may have had positions somewhere in between these extremes. Within this overall framework, it may be hypothesized that heterogeneity would have had more opportunity to grow in and around the critical nodes of Rome’s imperial networks, such as Mediterranean port cities, regional political centres, or cities that were otherwise situated at critical cross-roads.

Testing this imperial model of heterogeneity would need to start at the macro-level, by assessing larger-scale geographical patterns in the distribution of evidence reflecting social heterogeneity. This is not straightforward: many archaeological indicators of heterogeneity, such as funerary assemblages, domestic architecture, or even skeletal remains can only be analysed at a local or, occasionally, a regional level, and not at the level of the empire as a whole. To some extent, however, urbanism can be seen as a proxy for heterogeneity, as cities by nature generate encounters between people of diverse socio-economic statuses and cultural background. Urban communities in the Roman Empire almost without exception included some level of socio-economic differentiation, and cities were intimately connected with the surrounding countryside, thus facilitating contact between urbanites and country people. If heterogeneity is produced through networks of human encounter, cities were the critical nodes in those networks in the Roman world. From that perspective, understanding the density of urban networks — the proximity of cities to each other — is also relevant: everyday social interactions in isolated urban communities have a smaller chance of involving heterogeneous partners than those in urban communities that are part of dense urban networks, where there is frequent contact between urbanites from different but adjacent communities, and neighbouring cities may absorb echoes of each other’s heterogeneity, particularly in terms of cultural practices and knowledge.

The spread of urbanism over the Roman Empire has been widely debated by Roman scholars. Recent scholarship has highlighted how the distribution of cities over the empire was fundamentally uneven (see particularly Hanson 2016; de Ligt and Bintliff 2020). Geographically, there is a clear opposition between a limited number of regions that devel-



oped rather dense clusters of cities, and a large number of much vaster regions where cities remained much fewer and farther between (Flohr 2021, 210–15), with differences caused by the pre-Roman history of these regions, and by their role in Roman imperial networks. Relatively dense clusters of urbanism had emerged, early on, in Italy (Sewell 2016), and around the Aegean (Hansen and Nielsen 2004), and over the course of the Roman imperial period, these clusters grew in size, particularly in Italy (e.g. in Picenum) (cf. Vermeulen 2017) and Asia Minor (Willet 2019), while new clusters emerged in areas with previously much lower numbers of urban settlements, including particularly the southern part of the Iberian Peninsula (Houten 2021), and in the provinces of Africa Proconsularis and Numidia in Roman North Africa (Hobson 2020; Stone 2020).

In general, these clusters of urbanism will have facilitated social heterogeneity, but not necessarily everywhere to the same extent, or in the same way:

urbanism alone is too rough a proxy for our present purpose. To get a better view of what is going on, the epigraphic record offers a starting point. Since the turn of the millennium, Roman inscriptions have been made available in digital form through large, searchable databases, like the *Epigraphik-Datenbank Clauss-Slaby* (EDCS), the *Epigraphic Database Heidelberg*, and several other corpora. Of course, the collection of inscriptions assembled in these databases is the product of complex and uneven processes of rediscovery, recording, and publication, and this means that any big-data analysis will, to some extent, incorporate biases. Yet, inscriptions have been found in almost every corner of the Roman world: the unfiltered geographical spread of Latin inscriptions in the EDCS, which has the largest geographical spread of the databases available online, shows a dense coverage in large parts of Roman Italy, North Africa, and Europe, including the Iberian Peninsula (see e.g. Hermankova, Kase, and Sobotkova 2022, fig. 3).

In a Roman context, epigraphy was a global phenomenon (Laurence and Trifilò 2015, 104–05), and the geographical spread of the epigraphic record, even if it incorporates biases, can be used as a starting point for historical analysis, particularly if it is *internally* compared: if selected subsets of inscriptions from the same database have a different geographical spread, in absolute or relative terms, this can be historically meaningful.

For the present purpose, the *EDCS*, with its extensive geographical coverage, offers the most interesting opportunities, even though digital epigraphists have recently lamented the quality of the data for more detailed analysis of individual texts (e.g. Orlandi 2021). In what follows, the ways in which the epigraphic record reflects heterogeneity will be explored in two steps. The first step is to analyse the spread of inscriptions referring to urbanism in general; this will create a background against which subsequently three specific subsets of inscriptions can be understood. The method is straightforward: the *EDCS* can be searched for texts containing words reflecting official urban statuses, like *colonia* and *municipium*, or for the titles of key urban institutions and officials, such as the *ordo decurionum* and the *aediles*. Such official urban vocabulary will, as a rule, be more or less directly associated with settlements with an official urban status, even if some inscriptions may have been situated in the surrounding countryside. Searching the *EDCS* for inscriptions referring to these four terms returns a total of 7409 inscriptions. These inscriptions have been found in altogether 1164 localities, including a rich variety of ancient cities, modern settlements, and some isolated find-spots. This is a rough dataset, but its geographical spread is instructive. Figure 7.1 plots all these localities on a map. Within the Latin-speaking regions of the empire, it is clear that the density of epigraphic find-spots closely matches the spread of Roman urbanism as we know it from literature (see esp. Hanson 2016, 134, figs 45–46): there are large clusters of epigraphic evidence in peninsular Italy, particularly west of the Apennines, in the northern part of Africa Proconsularis — slightly less so in Numidia — and in the Guadalquivir Basin in the southern part of the Iberian Peninsula — Hispania Baetica. Additionally, there is a good spread of find-spots in northern Italy — Cisalpine Gaul — and in the Rhone Estuary in Gallia Narbonensis. These regions make up the core urban network of the Latin-speaking part of the Roman Empire. The fact that they saw the spread of a very specific (Roman) urban vocabulary emphasizes that the epigraphic record reflects not just the spread of urbanism, but also the circulation of a shared set of urban practices and concepts.

The proximity of urban settlements in these regions meant that they could function as one integrated urban network, in which information could circulate with ease from city to city. From the point of view of innovation, this intraregional hyperconnectivity makes these regions ideal incubators for novel ideas and practices: these could easily spread over a larger number of communities, and thus, more easily find a ‘fitting’ environment in which they could thrive and further develop. This is all the truer if these urban networks also became socially heterogeneous: if more people with diverse backgrounds, needs, and priorities participate in such networks, chances are higher that innovations will find sponsors and users.

The question is to what extent the cities in these regions became socially diverse in a similar way. The epigraphic record makes it possible to tentatively explore this issue a little bit further: Latin inscriptions not only mention urban statuses and urban officials, but also feature a broad range of urban individuals and groups beyond the urban elite. The range of social actors that can be identified in the epigraphic record of a certain urban community offers important clues about the way in which that community became heterogeneous. It highlights both the minimum level of diversity within the urban community, and the degree of participation by people from diverse backgrounds in a key social practice — the production of epigraphy (MacMullen 1982; Beltran Lloris 2015). In what follows, the spread of inscriptions referring to three non-elite groups will be analysed, again based on the data offered by the *EDCS*. Inscriptions mentioning freedmen offer a logical starting point: freedmen occupied a semi-independent position in urban communities alongside full citizens and in close interaction with elites, in whose households they once had been held as slaves (Mouritsen 2011). From the perspective of heterogeneity the presence of large numbers of freedmen can thus also be seen as a proxy for the existence of two other groups — people held in slavery and wealthy, slave-owning elites. The *augustales*, religious associations that were typically dominated by people of more modest social status (Laird 2015; Vandevoorde 2015), offer a second perspective on the presence and activities of social groups not belonging to the elite; professional associations, whose members were craftsmen and traders (Verboven 2011; Liu 2009; Tran 2006), a third. These groups partially overlap in composition — many *augustales* were freedmen, as were many members of professional associations — but they are by no means identical.

