Migration and Mobility in Imperial Rome

by
Kristina Killgrove

A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Anthropology.

Chapel Hill
2010

Approved by:

Dale L. Hutchinson, Advisor

Nicola Terrenato, Reader

C. Margaret Scarry, Reader

Carole L. Crumley, Reader

Drew S. Coleman, Reader

Abstract

KRISTINA KILLGROVE: Migration and Mobility in Imperial Rome.
(Under the direction of Dale L. Hutchinson.)

Migration to Rome in the Imperial period has been under-researched owing to a dearth of epigraphical and historical evidence, particularly regarding the lower classes. A new set of data has come to light in the form of thousands of skeletons from lower-class cemeteries in Rome's *suburbium*. Two of these cemeteries, Casal Bertone near the city walls and Castellaccio Europarco in an agricultural area of the Roman suburbs, yielded 183 skeletons for osteological analysis. Combined strontium and oxygen isotope analyses of a subsample of 55 individuals isolated 20 people who came to Rome following a birth elsewhere. Carbon and nitrogen isotope analysis of the same sample population demonstrated that there were significant differences between the childhood diet of immigrants to Rome and that of the locals. Immigrants were more likely to have consumed diets with significant amounts of the C_4 plant millet. Prevalence of skeletal and dental diseases, however, were not significantly different between the immigrant and local populations. Mobility in Imperial Rome can thus be characterized from isotope analyses as long-distance migration from the provinces as well as movement of individuals within the Italian peninsula. The biological identification of immigrants to Rome in the absence of historical and epigraphical data is a significant first step towards a new understanding of who migrants were, where they came from, and what experiences they had upon arrival in the Imperial capital.

For my Chickpea

Acknowledgments

First, none of this research could have been accomplished without the generous financial support of the National Science Foundation (BCS-0622452), the Wenner-Gren Foundation for Anthropological Research, and UNC's Center for Global Initiatives, Graduate School, and Research Laboratories of Archaeology. All of these organizations helped fund months' worth of data collection on-site in Rome and the stable isotope analysis of hundreds of samples. I also appreciate the year's worth of fellowship funding received from P.E.O. International, which allowed me to focus on my writing full-time.

Data collection in Rome would not have gotten underway had Nic Terrenato not reached a wrong number at the Soprintendenza Archeologica di Roma. His tireless advocacy of my desire to study skeletons from Rome was the catalyst for this project, and he was instrumental in everything from the visa process to research discussions. While in Rome, I had the pleasure of working with colleagues in the anthropological service of the Soprintendenza. Paola Catalano generously allowed me access to the Casal Bertone and Castellaccio Europarco skeletons and worked with archaeologists to obtain site reports and excavation notes on my behalf. Walter Pantano procured maps for me of Castellaccio Europarco and gave me access to his personal reports from the site. I am also grateful to "Orso" for his daily espresso, lunches, and retrieval of any skeleton or tool I could want.

Back in the U.S., I learned how to process teeth for strontium isotope analysis with the help of an amazing group of researchers at UNC. Dale Hutchinson provided me access to his Buehler saw and other bioarchaeology lab resources. Lee Boushell taught me to use that saw and a bit of dental wax to section teeth. Donna Surge generously permitted me access to her dental drill and light microscope to extract enamel from dozens of teeth, and Ting Wang helped me learn to use the MicroMill. For unfettered access to the Isotope Geochemistry Lab and for answering countless questions about strontium, I am indebted to Drew Coleman. He allayed my fears of screwing up the chemical analysis - and reassured me when I did - and made it fun to learn about chemistry and geology. The graduate students and undergraduate staff of the Isotope Geochemistry Lab were similarly patient with this anthropological interloper: Jenn Poole, Ayumi Shimokawa, Kevin Schrecengost, and Stephen Hughes. I am also grateful to Paul Fullagar for running my samples over holidays and weekends, and for help in interpreting some of the results.

Oxygen isotope analysis was done by my colleague Janet Montgomery, who graciously answered numerous questions about the use of oxygen isotopes in the ancient world. Janet also provided me with strontium and lead concentration results for the heck of it, and I was happy to receive an unexpected boon of new data. Jacqueline Towers gave me information about the methods of oxygen isotope analysis, and her quick email responses were greatly appreciated. Dale Hutchinson pushed me to do a dietary study of these skeletons, even though I was resistant to add more chemical analyses. Some of the most exciting results in this project arose through carbon isotope analysis, so I am grateful for his advice and assistance in pursuing this avenue of research. The carbon and nitrogen isotope analyses were performed on my behalf by Rob Tykot.

A great many friends made this work possible. In Rome, I found fantastic *coinquilini* first in Sara Campolonghi and then in Marco and Ivan Di Antonio. They didn't bat an eye when I brought home teeth and little chunks of bone to clean on the patio, and Marco graciously helped fix my hasty Italian translations. My friends and students back at home listened to me prattle on about isotopes, suggested bibliographic references and statistical methods, and just generally kept me sane: Erik Johannesson, Erika Zimmermann Damer, Patrick Reynolds, Juline Chevalier, Jeff Becker, Celeste Gagnon, Sara Becker, Kathy McDonnell, Chris Cameron, Shaena Montanari, Lara Frame, and Trey Newell. Blogging and social networking were actually not a complete waste of time, as I got great input on my ideas from Megan Perry, Tracy Prowse, and Walter Scheidel. The ladies of the local P.E.O. chapter deserve special mention, not only for nominating me for a fellowship and welcoming me to their meetings, but also for insisting on bringing me a month's worth of home-cooked food after my daughter was born. Stephanie Deal turned out to be the best nanny a mother could ask for, always excited to see Cecilia and unfailingly providing her the best care. Without her help over the past year, I could not have focused on writing.

Thanks are, of course, owed to my dissertation committee, composed of Dale Hutchinson, Nic Terrenato, Margie Scarry, Carole Crumley, and Drew Coleman, as each one of them was excited about the results of my project. Their suggestions on the text were invaluable in the final revisions. Carla Antonaccio was also supportive of this project, serving as one of my PhD examiners and proposal readers. Additionally, I am extremely grateful for the administrative support of my grants provided by Haeran Miller in the anthropology department.

My relatives and in-laws deserve extensive thanks for supporting me throughout the long process of doing what I have been dreaming about since I was a kid. Although he is not here to see the outcome, my father, Terrance Michaels, sparked my interest in dinosaurs and dead people decades ago. My mom, Gail Killgrove, singlehandedly put me and my brother, Clinton, through college and is the strongest and most patient woman I could ask for as a role model. My parents-in-law Lynn Heath and Paul Reynolds listened to my stories about school and research and provided their perspectives from different fields of academe. Craig Reynolds helpfully read and critiqued several of my grant proposals.

During the course of this dissertation, Patrick Reynolds and I went from spouses - with completely different research fields that led us to completely different parts of the globe - to parents of Cecilia Livia. Patrick has ceaselessly encouraged me to pursue higher degrees in physical anthropology, no matter the geographical distance it put between us. Over the years, he's read grant proposals, held down the fort while I traveled to Europe, visited me in Italy, and shown enthusiasm for projects only a bioarchaeologist would care about. I am very lucky to have him supporting me in every conceivable way. And finally, my daughter Cecilia is simply amazing. Watching her grow up is the ultimate in osteology geekdom, as it lets me personalize ontogeny. Other kids cut teeth, mine has mammelons erupting from crypts in a subadult mandible. None of this would have been worthwhile without them.

Contents

List of Figures

List of Tables

Part I

Theorizing Mobility in Imperial Rome

Chapter 1

Introduction

Mille viae ducunt homines per saecula Romam.
- A. de Lille (1175), *Liber Parabolarum* 591

The Medieval aphorism translated as "all roads lead to Rome" was likely a reference to the *milliarium aureum*, which Plutarch (*Life of Galba*, 24.2) described as a gilded column in the Forum Romanum where every road in the Italian peninsula ended. Early in his principate, Augustus set up this monument and inscribed distances between Rome and other cities in the Empire (Hülsen, 1906). Ancient authors and modern historians alike take for granted that Rome as the literal center of the Empire beckoned people into its walls with the promise of bread and circuses, jobs and culture, neglecting to fully investigate the effects that visitors had on various aspects of society. In contrast, quite a lot of multidisciplinary research has been done on Roman presence in the provinces. This research points out the complicated cultural relationships that obtained during the Empire and rejects the long-held belief that a monolithic Roman culture existed to which provincials were quickly acculturated. The same critical eye has not been turned onto Rome itself, and our understanding of migration to Rome is based solely on the written record. There has been no further investigation of those who made the journey to Rome either by force or by choice, of their biological and cultural characteristics, their effects on the Roman population, or their experiences negotiating a new geographical space.

A thorough understanding of migration to Rome has been written off as impossible by a number of scholars because of the lack of archaeological evidence found thus far and because migration is a difficult process to model. There are no tangible remains of neighborhoods or cemeteries in Rome that are known to have held large groups of immigrants. There is little evidence of separate housing or domestic spheres for foreign slaves. We do not see clear indications of the preservation of ethnic heritage in material culture assemblages at household or cemetery sites in Rome. It is therefore difficult to both identify and contextualize migrants with the archaeological data at hand. Roman demographers have marshaled the scanty historical and epigraphical evidence of migrants to the capital out of necessity, as migration, fertility, and mortality form the basis of demographic inquiry (Scheidel, 2001; Erdkamp, 2008). In the absence of a quantifiable data source such as a census, however, many demographers quite literally footnote migration (Parkin, 1992; Laurence, 1999; Frier, 1999).

In the past decade, construction projects in Rome have uncovered thousands of skeletons in Imperial period cemeteries, almost all of which represent the lower echelons of Roman society (Catalano, 2008). Very few of these cemeteries have been published, with many reports including only a small sample of the overall burial population (Buccellato et al., 2003). Investigating this new line of data - biological remains of the ancient Romans - is therefore imperative for understanding migration to Imperial Rome. Prior to this study, migration to Italy has rarely been investigated using osteological remains, and only one other study has employed chemical analysis to identify individual migrants (Prowse et al., 2007). Isotope analysis of human skeletal remains has been used for decades to isolate individuals whose enamel or bone composition differs from that of the local population. Using this method, it is possible to find people who were born elsewhere and who consumed significantly different food resources at that location. Further, traditional osteological analysis of demographic characteristics and disease prevalence within a cemetery population can yield additional information about patterns of migration and immigrants' experiences.

This dissertation therefore shifts the focus of human movement in the Roman Empire from the provinces to Rome itself in order to better understand those people who, for whatever reason, came to the Imperial capital from somewhere else. The geographical mobility of people within the Empire has direct consequences for the demographic composition of the city, the disease load of the population, the Roman economy, the process of urbanization, the institution of slavery, and the composition of society in general. Bioarchaeological data can be consolidated to investigate immigrants' common experiences - or lack thereof - at Rome as compared with the local population. Choices made in commemorative practices and foodways, as well as differential susceptibility to disease, constitute a starting point for investigating identity, ethnicity, and the quality of life of immigrants to Rome.

There are three main goals of this project. First, basic data on lower-class immigrants to Rome are virtually nonexistent. Through a combination of bioarchaeological and biochemical analysis, I address the following questions:

1. Is there evidence of immigrants at Rome?
2. Who immigrated? What was the sex ratio and age range of the immigrant population?
3. From which geographical areas were immigrants coming to Rome?
4. What form did migration take in the Empire? Unidirectional, bidirectional, long-distance, short-distance, urban-to-rural, rural-to-urban?

Second, assumptions are widespread in both historical and contemporary secondary literature about the quality of life of immigrants to Rome. Immigrants and slaves living in the urban center are thought to have been much more likely to have suffered physically than locals. In an argument ex silentio, foreigners and slaves are also assumed to have quickly acculturated to life at Rome. This project investigates these assumptions using osteological and archaeological information by asking:

1. What was the quality of life for nonlocals at Rome? Was their skeletal and dental health

significantly worse than that of the locals? Were they more prone to interpersonal violence? Do diet and deficiency diseases speak to poorer nutrition among immigrants?

2. Did immigrants to Rome maintain previous lifeways and indications of former identities or ethnicities?

Finally, this project on the bioarchaeology of immigrants to Imperial Rome contributes to a better understanding of one of the largest urban centers in the preindustrial world. As foreign-born people composed a large portion of the Roman population, this document concludes with an assessment of how immigrants affected the cosmopolitan nature of Imperial Rome.

The structure of this dissertation is as follows:

1.1 Part I - Theorizing Mobility in Imperial Rome

The first part of this dissertation deals with the ways in which we can understand mobility and migration in Imperial Rome. Although the historical record is often maligned because of its elite bias, it provides a wealth of information about the geopolitical structure in which movement occurred throughout the Empire. Using the written record, though, means questioning primarily its applicability to slaves and the lower classes, who constituted the vast majority of migrants in the Imperial period. Drawbacks of the historical approach notwithstanding, chapter 2 lays out the spatial context of movement within the Empire. The geography of migration is quite nuanced; some people came to Rome from far-flung provinces, while others left their homes in Tuscany or the suburbs and made their way to the Imperial capital. Both voluntary and compulsory migration contributed to the growth of the city of Rome and are examined in this chapter from an historical perspective, which suggests that certain time periods and circumstances contributed to large-scale population movements and diasporic events. An investigation into short-distance population migration in the Empire shows that there is little information on mobility between the city and the suburbs of Rome. Being able to reconstruct population movement at any or all of these scales would add significantly to our understanding of one of the largest urban centers in history.

In chapter 3, I present my approach to migration in ancient Rome. Studies of Imperial Rome tend to under-theorize mobility, taking it for granted that citizens moved freely within the geopolitical borders of the Empire. Further, almost every Roman researcher ignores slavery as a migratory phenomenon, choosing instead to use epigraphical inscriptions to focus on free (usually elite) citizens' reasons for moving and commemoration of identity in death. Rather than assuming that migration is an easily understood historical process that needs no theoretical explication, I argue that migration theory drawn from contemporary anthropology allows me to reconceive of migration to Rome as a patterned human process, one that can be investigated archaeologically. Recent perspectives in cultural anthropology emphasize transnationalism and diaspora as phenomena of migration in our increasingly globalized world. Although the Roman Empire was a highly connected geopolitical entity in its time, applying these modern ideas wholesale to ancient Rome would be anachronistic. Nevertheless, the concepts of diaspora and transnationalism are useful for forming questions about migration that have not yet been asked in regard to Rome. The limits of the currently analyzed archaeological data for answering questions about migration are examined, however, and a new data source, human skeletal remains, is introduced. The utility of biochemical analyses of skeletal tissue to this new approach to Roman migration is explicated. This chapter concludes with the role of mobility in urban Rome. Migration affects the demography and epidemiology of a population, it gives us a window into the ancient slave trade, and it helps us understand what life was like for the slaves and lower classes living at Rome.

1.2 Part II - Bioarchaeological Evidence

In the second part of this dissertation, I present a variety of bioarchaeological evidence collected from human remains from two Imperial-period cemeteries at Rome.[1] The Casal Bertone and Castellaccio Europarco cemeteries are thought to represent a cross-section of the Roman lower class. Chapter 4 includes all available archaeological information about these sites and where they fit into the typical Roman burial tradition. As a periurban cemetery with associated mausoleum, it is thought that individuals buried at Casal Bertone were more urban and of slightly higher social standing than individuals buried at the suburban cemetery of Castellaccio Europarco. Demographic information on age, sex, and stature from the cemetery populations indicates that there are differences between the two geographical contexts.

Chapters 5 and 6 further investigate the differences between Casal Bertone and Castellaccio Europarco in terms of evidence of disease and foodways. In general, the frequencies of both skeletal and dental pathologies at the two sites were significantly lower than at the few other published cemeteries of the Imperial period. It appears, however, that life in urban Rome may have been tougher than living in the suburbs, as evidence of interpersonal violence and disease is slightly higher at Casal Bertone. Nevertheless, the human remains indicate a surprisingly healthy life, or at least one without diseases that took a toll on the skeleton. The assumption that urban life had a demonstrably ill effect on the health of the lower classes is therefore questioned. A dietary assessment of a sample of individuals from the two study populations using carbon and nitrogen isotope analysis also shows some differences, particularly among adults. Variation existed within the Roman diet, as individuals who lived within a few kilometers of one another, who were very likely moving between the urban and suburban contexts frequently, ate significantly different foodstuffs.

[1] Appendix B gives the data gleaned from the earlier Republican burials at Castellaccio Europarco. These burials were too few to be of diachronic comparative value at this point in the development of bioarchaeology in Rome.