Figure 7.2 shows the spread of the 25,313 Latin inscriptions referring to *liberti*. They come from 1374

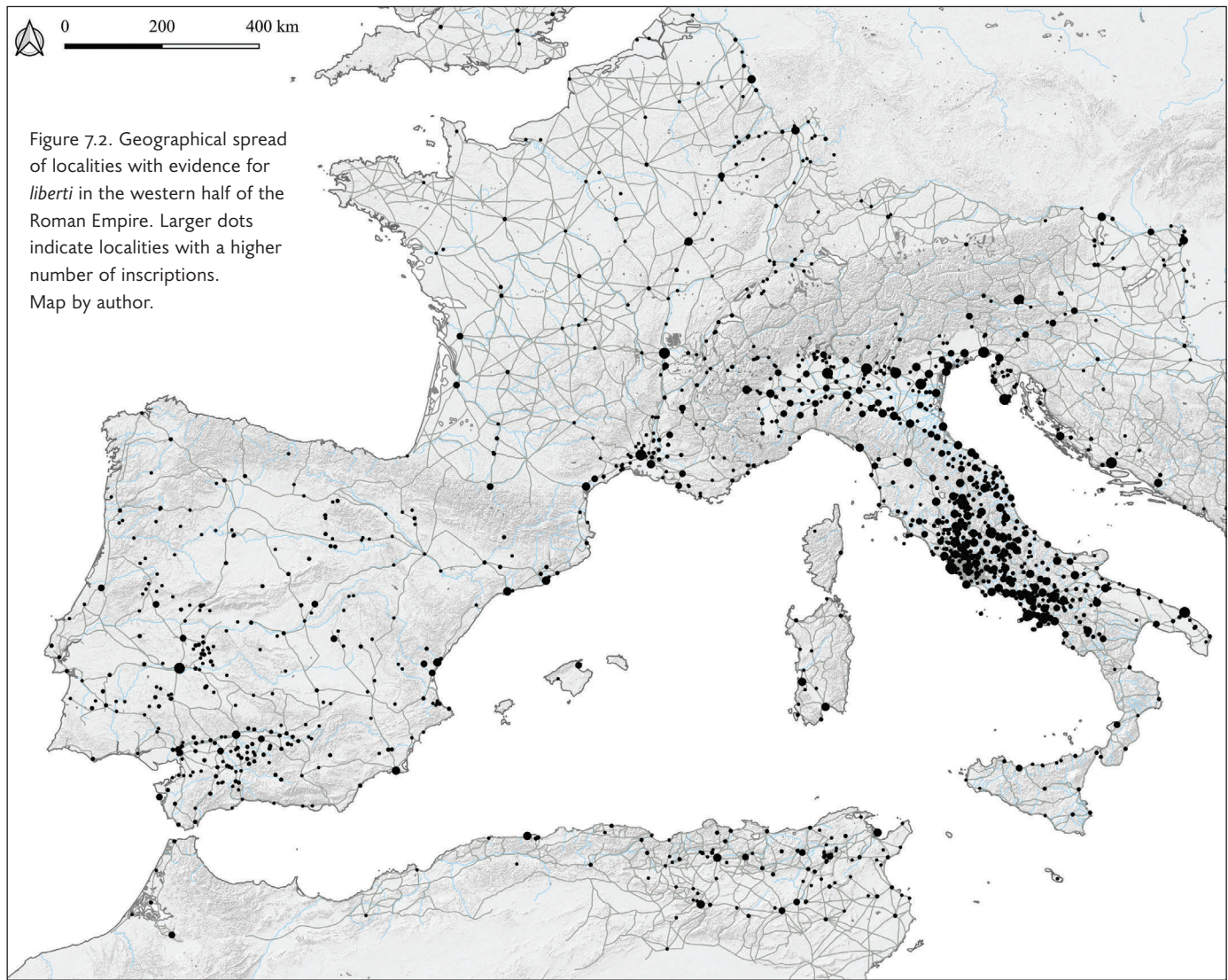
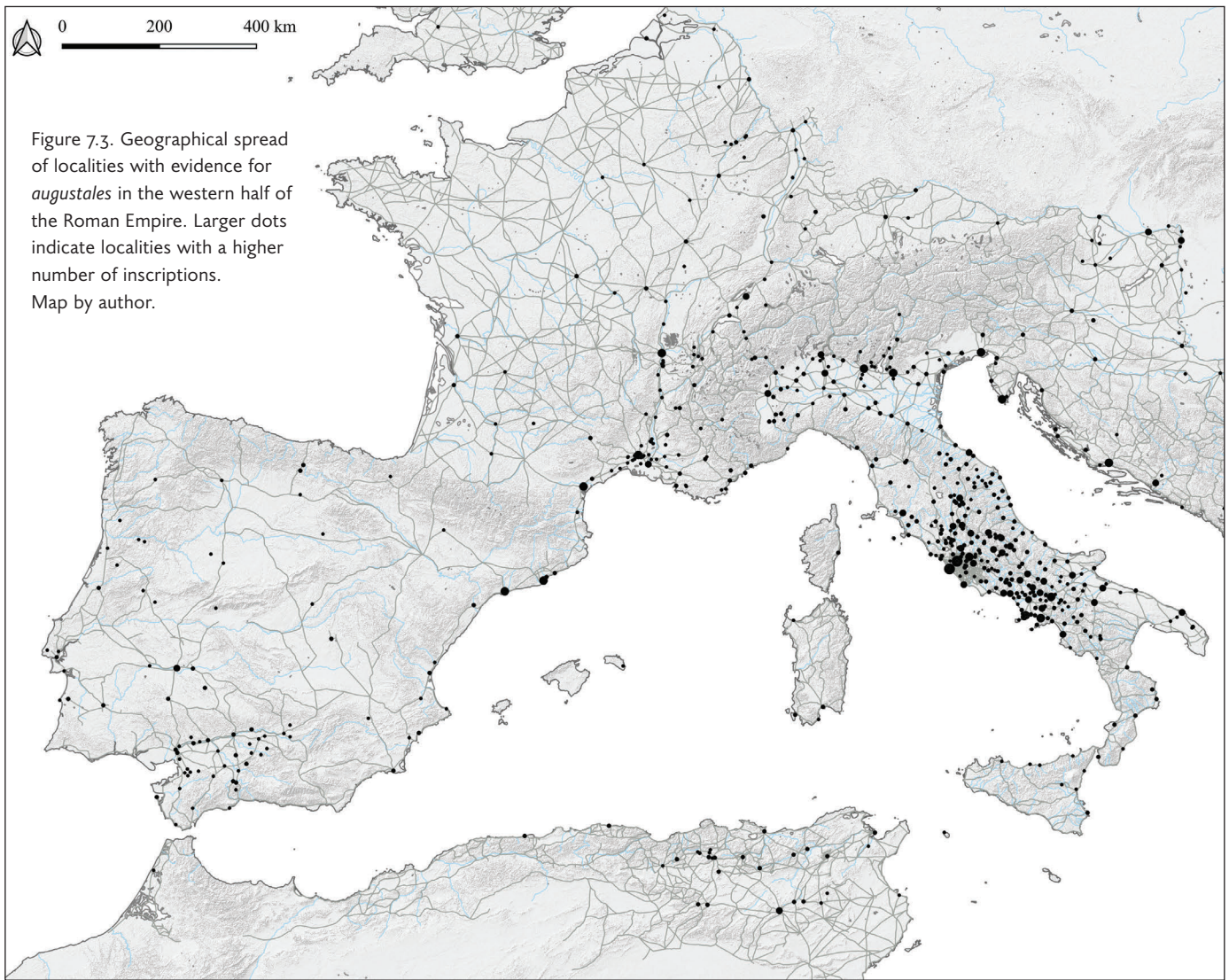


Table 7.1. Comparative analysis of urban phenomena attested in the inscriptions from selected regions in the Roman West. The percentages are based on the total number of inscriptions in the region as listed in the second column.

Data: Epigraphik-Datenbank Clauss-Slaby, 25 January 2023.

	Total inscriptions	Augustales	Collegia	Freedmen
Peninsular Italy (Regiones I–VII)	80,125	1227 (1.53%)	374 (0.47%)	7048 (8.80%)
Cisalpine Gaul (Regiones VIII–XI)	27,946	378 (1.35%)	217 (0.78%)	2528 (9.05%)
Latium and Campania (Regio I)	45,383	551 (1.21%)	160 (0.35%)	3607 (7.95%)
Gallia Narbonensis	22,691	219 (0.97%)	30 (0.13%)	860 (3.79%)
Hispania Baetica	7341	59 (0.80%)	12 (0.16%)	359 (4.89%)
Africa Proconsularis	33,847	50 (0.15%)	5 (0.01%)	313 (0.92%)

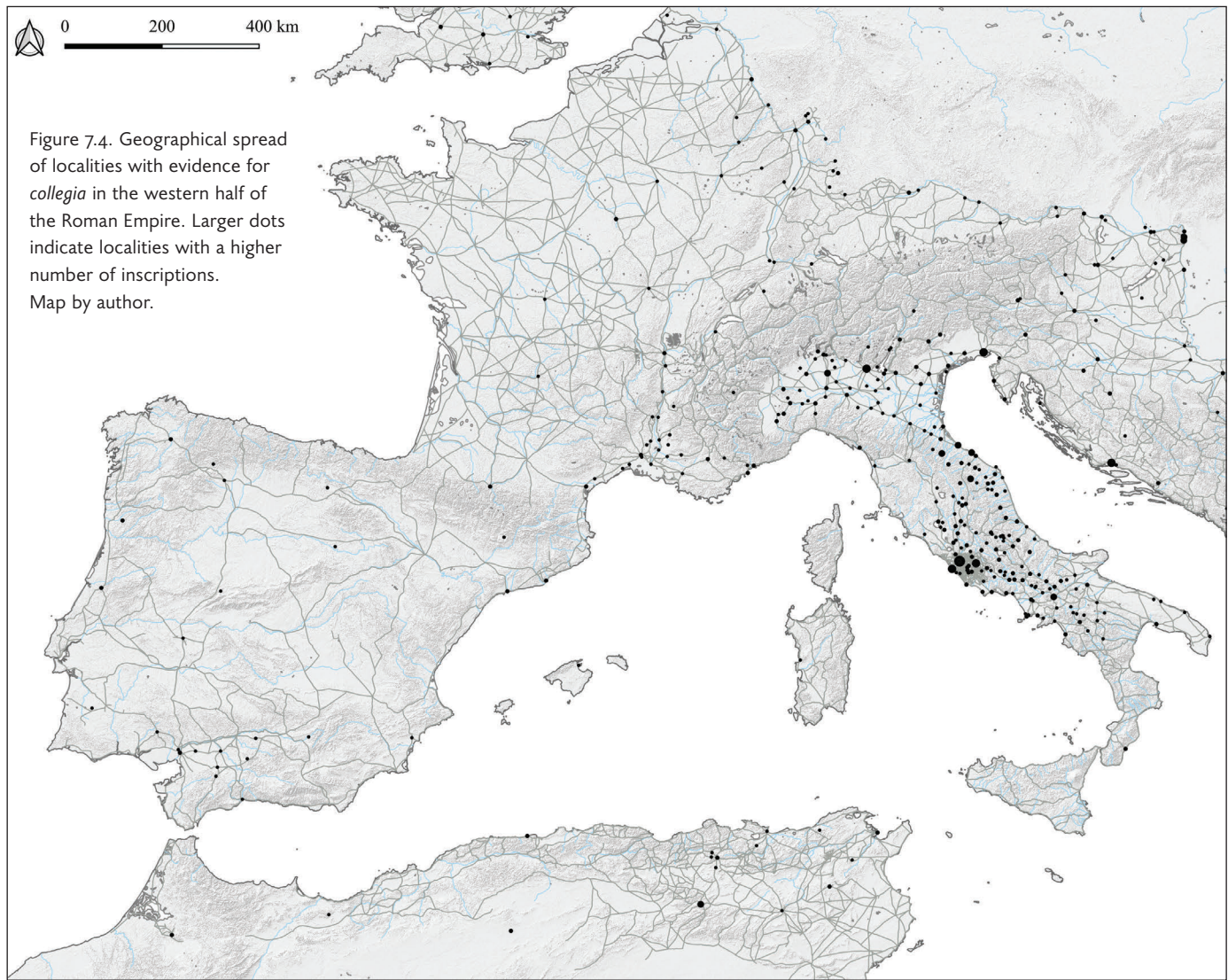
localities, though more than half (12,679) come from the Roman metropolis alone. The dataset is bigger than that represented on Figure 7.1, but it is very clearly spread over the western part of the Roman Empire in a different way. There are clusters of evidence in the same regions: in Baetica, around the Rhone Estuary, in Roman North Africa, and in Italy, but it can be observed that the amount of evidence for freedmen in Roman North Africa is much lower than the amount of evidence for urbanism in general; the evidence in the Italian Peninsula and Cisalpine Gaul, on the contrary, is much more substantial, particularly in the regions along the Tyrrhenian Coast — Latium and Campania. The difference is not only absolute, but also proportional. For instance, of the 33,847 inscriptions in the *EDCS* that come from Africa Proconsularis, just 313 (0.92 per cent) are associated with freedmen (cf. Table 7.1). In Latium and Campania, this figure is much higher — 3607 out of



45,383 (7.95 per cent). In Cisalpine Gaul, it is 2528 out of 27,946 (9.05 per cent), while Baetica takes an intermediate position: 359 out of 7341 (4.89 per cent). Freedmen are thus remarkably absent from the epigraphic record in Roman North Africa. Additionally, Figure 7.2 highlights that freedmen are particularly well represented in port cities and other nodal places: large numbers of inscriptions with freedmen have been found in places where travel- and transport routes came together, such as Lyon, Arles, Brindisi, Aquileia, Carthage, Caesarea, Carthago Nova, and Tarraco. This remarkably consistent pattern in the data connects well to the idea that freedmen played a role in longer-distance trade ventures, as has been argued by some scholars (Broekaert 2016).

Inscriptions referring to *augustales* and *collegia* are rarer, but their geographical spread is more pronounced, both in absolute and relative terms. Figure 7.3 shows the spread of 2999 inscriptions

referring to *augustales* — these have been found in a total of 671 localities. Compared to Figure 7.2, the paucity of evidence in Roman North Africa is much more extreme, particularly in the Medjerda Valley, where the evidence for urban statuses and urban officials was densest. According to the *EDCS*, there are only fifty inscriptions referring to *augustales* in Africa Proconsularis (0.15 per cent) (cf. Table 7.1). Elsewhere, the proportion of inscriptions referring to *augustales* is higher. In Baetica, evidence for *augustales* is proportionally more widespread (fifty-nine inscriptions, 0.80 per cent), though the cluster is not as dense as in Figure 7.2. In Gallia Narbonensis (219 inscriptions, 0.97 per cent), and in the Italian Peninsula (1227 inscriptions, 1.53 per cent) and Cisalpine Gaul (378 inscriptions, 1.35 per cent) even denser scatters of evidence can be seen, while the relative number of relevant inscriptions is also a bit higher; within Italy, there is a visible empha-



sis on Latium and Campania (551 inscriptions, 1.21 per cent of 45,383). The evidence for *collegia* (1454 inscriptions from 429 localities) (Fig. 7.4) is even more strongly concentrated in the Italian Peninsula, Cisalpine Gaul, and the Rhone Estuary; there is very little evidence for professional associations in both Baetica and Roman North Africa. In Baetica, *collegia* have left just twelve inscriptions (0.16 per cent); in Africa Proconsularis no more than five (0.01 per cent) — in the Italian Peninsula, the figure is 374 (0.47 per cent); in Cisalpine Gaul 217 (0.78 per cent).

Taken together, this macro-scale analysis of the epigraphic record highlights that urban communities, particularly in the more densely urbanized regions, became heterogeneous, but it also suggests there could be substantial differences from region to region. Epigraphically, heterogeneity appears most pronounced in Italy, where substantial concentrations of epigraphic evidence have been found for *lib-*

erti, for *augustales*, and for *collegia*. In Baetica, the *collegia* are lacking; in Roman North Africa, both *collegia* and *augustales* have barely any epigraphic presence, and there is a substantially lower amount of evidence for freedmen. Within Italy, epigraphic heterogeneity was concentrated in Cisalpine Gaul and in the central part of the Italian Peninsula, with an emphasis on Latium and Campania. At the same time, official urban vocabulary — references to official urban statuses (*colonia*, *municipium*) and institutions (*aediles*, *ordines decurionum*) — was abundant in the epigraphy of all densely urbanized regions. What does this mean? There are several options. The lower levels of heterogeneity in the epigraphic record of Baetica and Roman North Africa may mean that *augustales*, *collegia*, and *liberti* were simply less common in these regions; alternatively, it may mean that these people had fewer means to put up inscriptions, and thus had a less powerful voice in

the urban community. It is perhaps less likely that there were social or cultural reasons for their lack of participation in epigraphic practice: many of the urban practices that characterized urban communities throughout the Roman world — euergetism, honorific statuary, funerary epigraphy — are well attested for both Baetica and Roman North Africa (see e.g. Flohr 2021, 210–12), and freedmen, *augustales*, and *collegia* would have faced the same social and cultural incentives that they faced elsewhere. Hence, it is most likely that these groups either lacked the resources to produce epigraphy, or simply were not there. In both cases, the urban communities of these regions would have been less heterogeneous than those of Roman Italy, where non-elite groups were extremely well represented in the epigraphic record.

Close Reading Urban Heterogeneity in Roman Italy

This rough survey of the epigraphic record offers quite some support for the idea that heterogeneity in Italy became more pronounced than other regions of the empire. Purely on the basis of the epigraphic record, the cities of these regions appear more heterogeneous than those in the other densely urbanized regions in the Latin-speaking part of the empire, in Baetica, Africa Proconsularis, and Numidia. Further corroborating the starting hypothesis, the epigraphic record suggests that within Italy social heterogeneity was most developed in Latium and Campania, which constituted the social, political, cultural, and economic core of the empire in the first centuries AD. Focusing on this imperial heartland, the following section will explore what this emerging heterogeneity meant at the local and regional micro-level. Here, emphasis will be on the archaeological record, and on the gradual transformation of urban communities over time — the historical emergence of social heterogeneity.