1.3 Part III - Human Mobility in Imperial Rome

In order to discuss lower-class migrants to Imperial Rome, it is first necessary to locate them. The lack of historical information about the vast majority of migrants and the fact that very few Imperial period burials have been found with grave goods that could indicate different geographical or cultural origins mean that a new data set is necessary in order to identify individuals who moved to Rome from elsewhere. Part III therefore explicates my biochemical approach to identifying migrants and presents the results of strontium and oxygen isotope analyses.[2]

Chapter 7 begins by demonstrating the utility of biochemical analyses for questions of ancient migration in publications by other Old World researchers. The methods behind isotope analysis of both strontium and oxygen are presented, along with ways in which these isotope data can be interpreted, particularly in terms of identifying an approximate geographical area in which an immigrant was born. Generally, isotope analyses are performed on dental enamel, which forms during childhood and does not remodel like bone does. This study uses enamel from first molars to assess mobility in the Roman Empire, and the constraints on interpretation of the data produced by this method are also presented.

Chapter 8 details the process by which strontium was extracted from dental enamel and presents the results of the measurement of $^{87}Sr/^{86}Sr$ ratios in the 105 samples taken from Imperial-period individuals at Casal Bertone and Castellaccio Europarco. Although strontium passes from geological formations into the groundwater and eventually to human tissue unfractionated, the bioavailability of strontium within the environment relates to factors such as the origins of water sources in addition to the underlying geology of a region. Strontium isotope analysis has never been performed on human tissue from Rome before, so this chapter presents an in-depth discussion of how I constructed a local strontium range. Through analysis of the geology, a few scattered faunal data points, and modeling of the environment based on

[2] An approach to mobility that combines nonmetric trait data with biochemical analyses was considered, but the data sets overlapped in so few cases that the former are presented separately in appendix C.

information about Roman aqueducts, I provide a conservative estimate of the strontium range of Rome and its suburban hinterland. Immigrants to Rome are identified with respect to these ranges, and patterns indicative of possible geological homelands are investigated.

In order to support the strontium isotope data, a subset of 55 individuals was subjected to oxygen isotope analysis, which provides independent but complementary information on migration using the same dental enamel samples. Results of the oxygen isotope analysis are presented in chapter 9. The data were interpreted with reference to a published sample of modern Roman children's deciduous teeth, yielding numerous individuals who were probable immigrants to Rome.

In chapter 10, the results from the strontium and oxygen isotope analyses are combined. Whereas strontium tends to vary roughly north to south on the Italian peninsula, oxygen varies east to west. Immigrants are conservatively assumed to be from Italy unless an isotope value is outside the expected range for the peninsula. Many individuals were found to have significantly higher or lower strontium or oxygen values than the individuals defined as local, and others presented oxygen isotope values that are inconsistent with the environment of Italy. Those people shown to have originated somewhere other than Rome are of both sexes and died at a variety of ages, from preadolescence to senescence.

1.4 Part IV - Friends, Romans, Countrymen

The last section of this dissertation integrates the bioarchaeological and biochemical evidence presented in chapters 4 through 10 in light of the historical context of migration in Imperial Rome. These data are compiled in two different ways in chapters 11 and 12. First, I investigate immigrants' overall quality of life and strategies of integration/separation in chapter 11 by comparing the identified immigrant population from the two study sites with the local population in terms of demographics (age-at-death, sex ratios), burial style, diet, and disease. Second, I highlight the lives of particular immigrants in chapter 12, those whose skeletons yielded the most new information about life as a foreigner in Imperial Rome. Bioarchaeological analysis of human skeletal remains from ancient Rome is thus shown to create a nuanced picture of migrants in the Imperial capital and to contribute to the biography of people absent from history and materially invisible. This dissertation concludes with chapter 13, a summary of the new information generated by this research project. Strontium isotope analysis shows that people came to Rome from the provinces and from Italy and that the people of Rome utilized a variety of water resources during the Empire. The chapter concludes with a call for further research into mobility and migration in Imperial Rome informed by contemporary anthropological theories of transnationalism and diaspora, particularly regarding the themes of identity, ethnicity, and agency of slaves and the lower classes.

Chapter 2

All Roads Lead to Rome

Augustus initiated the use of the term *princeps* to refer to the Roman emperor, and it continued to be used through Diocletian's reign. As the "first citizen," Augustus was the face of the Empire, quite literally, propagating his image and his ideas throughout the Empire by means of coinage, building programs, and the visual language of art (Zanker, 1990). He also recognized the extreme importance of the road system for military, trade, and communication purposes (Laurence, 1999). From its inception, therefore, both the infrastructure and ideology of the Empire meant that people living far from central Italy had information about the urban center. The edict of Caracalla in 212 AD granted Roman citizenship to all free residents of the Empire, allowing them to permanently change residence without losing any legal rights. With many transportation and cultural barriers removed, it is unsurprising that people were voluntarily immigrating to Rome, perhaps drawn by the promise of economic betterment. The slave trade continued into the Imperial period as well, providing Rome, Italy, and the provinces with additional nonlocal residents.

This chapter sets up the structural conditions in which mobility to Rome during the early Imperial period occurred, inasmuch as we understand this phenomenon from written records referring to voluntary migration and slavery. The different scales at which movement occurred, both geographical and temporal, are reviewed. Presentation of the information currently known regarding migration to Rome includes discussion of the deficiencies in this research.

2.1 Briefly Defining Movement, Population, and Empire

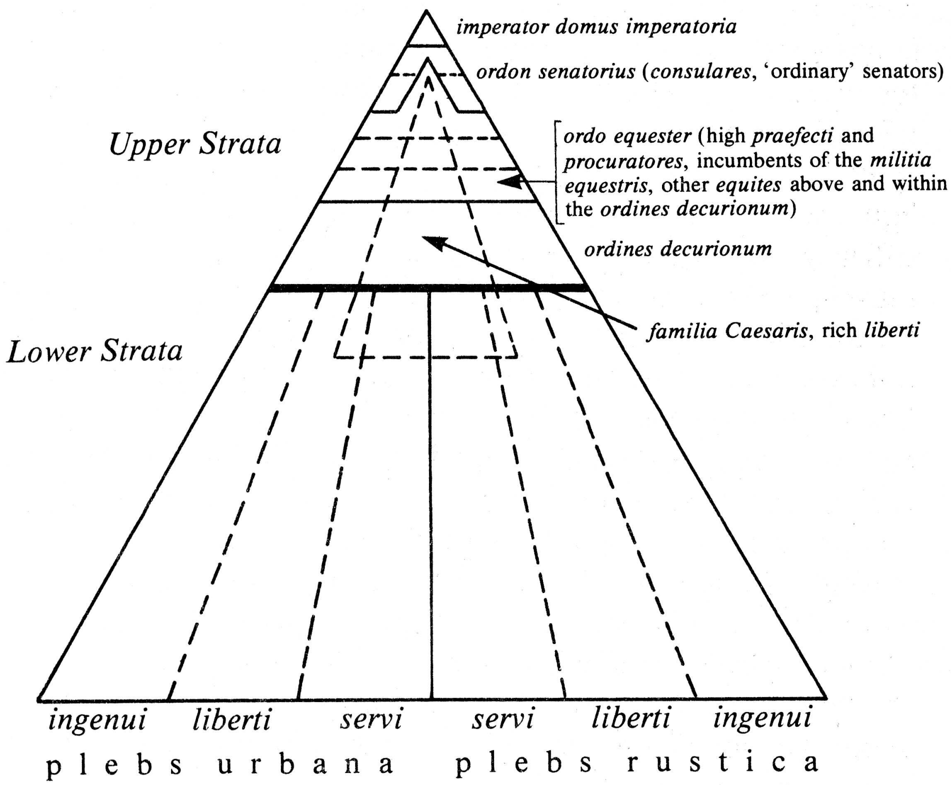
Movement

I start with the general premise that people are not stationary beings their entire lives, even in antiquity (Osborne, 1991). Theories of physical movement will be further explicated in chapter 3, but it is necessary at the outset to define terms that will be used throughout this work. Although I do agree with Kearney (1986, p. 331) that "migration is the movement of people through geographic space," that definition does not connote the duration of the movement. Rather, in this work I follow and expand on Erdkamp's (2008, p. 420-1) conception of human movement in the Roman world as a "spectrum" of migration and mobility.

At one end, *migration* involves permanent relocation, which can result in, for example, changes in subsistence strategy, the creation of an ethnic enclave at the destination, or voluntary acculturation. *Physical mobility* is less permanent than migration, involving seasonal or temporary relocation, such as an itinerant musician, a shepherd engaged in transhumance, or rural farmers who regularly journey to city markets. Finally, *travel* does not result in any significant change in a person's learned behavior or foodways but might lead to a more permanent form of relocation. It is therefore not always possible to identify which of these categories best fits the movement under investigation, as overlap can occur and individuals can engage in one or more of these movement patterns during the course of their lives.

Population

The population of Rome during the Empire was divided into different strata based primarily on social, legal, and economic standing, but all individuals had the potential to be physically mobile. The diagram in figure 2.1 gives a general picture of the organization of the population. Among the upper strata of Roman society were the emperor and his household, senators (*senatores*), and equestrians (*equites*). The decurion order comprised some *equites* but mainly reflected the local ruling elite of other cities in the Empire. Among the lower strata of Roman society were the free commoners (*ingenui*), the freedpeople or former slaves (*liberti*), and the slaves (*servi*). The latter two strata of people were not legal citizens of the Empire. Before the early 3rd century AD, other non-citizens at Rome included *peregrini* or free foreigners, those who came to the city voluntarily from other areas of the Empire.



From Alföldy (1985), Fig. 1

Figure 2.1: Social Structure of Imperial Rome

There was very little chance of individuals from the lower strata gaining entry into the upper strata of Roman society, indicated in figure 2.1 by a thick black line. Social mobility within the upper strata did exist, as men could work their way up from *eques* to *senator*, for example. In the lower strata, slaves could be freed. Economic betterment, however, did not necessarily bring a change in status at either end of the social hierarchy.

There was no middle class in the true Marxist sense of the term; rather, the Roman social hierarchy maintained a strong division between the wealthy elite of the upper strata and the *plebs*, the lower strata of commoners, freedpeople, and slaves of modest or few means.

Alföldy (1985, p. 149) has argued that, without a middle stratum that both owned the means of production and engaged in production, it is unwise to refer to the Roman population in terms of upper and lower *classes*. With all due respect to the original denotation of *class* and with the recognition that the Roman social system is rather unique among preindustrial societies, in this dissertation I follow the convention of many classical scholars in using the terms *upper class* and *lower class* to broadly connote the primary dichotomy of the Roman social structure.

The pyramidal depiction of Roman society represented in figure 2.1 imparts only a general conception of the social structure; it does not represent the imbalance between the population size of each stratum. Table 2.1 is drawn from a variety of sources to show the relative size of each social stratum (MacMullen, 1974; Alföldy, 1985; Bradley, 1994; Scheidel, 1997). Less than 2% of the population of Rome would have been in the upper strata of society; the elite or the upper class thus controlled the government, religion, and economy of both Rome and the Empire.

Upper Class	Imperial Family (*Imperator & Domus*)	0.002%
	Senators (*Senatores*)	0.2%
	Equestrians (*Equites*)	1.3%
Lower Class	Free Commoners (*Ingenui*)	58%
	Freedpeople (*Liberti*)	6%
	Slaves (*Servi*)	35%
	Total	100%

Table 2.1: Distribution of the Imperial Roman Population by Social Class

The remaining 98% or so of the Roman population was composed of the non-elite, people whose social, economic, or legal status prevented them from joining the ranks of the upper strata. My use of the term *lower class(es)* thus refers to the vast majority of the population of Rome, including the free commoners (*ingenui*), slaves (*servi*), and freedpeople (*liberti*). In chapter 4, I will discuss how material remains from burial have been used to address social status.

Empire

There are various dates cited as the start and end of the Roman Empire, most notably for the latter because of the difficulty pinpointing its precise "fall." On account of the imprecise nature of the archaeological dates used in this work, I refer to large periods of time with the following shorthand terms:

Early Empire - Approximately the reign of Augustus and the succeeding Julio-Claudian and Flavian dynasties: 27 BC-96 AD.

Middle Empire - The period in which the greatest geographical and population size was reached, approximately the reigns of the 5 Good Emperors and the Severan dynasty: 96-235 AD.

Late Empire - The events after the crisis of the third century through the decline and "fall" of the western Roman Empire: 235-395 AD.

For the purposes of this work, I am mainly concerned with the 1st to 3rd centuries AD, approximately the reigns of Augustus (27 BC-) through Diocletian (-305 AD). The majority of this time period is also known as the Principate, as it was in antiquity. Reference will, however, be made to the Republican period (509-27 BC) as necessary through discussion of structural factors of Roman society and economy that might have affected migration in the Imperial period.

In terms of geographical area, the greatest extent of Rome's imperial expansion was during the reign of Trajan (98-117 AD). Movement within the Empire was not necessarily restricted to Roman-conquered areas, but most of the movement towards Rome likely came from the lands of the known Empire. Mobility and migration, as implied above, are known from historical sources to have taken place in different geographical spaces and at a variety of scales. Current knowledge about the kinds of people who traversed the Roman Empire and how and why they engaged in mobility and migration is presented in the following sections.

2.2 Spatial Context of Movement within the Roman Empire

When Roman scholars discuss migration and mobility in the Empire, the geographical spaces they allude to are often presented in implicit structuralist terms, the contrasting dichotomies of Empire with Italy and Rome with its suburban hinterland (*suburbium*). Movement in the first pairing thus represents long- versus short-distance migration (Noy, 2000), and movement within the second represents a rural-to-urban pattern (Erdkamp, 2008). At a more myopic scale, a central concern of migrants is housing at the destination. Movement within and between neighborhoods and households in Rome is less often discussed, yet it is likely both that ethnic enclaves existed and that there was integration of people from a variety of backgrounds (Noy, 2000). These categories are meant to convey the general scale of geographical thinking in the Roman world; where physical boundaries existed, they were in most cases permeable (Witcher, 2005).

2.2.1 Empire and Italy

The extended reach of Rome began in the Republic, when the city and its growing territory were governed by the Senate and the Roman people. Rome's military might was proven early in its history, as the organization served to secure the borders of ever-growing Rome, collect tribute and taxes from conquered peoples, and maintain order (Goldsworthy, 2003). Military campaigns were thus the lynchpin in expansion of the territory governed by Rome.

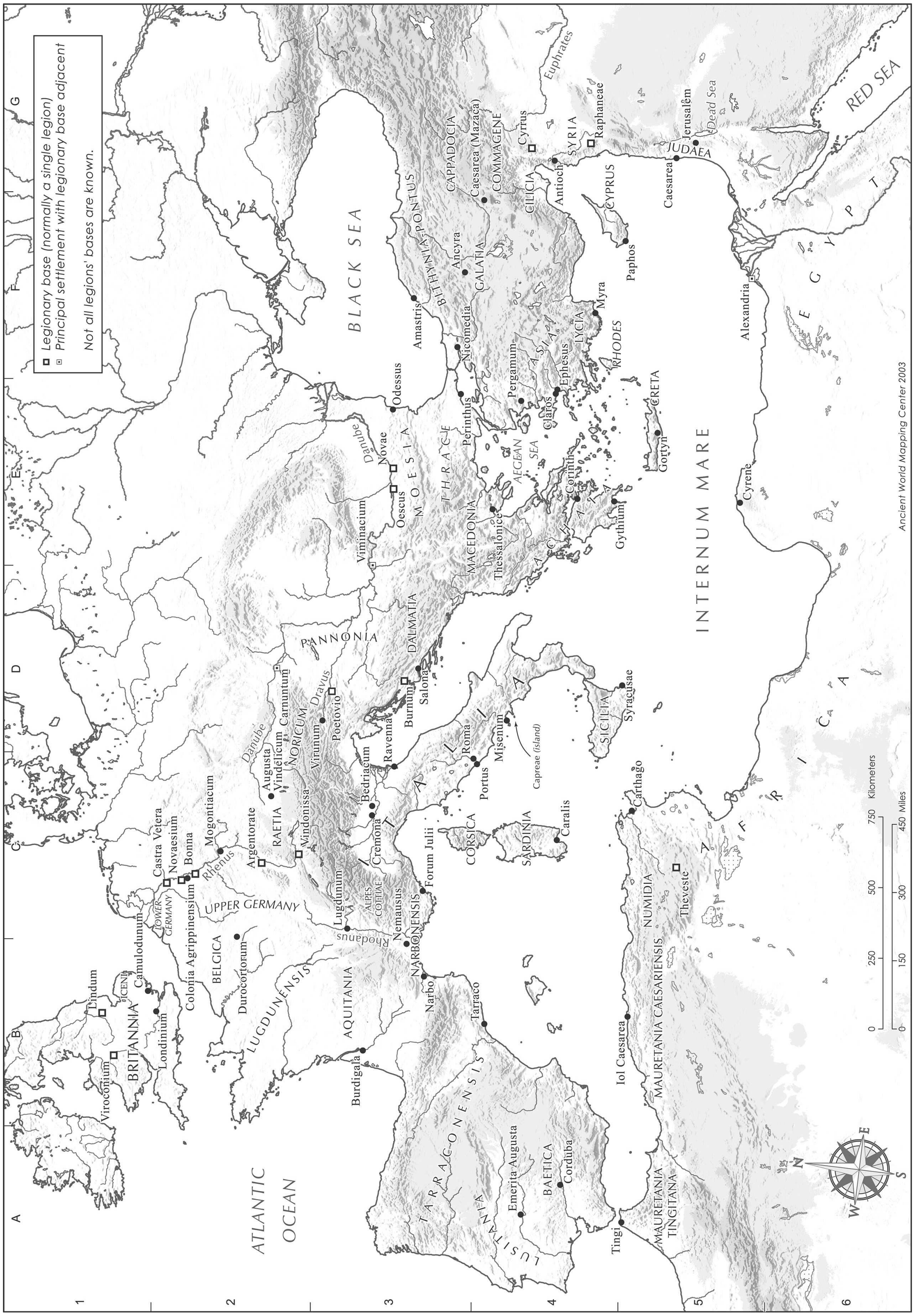
Different peoples came into contact with one another for the first time during these military excursions, and population interaction was a lasting result of Rome's expansionist mindset. Following the subjugation of the Etruscans and Latins surrounding Rome in the 5th century

BC, the city expanded its jurisdiction to a large part of the Italian peninsula by the 3rd century. The 3rd century also brought conflict with another major Mediterranean power, Carthage, and the Punic Wars continued into the 2nd century. The theater of war included much of the north coast of Africa and a large part of Spain across the Strait of Gibraltar. The 2nd century also saw conflict in the east, as Rome defeated Greece and Macedonia, and the 1st century brought antagonism from Asia Minor. As general, Julius Caesar began his campaigns in the northeast in the 1st century BC, famously invading Gaul. By the end of the Republic, the Roman world stretched from France to north Africa, from Spain to Syria (Keppie, 1998).