Pompeii offers a unique opportunity to study the history of heterogeneity in one urban setting. Situated on a low volcanic hill overlooking the Sarno Estuary, the city had emerged as a regional centre before the middle of the first millennium BC, and by the third century BC, it had become quite a big city that covered approximately the same area as the early imperial town. This pre-Roman city was dominated by small- to medium-sized atrium houses, with an entrance surrounded by, often, two inwardly oriented rooms, rooms on both sides of the front hall, and a *tablinum* in front of the entrance, but nothing but a modest backyard further to the back (Fig. 7.5a) (Peterse 1999). Compared to contemporary cities

elsewhere in Italy — such as Norba and Fregellae — the largest Pompeian houses even seem relatively modest (Carfora, Ferrante, and Quilici Gigli 2010; Battaglini and Diosono 2010). Third-century BC Pompeii was not an egalitarian community. There was quite a bit of variation between these houses in their size and in the number of rooms (Fig. 7.5a). However, social, and as far as we can see cultural, heterogeneity remained limited: Pompeii was a city of families living in structurally independent houses. This relatively homogeneous community went through a radical transformation in the second century BC: a new class of elite houses emerged, which not only had a much larger atrium, but also had a second, more luxurious part added — the peristyle — a large garden surrounded by porticos that gave access to often vast residential rooms with luxurious decoration on walls and floors (Fig. 7.5b). The city's elite also got access to exclusive forms of high-quality decoration, such as *opus vermiculatum* mosaics, which were uniquely detailed (Flohr 2019a, 108–12). Urban palaces like the House of the Faun (VI 12, 2) and the *Insula Arriana Polliana* give an idea of the impact these transformations had on the urban elite (Faber and Hofmann 2009; Peterse 1985). On the other side of the social spectrum, there was a boom in the construction of *tabernae*, small-scale commercial facilities that often were associated with modest living accommodation (Holleran 2017). Additionally, large quantities of upper floor apartments were constructed — these were directly accessible from the street via a narrow staircase, and often they were rented out (Pirson 1999). Thus, both on the top end of the social spectrum and on the bottom end, Pompeii's housing market was completely redefined, and the city's urban landscape became thoroughly diversified: along the through roads, there was a clustering of both elites and of their dependents (Fig. 7.6), while middling groups clustered overwhelmingly in the more marginal parts of the city, away from the city centre (Flohr 2023). This transformation was closely linked to the emergence of Rome's Mediterranean hegemony, which proved extremely beneficial for the local community: Pompeians were actively involved in late republican Roman warfare, and may occasionally have shared in the booty (Pesando 2006), while their agricultural economy was boosted by increasing demand from the Roman metropolis (Flohr 2019b).

The transformation of Pompeii in the late second and early first century BC exemplifies how Roman hegemony could affect urban heterogeneity in the heart of the empire. In the Bay of Naples, however, the practical impact of this heterogeneity was not limited to the local urban community (Fig. 7.7).

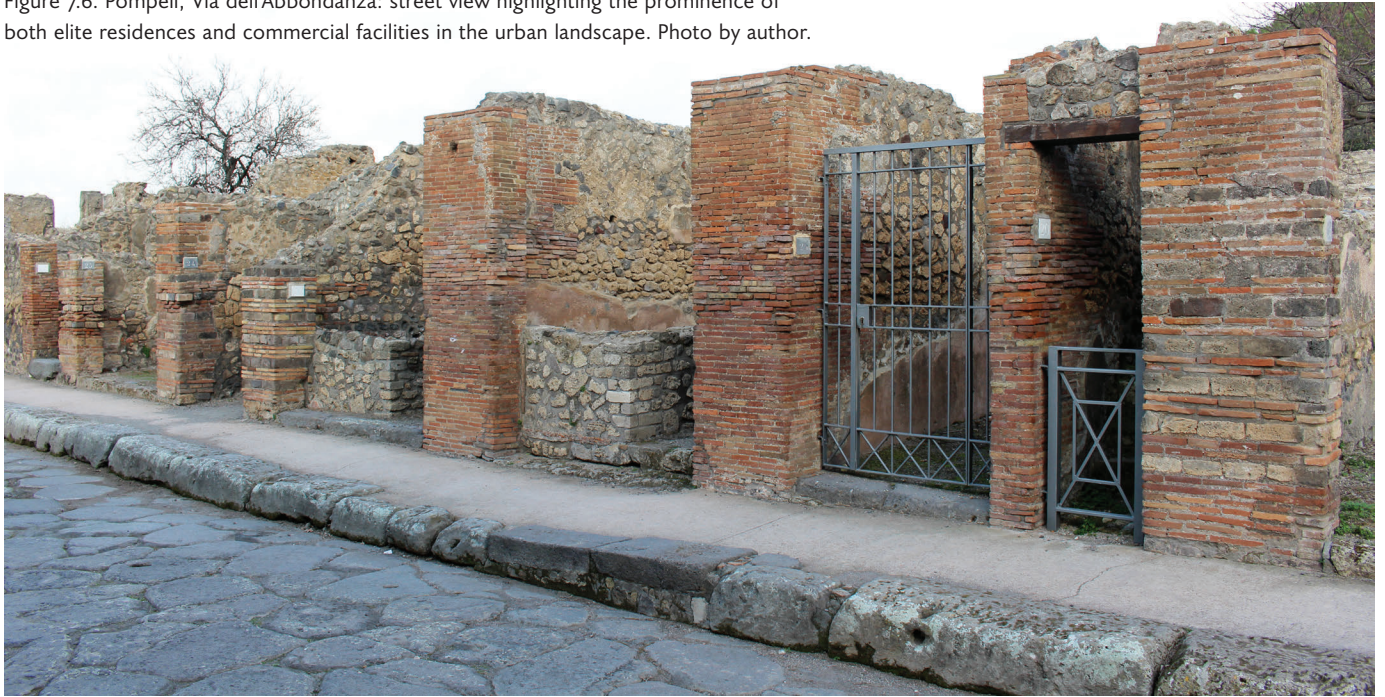
Figure 7.5. **a)** Five third-century BC houses in Pompeii. Based on Peterse 1999. **b)** Eight Pompeian houses in their AD 79 state. Figure by author.



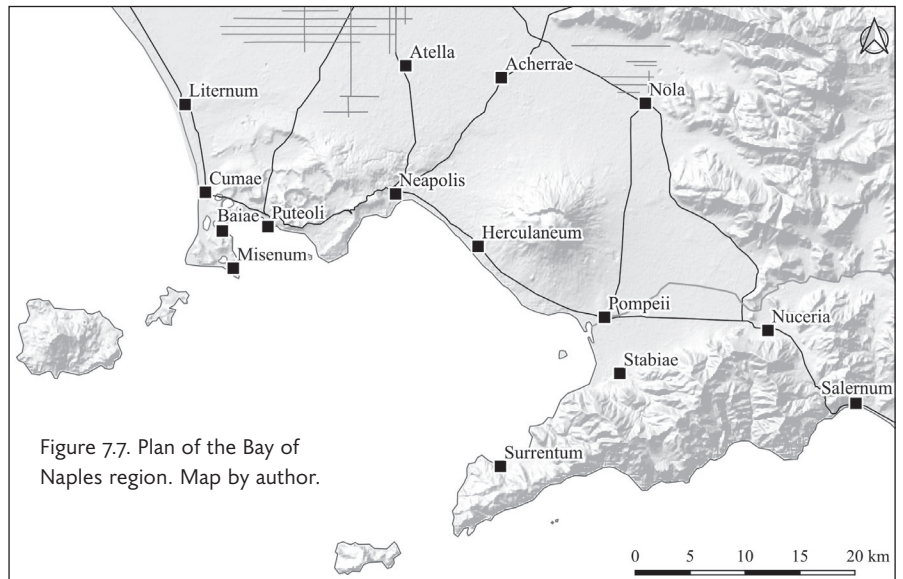
Evidence from the first century AD leaves no doubt that Pompeii was intimately connected to several neighbouring cities. The close ties between Pompeii and Nuceria are well known through the amphitheatre riot of AD 59 (Tac., *Ann.*, XIV. 17), but also through many graffiti scratched on Pompeian walls (e.g. *CIL* IV, 1293, 8356, 8903) — the apparent antagonism between the two cities confirms rather than denies the closeness of their familiarity. Places like Nola, Surrentum, Herculaneum, Neapolis, Puteoli, and Cumae are also well represented in the epigraphic record of Pompeii; the discovery, just outside Pompeii, of the archive of the Sulpicii brothers, who

were active in Puteoli, further illustrates the close ties between the cities of the region (Camodeca 1992). In addition, a crucial role in the social heterogeneity of Pompeii and other cities around the Bay of Naples was played by the presence of villas belonging to the imperial elite (D'Arms 1970). As Strabo (v. 4. 8) observed, by the Augustan period, the entire Bay of Naples from the sea looked like one uninterrupted city. The entire region had, essentially, become one intensely integrated urban agglomeration, in which the heterogeneity of social networks within local communities was directly influenced by and affected the extent and nature of social and cultural hetero-

Figure 7.6. Pompeii, Via dell'Abbondanza: street view highlighting the prominence of both elite residences and commercial facilities in the urban landscape. Photo by author.



geneity in the region as a whole. While the Bay of Naples had been a cultural melting pot from the eighth century BC onwards, the region underwent a spectacular transformation in the last two centuries BC and the first centuries AD, as it became the epicentre of Roman imperial prosperity. This particularly affected the north edge of the bay, between Herculaneum and Cumae. The most exuberant senatorial villas were situated in this part of the region, such as the villa of Vedius Pollio in Pausylipon and the villas at Baiae. The presence of the imperial elite brought large amounts of slaves to the region, which led to exceptionally high numbers of freedmen, as is suggested by the demographics of Herculaneum (de Ligt and Garnsey 2012). At the same time, Puteoli developed, from the later first century BC onwards, into the leading trade hub of the Roman world, resulting in the presence of multiple trading communities from the eastern part of the Mediterranean: Aramaic inscriptions by Nabataeans are attested in the first decades AD (Terpstra 2015, 81–84), and in the second century AD, groups of traders from Berytus, Heliopolis (Baalbek), and Tyros appear to have been permanently settled in the city (Terpstra 2013, 70–84; Jaschke 2010). From the Augustan period, there were also strong ties with Egypt, as Puteoli was the primary destination of the Alexandrian grain fleet (Rickman 1981, 266). Moreover, the establishment



of the Roman fleet at Misenum brought large and ethnically diverse crews to the region (Saddington 2007, 208–13). As a micro-region, the Bay of Naples, including Pompeii, was exceptionally well connected, and it enjoyed privileged access to all kinds of ideas and practices circulating in Roman imperial networks. Crucially, it also contained a heterogeneous and partially socially ambitious audience that could have taken new ideas and practices on board and used them — and often also had substantial means to do so.



Figure 7.8. *Forma Urbis Romae*. Fragment 10g showing the Clivus Suburanus and its surroundings. Photo: Stanford Digital Forma Urbis Project.



Figure 7.9. *Forma Urbis Romae*. Fragment 40cdefgh showing the *insula* architecture in the imperial-period quarters that emerged in the Tiber flood-plain. Photo: Stanford Digital Forma Urbis Project.

The Bay of Naples stood out compared to most other parts of Latium and Campania, where the impact of imperial hegemony was less extreme, though members of the imperial elite appear to have been well represented in the entire region. One conurbation, of course, was even more exceptional: the Roman metropolis. In Rome, social heterogeneity had become entrenched in the urban landscape already by the late republic, when the hills on which the city originated were dominated by private houses, whereas the valleys between them became dominated by rows of

tabernae, which clustered along the roads between the city gates and the city centre, and which were operated (and often inhabited) by people of lesser means — the Clivus Suburanus, known from a large fragment of the third-century AD *Forma Urbis Romae* is a key example (Fig. 7.8). The increasing wealth of the elite was expressed in the development of *horti* — large elite gardens, which appeared just outside the city in the first century BC (Wood 2010). It is also likely that, already by the late republic, the metropolis contained many people with roots further away, who had been brought to the city as slaves, or who had migrated there. However, it is only in the imperial period that the full heterogeneity of the Roman metropolis became visible. In this period, the city expanded into the flood-plains around the Tiber — the Field of Mars and Transtiberim (cf. Tucci 2004). The new quarters that were built in these zones were homogeneous from a socio-economic perspective: they almost completely consisted of multi-storey apartment buildings that offered accommodation for people who belonged to the bottom half of the social spectrum (Fig. 7.9). Wealthier people were almost completely lacking: their homes continued to be concentrated on the hills, within the republican city walls. At the same time, the quarters in the flood-plains seem to have become highly heterogeneous culturally. Particularly for Transtiberim, a wide range of ethnicities has been attested, including Palmyrenes, Syrians, and Jews; a range of foreign sanctuaries clustered on the outskirts of the extended imperial city. While these urban extensions cannot be seen as true ‘migrant quarters’ (Tacoma 2014), they were exceptionally diverse ethnically, and they show how both socially and culturally, the Roman metropolis developed into a truly heterogeneous place, where objects, knowledge, and practices from a wide variety of backgrounds could be seen to circulate in a small, densely populated urban area.

Opportunity Niches in Practice: Urban Heterogeneity and Technological Innovation

Thus, if the epigraphic evidence suggests that, by the early imperial period, many cities in Latium and Campania had become socially heterogeneous, the Bay of Naples and the Roman metropolis appear to have reached exceptional levels of urban heterogeneity. As these two micro-regions were also extremely well connected, they enjoyed privileged access to information about new practices and ideas circulating in the formal and informal networks of encounters that made up the Roman Empire,

and their communities included about the broadest possible range of social actors that could embrace technological innovations and integrate them into their everyday practices. Socially and economically, they were unprecedented environments: nothing like the Roman metropolis had ever existed in the Mediterranean, and the same is true for the unique conurbation around the Bay of Naples. As the Roman metropolis and the cities around the Bay of Naples grew and became more heterogeneous, their consumer markets developed into uncharted territory, thus creating patterns of demand unprecedented in quantity and quality. From the perspective of innovation, the Bay of Naples and the Roman metropolis very much look like potential ‘opportunity niches’ as defined by Arthur: they offered extremely fertile ground for new ideas and practices to take root and flourish. Can this be linked to the actual history of technological innovation?

Arguably, the present article can only offer a provisional perspective. Debates about technological innovation in ancient Rome have mostly taken place on the level of the Roman Empire as a whole, and have generally lacked geographical sensitivity (esp. true for Terpstra 2020; Erdkamp 2020; Scheidel 2009; but see Lancaster 2012). Nevertheless, there is a substantial body of evidence suggesting that Italy, the Bay of Naples, and the Roman metropolis indeed tended to play a critical role in the emergence and development of new technological practices in the Roman world. Several key innovations can be directly associated with the Bay of Naples and its elite villas; several others can be seen to emerge in and around the Roman metropolis; yet others can be linked with central Italy. As far as the Bay of Naples is concerned, the evidence is partly discursive — there is a lot of talk about innovation taking place in the area by Roman authors — and partly material. The case of Sergius Orata, an early first-century BC *equus* based in the environs of Baiae, is well known. His story, discussed in some detail by Pliny the Elder (Plin., *HN*, IX. 167–69) highlights how the profound socio-economic transformation of the region in this period could create an ideal breeding ground for several kinds of innovations. Orata (‘Bream’) was nicknamed for his involvement in fish industry, and he is credited with the invention of oyster ponds in the Lucrine Lake, which is on the northern coast of the Bay of Naples, next to Baiae. Additionally, he was thought to have invented the hypocaust, and Pliny emphasized how this invention made him rich, as he equipped villas with heated baths and then sold them for good money. These inventions were made possible by the fact that Orata both controlled enormous resources, and, as member of the slave-own-



Figure 7.10. Ostia, s.c. Taberne Repubblicane (1 x 1). Late republican wall in *opus reticulatum*. Photo by author.

ing imperial elite, had access to a substantial pool of workers: the very construction projects that brought these innovations about were made possible by the increasingly heterogeneous character of the region's population. Another example of innovation can be found in the material remains of Pompeii, where the social transformations of the late second century BC went hand in hand with the emergence of a set of new building technologies that combined the increasing ability to make strong mortar with locally and regionally available building materials that had not been used in large quantities before this period. Interestingly, these new mortar-based techniques appear not to have been used in contemporary Paestum, where traditional techniques continued to dominate building practices (Flohr 2022, 163–64).

What is known of the early stages of the development of Roman concrete also fits extremely nicely with a model in which regions with exceptional levels of heterogeneity could become hot spots of innovation: both the Bay of Naples region and the Roman metropolis play a critical role in the development of this new construction technique. As Marcello Mogetta has argued, the technique was first embraced in second-century BC elite domestic architecture, both in Rome (Mogetta 2015; 2021, 46–90) and in the Bay of Naples region (Mogetta 2016; 2021, 136–46). Thus, concrete first appeared precisely in those regions that became increasingly heterogeneous — and it did so *at the very moment in which* these places started to become increasingly heterogeneous at an unprecedented speed. Again, it can be argued that in the economy of concrete construction this heterogeneity was crucial. On the one hand, concrete was pushed forward by elite build-



Figure 7.11. Ostia, *fullonica* III II 2, showing the complex of rinsing basins at the centre, surrounded by fulling tubs on three sides. Map after De Ruyt 2002.

ing projects — Mogetta argued that it emerged in the construction of large elite urban houses and quickly spread to public construction, which was controlled by the same people, and that it began to boom because of the prosperity of this group. On the other hand, concrete construction was facilitated by the availability of cheap, unskilled labour: working with strong mortar reduced the need to carefully shape the *caementa* of walls, and minimized the skills needed in placing them in the right position. The subsequent emergence of standardized building materials, which appears to have been a product of the Roman metropolis specifically, fits this model: early *opus reticulatum* (Fig. 7.10) is strongly associated with building projects led by the Roman elite (Coarelli 1977; Torelli 1980) and further adapted Roman building practice to an imperialized reality that combined large-scale elite building projects, private and public, with a sizable, but less skilled workforce. While brick as a building material had existed

throughout Italy in the Hellenistic period (Östborn and Gerding 2015), it became integrated into Roman concrete construction practice in the Roman metropolis from the mid-first century BC onwards (Lugli 1957, I, 587–88; Flohr forthcoming a. See also Van Oyen 2017).