The ascension of Augustus to the head of the government of Rome, however, brought a new era of cognizance of geography on the part of the Roman people, at least as judged by the ethnonyms in his *Res Gestae* and historical references to a multitude of peoples and geographical areas (Nicolet, 1991). Yet Augustus also ushered in an era of peace, the so-called *Pax Romana*, by checking expansion and concentrating on the maintenance of the Empire. Under succeeding emperors, the territory governed by Rome grew. In addition to pushing the boundaries of the Empire northward in Germany and Britain, Rome expanded eastward after taking over Pannonia and Dacia, and pressed further east to struggle with the empire of Parthia. The greatest extent of the Empire, under the leadership of Trajan, can be seen in figure 2.2. Rome's military leaders in the Republic and Empire thus acted both as de facto ambassadors in their interactions with people in the colonies and human traffickers as they brought conquered peoples back to Rome as slaves. Slavery and military service as compulsory migration in the Republic and Empire will be discussed further below.

Not only was the territory of the Empire partitioned into different provinces, but the Italian peninsula under Augustus (c. 7 BC) was demarcated into eleven administrative regions (figure 2.3) (Nicolet, 1991).[1] Rome was, of course, in Region I, but the remainder of the regions were more or less arbitrarily drawn by Augustus and did not relate to the geographical thinking

[1]The regions were: I = Latium and Campania. II = Calabria and Apulia. III = Lucania and Bruttium. IV = Samnium. V = Picenum. VI = Umbria. VII = Etruria. VIII = Aemilia. IX = Liguria. X = Venetia. XI = Transpadana.



Map courtesy of the Ancient World Mapping Center at UNC (2003).

Figure 2.2: The Roman Empire in 69 AD

at the time nor to any inherent ethnic divisions of the peninsula (Laurence, 1998, p. 99). The Greek geographer Strabo took pains to equate these regions with ethnicity, the primary feature by which many ancient geographers organized their work (Laurence, 1998, p. 95). Ethnicity was conceived as including: shared territory, common descent, shared language, shared customs or beliefs, a name (ethnonym) for group identity, and a shared history (Renfrew, 1996, p. 130). Yet by the beginning of the Empire, the Italian peninsula was already quite heterogeneous in its population, and there were no stark cultural or linguistic borders between Italic peoples.

From Nicolet (1991), Map 1.

Figure 2.3: Augustan Regions of Italy

Towns, cities, and peoples could choose to distance themselves from Rome culturally, often in opposition to their common perceptions of the city and its culture (Laurence, 1998). Further, Laurence (1998, p. 109) points out that “tota Italia and the use of ethnonyms... stressed the distinctness of the Italian peoples yet united them politically with Rome at the center.” The extensive network of Roman roads that crossed Italy and ran through the Empire made transportation of goods, movement of people, and exchange of ideas between Rome and the Empire that much easier (Laurence, 1999). The roads connected regions to one another, connected Italy to the provinces, and contributed to the heterogeneity of ethnic backgrounds in the city of Rome. A proper study of ethnicity and identity in ancient Rome is beyond the scope of this work, as there is significant primary literature and recent secondary literature in both philology and archaeology (e.g., Laurence and Berry, 1998; Huskinson, 2000; Hales, 2003). By the end of the 3rd century AD, however, the extension of Roman citizenship to every person in the Empire became the primary way by which people organized and conceived of themselves as Roman (Laurence and Berry, 1998). The population of Italy was no longer more politically influential than that of the provinces, and the people of the Empire became more geographically dispersed.

2.2.2 Rome and Its *Suburbium*

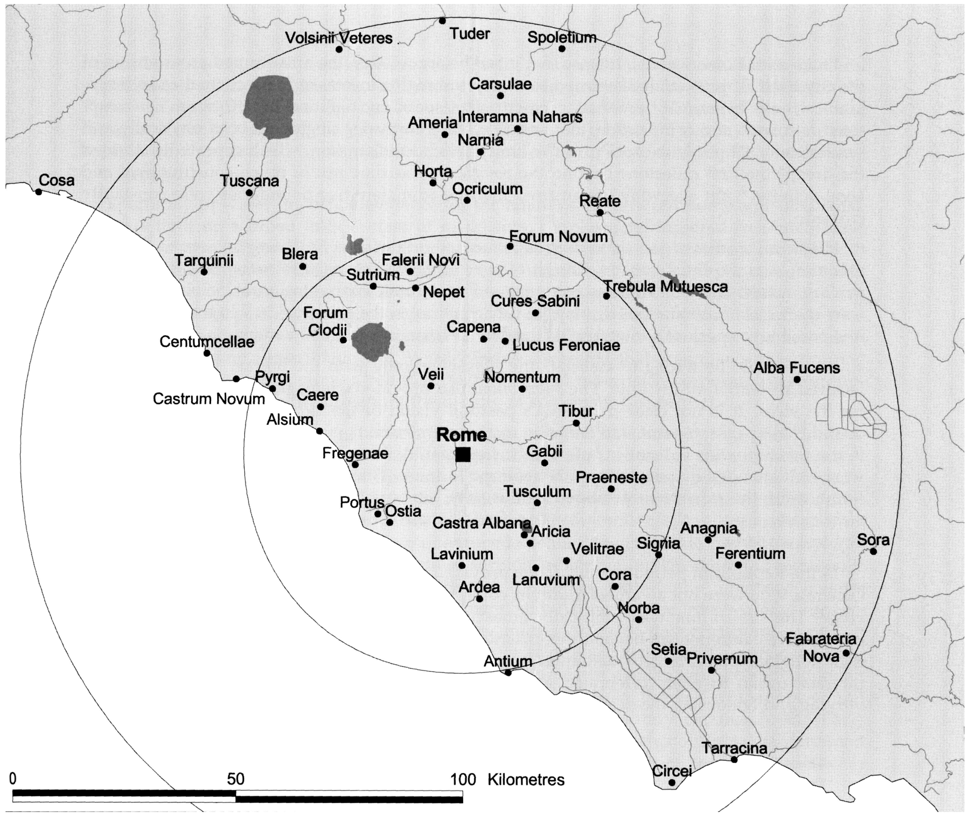
By the early 1st century AD, the 14 km^2 city of Rome had a population of between 750,000 and one million people living within its walls and an additional 300,000 to 500,000 people living in the periurban area just outside the city walls (Wiseman, 1969; Hopkins, 1978; Morley, 1996; Storey, 1997b; Scheidel, 2001). The canonical model of Rome as an urban center was created by M.I. Finley (1981), who adapted Max Weber's idea of the consumer city to the ancient Mediterranean. In recent years, classical scholars have demonstrated the inadequacy of this economic model for understanding sociopolitical interactions in both Rome and the Empire (Whittaker, 1995; Morley, 1996; Lomas, 1997; Storey, 2006).

The concept of the city of Rome as a monolithic, spatially distinct area of Italy has been challenged by archaeologists and historians interested in the *suburbium*, a term that literally means the area below or outside the walls of Rome. Although this word is infrequently used in ancient literary accounts and thus difficult to define, the *suburbium* was thought of as a part of the city (*urbs*) that performed certain functions (Champlin, 1982). Urban planners note that suburban sprawl has been common since antiquity as a "region just outside the city that housed activities and individuals that were still intimately connected with the social and economic life of the city but that could not be accommodated easily within the walls" (Bruegmann, 2005, p. 21). The Roman suburbs were an extension of the city itself, yet at the same time a liminal area between the city and the rural countryside, replete with roads that led to far-flung parts of the Empire.[2]

The Greek historian Dionysius of Halicarnassus (4.13), writing in the early Imperial period, commented that the suburbs of Rome were so large that they gave one the impression of a city stretching out indefinitely. The *suburbium* was therefore neither rural nor urban, and has largely been defined by contemporary scholars of ancient Rome. The limit of the Roman *urbs* is generally taken as the walls of the city, but there is no specific demarcation of the end of the *suburbium* and the beginning of the rural countryside. Quilici (1974) sees the suburbs extending perhaps 5-10 km from the city walls, and Champlin (1982) as a few kilometers. Witcher (2005, p. 121), on the other hand, defines as the *suburbium* as "an 'urbanized' version of the countryside" and draws its limit at a radius of about 50 km from Rome because of the distinctive settlement patterns and material culture found in the region (figure 2.4). In this scenario, the *suburbium* includes cities like Portus Romae and Gabii in a web of interdependent urban and suburban development.

Archaeological field surveys suggest that population density within the *suburbium*, while not on par with that within the walls, was still exceptionally high, holding about one-third of a million people (Morley, 1996; Witcher, 2005). The residents of this area lived in either poorly-built, crowded dwellings or in large, expansive villas, indicating the dichotomous use of the *suburbium* as both inexpensive housing for those who could not afford city dwelling and palatial estates for those wealthy city-dwellers who wanted to relax outside of the busy metropolis

[2]The five-volume *Lexicon Topographicum Urbis Romae: Suburbium*, hereafter *LTURS*, contains a wealth of information about a variety of archaeological features in this area, including roads, aqueducts, cemeteries, monuments, and villas. The cemeteries of Casal Bertone and Castellaccio Europarco, however, are not included in this work, both having been recently excavated.



From Witcher (2005), Fig. 1. Circles represent 50 km and 100 km radii from Rome.

Figure 2.4: The Roman *Suburbium*

of Rome (Champlin, 1982). Land use in this area also included marginal businesses excluded from the city for religious or public safety reasons, such as slaughterhouses, brick-making facilities, quarry pits, landfills, and cemeteries (Witcher, 2005). A peak in both suburban and urban populations during the Imperial period would have put great pressure on the *suburbium* and its lower-class residents to accommodate additional housing, infrastructure, and cemeteries (Carafa et al., 2005). Archaeological field survey is beginning to flesh out details of life in the *suburbium*, but the majority of our information is still inferred from historical sources.

Movement within and between the *urbs* and *suburbium* is known mainly from the elite, who wrote about their need to escape the claustrophobic city for the healthy air of the countryside (Champlin, 1982). The life of leisure in the country and the political life of the city were both within reach for the elite (Morley, 1996). For example, Pliny wrote a lengthy letter to his friend

Gallus extolling the virtues of having a villa in the *suburbium*. It is worth excerpting a large part of that letter in order to illustrate the infrastructure of the road network, the ease with which the elite could travel between the contexts of city and suburbs, and the ability to procure necessary items without traveling long distances.

> You are surprised, you say, at my infatuation for my Laurentine estate, or Laurentian if you prefer it so. You will cease to wonder when you are told the charms of the villa, the handiness of its site, and the stretch of shore it commands. It is seventeen miles distant from Rome, so that after getting through all your business, and without loss or curtailment of your working hours, you can go and stay there. It can be reached by more than one route, for the roads to Laurentium and Ostia both lead in the same direction, but you must branch off on the former at the fourth, and on the latter at the fourteenth milestone. [...] The neighbouring woods furnish us with abundance of fuel, and other supplies we get from a colony of Ostia. The village, which is separated only by one residence from my own, supplies my modest wants. [...] The shore is beautified by a most pleasing variety of villa buildings, some of which are close together, while others have great intervals between them. They give the appearance of a number of cities, whether you view them from the sea or from the shore itself. - *Pliny, Epistulae 2.XVII* [3]

Many of the elite of Roman society experienced the *suburbium* in the way Pliny did, but the lower classes likely had a different experience. Roads and villages were equally open to them as to the elite, but much less is known about the frequency or nature of mobility of the *plebs urbana* (urban lower class) and the *plebs rustica* (rural lower class) between Rome and the suburbs. People living in the more rural contexts of the *suburbium* often came to the city to sell or buy goods at markets and fairs (de Ligt, 1993). Witcher (2005, p. 132) additionally argues that the permanent migration that maintained the population of the city of Rome largely came from the *suburbium*. It is also likely that people living in the city traveled into the *suburbium*, perhaps to engage in agricultural labor or skilled trades (such as brick-making), but there are no specific references to mobility in this direction in the historical literature (Witcher, 2005).

The relationship between the city of Rome and the mixed-use area beyond its walls is economically complicated. This dichotomy of rural production versus urban consumption is quite

[3] Translation by J.B. Firth (1905).

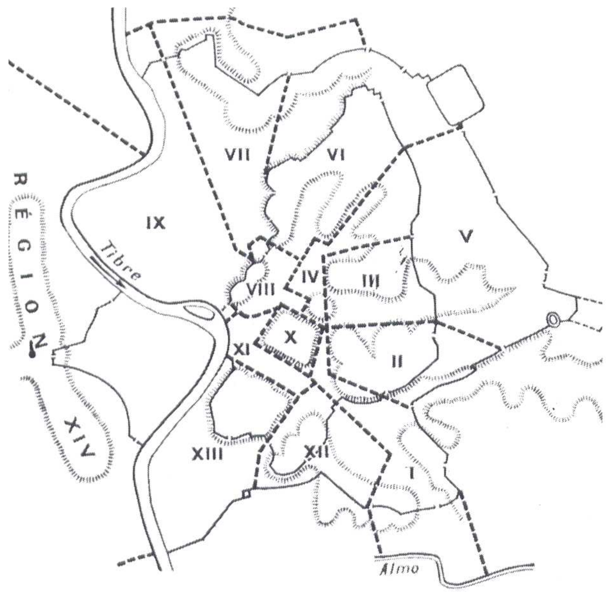
hoary and belies the blurring of land use in the *suburbium* in particular. There is little historical and archaeological information about movement between these two contexts, particularly among the lower classes, although modern migration theory shows that a bidirectional flow of people is most intense in periurban areas such as the *suburbium* of ancient Rome (Tacoli, 1998). Migration to the city of Rome can therefore take place at a variety of scales: from outer areas of the Empire, from other cities and regions of Italy, and from the *suburbium*.

2.2.3 Neighborhoods and Households of Rome

In the same year that he restructured the regions of Italy (7 BC), Augustus launched an urban renewal program in the city of Rome, in regard to which he later noted that he had turned a city of brick into a city of marble. Prior to the Empire, Rome had only four regions with several neighborhoods (*vici*) in each. The lower classes of society were the primary people active in local cultic and other neighborhood activities. Shared ethnic identity and religious background characterized the *vici* of the Republic, geographical spaces that comprised an organizing mechanism of lower-class society by which they could participate indirectly in the politics of Rome (Lott, 2004, p. 4-5).

Augustus' reorganization of space in the Imperial capital created fourteen *regiones* (figure 2.5), areas of social and civic life rather than the mainly religious entities of the Republic (Lott, 2004, p. 9). Communities of the lower classes in urban Rome were further divided and cross-cut into social groups by a variety of cultural factors such as occupational guilds (*collegia*) and eligibility for the grain dole (Lott, 2004, p. 11). Neighborhoods, however, seem to have had no clear boundaries, even following Augustus' changes, and it is generally unknown who lived in which area (Noy, 2000). That is, physical location might not have been the only factor in identifying with a particular neighborhood (Lott, 2004, p. 26). In short, the fourteen neighborhoods under Augustus reflected the changes in the size and composition of the population of Rome.

With population size and density reaching their apex and influxes of immigrants coming



From Nicolet (1991), Fig. 54 (reproduced from Homo 1971).

Figure 2.5: Regions of Rome

from all areas of the Empire, neighborhoods became less associated with common ethnicity and religion and more heterogeneous in composition. Although we have archaeological and epigraphical sources that deal with the definition and administration of neighborhoods in the Imperial city (Lott, 2004; Nicolet, 1991), it is still difficult to envision a peopling of and movement within this urban space. The ability of the lower class, including slaves, to move among different areas of the city does not seem to be a popular subject of scholarship; presumably, the *plebs urbana* frequently traversed Rome's streets for reasons both occupational and social, and many likely changed residences during their lifetimes. Human mobility in Imperial Rome can therefore be seen at all scales of political and social organization, and it is to a characterization of the forms of mobility that I now turn.

2.3 Human Mobility in the Roman Empire

Against the dual thematic background of an increasingly dispersed geographical area and wholesale reorganization of space in the Empire, the nature of human mobility within and between these spaces and places is often overlooked. In particular, little is known about migration to the city of Rome or about the migrants themselves, as there are no census data listing number and origin of foreigners at Rome. The general context of slavery and the mechanics of the slave trade are reported in the primary literature, but the experiences of slaves at Rome are rarely detailed. Similarly, the movement of the free lower classes to Rome from the provinces, from Italian regions, from the *suburbium*, and within the city itself is especially woefully under-researched, in spite of tantalizing bits of literature such as Seneca's description of a Roman population half composed of nonlocals of all social classes:

> Every class of person has swarmed into the city that offers high prizes for both virtues and vices. Have all of them summoned by name and ask of each: 'Where do you come from?' You will find that there are more than half who have left their homes and come to this city, which is truly a very great and very beautiful one, but not their own. - *Seneca, ad Helviam, 6.2-3* [4]

The scholarly study of migration to Rome, particularly among the lower classes, has largely been the domain of historical demographers, who have marshaled the available evidence of tombstone inscriptions and records pertaining to the slave trade to investigate directional migration. Using demographic modeling techniques to reconstruct the size and composition of the population of Rome, these researchers have provided wildly divergent estimates of the number of migrants, both voluntary and compulsory, at Rome. Furthermore, the nature of mobility within and between the *suburbium* and the *urbs* complicates both the definition of migrant and our understanding of population interaction within the larger urbanized area of Rome.

[4]Translation by J.W. Basore (1928).

In this section, I present the information currently available on types of migration to Rome within the geographical structure presented in section 2.2. The sources detailed below provide a significant amount of information about human mobility to Rome during the Empire, a phenomenon sometimes called "centripetal migration" (Scheidel, 2004). Migrants to Rome came voluntarily and by force. They came from provinces of the Empire, regions of Italy, and the *suburbium*. Not everyone was interested in permanent relocation; travel, commuting, and transhumance brought individuals to Rome for short periods of time. Basic knowledge of migrants drawn from historical sources can provide partial answers to questions such as: Who were migrants to Rome? Where did they come from? How often did they move?

2.3.1 Defining Roman Migrants

The beginning of the Empire marked a relative peace throughout the land. Augustus' *Pax Romana* in effect created a contiguous geopolitical area in which peoples of the Empire could move freely if they had the financing necessary to undertake such a move. Freed from the threat of war, provincials could come to Rome and inhabitants of Italy and the urbanized area of Rome could move to the provinces to start new lives. The infrastructure of the road system, the possibility of sea travel, and the spread of the material trappings of the Roman Imperial system throughout the land meant that there were few transportation or ideological barriers to movement. Further, the legacy of numerous wars of expansion that resulted in captives and slaves meant that the Roman population was already quite diverse in its geographical, ethnic, and cultural background before the beginning of the Empire.

The most thorough secondary resource on immigration to Rome is David Noy's (2000) *Foreigners at Rome*, which forms a large part of this discussion of the context and types of movement to Rome, particularly during its tenure as the Imperial capital. Noy (2000, p. xi) defines a foreigner as "someone who was born outside Italy and moved to Rome but continued to have a 'home' (in their own thinking or in other people's) elsewhere." This term is distinct from immigrant, which implies movement to a destination with the intention of staying more or less permanently (ibid.). In looking at the primary historical evidence, however, it becomes difficult to find a Latin term that includes the shades of meaning implied by our English concept of foreigner. Archaic Latin originally used the word *hostis* for foreigners, referring to them as guests; this term, however, later came to refer to an enemy (Moatti, 2006). In the Empire, *provincialis* could refer to the inhabitant of a province but not to individuals who came to Rome from beyond the Imperial boundaries (Noy, 2000, p. 1). The Latin term most similar to our concept of foreigner or migrant is probably *peregrinus*. Noy (ibid.) implies that the original use of this term conveyed the lack of citizenship, but following the edict of Caracalla in 212 AD that granted citizenship to all members of the Empire, the term *peregrinus* came to mean anyone whose birth place was not at Rome.

The discussion of words for foreigners highlights by omission the fact that slaves were thought of differently, namely, as a different class of migrants because of their compulsory movement to Rome and legal standing. In fact, scholars such as Noy (2000), Moatti (2006), and Erdkamp (2008) deal only with free immigrants, opting to view slavery as a special kind of migration that has to be treated separately, as a distinct, diasporic phenomenon. Nevertheless, Noy (2000, p. 4) notes that migrants to Rome can in theory be put into three sociolegal categories - slaves, soldiers, and civilians - but that "in practice, there were permeable boundaries between them."

2.3.2 Voluntary Migration

Noy (2000, p. 26) estimates the percentage of free migrants at Rome in the third century AD, the time period in which the upper limit of the population of ancient Rome was probably reached, at 5%. Of this, he thinks 2% represented soldiers and their families and 3% civilian provincial immigrants. However, these numbers only apply to individuals coming to Rome from outside of the Italian peninsula.

Voluntary migration from the provinces to Italy is therefore the major focus of Noy's work. He admits that the scale of migration could have been larger than his figures account for, but suggests that this kind of migration "was probably not a viable option for the really destitute" (Noy, 2000, p. 57). As shown below, once migration from other regions of Italy to Rome and the percentage of imported slaves in Roman society are accounted for, the total of the Roman population that was born elsewhere is closer to 40-50%. Noy's main discussion of reasons that people voluntarily moved to Rome therefore relates to the small number of people who immigrated to Rome from the provinces.

Noy finds in the epigraphical record that there are two main themes in terms of motivation to migrate: push factors relating to an individual's specific temporal, geographical, and socio-cultural context and generalizations about the pull factors of Rome. These themes are broad sketches of what were undoubtedly multifarious reasons for any given individual or family to move to Rome, but there are very few documents that record migrants' decision-making processes (Noy, 2000, p. 86). Thus, Noy (2000, p. 87) uses the theory of push and pull factors influencing migration (Lee, 1966) to argue that people might voluntarily leave their homes because of economic decline, loss of employment, cultural alienation, or natural disaster. Pull factors that might induce people to immigrate include better employment opportunities or the attraction of a new environment. The pull factors of Rome that have been attested in the historical record include: the city as the center of liberty; the city as a more interesting environment than a small town; and Rome as a place to obtain better physical health. Noy (2000, p. 87) does not further delve into reasons that Rome might be a draw, saying that "the attractions of Rome are well documented in the ancient literature" by such authors as Seneca. For the lower class, pull factors of Rome are not clearly known. The presence of the grain dole and expanded citizenship, however, could have led to migration to the capital (Scheidel, 2004). Similarly, push factors are almost never recorded. Augustine (354-430 AD), for example, notes that he was dissatisfied with life at home in Algeria, but information like this on the decision process is extremely rare for the elite and erudite and nonexistent for the lower classes (Noy, 2000, p. 86).

The notion of voluntary migration to Rome as laid out by Noy (2000) hinges on the idea that people in the provinces made a conscious choice to move to Rome. It is extremely difficult to recover reasons for migration in the ancient world, but historical documents give some indication as to possible characteristics of the city of Rome that might have enticed outsiders. Immigrants coming to Rome of their own free will, specifically emigrants from the provinces, represented a small part of the overall nonlocal population at Rome. Most of the nonlocal individuals at Rome were either voluntary migrants from the Italian peninsula or slaves from Italy and the Empire.

2.3.3 Compulsory Migration

Quite a bit of research has been done on the practice of slavery in the ancient Roman world; to cite but a few canonical works: Barrow (1928); Hopkins (1978); Wiedemann (1981); Bradley (1994); Thompson (2003). Recently, however, more scholars have started seeing slaves as (forced) migrants and incorporating them into a model of migration to Rome (Jongman, 2003; Scheidel, 2005). Members of the Roman military and their families were also given no choice about the destination of their move, although upon discharge they could select where they wanted to live. The number of military personnel that came to Rome from elsewhere in the Empire was likely quite small, perhaps 2% of the overall population (Noy, 2000, p. 23). On the other hand, enslaved people at Rome could very well have accounted for up to 40% of the populace (Noy, 2000; Scheidel, 2004). Some of these individuals would have been *vernae*, offspring of a slave mother, but many of them would have come to Rome from other Italian provinces or from far-flung regions of the Empire.[5]

Roman slaves came from vastly different geographical areas, many of them captives of wars begun by generals and emperors bent on imperialism. Two of the Punic Wars, for example, provided Rome with 75,000 slaves from North Africa; Alpine campaigns garnered 44,000

[5]The actual composition of the slave population at Rome was not static. Following wars, foreign-born slaves flowed into the city. Within a generation, though, the ratio of imported slaves to *vernae* could change as the former produced the latter. As noted, manumission also changed the number of enslaved people. The slave population of Rome, then, is difficult to quantify.

prisoners; Septimius Severus' Parthian war yielded 100,000 captives who were taken from their homeland in Iran as slaves; and the Jewish wars provided another 100,000 or more enslaved prisoners from Jerusalem (Bradley, 1994, p. 33,40). Other major sources of slaves included *vernae*, exposed infants, other cultures with slaves to export (e.g., western regions of the Black Sea, the Caucasus, Somalia, and Egypt), and piracy in the Mediterranean (Bradley, 1994, p. 33-39).

The scale of slavery in the Roman Empire was therefore enormous. Approximately half a million new slaves were required for the Empire each year from 50 BC to 150 AD, in contrast to the approximately 60,000 per year in the New World slave trade (Bradley, 1994, p. 32). In Italy, there were about 1.5 million slaves living in the peninsula at the height of the Roman slave trade (Scheidel, 2005, p. 64). There are no definite numbers for the total slaves in the city of Rome, but Scheidel (2005, p. 67) estimates between 300,000 and 450,000 at a time, with up to 300,000 more at other major cities, such as Pompeii. About 600,000 additional slaves were engaged in agriculture in rural areas of Italy (Scheidel, 2005, p. 71).

The two general categories of slaves were those who belonged to households in the city and those who belonged to households in the country (Bradley, 1994). All of the city slaves would have been engaged in non-agricultural work: domestic service for the upper echelons of society and other urban occupations, with domestic tasks defined very broadly. In addition to unskilled servants, household jobs required much skilled labor. Occupational titles of slaves attested in the literature include, for example: groom, architect, singer, surgeon, cook, fuller, secretary, food-taster, dwarf, courier, weaver, barber, and tailor (Treggiari, 1973). Some rural slave jobs noted by Columella include: ploughman, poultry-keeper, goatherd, mower, stableman, reaper, oilpress worker, vine-trimmer, pig-breeder, and veterinarian (Bradley, 1994, p. 60). Slaves might have felt commonality with other slaves not based on geographical origin but rather based on shared occupations (Joshel, 1992).

Individuals of both sexes and all ages comprised the Roman slave population (Scheidel, 2005). Children worked from a young age in the rural sector by pruning or harvesting fodder, and in the urban sector they might be trained in handicrafts (Bradley, 1994, p. 68). Men and women could expect to move up the ranks to different positions through their lives, and many would be manumitted either before or after the death of the master - in their 30s for men and following menopause for women (Scheidel, 2005, p. 72). Because of the disparate geographical origins, demographic characteristics, and skill sets of slaves, the enslaved population at Rome is thought to have been quite heterogeneous (Noy, 2000). This heterogeneity might have contributed to a lack of common identity or class consciousness, as there were few slave uprisings (Bradley, 1994, p. 72). Such striking diversity among slaves also means that it is extremely difficult to generalize the slave experience in Rome.

Epigraphical and historical records provide some information on the life of the average slave, more so than the lives of the freeborn poor, but the evidence is very thin (Noy, 2000; Bradley, 1994). In short, the prospects faced by a slave in ancient Italy would have been bleak, especially with regard to consistent food supply and exposure to disease. However, the life of a slave and the life of a freeborn rural poor person were likely not significantly different if we can believe descriptions of peasant life in Vergil, Martial, Apuleius, and Ovid (Bradley, 1994, p. 91). Slaves, of course, had no choice about their destination nor whether their master would treat them well or with dignity. It has been suggested that slaves might have suffered greater mortality than the local free population, in that foreign slaves might succumb more easily to diseases endemic to the Italian population, but this suggestion is drawn from analogy with the slave system of 19th century Brazil and does not have any historical or epigraphical evidence to support it (Noy, 2000, p. 18). It is possible that slaves working in low-lying marshy areas had greater exposure to malaria (Sallares, 2002), but there is currently no evidence that legal status correlated with longevity (Scheidel, 2005).

On the other end of compulsory migration is the Roman army. Soldiers were by and large engaged in the Empire, keeping watch at frontiers and borders and keeping the peace in less friendly areas. The military was mostly recruited from areas outside of Rome, so the majority of the few stationed at or near Rome were from other areas of Italy or the Empire. As noted above, Noy (2000) estimates that the military (both soldiers and their families) accounted for about 2% of the nonlocal people at Rome, or perhaps 15,000 people. The greatest number of foreign military personnel at Rome was enlisted as the Praetorian Guard, which might have composed anywhere from half to all of the 2% nonlocal military presence depending on time period. In the 1st-2nd centuries AD, the Praetorian Guard was largely drawn from Italy, but in the 3rd century more of them came from provinces such as Pannonia (Hungary) and Thrace (Bulgaria) (Noy, 2000, p. 20-21). Although a lot is known about the Roman military experience, the same cannot be said for the experience of the foreign-born Praetorian Guard at Rome. Unlike normal enlisted men, the Guard interacted with the emperor and his family, and they commanded a higher salary, one and a half times that of other soldiers (Southern, 2006). The Guard should be viewed as equivalent to the upper echelons of civilian society. According to Noy (2000), however, very few foreign-born soldiers seem to have stayed in Rome following retirement from the military, so their contribution to the archaeological and historical records is unclear.

2.3.4 Mobile Individuals

> On the ninth day, he carried bundles of goods into the city on his shoulder, returning from there with a lighter neck but heavier purse since he hardly ever brought any purchases with him from the meat-market of the city. - *(Pseudo-)Vergil, Moretum 79-82* [6]

It has already been established that mobility was a hallmark of Romanness. Human movement to Rome occurred from both far-away provinces and nearby Italian regions, and the structure and characteristics of these migrations have been explicated inasmuch as the evidence allows (Ricci, 2005, 2006). Less often mentioned in secondary literature is frequent mobility on a small scale, namely the rural-to-urban or urban-to-rural movement of commuters between

[6] Translation in Lomas (1996, p. 155).

the *urbs* and the *suburbium* or hinterland of Rome (Erdkamp, 2008).