Other innovations that emerged in the Roman metropolis are also related to the emergence of a class of wealthy entrepreneurs operating on a large scale and a cheap, untrained labour pool. In Rome and Ostia, this led to the emergence of purpose-built factory buildings organized like a rationalized production line (Fig. 7.11). This development can be seen most clearly in the fulling workshops of Rome and Ostia (Flohr 2013, 96–180). These workshops were constructed in the second century AD, and there is no evidence of them existing, on this scale, before the first century AD. They had a completely planned division of labour. Clothes were treated with chemicals in the fulling tubs, which were situated around a centrally placed complex of rinsing basins, and in these

rinsing basins, they went from basin to basin in what appears to have been a production line system with counter-current exchange. The water flowed in one direction, while the clothes went in the opposite direction, meaning that they entered ever cleaner water — gradually, the dirt and the chemicals were washed out. What is more interesting still, the latest, most skill-dependent, phase of the fulling process — the roughing and shearing of the garments, and the surface treatment that made them look good and more comfortable to wear — was not done in these workshops, as it made no sense to scale it up. These workshops were rigorously designed fulling factories, where the organization of labour was planned in advance; at the same time, the production process was separated into a non-skilled part, executed in large-scale fulling factories, and a skilled part, executed elsewhere, probably on a smaller scale. This was a massive innovation in the organization of labour, that made use of advanced water technology, and it first appeared at the very heart of the empire and built directly upon the social heterogeneity in that region.

Several key technological innovations that emerged and became successful in the Roman Empire

were thus directly associated with two of the most heterogeneous places in the empire. Some other important developments in technological practice can be associated with central Italy in general. One example is the emergence of red-slipped Italian *terra sigillata* (Fig. 7.12) in and around Arretium around 30 BC (cf. Sternini 2019, 491–94; Van Oyen 2015, 283–84). This innovation in pottery technology, which would have a profound impact on the material culture of the Roman Empire, first appeared in a region that was closely integrated into central Italy's dense urban network — both through the Tiber Valley and through the Via Cassia, which connected Arretium directly to Rome. It was this close connection to a region full of socially and culturally heterogeneous communities that made sure that the products of the new technology would eventually reach a pan-imperial audience. Similarly, Italy played a pivotal role in the revolution in glass-working. Around the start of the first century BC, glass-blowing emerged as a technique to turn molten glass into artefacts; around the same time, the technique to make glass transparent and colourless improved sharply (Fig. 7.13). This revolution, it seems, started in the Levant, but it got steam, it is assumed, when glass was picked up by the Italian consumer market, and when the technique to make glass spread to Italy (Stern 1999, 442–44). The heterogeneity of communities at the heart of Rome's imperial networks, combined with their privileged access to ideas circulating in these networks can be seen to have played a crucial role in picking up an innovation in the Near East, and spreading it over the entire Roman world. By the first century AD, blown glass was being made almost everywhere, and regional traditions had emerged in several places in Roman Europe (Larson 2019, 19).

Discussion: Heterogeneity in Roman Studies

What to make of this? This article has, essentially, presented two tentative arguments. The first part of this article has argued that the urban networks that emerged under Roman imperial hegemony generated higher levels of heterogeneity in a limited number of regions in the Latin-speaking western half of the Roman Empire, and particularly in the Italian Peninsula. Within Italy, heterogeneity developed most strongly in and around the Roman metropolis and around the Bay of Naples. The second part of this article has argued that this heterogeneity can be associated with several key technological innovations of the last centuries BC and first centuries AD, which had a substantial impact on Roman

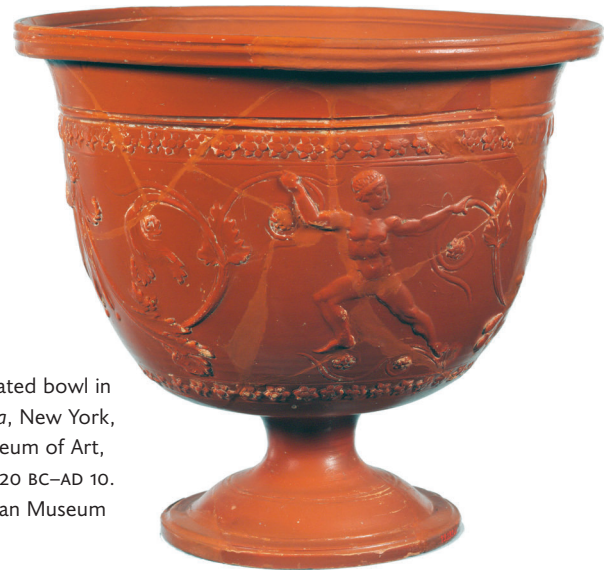


Figure 7.12. Decorated bowl in Italian *terra sigillata*, New York, Metropolitan Museum of Art, inv. no. 10.210.37. 20 BC–AD 10. Photo: Metropolitan Museum of Art.



Figure 7.13. Ribbed bowl in transparent glass, New York, Metropolitan Museum of Art, inv. no. 81.10.39. First century AD. Photo: Metropolitan Museum of Art.

urban development and on Roman material culture. In some cases, it was the social heterogeneity that emerged in this region that created the circumstances under which innovations could come to fruition; in other cases, it was rather its cultural heterogeneity that made the difference. On these grounds, it can be suggested that increasing urban heterogeneity probably had a positive impact on the amount of technological innovation in the Roman Empire and was a decisive factor in its historical geography. The long history of innovation in building technology suggests that heterogeneity did not just lead to the one-off cross-fertilization event that has been a recurring element of recent scholarship, but created structural conditions for innovations to emerge over a longer period of time. The examples of the fulling factories at Ostia and of *terra sigillata* and glass highlight that this effect was not limited to the building industry, but could be found across fields of technological practice. It remains to be seen whether the other densely urbanized regions in the empire also generated technological innovation —

their technological histories have not been studied as well as that of Italy.

What does that mean for heterogeneity as a conceptual tool in Roman studies? In this article, a clear strength of heterogeneity as a concept has been that it transcends the traditional boundaries that separate social, economic, and cultural history and offers one overarching concept that connects apparently disparate developments like increasing inequality and cultural diversity, both of which are crucial factors in facilitating technological innovation. Heterogeneity offers an elegant way to describe several categories of social diversification that occur when cities grow in size, become better integrated in regional or suprar-regional networks, or become wealthier. Processes like increasing inequality, multicultural or ethnic diversity, and specialization are to a certain extent branches of the same tree. This makes heterogeneity a useful perspective through which one can look at processes of urban change and urban development.

At the same time, some caution is appropriate. It is important to observe that as a heuristic device, heterogeneity does not stand on its own. It needs a cause and an effect. That is to say: urban heterogeneity as a 'state of affairs' emerges and develops under the influence of historical forces of change — such as, in this article, (Roman) empire formation. At the same time, it can, but does not need to have, a transformative effect on everyday human practices or experiences. In contexts where it can be identified through material or written culture, heterogeneity can be used to explore such macro-scale causes and micro-scale effects — but heterogeneity itself cannot be seen to predict any of

those. Not all innovations in the Roman world can be associated with urban heterogeneity; not all ancient empires developed patterns of heterogeneity similar to that of the Roman Empire. In other words: heterogeneity offers a valuable starting point for empirical research, but has little to offer without that empirical backup.

Moreover, practically, heterogeneity works alongside and in interaction with other agents of societal change, such as prosperity and connectivity. Its exact role cannot always be distinguished: it is clear that in the emergence of concrete, prosperity — and the resulting architectural boom — also played a key role; in the spread of glass-blowing, connectivity — and the exchange of ideas — over longer distances was *also* fundamental. However, neither prosperity nor connectivity are enough to fully understand these processes of innovation and diffusion. In the case of concrete, it is not only elite wealth, but also the availability of cheap labour that came to shape innovations in construction practice. Here, heterogeneity helps us out. In the case of glass, connectivity is not enough to understand why glass not only came to Italy but also became anchored there — it is through Italy's culturally heterogeneous urban networks that Levantine skills and practices were transferred to Italian craftsmen. Here, heterogeneity helps to point to an aspect of the process that connectivity overlooks. This makes the concept of 'heterogeneity' a great tool for sharpening our understanding of social geographies of technological innovation in the Roman world, as long as it is clear that it offers a perspective that illuminates rather than a model that predicts.