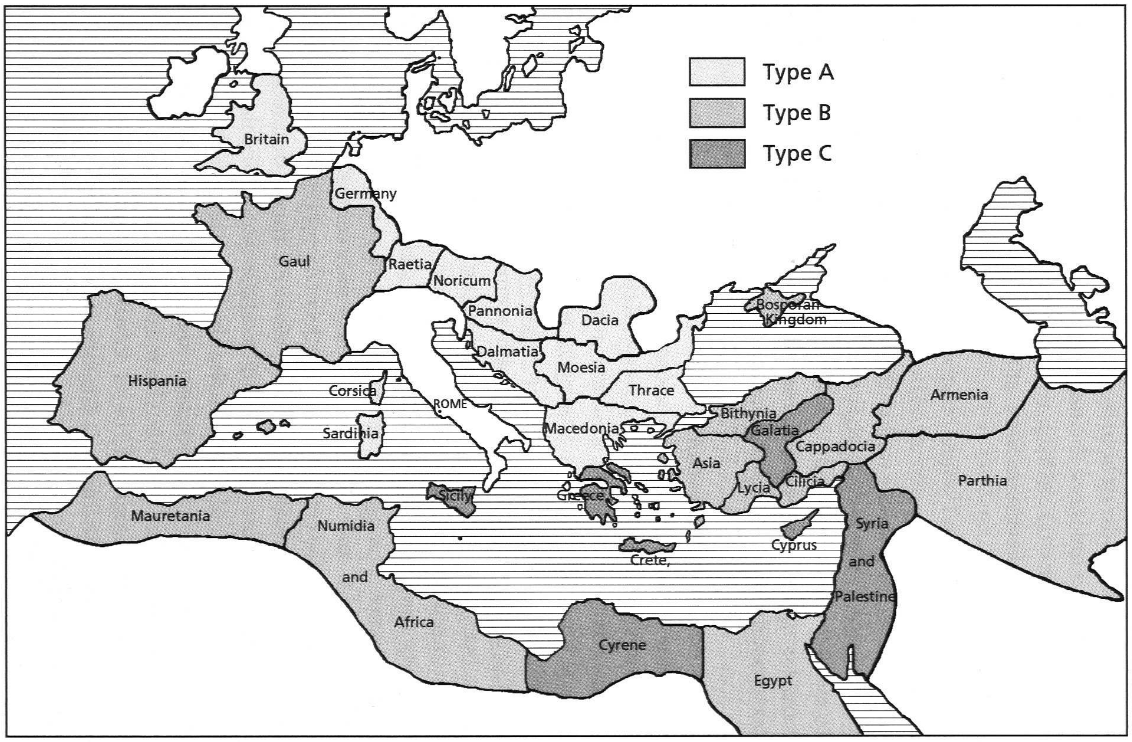
In his letter to Gallus excerpted on page 23, Pliny explains why he enjoys traveling to his Laurentine villa and how easy it is to reach it after a day's work in the city. Many members of the upper class had villas outside the city to which they retired for *otium* and *salubritas* - health and relaxation. At the opposite extreme, the poem *Moretum*, commonly attributed to Vergil, recounts a day in the life of Simulus, a peasant in the countryside. Lines 79-82 excerpted above indicate that the (presumably free) peasant traveled to the city every nine days to sell his produce in the urban marketplace, which would not have been an unusual method of making money as a smallholder (de Ligt, 1993; Erdkamp, 2008). Simulus then returned home with cash in his pocket, as he made sure not to spend it on luxury items like meat while he was in town. Other occupations could bring individuals from the *suburbium* to the city, such as jobs in the education, construction, and craft sectors (Morley, 1997). Lower class people who could afford tombs outside the city walls often cultivated the land, which would have required frequent travel to the plot along one of the main roads (Morley, 1996, p. 95). Members of the upper class might similarly have lived in the countryside for most of the time and come to the city to take care of political or legal matters (Witcher, 2005). Members of the lower class might have lived in the city but moved into the *suburbium* in order to work as brick-makers, undertakers, or other professions that were excluded from the city because of the threat to safety or health that their industries created.

Since the main source of information about migration is the historical record, very little is known about the scale of bidirectional rural-to-urban/urban-to-rural movement among the lower classes. Added to these patterns could be upper- or lower-class individuals who had frequent contact with their original home. Individuals like artists and students would have made their way to Imperial Rome for a limited time. Foreign students, for example, were required to have a sort of visa which, once obtained, allowed them to remain in the city for two years (Moatti, 2006). The city of Rome was therefore composed of permanent residents, temporary residents (e.g., students), and transients (e.g., travelers, market-goers) (Erdkamp, 2008). Although there is a semantic difference between the *urbs* and the *suburbium*, mobility of the Roman populace meant that in reality there were no discrete hinterlands, nor a rural/urban or town/country divide (Witcher, 2005). Migrants, therefore, would be just as likely to take up residence in the suburbs as in the city itself.

2.3.5 Places of Origin

There were likely people from all conceivable areas of the Empire at Rome. Patterns in the epigraphical record emerge, however, when the homelands of individuals are examined from tombstones and other inscriptions. Figure 2.6 reproduces Noy's (2000, p. 58) map of the home areas of freeborn and military foreigners. The majority of the provincial soldiers who died and were commemorated at Rome were from Pannonia, Germany, and Thrace - in general, provinces northeast of the Italian peninsula. These provinces were some of the last to be added to the Empire, and civilian immigration is also known from this area (Noy, 2000, p. 59). Civilian immigration mostly came from the remainder of the Empire, however: older provinces such as Gaul, Hispania, Egypt, and Asia Minor. Noy (2000, p. 59-60) further breaks down the civilian immigrants into pagan and Christian, the latter of which came to Rome mostly from Greece, Syria, and Palestine.

Migration owing to slavery generally coincides with areas that had protracted wars with Rome and whose people were captured. Whereas the earliest slaves at Rome were Italians, the earliest non-Italian slaves were likely from Gaul and Hispania. These provinces, however, were also sending free migrants by the Imperial period. Central and eastern Europe sent many slaves to Rome and rural areas of Italy until the time of Trajan (Noy, 2000, p. 213). More specifically, German slaves came in large numbers in the early 1st century AD, as did slaves from Dalmatia, Pannonia, and Thrace. In 106 AD, Dacia was annexed, leading to a significant wave of slaves during the early 2nd century AD (ibid). Once these eastern European provinces were sufficiently under Roman control, however, the military began recruiting men from this area (Noy, 2000, p. 214). In the late 2nd century AD, Septimius Severus took on the Parthians



From Noy (2000), Map 1. Type A = Mainly military (1st-4th c AD). Type B = Mainly pagan civilian (1st-3rd c AD). Type C = Mainly civilian, substantial Christian/Jewish (3rd-5th c AD).

Figure 2.6: Epigraphical Evidence of Homelands of Foreigners in Imperial Rome

and gained a significant number of captives, and Rome enslaved a large number of people from Jerusalem following the Jewish Wars (Bradley, 1994). Since slaves could be created by wars, piracy, infant exposure, or simply selling another human being (such as one's daughter) into slavery, these individuals came to Rome from all ends of the Empire.

Finally, it should be mentioned that the movement of freeborn, soldiers, and slaves within Italy is basically unknown. Noy (2000) treats the entirety of the Italian peninsula as short-distance migration, even though points to the north and south were up to 600 km from Rome. There are records of elite authors hailing from regions such as Tuscany and frequently returning there, but the lower classes and slaves do not get noticed by history. The quantity of migrants from Italy and their homelands are thus not known as well as those of slaves and soldiers.

2.3.6 Theories of Migration to Rome

Movement in the Empire has been split by researchers into a series of dichotomies that are used, either explicitly or implicitly, in the secondary literature. The reason for migration can be seen as either voluntary (free citizens) or compulsory (military service and slavery). Immigrants are often classified as either short-distance (those from Italy) or long-distance (those from the provinces of the Empire). Length of stay at Rome means people can be called travellers (short visit) or immigrants (permanent relocation). Finally, frequency of visitation to Rome is sometimes taken into account. Commuters are usually the lower class who live in the *suburbium* and come to the city to work or to attend markets or sporting events, but could be elite like Pliny who routinely retire to country villas; these individuals move frequently between two contexts. Seasonal workers in the agricultural sector might be mobile during certain times of the year. Itinerant occupations such as musician, teacher, or shepherd might bring individuals to Rome a bit less frequently, perhaps once every year or more.

The understanding of migration to Rome has therefore been framed primarily by modernization theory (see chapter 3 for further discussion). In this view, areas that send migrants are different from areas that receive migrants, and the differences are usually presented as dichotomies, such as the provinces versus Rome or rural versus urban contexts. This approach also utilizes push and pull factors that govern out- and in-migration, respectively, usually related to economic issues or to the excitement of life in the city. Rome is seen as an economic draw for free migrants by both Noy (2000) and Erdkamp (2008) and, as noted above, Noy (2000) cites numerous attractions of the city that might have enticed people to Rome. The primary limitation of this approach is that contemporary migration research has found that a migrant's motivation to move is not as simple as the reductionist dichotomies that modernization theory implies. The secondary limitation is, of course, that this approach to understanding migration to Rome can only be used for free migrants, who represented a small fraction of the foreign population at Rome compared to slaves.

2.4 Conclusions

Mobility is a defining characteristic of the population of the Roman Empire (Braudel, 1995; Horden and Purcell, 2000; Scheidel, 2004), but migration to Rome has been studied only from the sparse and biased historical record. Further, many primary and secondary sources ignore bidirectional migration entirely and instead focus discussion of migration on Romans in the provinces (Brunt, 1971; Stambaugh, 1988). Movement through space occurred at a variety of scales. People came to Rome from the suburban area around it, from other regions of Italy, from provinces of the Empire, and beyond. Voluntary migrants are known through epigraphical evidence but generally represent the higher social classes: literate, wealthy citizens. Compulsory migrants, on the other hand, are less well known in spite of the fact that slaves made up about one-third of the entire population of Rome. When migrants arrived at Rome, they might have been assigned a household in which to live as a slave. Free migrants might have chosen to congregate with affines in an ethnically homogeneous neighborhood in the *suburbium* or might have lived in a polyethnic community in the heart of the city. Movement between contexts, such as commuting between the *urbs* and *suburbium*, occurred at all levels of Roman society, and travelers and other itinerants came to Rome in droves. By and large, movement at all scales is under-researched and under-theorized, largely owing to the presence of an historical record and to the widespread assumption that archaeological remains cannot provide any information on migration to Rome. The following chapter presents an anthropological approach to mobility during the Empire, which uses contemporary migration theory and bioarchaeological data sources to reframe the questions we can ask about migration to Rome.

Chapter 3

An Anthropological Approach to Roman Migration

Migration is an important characteristic of urban centers yet one that has been difficult to problematize in past societies. Scholarship on contemporary migration has shown that this patterned human phenomenon is linked to urbanization, demography, ideology, family structure, and gender roles (Anthony, 1990). In the last couple of decades, archaeologists have moved away from unidirectional concepts that do not allow for human agency in culture change, such as diffusionism and acculturation. This paradigm shift occurred later in Roman archaeology, however, and interregional interactions in Rome have not been the focus of research. Recently, classical archaeologists have begun to study diasporas and diasporic events of both voluntary and compulsory migrants using the archaeological record. Understanding migration to Rome requires analysis of a new data set, as epigraphical information is strongly biased towards the literate elite, and the lack of "ethnic" material culture in the archaeological record of Rome is generally seen as evidence of acculturation. Biochemical analysis of skeletons from Roman cemeteries can yield information about migration in the absence of epigraphical and archaeological indications. This chapter presents the theoretical approach to migration taken in this dissertation, identifies the data sources and their limitations for investigating migration, and discusses the pivotal role that mobility plays in reconstructing the urban center of Rome.

3.1 Rethinking Mobility in Imperial Rome

Significant changes in migration theory have occurred in the past four decades, and modern immigrants are now seen as fully contextualized actors within a global network linked by economies and communication. While these approaches cannot be applied wholesale to studies of the ancient world, there is merit to using them to develop a better understanding of migration to Rome. When the Roman Empire is approached anthropologically using all available data sources, migrants become actors and slaves become diasporic individuals, and the effects of population interaction on both locals and foreigners can be assessed. A new way of looking at migration in the Roman Empire is needed, and the theoretical perspectives used to frame the research questions in this project are a step towards seeing migration as an integral part of research on the Roman Empire.

3.1.1 Migration Theory in Anthropology

There are three broad ways that migration has been theorized in anthropology: modernization theory, dependency theory (the historical-structuralist approach), and transnationalism. Modernization theory was the main explanatory framework for migration in the social sciences until the 1970s (Kearney, 1986, p. 333). Born out of neoclassical economics and models of social change, modernization theory is ultimately an expression of us versus them. Dichotomies such as folk/urban (Redfield, 1941), traditional/modern, city/country, immigrant/citizen, and push/pull factors form the basis for investigation of migration. The individual migrant is of concern to modernization theory, particularly in terms of the decision to migrate and the way that immigrants adapt, assimilate, and adjust to their new home (Kearney, 1986, p. 333). The origins of this theory also relate to the rural/urban divide, as it was assumed that movement to the city meant progress and that an economic equilibrium would be reached between the rural-agrarian and urban-industrial areas (Brettell, 2008, p. 119).

An alternative to modernization theory arose in the 1960s and 1970s as dependency theory or the historical-structuralist approach. Research into the colonial encounter in Latin America caused social scientists to see urban and rural as connected, interdependent economies of core and periphery (Kearney, 1986, p. 338). Whereas modernization theory is focused at the micro level and contrasts the modern and the traditional, dependency theory is focused at the macro level, looking at the national and international capitalist system (ibid.). Rather than focusing on individual migrants' motivations to move, dependency theory looks at both historical and structural causes of migration (Brettell, 2008). This macrotheory of migration is difficult for anthropologists to operationalize, however, as dependency theory does not allow for generation of local-level research questions. Further, dependency theory does not function well as a way to understand migrants' dynamics and relationships with their home communities (Kearney, 1986, p. 340).

The concept of transnationalism arose in the 1990s as a prominent critique of the historical-structural and modernist theories of migration. As defined by anthropologist Caroline Brettell (2008, p. 120), transnationalism is "a social process whereby migrants operate in social fields that transgress geographic, political, and cultural borders." Transmigrants "develop and maintain multiple relationships – familial, economic, social, organizational, religious, and political – that span [these] borders" (Basch et al., 1993, p. 7). As the world became increasingly globalized, social scientists began to debate the future of nation-states and sought to address individual agency in the construction of society (Glick Schiller et al., 1995; Horevitz, 2009). Transnationalism was thus bound up in discussions of postmodernity and postcolonialism, with focuses on the individual and the structure: "newly created transnational spaces are sites at which new and multiple identities are fashioned and a variety of old and new forms of power or domination are exercised" (Szanton Blanc et al., 1995, p. 684). Social scientists using transnational theories to approach migration focus less on the big picture and more on "the articulation between the place whence a migrant originates and the place or places to which he or she goes" (Brettell, 2008, p. 114). Or, to view it another way, transnationalism is a move away from previous interpretations of migration as bounded, whether economically, geographically, or socially; it is a novel approach to space and place and to the movement of humans within and between them (Brettell, 2008, p. 121).

An important concept to come out of transnational theories is diaspora. Although originally a term that denoted the forced movement of ethnic groups of individuals from their homeland, diaspora has recently been reconceived as a more metaphorical and inclusive term.[1] Sanjek (2003, p. 323) feels that diaspora "occurs when people voluntarily leave their home area for distant regions within or beyond the state in which they reside, and continue to remain in contact in various ways with their point of origin," a definition that is based on transnational theories about the nature of community (Brettell, 2008). Diaspora can still be understood as caused by forced movement of individuals, but it is also used to refer to migrations because of trade, labor, and ideology. A key outcome of diaspora is that it often results in heterogeneous communities at the destination, variously termed polyethnic communities, transnational communities, imagined communities, diaspora communities, or diasporic pluralism (Anderson, 1983; Appadurai, 1996; Sanjek, 2003; Lilley, 2004, 2006). Diaspora is a useful concept in terms of migration because it allows for individual agency, can be spatially and temporally discontinuous, and involves continuing ties to the homeland (Sanjek, 2003). Current migration research in anthropology is thus focused on how transnational individuals create and negotiate both the structure and their identities (Brettell, 2008).

3.1.2 Migration Theory in Archaeology

In the 1990s, archaeologists began resurrecting studies of migration, which had been overlooked for decades as a result of past diffusionist and functionalist thinking that oversimplified a complex social process. David Anthony, in a 1990 article still widely cited, noted that "migration has been avoided because archaeologists lack the theory and methods that might allow them to incorporate migration into the explanation of culture change, not because migration

[1] One of the critiques of transnationalism, however, is that it neglects the forced movement of individuals or groups of people, such as slaves or refugees (Black, 2001; Horevitz, 2009).

is regarded as unimportant" (1990, p. 895). Further, Anthony points out that modern migration studies are essential for archaeologists to see patterned movement in the past and that, although push and pull factors are useful in understanding migration, ideological and cultural factors might be equally relevant. Migration is not a one-way street, and Anthony advocates that archaeologists use all available evidence, including material culture, the literary record, and biological remains, to ask and answer research questions (Anthony, 1990, 1997).