Abbreviations

CIL	<i>Corpus Inscriptionum Latinarum</i>
EDCS	<i>Epigraphik-Datenbank Clauss-Slaby</i> < http://www.manfredclaus.de/ > [accessed 25 January 2023]
Plin., HN	Plinius maior, <i>Naturalis historia</i>
Tac., Ann.	Tacitus, <i>Annales</i>

Works Cited

- Arthur, W. B. 2009. *The Nature of Technology: What It Is and How It Evolves* (New York: Free Press).
- Battaglini, G. and F. Diosono. 2010. 'Le domus di Fregellae: case aristocratiche di ambito coloniale', in *Etruskisch-italische und römisch-republikanische Häuser*, ed. by M. Bentz and C. Reusser, *Studien zur antiken Stadt* (Wiesbaden: Reichert), pp. 217–32.
- Beltran Lloris, F. 2015. 'The "Epigraphic Habit" in the Roman World', in *The Oxford Handbook of Roman Epigraphy*, ed. by C. Bruun and J. Edmondson, *Oxford Handbooks* (Oxford: Oxford University Press), pp. 131–48.
- Bowman, A., E. Champlin, and A. Lintott. 1996. *The Cambridge Ancient History*, x: *The Augustan Empire, 43 B.C. – A.D. 69* (Cambridge: Cambridge University Press).
- Bowman, A., P. Garnsey, and D. Rathbone. 2000. *The High Empire, A.D. 70–192* (Cambridge: Cambridge University Press).
- Broekaert, W. 2016. 'Freedman and Agency in Roman Business', in *Urban Craftsmen and Traders in the Roman World*, ed. by A. Wilson and M. Flohr, *Oxford Studies on the Roman Economy* (Oxford: Oxford University Press), pp. 222–53.
- Camodeca, G. 1992. *L'archivio puteolano dei Sulpicii* (Naples: Eugenio Jovene).
- Carfora, P., S. Ferrante, and S. Quilici Gigli. 2010. 'Edilizia privata nell'urbanistica di Norba tra la fine del III e l'inizio del I secolo a. C.', in *Etruskisch-italische und römisch-republikanische Häuser*, ed. by M. Bentz and C. Reusser, *Studien zur antiken Stadt* (Wiesbaden: Reichert), pp. 233–42.
- Coarelli, F. 1977. 'Public Building in Rome between the Second Punic War and Sulla', *Papers of the British School at Rome*, 45: 1–19.
- D'Arms, J. 1970. *Romans on the Bay of Naples: A Social and Cultural Study of the Villas and their Owners from 150 B.C. to A.D. 400* (Cambridge, MA: Harvard University Press).
- De Ruyt, C. 2002. 'Boulangers et foulons d'Ostie à l'époque impériale. Quelques réflexions sur l'implantation de leurs ateliers et sur leurs fonctions précises dans la ville portuaire', in *Les artisans dans la ville antique*, ed. by J.-C. Béal and J.-C. Goyon (Paris: de Boccard), pp. 49–54.
- Düring, B. and T. Stek. 2018. *The Archaeology of Imperial Landscapes: A Comparative Study of Empires in the Ancient Near East and Mediterranean World* (Cambridge: Cambridge University Press).
- Erdkamp, P. 2020. 'Population, Technology, and Economic Growth in the Roman World', in *Capital, Investment, and Innovation in the Roman World*, ed. by P. Erdkamp, K. Verboven, and A. Zuiderhoek, *Oxford Studies on the Roman Economy* (Oxford: Oxford University Press), pp. 39–66.
- Faber, A. and A. Hofmann. 2009. *Die Casa del Fauno in Pompeji (VI 12), I: Bauhistorische Analyse: Stratigraphische Befunde der Ausgrabungen in den Jahren 1961 bis 1963* (Wiesbaden: Reichert).
- Finley, M. I. 1965. 'Technical Innovation and Economic Progress in the Ancient World', *The Economic History Review*, 18.1: 29–45.
- Flohr, M. 2013. *The World of the Fullo: Work, Economy and Society in Roman Italy*, *Oxford Studies on the Roman Economy* (Oxford: Oxford University Press).
- . 2019a. 'Artisans and Markets: The Economics of Roman Domestic Decoration', *American Journal of Archaeology*, 123.1: 101–25.
- . 2019b. 'Prosperity, Investment, and the History of Pompeii's Urban Economy', in *Popolazione, risorse e urbanizzazione nella Campania Antica: dall'età preromana alla Tarda Antichità*, ed. by M. Maiuro and M. Balbo (Bari: Edipuglia), pp. 75–90.
- . 2021. 'Information Landscapes and Economic Practice in the Roman World', in *Managing Information in the Roman Economy*, ed. by C. Rosillo López and M. Garcia Morcillo, *Palgrave Studies in Ancient Economies* (London: Palgrave), pp. 205–28.
- . 2022. 'Between Aesthetics and Investment: Close-Reading the Tuff Façades of Pompeii', in *Architecture and the Ancient Economy*, ed. by M. Trümper and D. Maschek, *Analysis archaeologica* (Rome: Quasar), pp. 155–72.
- . 2023. 'Prosperity and Inequality: Imperial Hegemony and Neighbourhood Formation in the Cities of Roman Italy', in *Ancient Neighbourhoods and City Quarters*, ed. by A. Haug, A. Hielscher, and A.-L. Krüger (Berlin: De Gruyter), pp. 157–73.
- . Forthcoming a. 'From Ashlar to Brick: Anchoring and the Evolution of Building Practice in Roman Italy', in *Anchoring Technology and Science in the Greco-Roman World*, ed. by M. Flohr, T. Tieleman, and S. Mols (Leiden: Brill).

- González, R. M. 2021. 'The Global, the Local, and the Glocal: A New Reading of the Priapus Mosaic from the Hispano-Roman Villa of Bobadilla (Antequera, Málaga)', *Memoirs of the American Academy in Rome*, 66: 92–114.
- Greene, K. 2000. 'Technological Innovation and Economic Progress in the Ancient World: M. I. Finley Re-Considered', *The Economic History Review*, 53.1: 29–59.
- Hansen, M. H. and T. H. Nielsen (eds). 2004. *An Inventory of Archaic and Classical Poleis* (Oxford: Oxford University Press).
- Hanson, J. 2016. *An Urban Geography of the Roman World, 100 BC to AD 300*, Archaeopress Roman Archaeology, 18 (Oxford: Archaeopress).
- Hermankova, P., V. Kase, and A. Sobotkova. 2022. 'Inscriptions as Data: Digital Epigraphy in Macro-Historical Perspective', *Journal of Digital History*, 1.1: 99–141.
- Hobson, M. 2020. 'Roman Towns and the Settlement Hierarchy of Ancient North Africa: A Bird's-Eye View', in *Regional Urban Systems in the Roman World, 150 BCE – 250 CE*, ed. by L. de Ligt and J. Bintliff, Mnemosyne Supplements, History and Archaeology of Classical Antiquity, 431 (Leiden: Brill), pp. 281–323.
- Holleran, C. 2017. 'Finding Commerce: The *taberna* and the Identification of Roman Commercial Space', *Papers of the British School at Rome*, 85: 143–70.
- Hopkins, K. 1978. *Conquerors and Slaves* (Cambridge: Cambridge University Press).
- Houten, P. 2021. *Urbanisation in Roman Spain and Portugal: Civitates Hispaniae in the Early Empire*, Studies in Roman Space and Urbanism (London: Routledge).
- Jaschke, K. 2010. *Die Wirtschafts- und Sozialgeschichte des antiken Puteoli, Pharos. Studien zur Griechisch-Römischen Antike*, 26 (Rahden: Leidorf).
- Laird, M. 2015. *Civic Monuments and the Augustales in Roman Italy* (Cambridge: Cambridge University Press).
- Lancaster, L. 2012. 'A New Vaulting Technique for Early Baths in Sussex: The Anatomy of a Romano-British Invention', *Journal of Roman Archaeology*, 25: 419–40.
- Larson, K. A. 2019. 'Cheap, Fast, Good: The Roman Glassblowing Revolution Reconsidered', *Journal of Roman Archaeology*, 32: 7–22.
- Laurence, R. and F. Trifilò. 2015. 'The Global and the Local in the Roman Empire: Connectivity and Mobility from an Urban Perspective', in *Globalisation and the Roman World: History, Connectivity and Material Culture*, ed. by M. Pitts and M. J. Versluys (Cambridge: Cambridge University Press), pp. 99–122.
- Ligt, L. de and J. Bintliff. 2020. *Regional Urban Systems in the Roman World, 150 BCE – 250 CE*, Mnemosyne Supplements, History and Archaeology of Classical Antiquity, 431 (Leiden: Brill).
- Ligt, L. de and P. Garnsey. 2012. 'The Album of Herculaneum and a Model of the Town's Demography', *Journal of Roman Archaeology*, 25: 69–94.
- Liu, J. 2009. 'Collegia centonariorum': *The Guilds of Textile Dealers in the Roman West*, Columbia Studies in the Classical Tradition, 34 (Leiden: Brill).
- Lugli, G. 1957. *La tecnica edilizia romana: con particolare riguardo a Roma e Lazio*, 2 vols (Rome: Bardi).
- MacMullen, R. 1982. 'The Epigraphic Habit in the Roman Empire', *American Journal of Philology*, 103: 233–46.
- Milanovic, B., P. Lindert, and J. Williamson. 2011. 'Pre-industrial Inequality', *The Economic Journal*, 121: 255–72.
- Mogetta, M. 2015. 'A New Date for Concrete in Rome', *The Journal of Roman Studies*, 105: 1–40.
- . 2016. 'The Early Development of Concrete in the Domestic Architecture of Pre-Roman Pompeii', *Journal of Roman Archaeology*, 29: 43–72.
- . 2021. *The Origins of Concrete Construction in Roman Architecture: Technology and Society in Republican Italy* (Cambridge: Cambridge University Press).
- Mouritsen, H. 2011. *The Freedman in the Roman World* (Cambridge: Cambridge University Press).
- Orlandi, S. 2021. 'Digital Projects in Epigraphy: Research Needs, Technical Possibilities, and Funding Problems', in *Epigraphy in the Digital Age: Opportunities and Challenges in the Recording, Analysis and Dissemination of Inscriptions*, ed. by I. Velázquez Soriano and D. Espinosa Espinosa (Oxford: Archaeopress), pp. 1–8.
- Östborn, P. and H. Gerding. 2015. 'The Diffusion of Fired Bricks in Hellenistic Europe: A Similarity Network Analysis', *Journal of Archaeological Method and Theory*, 22.1: 306–44.
- Pesando, F. 2006. 'Il "secolo d'oro" di Pompei. Aspetti dell'architettura pubblica e privata nel II secolo a.C.', in *Sicilia ellenistica, consuetudo italica: alle origini dell'architettura ellenistica d'Occidente*, ed. by M. Osanna and M. Torelli, Biblioteca di 'Sicilia antiqua' (Rome: Edizioni dell'Ateneo), pp. 227–41.
- Peterse, C. 1985. 'Notes on the Design of the House of Pansa (VI 6, 1) in Pompeii', *Mededelingen van het Nederlands Instituut te Rome*, 46: 35–55.
- . 1999. *Steinfachwerk in Pompeji: Bautechnik und Architektur*, Circumvesuviana, 3 (Amsterdam: Gieben).
- Petrokovits, H. von. 1981. 'Die Spezialisierung des römischen Handwerks', in *Das Handwerk in vor- und frühgeschichtlicher Zeit*, ed. by H. Jankuhn, W. Janssen, R. Schmidt-Wiegand, and H. Tiefenbach (Göttingen: Vandenhoeck und Ruprecht), pp. 63–132.
- Pirson, F. 1999. *Mietwohnungen in Pompeji und Herculaneum: Untersuchungen zur Architektur, zum Wohnen und zur Sozial- und Wirtschaftsgeschichte der Vesuvstädte*, Studien zur antiken Stadt (Munich: Pfeil).