A decade after Anthony's (1990) call to arms, Burmeister (2000) noted that nothing had changed with respect to archaeological conceptualizations of migration.[2] Burmeister advocates an approach to migration that relies heavily on contemporary migration theory in the social sciences. In assessing the literature, he notes that, in general, men are more likely to migrate than women, the 20- to 30-year-old age group is the most mobile, and the upper classes are more likely to have the financing to afford long-distance and long-term moves (Burmeister, 2000, p. 543). Archaeologists should look for proof of migration in the internal domain, Burmeister suggests, that of social structure and ritual, and he advocates a model of migration formed by the demographics of the migrants, their motives for moving, the direction of migration, and the impact of migration on both the sending and receiving areas. In his discussion of theory appropriate to investigations of migration, however, Burmeister sees only the macrotheoretical approaches as applicable to archaeological studies. Focusing migration study on the individual, Burmeister (2000, p. 547) notes, cannot be operationalized: "Neither individual migratory movements nor personal supraregional networks of relationships can be traced or reconstructed archaeologically; in fact, most often not even the exact regions of origin or destination can be localized archaeologically."

Both Anthony (1990) and Burmeister (2000) use the word migration to imply a voluntary process. Slavery is, presumably, a separate phenomenon to them as it did not exist in all ancient

[2]Burmeister (2000, p. 539) further characterizes migration in European archaeology as "an axiomatic precondition of the phenomena observed." That is, European archaeologists in particular generally see no reason to explain or study migration, as they are more concerned with proving that it happened through material culture changes.

societies. The concept of diaspora has seen increased use in archaeological studies, such as in Stein's (2002) discussion of trade diaspora between a political core and its provinces, and in Lilley's (2006) analysis of waves of migration, which uses diaspora to discuss the effects on both the colonizers and the colonized. Both of these examples, however, use the term diaspora to mean largely voluntary migration. As noted above, the definition of diaspora has cycled back to its original Greek meaning of a dispersal from its 19th-20th century denotation of forced movement, as of Africans to America via the slave trade or the Jewish diaspora from Israel.

The redefinition of diaspora and recognition that modern models of migration can be applied to the past have caused a veritable paradigm shift in archaeological thought about interregional interaction. Yet archaeological studies of migration are still focused on the group level, asking questions about why groups of people migrated and how groups of people assimilated or maintained a group identity. The obvious next step in approaching ancient migration is to attempt to understand the individual migrant, to situate the immigrant and her lived experiences within a community and within a culture as a whole.

3.1.3 Migration Theory in Roman Archaeology

The historical tradition of Roman archaeology makes it well-suited to investigating migration as both a systemic and an individual phenomenon. However, as noted in chapter 2, section 2.3.6, migration to Rome has been discussed, almost always implicitly, in terms of modernization theory and in terms of the Victorian ideas of history and development that pervade classical studies in general. Modernization theory runs through decades of previous research, providing explanations for material culture change in the provinces and the lack thereof at Rome, as immigrants assimilated through the process of "Romanization."[3] The push and pull

[3]The term Romanization was born out of a colonialist perspective through which archaeologists sought to understand the adoption of "core" Roman culture by the "peripheral" provinces. This model of acculturation was unidirectional and privileged Roman material over that of the so-called primitive communities. In the past decade, Roman archaeologists have recognized the inherent biases in Romanization and have sought to redefine

elements of modernization theory are particularly compelling for classicists because they allow for discussion of the individual's reasons for migrating in terms of the "pushes" from traditional society and the "pulls" of developed areas (Kearney, 1986, p. 338). The city center of Rome is categorically seen as a powerful draw for free immigrants, yet in large part researchers assume that the reasons Rome is a draw are understood (Noy, 2000). Finally, as a field with a rich historical tradition, it is unsurprising that Roman studies would be focused on the motivations of migrants and therefore embrace modernization theory. Although it is quite difficult to reconstruct immigrants' motivations from the epigraphical record, the largest chapter of Noy's (2000) *Foreigners at Rome* is entitled "Why Did People Move to Rome?," showcasing what Anthony (1990, p. 897) has called archaeology's "paralyzing fascination" with individual reasons for migration. The modernization theory of migration as applied to ancient Rome is an extension of the classical tradition, one that assumes the city is more progressive than the countryside and therefore that *peregrini*, *provinciales*, and *rustici* cannot help but be drawn to the *urbs*.

Roman archaeology is, however, coming around to modern theories of migration with a recent focus on diaspora and diasporic communities, particularly in Roman Britain. The redefinition of diaspora does make studying migration in the Roman world a bit confusing, as both voluntary migration and forced slavery accounted for the movement of people to Rome during the Empire. Further, as mentioned in chapter 2, slaves were often manumitted and freeborn people could become slaves, meaning these sociolegal categories were not rigid. Nevertheless, since Roman archaeologists are by and large not doing research on slavery *per se*, diaspora tends to be used in the voluntary sense (Webster, 2008). The upcoming *Journal of Roman Archaeology* supplement, *Roman Diasporas: Archaeological Approaches to Mobility and Diversity in the Roman Empire* (2010), is an important first step in theorizing migration in the

---

the term to include a dialectical framework and bidirectional cultural negotiation (e.g., Terrenato 2001). Others argue, however, that even a revised Romanization concept represents only one dichotomy, that of indigenous versus Roman influence, and have suggested terms like "creolization" instead (e.g., van Dommelen 2001, Webster 2001). In this often heated discussion, migrants and migration can get lost in the foregrounding of material culture change.

classical world and in defining methodologies that can bring us closer to an understanding of the phenomenon. A variety of scholars from around the world have contributed papers not just on diaspora but also on the effects that migration has on health and diet. Those who use the term to imply mostly voluntary migration include David Noy (2010), who builds on his earlier book to discuss professional, religious, and military diasporas to Rome, and Hella Eckardt (2010), who questions whether there were diasporic communities in Roman Britain. Jane Webster (2010), on the other hand, uses the concept of diaspora to talk about slavery in Roman Britain. Disagreement about semantics and a general lack of explication of theories and methods used in approaching ancient migration indicates that additional work needs to be done in order to advance the state of migration research in classical archaeology.

3.1.4 Migration Theory in Roman Bioarchaeology

In this project, I view migration as a patterned human process, but also one that can and should be investigated at the level of the individual. Similar to Stein's (2002) encapsulation of the new wave of archaeological conceptualization of migration, my work combines processual approaches to data (namely, an understanding of the geopolitical structure in which migration occurred and use of the replicable methodologies of osteological and biochemical analyses) with postprocessual approaches to theory (that is, research foci on agency, gender, ethnicity, and identity). Because of the nature of my data set – human skeletal remains – my approach to migration is largely microtheoretical in character. Contemporary anthropological discussions of transnationalism and diaspora therefore inform the research streams of this study, with the recognition that some aspects of these modern phenomena are not applicable to the preindustrial world.[4]

[4]For example, anthropologists are interested in contemporary transmigrants' economic ties to their homeland, such as whether they send money to family back home or own property in different nations. Although the preindustrial world on which most archaeology is focused did not allow for such events, there is evidence from the Roman Empire that soldiers stationed elsewhere wrote letters home, as from Vindolanda (Bowman, 1998), and that people could send money (Andreau, 1999). Nevertheless, it was likely only the elite who had access to these forms of communication, and the majority of migrants at Rome were members of the lower class.

The traditional data sets used in investigating migrants at Rome are archaeological remains and epigraphical inscriptions on tombstones, in addition to the historical record (Dyson, 1988). These data sources, however, come up short in a variety of ways. First, the historical record is notoriously biased towards elite men, those with money, power, and literacy. As discussed in chapter 2, while written records can indicate an individual's motivation to migrate, by and large they focus on the elite's perception of foreigners and slaves at Rome, which is not useful for understanding either the context of migration or immigrants' day-to-day experiences at Rome.

Second, although there have been numerous archaeological surveys of the *suburbium*, no solid evidence of immigrants, either free or slave, has been found (Witcher, 2005). Slaves in particular were integrated into the household; although they had their own quarters, these were not separate from the main house in the way slave quarters were on Southern U.S. plantations and therefore not recoverable archaeologically.[5] Further, no material culture has been identified that is clearly slave in nature unlike in the Southern U.S., where certain types and assemblages of pottery (e.g., Colonoware) are thought to have been generally slave-created and therefore indicative of a slave household (Webster, 2008). Without clear items indicating restraint or ownership, the widespread belief is that slaves in Rome were archaeologically invisible (Webster, 2005, 2008). One approach to using archaeological data to see immigrants is in investigating the ritual behavior surrounding marginal members of society. Burmeister (2000, p. 542) suggests that burial of infants and children, for example, can be sites of ritual enaction and therefore might not be outfitted based on social convention.

Third, the epigraphical record is useful in telling us specifically when an individual was commemorated as a foreigner. Noy's (2000) exhaustive treatment of free foreigners at Rome lists numerous geographical origins, shows evidence of migrants of all ages and both sexes, and

[5] Carandini (1988), however, has suggested in his analysis of the Settefinestre villa in Tuscany that slave quarters are identifiable in this surprisingly utilitarian domestic structure. His identification references the structure of plantations in the Southern U.S. during slavery. I do not know of any specific analysis of structures or objects of slavery in Rome, however.

greatly contributes to the argument that migration was an integral part of Roman society. However, we cannot see foreigners who were not mentioned as such on their tombstones. Every person is buried by those he left behind, but slaves in particular would have been commemorated at the whims of their masters rather than by their own families or any ethnic or social group to which they belonged. The vast majority of immigrants to Rome would have come as slaves, and these are also the people least likely to appear in the epigraphical record of Rome.

The major barrier to a study of migration to Rome is therefore in finding concrete evidence of foreigners, and the absence of material culture and written records has caused research into migrants at Rome to stagnate. Contrary to the assumption that archaeological data cannot speak to the individual migrant (Burmeister, 2000), I start from the premise that osteological remains and bioarchaeological context provide a significant amount of information about migration to Rome. These data can be informed by primary source material and epigraphical inscriptions, provided authorial biases are appropriately acknowledged. More importantly, skeletal remains can lead to the identification of immigrants who were never commemorated epigraphically and who are archaeologically invisible.

Operationalizing migration to Imperial Rome thus necessitates osteological and biochemical analysis of human skeletal remains. Bioarchaeological investigations of migration around the world have been ongoing for over a decade through the use of strontium and oxygen isotope analysis of dental enamel (Ezzo et al., 1997; Grupe et al., 1997; Knudson and Price, 2007; Montgomery et al., 2000, 2005; Price et al., 1994b,a, 2000, 2001, 2002; Schweissing and Grupe, 2003). The basic premise of these biochemical methods, which are fully discussed in chapter 7, is that consumption of food and water resources at a specific geographical location leaves a chemical signature in the dental enamel that forms during childhood. An individual whose enamel isotope results are significantly different from the local isotope range is considered to have been born and raised in a different geographical area, and therefore an immigrant. Isotope analysis of human skeletal remains is thus the primary method by which I identify immigrants at Rome. Each individual is also studied using standard osteological methodology

(Buikstra and Ubelaker, 1994), which yields information on age at death, sex, and disease. In this way, the basic demographic structure of the immigrant population at Rome starts to unfold.

After individuals are identified as nonlocal, it is possible to ask additional questions in an attempt to understand the quality of life at Rome. The disease load of the immigrant population can be compared with that of the local to investigate whether life was more difficult for the newcomers to Rome, as is suggested by both primary and secondary sources. Similarly, dietary analysis can indicate general trends in consumption of food. If immigrants, particularly slaves, were mistreated and underfed, the carbon and nitrogen isotope analysis of their bones could indicate a diet heavily reliant on inexpensive cereals, which might have led to protein-calorie malnutrition.

Pushing the data further within a theoretical framework of transnationalism and diaspora, it becomes possible to assess acculturation from a physical standpoint. As footnoted above, Roman archaeologists argue about the causes for material culture change in the provinces, many advocating the permanent retirement of the hoary concept of Romanization as a unidirectional acculturative force. It is unsurprising, then, against this background of assumed acculturation and a lack of “ethnic” and “slave” material culture at Rome, that topics such as identity, ethnicity, and resistance do not arise in studies of migrants at Rome. However, Noy (2000) does note that immigrants might have pursued a “strategy of integration” (ibid., 10) and therefore “it is possible to look for signs that foreigners at Rome tried to preserve their separate identity, but much harder to look for signs that they did not” (ibid., 160). Migrants to Rome could look the same archaeologically as locally-born Romans; however, absence of “foreign” culture does not necessarily imply acculturation (Stein, 2002). Given the fact that immigrants to Rome can be identified on the basis of their physical remains, analysis of another data set is necessary to investigate identity, ethnicity, or resistance. Burmeister (2000, p. 542) notes that archaeological proof of migration can be found in the internal, private domain rather than the external, public domain. Because the internal domain is not directly connected to the external one, old habits can persist. Some private practices that immigrants might translate to material remains at their destination include the interior architecture of houses, dietary practices given similar food resources at the sending and receiving areas, and burial ritual of marginal persons. In this study, therefore, following identification of immigrants using isotope analysis, I investigate patterns of burial between immigrants and locals and patterns in their foodways both in childhood and before death. Maintenance of traditional ways – and therefore preservation of foreign identity or lack thereof – can thus be investigated in Roman (bio)archaeology in a way that has never before been possible.

Biochemical analyses are far from perfect, particularly in regard to their application to the geologically complex area of the Roman *suburbium*. As further discussed in chapter 8, short-distance migration cannot be seen through the current model of the strontium isotope range at Rome. Additional studies of human skeletal remains will greatly help refine the results of this initial study, but it is possible that the combination of geological complexity and aqueduct-transported water will stymie a more microscopic view. Further, neither isotope nor osteological analysis can judge whether an individual came to Rome voluntarily or by force, or whether that individual was manumitted during life or at what age manumission occurred. Isotope analysis is not a panacea to the limitations in the archaeological and epigraphical evidence, but its utility for answering questions about migration to Rome has never been investigated. As Phil Walker (2000, p. 14) has noted, "By using a series of data sources that, standing alone, would be open to many different interpretations, it is in this way possible to triangulate on what really happened in the past." Human skeletal remains, subject to different taphonomic processes and issues of interpretation than linguistic and material evidence, can aid Roman archaeology in establishing a base from which we can formulate hypotheses and answer questions about migration to Rome.

Methodologically, new techniques in bioarchaeology allow us to find the biological remains of individual immigrants, investigate changes at various times in their lives, and view individuals within the context of the community (Buikstra, 2006). There is a dialectical quality to this sort of research, as an individual skeleton is interesting for the unique set of information it can yield, but only by placing that individual within a mosaic of individuals can we interpret the patterns, similarities, and differences seen. Bioarchaeology, then, allows us to ask and answer questions about migrants at different scales, from the individual to the group to the larger community. Contemporary anthropological theories of transnationalism and diaspora are thus best suited to a bioarchaeological study of migration to Rome. The combination of all available data sources about migrants – historical, archaeological, and biological – within the frameworks of geopolitical and population interaction in the Empire sets this research apart from traditional approaches to migration to Rome.

3.2 The Role of Mobility in the Model of Urban Rome

The consequences of importing millions of slaves during the Republic and Empire are far-reaching. In addition to changing the basic demographic makeup of the city, foreigners affected the economic balance, the disease load, and the nature of society, all of which were interrelated and interdependent in the urban Roman world. This section presents in more detail the effects that mobility had on Roman civilization, the contributions of this project, and the need for research streams that complement knowledge drawn from the historical and archaeological records.

3.2.1 Demographic Structure

The three key processes involved in the demographic makeup of a population are fertility, mortality, and migration. Whereas fertility and mortality are frequently modeled in archaeological populations, migration and movement rely much more heavily on situational conditions (economy, politics) and individual decision making (Chamberlain, 2006). Migration, however, is critical to an understanding of demography because it affects the age and sex characteristics of the recipient population (Burmeister, 2000). When patterns in migration exist, such as mostly males or large numbers of 20- to 30-year-olds moving to find work, the age and sex ratios of the recipient population change (Noy, 2000; Scheidel, 2004; Erdkamp, 2008). Large influxes of people from compulsory migration (diaspora) similarly change the population structure at the destination. A contingent of slaves brought to Rome following a war might be disproportionately composed of women and children who were not killed during the conflict.

Ancient demographers face a major barrier to inclusion of migration in models of the population of Rome: very little information is available on long-distance population transfers, and knowledge of short-range transfers is virtually nonexistent (Scheidel, 2001, 2004). Some Roman demographers attempt to model migration by analogy with early modern societies (Morley, 1996), but those figures do not take into account the massive flow of slaves in the Empire. For Rome, there are no census data on free foreigners, there is no thorough accounting of importation of slaves, and epigraphical references to homelands on tombstones privilege literate, elite males (Scheidel, 2001). The dearth of historical records of foreign-born people at Rome frequently prompts comments such as Parkin's (1992, p. 135): "Migration in particular requires careful consideration, though I cannot see how our knowledge of it will ever be so adequate in demographic terms as to make it possible to bring it into the basic equation for natural population growth." Other Roman demographers, however, look forward to developments in information-gathering from a completely new data source: human skeletal remains. In his chapter "Progress and Problems in Roman Demography," Walter Scheidel (2001, p. 48) notes that "in the future, appraisals of migration will benefit from the biomolecular analysis of skeletal remains, which may shed light on geographical provenance."