- Pitts, M. 2021. 'Towards Romanization 2.0: High-Definition Narratives in the Roman North-West', *Journal of Urban Archaeology*, 5: 117–30.
- Pitts, M. and M. J. Versluys. 2015. *Globalisation and the Roman World: History, Connectivity and Material Culture* (Cambridge: Cambridge University Press).
- Pleket, H. W. 1973. 'Technology in the Greco-Roman World: A General Report', *Talanta*, 5: 6–47.
- Rickman, G. 1981. 'The Grain Trade under the Roman Empire', *Memoirs of the American Academy in Rome*, 36: 261–75.
- Ruffing, K. 2016. 'Driving Forces for Specialization: Market, Location Factors, Productivity Improvements', in *Urban Craftsmen and Traders in the Roman World*, ed. by A. Wilson and M. Flohr, Oxford Studies on the Roman Economy (Oxford: Oxford University Press), pp. 115–31.
- Saddington, D. B. 2007. 'Classes: The Evolution of the Roman Imperial Fleets', in *A Companion to the Roman Army*, ed. by P. Erdkamp (Oxford: Blackwell), pp. 201–17.
- Scheidel, W. 2009. 'In Search of Roman Economic Growth', *Journal of Roman Archaeology*, 22: 46–70.
- (ed.). 2012. *The Cambridge Companion to the Roman Economy* (Cambridge: Cambridge University Press).
- Sewell, J. 2016. 'Higher-Order Settlements in Early Hellenistic Italy: A Quantitative Analysis of a New Archaeological Database', *American Journal of Archaeology*, 120.4: 603–30.
- Stern, E. M. 1999. 'Roman Glassblowing in a Cultural Context', *American Journal of Archaeology*, 103: 441–84.
- Sternini, M. 2019. 'The Production Centres and River Network of Italian Terra Sigillata between the Arno and Tiber Valleys: A Geographical Point of View', *Journal of Roman Archaeology*, 32: 485–94.
- Stone, D. 2020. 'A Diachronic and Regional Approach to North African Urbanism', in *Regional Urban Systems in the Roman World, 150 BCE – 250 CE*, ed. by L. de Ligt and J. Bintliff, Mnemosyne Supplements, History and Archaeology of Classical Antiquity, 431 (Leiden: Brill), pp. 324–49.
- Tacoma, L. E. 2014. 'Migrant Quarters at Rome?', in *Integration in Rome and in the Roman World*, ed. by G. De Kleijn and S. Benoist, Impact of Empire, 17 (Leiden: Brill), pp. 127–45.
- Temin, P. 2013. *The Roman Market Economy*, The Princeton Economic History of the Western World (Princeton: Princeton University Press).
- Terpstra, T. 2013. *Trading Communities in the Roman World: A Micro-economic and Institutional Perspective*, Columbia Studies in the Classical Tradition, 37 (Leiden: Brill).
- . 2015. 'Roman Trade with the Far East: Evidence for Nabataean Middlemen in Puteoli', in *Across the Ocean: Nine Essays on Indo-Mediterranean Trade*, ed. by F. De Romanis and M. Maiuro (Leiden: Brill), pp. 73–94.
- . 2020. 'Roman Technological Progress in Comparative Context: The Roman Empire, Medieval Europe and Imperial China', *Explorations in Economic History*, 75: 101300.
- Torelli, M. 1980. 'Innovazioni nelle tecniche edilizie romane tra II I sec. a.C. e II I sec d.C.', in *Tecnologia, economia e società nel mondo romano*, ed. by E. Gabba (Como: Comitato promotore delle manifestazioni celebrative del XIX centenario della morte di Plinio il Vecchio), pp. 139–62.
- Tran, N. 2006. *Les membres des associations romaines: le rang social des collegiati en Italie et en Gaules, sous le Haut-Empire*, Collection de l'École française de Rome, 367 (Rome: École française de Rome).
- Tucci, P. L. 2004. 'Eight Fragments of the Marble Plan of Rome Shedding New Light on the Transtiberim', *Papers of the British School at Rome*, 72: 185–202.
- Van Oyen, A. 2015. 'The Roman City as Articulated through Terra Sigillata', *Oxford Journal of Archaeology*, 34.3: 279–99.
- . 2017. 'Finding the Material in "Material Culture": Form and Matter in Roman Concrete', in *Materialising Roman Histories*, ed. by A. Van Oyen and M. Pitts (Oxford: Oxbow), pp. 133–52.
- Vandevoorde, L. 2015. 'Of Mice and Men: Financial and Occupational Differentiation among *Augustales', *Cahiers: mondes anciens*, 7 <<https://doi.org/10.4000/mondesanciens.1534>>.
- Verboven, K. 2011. 'Professional Collegia: Guilds or Social Clubs', *Ancient Society*, 41: 187–95.
- Vermeulen, F. 2017. *From the Mountains to the Sea: The Roman Colonisation and Urbanisation of Central Adriatic Italy* (Leuven: Peeters).
- Versluys, M. J. 2014. 'Understanding Objects in Motion: An Archaeological Dialogue on Romanization', *Archaeological Dialogues*, 21.1: 1–20.
- Willet, R. 2019. *The Geography of Urbanism in Roman Asia Minor* (Sheffield: Equinox).
- Wilson, A. 2002. 'Machines, Power and the Ancient Economy', *The Journal of Roman Studies*, 92: 1–32.
- Wood, S. 2010. 'Horti in the City of Rome: Emulation and Transcendence in the Late Republic and Early Empire', *Theoretical Roman Archaeology Journal*, 19: 75–90.
- Zuiderhoek, A. 2009. *The Politics of Munificence in the Roman Empire: Citizens, Elites and Benefactors in Asia Minor*, Greek Culture in the Roman World (Cambridge: Cambridge University Press).
- . 2016. *The Ancient City*, Key Themes in Ancient History (Cambridge: Cambridge University Press).