Studies of demography in the Roman would would thus benefit significantly from additional information on migration and mobility. Identification of migrants in groups that are notoriously excluded from historical records – particularly the lower class, slaves, women, and children – is next to impossible. The way forward in Roman demography with respect to migration is large-scale analysis of human skeletal remains. Analysis of a variety of isotopes in the human skeleton can both isolate people who were not born at Rome and approximate their geographical origins, which can be coupled with a standard osteological profile of age-at-death and sex. Skeletal analysis is currently the most promising new avenue of demographic research in Rome. The contribution of this project to Roman demography is detailed in chapters 11 and 13.

3.2.2 Epidemiological Issues

Since mortality is a key factor in understanding the population structure of ancient Rome, anything that affects mortality rates is therefore of critical importance to our knowledge of demography. Epidemiology, or the study of health and disease in a population, requires information about population interaction, particularly in investigating infectious diseases. Different populations have differential susceptibility to disease, and the commingling of people of vastly different geographical origins at Rome opens up the possibility of pathogen transfer on a massive scale. The three major diseases that likely affected the Roman population and caused widespread morbidity and mortality were the same that affected impoverished areas of third world countries into the 20th century: malaria, smallpox, and tuberculosis (Morley, 2005).

It is well known that ancient Rome was an area of endemic malaria (Sallares, 2002). Cicero and Livy note that Rome was founded on seven hills because the area was healthy; indeed, low-lying areas with stagnant water are more likely to have mosquitoes carrying malaria than higher elevations. Although Galen commented on quartan fever and pioneered an understanding of the disease, nothing was known in antiquity of differential susceptibility to malaria. Decades of research in the 20th century has confirmed that heterozygosity for the sickle-cell trait confers protection against the malaria-causing parasite *Plasmodium falciparum* by interrupting its reproductive cycle. This genetic mutation is largely associated with African peoples, although it is present in Mediterranean peoples as well. Similarly, the genetic condition thalassemia is present chiefly in people of Italian and Greek descent, and it is thought that this disease confers protection against the dangerous *Plasmodium falciparum* by making people more susceptible to the less virulent *Plasmodium vivax*. Migration of individuals from non-malarial areas of the

Empire, such as England, could bring people with no genetic advantage into a region replete with malaria, resulting in differential mortality. On the other hand, individuals who migrated to Rome from malarial areas of Africa might be less susceptible to the disease than their local counterparts.

To provide another example of the possible interplay between migrants and disease, it is thought that the Antonine Plague, which swept through the Roman Empire from about 165-180 AD, was a pandemic of smallpox that the Roman army brought back from campaigns in the Near East (McNeill, 1976). Pathogens migrate when people migrate, resulting in significant levels of mortality from infectious disease in populations never before exposed. If the Antonine Plague was indeed smallpox, certain segments of the foreign population at Rome might have had lower levels of morbidity and mortality than the locals. Modern anthropological and clinical findings have shown a relationship between blood type and smallpox: those with A and AB blood types are more susceptible than those with B and O types (Berger et al., 1989). Blood types are related to geographical origin, with a high frequency of the B blood type in central and eastern Asia but moderate frequencies in central Africa and eastern Europe (Cavalli-Sforza et al., 1993). Migrants are known to have come to Rome from these areas and might have enjoyed a genetic advantage during a plague of smallpox.

As mentioned, there is some historical information on the presence and prevalence of diseases in antiquity, as well as a growing body of secondary literature in the last decade (Patrick, 1967; Grmek, 1989; Sallares, 2002; King, 2005; Morley, 2005). No research has been done, however, on the disease load of different populations at Rome.

Studies of modern immigrant mortality patterns find that in some cases immigrants fare better than the local population, and in some cases they do worse (Cookson et al., 1998; Marmot et al., 1984; Singh and Siahpush, 2002). Better health outcomes might be obtained by immigrants who journey to their destination to seek medical care or to escape a disease-ridden homeland. People who came to Rome from an area of the Empire with endemic smallpox or high levels of anthropogenic lead, for example, might have had a good health outcome in the city. Longitudinal studies have shown that immigrants to the U.S. in the 20th century have a higher age at death and lower incidences of obesity and hypertension than native-born Americans (Singh and Siahpush, 2002). Cultural factors might have similarly been at work at Rome; local elites who enjoyed a hedonistic lifestyle might have died at earlier ages than immigrants unaccustomed to such excesses. On the other hand, environmental and cultural factors could affect whether the immigrant or the local population is more susceptible to diseases and conditions (Marmot et al., 1984; Cookson et al., 1998). Immigrants to Rome might have poorer health outcomes than locals owing to a variety of environmental factors. Famine or dehydration during the journey to Rome might leave some immigrants in poor health upon arrival. People displaced by the eruption of Vesuvius in 79 AD might have made their way north to Rome, many in poor health because of the environmental effects of ash and lava, suffering from conditions such as fluorosis (D'Alessandro, 2006). The study of morbidity and mortality of immigrants in the contemporary world has indicated that genetic, environmental, and cultural factors are all necessary parts of the epidemiology of a population.

Slaves and immigrants to Rome are often assumed to have suffered from disease disproportionately to freeborn and elite Romans (Noy, 2000; Burmeister, 2000), but other researchers suggest this assumption is untenable (Scheidel, 2005; Erdkamp, 2008). Information on the quantity of migrants at Rome and their homelands could therefore aid our understanding of the disease load of the population, morbidity and mortality, and the concomitant change in demographics resulting from disease-related deaths. This project contributes to the current knowledge of disease in the past through a palaeopathological analysis of the skeletal remains of both migrants and locals (chapters 5 and 11).

3.2.3 Slavery and Diaspora

The slave population in Imperial Rome constituted a significant minority group, making up perhaps 30-40% of the population (Noy, 2000; Scheidel, 2005). They were only a cohesive social group, however, in terms of their legal status. Anybody in any region of the Empire could be made a slave through war, piracy, or other means, so slaves at Rome were likely an extremely diverse group in terms of cultural and geographical background. Most researchers, however, simply note that the slave population at Rome was heterogeneous and do not elaborate further (Noy, 2000; Bradley, 1994). For such an important group of people at Rome, we know very little about the sex ratio of slaves or their precise homelands. We do know a significant amount about the structure of slavery in the Roman world from historical records, but there is very little from the perspective of the slave, save some inscriptions on tombstones.

The biggest barrier to investigation of slavery in the Roman world is the assumption that slaves are invisible: not just absent from the histories, but unidentifiable archaeologically (Webster, 2005, 2008). Diasporic events are known to have existed, in which tens of thousands of slaves were sent to Rome from a newly-conquered land. Identifying slaves in the absence of historical records, epigraphical information about a person's legal status, or material remains of artifacts of restraint is a heavy burden for archaeology to bear but an avenue that demands further research. Even given the fact that immigrants can be identified in the archaeological record in spite of the lack of traditional evidence – which is proven in the remainder of this dissertation – a person's status as a free migrant or a slave is still only a guess. Manumission further complicates identification of slaves (Scheidel, 1997). A young adult enslaved following a war and freed in his 30s might spend only a decade in slavery. It is necessary therefore to begin investigating slavery from the basis of a better understanding of migration to Rome as a patterned human process. If we do not know the scale of movement to Rome in general, we cannot know the scale of slavery or see diasporic events in the material record. Migration is therefore a critical element in forming a new approach to Roman slavery advocated by archaeologists like Jane Webster (2005, 2008).

3.2.4 Social and Economic Pressures

Ancient Rome has often been conceived of as an urban jungle where life, especially for the slaves and the *plebs urbana*, was cut short by disease, plagued by interpersonal violence, and full of uncertainty about the next meal (Yavetz, 1958; Scobie, 1986). The lower classes, like slaves, are by and large absent from the historical and archaeological records. By analogy with other premodern cities, researchers like Scobie (1986) have created a view of Rome in which life was nasty, brutish, and short. There is little archaeological research, however, to support or reject these assumptions.

Migration to Rome of both slaves and freeborn people undoubtedly put pressure on the area's economic resources. Grain was imported in massive quantities, but the number of urban poor fed by the grain dole fluctuated with economic stability in different time periods (Garnsey, 1988). One way the Romans sought to deal with economic pressures was to expel foreigners from the city. In most cases, groups of people were expelled en masse based on religion, nationality, or occupation, and almost all of them were non-citizens. In the early Empire, 4,000 Jews were sent to Sardinia and others were denied the grain dole. Rome evicted Germans and Gauls in the 1st century AD following a crushing defeat at the Battle of Teutoburg Forest (Noy, 2000, p. 41-44). Even free migrants at Rome were not immune from eviction when the economic situation was dire. A change in residence likely equaled a change in diet as exiles adopted foodways consistent with the resources in their new location (Erdkamp, 2008).

It is not unthinkable that population pressure at Rome would lead to the spread of disease with an increase in density of living; nor that social pressure would lead to interpersonal violence as people of diverse backgrounds living in close quarters failed to come to an agreement; nor even that economic pressure would result in a diet composed of whatever foodstuffs could be found in the urban or suburban environment. The problem with conceiving of Rome as a urban wasteland is that the historical records do not support such an extreme view and archaeological information on these topics is virtually nonexistent. Migrants formed a significant portion of the Roman populace, but aside from Noy's (2000) monograph, scholars have not fully delved into questions of what life was like for them. Were migrants a marginalized social group? Did they live in polyethnic communities or in neighborhoods characterized by their home culture? How did they construct their identity or identities in the face of the realities of life in a large urban center? Is there evidence of resistance to slavery?

This project offers a small contribution toward dismissing the notion of Rome as an urban jungle. Frequencies of numerous diseases and evidence of interpersonal violence among the lower classes are investigated in chapter 5. Information about the diet of the lower classes is presented in chapter 6. The patterns of diet and disease, as indicators of social and economic pressure, are further discussed in chapters 11, 12, and 13.

3.2.5 Urbanism

Recent scholarship on the ancient city lacks a thorough approach to the experience of non-elite groups living in an urban environment. In spite of more than a decade of research into complex societies in the New World, studies of urbanism still deal primarily with the economic and political origins of the state (Smith and Schreiber, 2006). Urbanism in the Old World is similarly lacking, where the foci remain on urban organization and function as well as craft and agricultural production (Stein, 1998). A recent attempt at cross-cultural analysis, *Urbanism in the Pre-Industrial World* (Storey ed., 2006) seeks to address the criticism that urbanism in archaeology is undertheorized (Cowgill, 2004). Nevertheless, the majority of the contributions to this volume, particularly those about Rome (Paine and Storey, 2006; Lo Cascio, 2006), deal exclusively with demography and engage issues such as migration, diet, and disease only peripherally.

Rome is easily identifiable as an urban center in the archaeological record, but the current model of urbanism in Roman archaeology tells us little about daily life, cultural negotiation, or the social role of the lower classes who made up the majority of the urban center. Ancient urbanism is not merely a function of population magnitude; it is a cultural undertaking by a variety of people, a multidimensional idea that includes population size and density in addition to environmental, social, and economic stressors (Schwirian et al., 1995). These dimensions can be empirically measured in modern populations and are known to be causally related to one another. It is imperative to assess demographics, disease, slavery, and social and economic pressures in Imperial Rome in order to form a new understanding of both the city of Rome and the experiences and contributions of the lower classes, women, children, and immigrants who are under-represented in the historical record.

Migration is therefore integral to a novel approach to urbanism in the ancient world. Demographically, during the Imperial period, the population of Rome was increasing not only as a result of slavery and natural reproduction but also because of centripetal migration to Rome from the provinces, other regions of Italy, and the *suburbium*. The scale at which rural people moved to the cities of Italy, however, is currently unknown but must have been substantial in order to overcome the natural population decrease seen in other preindustrial cities (Scheidel, 2004; Erdkamp, 2008). Epidemiologically, immigrants to Rome could have brought new pathogens along for the ride, or might have succumbed in greater numbers to diseases that had long been endemic in central Italy (Acsádi and Nemeskéri, 1970). Very little is known about the disease load of the Roman population or whether immigrants were healthier or less healthy than locals. Slavery brought millions of people to Rome from across the Empire, yet their origins and conditions of life while at Rome remain unknown owing to difficulties identifying them in the archaeological and historical records. Socially, the extremely heterogeneous population of Rome and close living quarters could have led to numerous conflicts, creating a significant amount of stress for urban inhabitants (Scobie, 1986). Migrants could have suffered disproportionately, as there is historical evidence of expulsion of foreigners and poor attitudes towards nonlocals at Rome (Noy, 2000). Finally, the growing population of Imperial Rome taxed the local resources, and lower-class individuals would have suffered more than the upper class in terms of shortages of food and jobs. Although Imperial Rome had a wheat dole for the lower classes, this allotment of grain was subject to economic conditions and likely could not feed an entire family. Economic stressors would have necessitated supplementation of the lower-class diet (White, 1995; Garnsey, 1999).

By correlating demographic variability with environmental, economic, and social stressors, this project challenges the current thinking about how the urban environment affected lower-class inhabitants of Rome. Environmental stress is directly examined through palaeopathological analysis, economic stress is investigated through dietary choice as revealed by stable carbon and nitrogen isotope analyses, and social stress is investigated through heterogeneity of the Roman population as revealed by strontium and oxygen isotope analyses. Results indicating the nature of cosmopolitan Rome are presented in chapter 13.

3.3 Conclusions

Migration has arisen as an important global issue in a variety of disciplines in the last decade (Brettell and Hollifield, 2008). Although migrants and mobile individuals composed a large portion of the population of ancient Rome, migration as a process is under-theorized, and approaches to understanding the phenomenon are confined to free migrants' motivations to move. The importance of mobility in the Roman Empire cannot be overstated. Migration affected the demographic makeup of the city of Rome and the disease load of the population. Enslaved individuals at Rome were migrants, many of whom came to Rome in a diasporic event. Heterogeneity of the Roman population likely contributed to social unrest in the city, as an increasing population density forced diverse peoples to attempt to live in harmony. A quickly increasing population also put pressure on the city's resources, causing the emperor to periodically expel groups of people from the city and deny them the grain dole in times of economic stress. The contribution of migrants to the creation and maintenance of the urban center of Rome should not therefore be overlooked.

The historical record of ancient Rome can provide clues to the motivations of migrant groups and possible systemic push and pull factors influencing the individual decision to migrate. The data sets best suited to this kind of analysis, however, are biased towards the elite classes and limited in scope. This project therefore takes as a starting point contemporary anthropological theories of migration and combines them with the known geopolitical constraints on migration in the Empire. Within this framework, human skeletal remains can be analyzed biochemically to yield new data on the demography and life experiences of lower-class migrants and imported slaves. By combining these lines of evidence, this project both uses and refines anthropological ideas of migration. The questions of migration that this project answers, particularly in regard to a preindustrial urban center, are applicable to studies of migrants in the past and in the present. The bioarchaeological approach of this project contributes data and interpretations to the study of Roman migration as both an individual and a systemic phenomenon.

Part II

Bioarchaeological Evidence

Chapter 4

Context of the Populations

The use of human skeletal remains to answer anthropological questions in the Roman world is a very recent undertaking, as I have outlined previously (Killgrove, 2005). Although archaeologists and anthropologists work side-by-side on digs in Rome, contextual information is not often shared until a site is published. This chapter presents all the background information available on the two study sites, Casal Bertone and Castellaccio Europarco, including archaeological context and burial style. Basic demographic information is calculated, including age-at-death, sex, and stature. Finally, comparisons are made with the few other published Imperial populations from Rome.

4.1 Burial in Imperial Rome

Some of the most prominent architectural sights in Rome are tombs of emperors and the wealthy. Just outside the walls can be found the oddly designed tombs of Eurysaces, whose monument has a frieze depicting his occupation in bread-making, and Cestius' eastern-inspired pyramid. For the vast majority of the Imperial Roman population, however, commemoration of their death was not so dramatic. This section summarizes current knowledge about burial of the lower class of Imperial Rome from archaeological and textual sources.

4.1.1 Location of Cemeteries

The ancient Roman cemetery, burial styles, and funeral rites are known from historical sources and from archaeological excavations around the Empire. The variety of peoples who were part of the Roman Empire meant that no one practice was ever mandated, and we find remains of opulent above-ground mausolea and ashes in simple pots coexisting in location and time (Toynbee, 1971, p. 39-40).

One practice that was almost always followed, however, was the placement of graves. In *de Legibus* (ii, 23, 58), Cicero notes that the Twelve Tables specifically forbade both burying and cremating the dead within the city: *Hominem mortuum in urbe ne sepelito neve urito.* Until the late Empire, the very few deviations from this law were made in the case of exceptional people, such as emperors (Toynbee, 1971, p. 73). Although older explanations assumed this law was promulgated for religious reasons, current scholarship cites predominately sanitary and safety reasons for prohibiting cremation and burial within the city (Toynbee, 1971; Bodel, 2000; Lindsay, 2000). Land use in the *suburbium* included marginal businesses excluded from the city for religious or public safety reasons, such as slaughterhouses, brick-making facilities, and cemeteries (Purcell, 1987; Champlin, 1982). Thus, no matter where an inhabitant of Imperial Rome lived, that person would almost certainly end up in a cemetery outside the walls, in the periurban or suburban area surrounding the city of Rome.

Cemeteries thus often sprang up along roads in the Roman world, both for ease of access and for display (Purcell, 1987; Patterson, 2000). For example, the major route to Rome, the Via Appia, consisted of graves lining the road for miles south of the Porta Appia (Toynbee, 1971, p. 73). Some of these graves would have been designated with elaborate carved markers (*cippi*), some might have been identified with simple pottery such as an amphora half-buried in the ground, and the poorest graves might not have been marked at all (Toynbee, 1971, p. 75). Just off the Via Appia, on the other hand, space was densely crowded by the poor, who sometimes used large tombs as houses (Justinian, *Digest* 147.12.3) or as brothels (Martial, *Epigrams* 1.34). Oftentimes the land on which a tomb was placed was cultivated, with the owners of the plot growing vegetables to sell at market in Rome (Morley, 1996). Although there were areas of Rome that were grandfathered into the proscription against burial within the *pomerium*[1] and thus legal for burial, such as the *puticuli* (mass graves) on the Esquiline Hill, "the great majority of people in the Roman world were laid to rest in tombs of very varied types strung along the roads beyond the city gates" (Toynbee, 1971, p. 49).

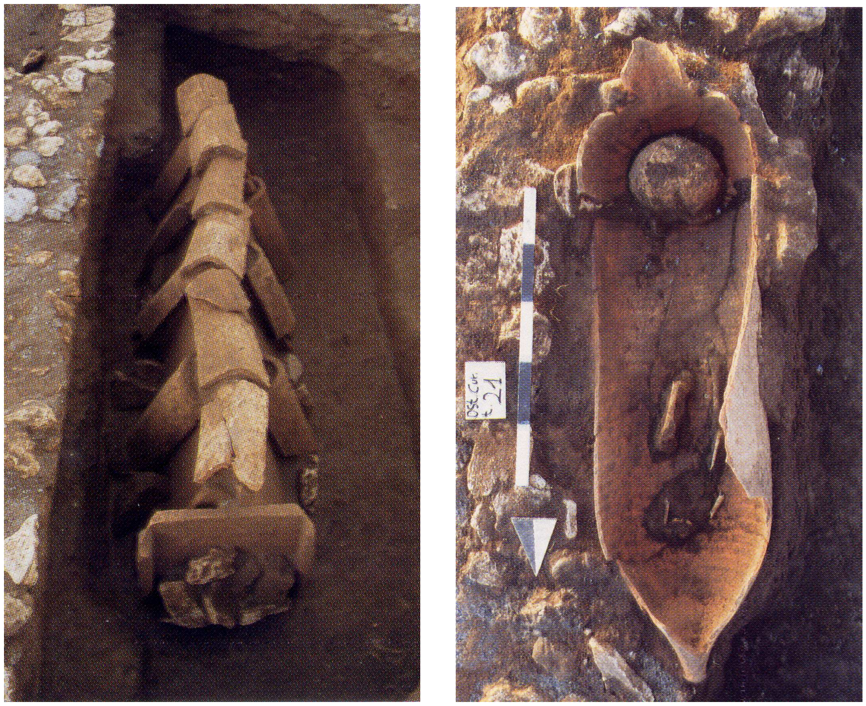
4.1.2 Burial Styles and Rites

A significant amount is also known about Roman rites for the dead, from the immediate aftermath at the deathbed to the disposal of the body to the recurring duties of mourners left behind (see Toynbee, 1971; Lindsay, 2000; and Hope, 2007, among others, for a full description of postmortem rituals). Most of these activities, however, are enacted rituals that leave neither an archaeological nor a biological trace. The aspects of the average Roman funeral that could be seen millennia later include burial style and rituals that involve deposition of material goods or organic remains.

The minimum requirement for a proper burial consisted of a handful of dirt scattered over the deceased (Toynbee, 1971, p. 43). Only the very poorest of Romans were exposed, tossed into the Tiber River, or thrown into *puticuli*.[2] At the next economic level, burial would have been effected in a pit dug into the ground, into which the body (or, in cases of cremation, the inurned ashes) would have been placed. The most popular burial style among the economically modest social classes (i.e., laborers, freedmen, and slaves) in the Imperial period was the *cappuccina* tomb (figure 4.1a). By way of description, Toynbee (1971, p. 102-3) notes that "the simplest method was to lay the body in the earth, but to cover it with pairs of flat *tegulae* set gable-wise and generally with *imbrices* (curved and hollow roofing tiles) along the

[1]The *pomerium* (from the Latin *post* and *murum* or wall) was the traditional boundary of the city of Rome, first created by Romulus and expanded by several later emperors. Beyond the *pomerium* and the city walls was the *suburbium*.

[2]Bodel (2000) notes, however, that as many as 1 in 20 corpses may not have received a proper burial due to indigence.



(a) *Cappuccina* burial from Osteria del Curato (Egidi et al., 2003, p. 66).

(b) *Enchytrismos* burial from Osteria del Curato (Egidi et al., 2003, p. 66).

Figure 4.1: Two Common Imperial Burial Styles

ridge." Italian archaeologists have dubbed these *cappuccina* burials because the tiles form a cowl-shaped protection, *cappuccio* being the Italian for cowl. Another modest style of burial was to place the deceased on top of two halves of a large amphora laid end-to-end, covering the body with an additional two amphora halves, a variant on the use of tiles to protect the body (Toynbee, 1971, p. 103). Children were often placed directly inside an amphora or other large pottery vessel (figure 4.1b), a style of burial referred to as *enchytrismos* after the Greek practice (Egidi et al., 2003). Because these methods of burial involved reused roof tiles or pottery and required little to no skill to accomplish, nearly everyone could afford a burial *a cappuccina* or in a simple pit (Toynbee, 1971, p. 103). Finally, although burial in mausolea or *columbaria* (large vaults that held a number of skeletal and cremated remains, respectively) was usually sought by those individuals with more financial means, there is evidence from sites such as Isola Sacra that freedmen and -women, slaves, and others of low social status were buried in more elaborate ways (Toynbee, 1971; Patterson, 1992). For the most part, though, "anonymity and simplicity are the hall-marks of the normal ancient grave" (Purcell, 1987, p. 34).[3]

Just as burial style in the Roman world was varied, funerals also differed based on age, sex, and social class, to name but a few variables. Common burial rituals in the Roman world that would leave material traces for the bioarchaeologist, however, include those related to dining at the gravesite and those related to the deceased's afterlife.

Likely originating with the Greeks, the Romans adopted the custom of providing the deceased with money for his or her passage to the underworld. Alternatively called "Charon's obol" or, in Latin, *viaticum*, this practice involved placing a coin in the mouth of the deceased as a payment to Charon, the ferryman who ushered souls into the afterlife. Although there is significant discussion as to whether or not the coin in the mouth of the deceased was an embodiment of this myth (Morris, 1992), archaeologically we find the practice to be common in Rome.[4]

Rites related to celebration and veneration of the dead often involved food or drink. On the day of burial, a feast called *silicernium* was eaten at the grave of the deceased (Toynbee, 1971, p. 50). It was expected that the heir would sacrifice a pig in a ceremony known as *porca praesentanea* (Lindsay, 2000, p. 166). Depending on the sequence of feasting and final covering of the grave, it is not unreasonable to expect to find faunal remains within a grave, especially remains of *Sus scrofa*. Throughout the year, the Roman dead were honored, with

[3]Parker Pearson (2001) makes the valid point that burials are an actively contested social arena. Thus, individuals (or the people who bury them) might choose to represent the deceased in a way that does not directly reflect his or her social or economic status. In ancient Rome, public display of status was incredibly important, particularly for the upper class (MacMullen, 1974). Status was displayed in a variety of ways, including on material items (e.g., clothing, statues), in interpersonal interactions (e.g., the patron-client relationship), and in ritual (e.g., burial rites and grave markers). As such, it is highly unlikely that a member of the upper class (or his family) would have chosen a burial site or style that would hide social status. Members of the lower class, on the other hand, could achieve ostentatious burials. The aforementioned Eurysaces was a freedman who built a giant tomb quite near the city walls. At a smaller scale, membership in burial *collegia* in Rome provided the lower classes with a way of achieving higher-status interment in a mausoleum or *columbarium* (Toynbee, 1971). Although burial style can mask class structure and socioeconomic relationships of individuals in the past, the importance of public displays of status among the small fraction of the Roman population that could be called upper class suggests that the majority of the individuals whose skeletal remains have been found in the *suburbium* in recent years were members of the lower strata of Roman society.

[4]At Osteria del Curato, for instance, between 5-20% of the individuals in each cemetery were found with coins in or near the mouth (Egidi et al., 2003).

family visiting the grave on the deceased's birthday or during the *Lemuralia*, the annual festival of the dead. In the rite of *profusio*, liquids such as wine and olive oil were poured directly onto the burial as libations to the deceased. Toynbee (1971, p. 51) notes that it is not uncommon to find burials, both inhumations and cremations, with a pipe made of lead or terracotta running from the body of the deceased to the ground above in order for the person to receive the gift (see figure 4.7a).

Finally, individuals were often buried with a wide variety of material goods. Artifacts that have been found most often include items of personal adornment (e.g., hair and clothes pins, other jewelry), toiletry items (e.g., *unguentaria*), and vessels related to cooking and eating (Toynbee, 1971, p. 52). Not every skeleton found in Rome was given materials for accompaniment to the afterlife, however. As noted below, in lower-class cemeteries, only about one-tenth to one-quarter of the burials involved grave goods.

4.1.3 Biological Remains

Death in ancient Rome has been a topic of scholarship for decades, with researchers writing compendia based largely on textual evidence and visible tombs in the landscape of Rome and the Empire (Toynbee, 1971; Kyle, 1998; Edwards, 2007; Hope, 2007; Erasmo, 2008; Hope, 2009). With tens of thousands of inscriptions from tombstones, it is unsurprising that scholars interested in the ancient Roman population chose that evidence as their primary data source. Skeletal remains were rarely collected for the majority of the 20th century by Roman archaeologists, and as recently as the 1990s, demographers lamented that "the number of cemetery sites of the Roman period excavated and properly recorded for demographic purposes remains very small" (Parkin, 1992, p. 43). With modern Rome resting atop the ancient city, cemeteries would only come to light when construction necessitated archaeological excavation in the city.

During the decade of 1985-1995, only a handful of small cemeteries were found in Rome, the *suburbium*, and Lazio (Catalano et al., 2001a). Then, in 1994, preparations for the *Grande Giubileo* (Grand Jubilee) were begun. Presided over by Pope John Paul II at the end of 2000, the Grand Jubilee was a way for Catholics to usher in the new millennium. As new transportation infrastructure was created in anticipation of the event, dozens of sites were found, about one-third of which held human remains (Filippi, 2001). Especially productive were excavations along ancient routes to Rome; because graves were often located along the sides of roads, thousands of skeletons came to light in a very short time (Catalano et al., 2001a). The southeastern quadrant of the *suburbium* yielded numerous graves along the ancient Via Appia and Via Praenestina.[5] Although some of the cemeteries are late antique and Medieval in date, the majority date to the Imperial period, when the city of Rome and its *suburbium* were both densely populated (Purcell, 1987). Few scholars are aware of the huge number of skeletons recovered from Imperial contexts because of their publication in compendia and non-English-language journals.[6]

Although the quantity of recovered skeletons has grown exponentially, unfortunately Parkin (1992, p. 43) is still correct: the number of skeletons fully analyzed and published in the last decade is shockingly small. There are only six cemeteries from the *suburbium* of Rome that have been even partially published: Basiliano, Quadraro, Tomba Barberini, Osteria del Curato, Casal Ferranti, and Vallerano (see below, figure 4.9). Whereas Basiliano (Buccellato et al., 2003), Vallerano (Cucina et al., 2006; Ricci et al., 1997), and Osteria del Curato (Egidi et al., 2003) have been published as independent sites, the remaining three only appear in summary publications of suburban cemeteries. For the larger sites of Basiliano and Osteria del Curato, which each have hundreds of individuals, only a sample of the excavated skeletal population has been published. Adding up the Imperial skeletons from Rome and the *suburbium* published in more detail than simple demographic summaries, the number of individuals represents less

[5] See Catalano et al. (2001, p. 356), Egidi et al. (2003, p. 17), and Catalano (2008, p. 11) for maps showing the various sites found during excavations leading up to the Jubilee.

[6] Even researchers who have worked on Italian skeletal material in the past do not realize the quantity of bones excavated in recent years. In a book chapter published early this year, an isotope chemist who dealt with skeletal material from Isola Sacra matter-of-factly asserted that “few burials from this period [Imperial] have been recovered” (Schwarcz et al., 2010, p. 342).

than 10% of the human remains uncovered by 2000. Excavations continue in the Roman suburbs, where new cemeteries are frequently uncovered and previous cemeteries are more fully excavated, contributing additional individuals to populations at, for example, Casal Bertone and Castellaccio Europarco.

More information on the above-mentioned comparative cemeteries can be found below, as summary data on the demographic basics of age, sex, and stature have been published from almost a dozen Imperial cemeteries. Other than demographic information, some of these publications report on the number of individuals affected by dental caries, porotic hyperostosis, and cribra orbitalia. Comparisons of palaeopathological data between the study sites and the published Imperial cemeteries will be made in chapter 5.

With such a small percentage of uncovered skeletal remains published to date, I endeavor in this chapter to lay out the demography of the study populations as fully as possible. See appendix A for a full table of demographic data from both Imperial period study populations.

4.2 Demographic Methods

The basic demographic data produced in this study include the age at death of every individual and the sex of the adults. Because measurements of the postcranial skeleton were taken, premortem stature was also calculated for adults whose sex could be estimated. Techniques used to estimate age, sex, and stature were drawn from multiple sources, recorded separately, and then combined to produce the most accurate assessment. Care was taken to record enough information for comparative analysis with other published Imperial cemetery populations.

4.2.1 Sex Estimation

Sex of adult skeletons was estimated using a variety of techniques reproduced in Buikstra and Ubelaker's *Standards for Data Collection from Human Skeletal Remains* (1994), including pelvic morphology, cranial morphology, and long bone measurements. Phenice's (1969) technique for sex determination was used above all to estimate sex from the subpubic region of the os coxae. In addition, individuals with intact pelves were assessed for differences in the greater sciatic notch and the preauricular sulcus (Buikstra and Ubelaker, 1994). Sexually dimorphic cranial features were scored as per Acsádi and Nemeskéri 1970. Finally, in some cases, long bone measurements were used in the discriminant function analysis of FORDISC 2.0 (Ousley and Jantz, 1996).

In the pooled population, I was able to estimate sex for 110 adults. Of these, 77 presented intact pelves with sex characteristics (70%), 83 presented sexually dimorphic cranial features (75%), and 109 (99%) presented bones that could be measured and used in a discriminant function analysis. In total, I estimated the sex of 91 out of 110 adults (83%) based on multiple methods. The pelvic methods were weighted more heavily than cranial morphology, which was more heavily weighted than long bone measurements, in estimating sex as indeterminate (I), female (F), probable female (PF), male (M), or probable male (PM). For the purposes of analysis of these small samples, the probable females/males are grouped with the other individuals of the same sex.

4.2.2 Age Estimation

Adult age was also arrived at using several different techniques.[7] First, I visually examined the pubic symphysis using the criteria of both Suchey and Brooks (1990) and Todd (1921a,b). The auricular surface of the ilium was used for age estimation as per Lovejoy and colleagues

[7] In the field, Roman bioarchaeologists often rely on dental wear to estimate the age of skeletons based on the charts reproduced from Lovejoy's (1985) Libben study. Lovejoy (1985) and others note that dental (molar) wear can be a reliable indicator of age at death, but populations must first be seriated, and activity-related changes must be removed. This has not been done for Roman samples. In addition, age based on dental wear assumes a more or less standard diet within the population, an assumption that has not been tested for the Roman population. Based on comparisons between my age-at-death profile for Casal Bertone and the one presented by Nanni and Maffei (2004) for the same site, it is clear that using only dental wear significantly underages the population. Dental wear was, however, recorded for all individuals according to *Standards*, which uses Smith (1984) for anterior teeth and Scott (1979) for posterior teeth, in the hopes of using these data eventually to create a more reliable age-at-death rubric from Roman dental wear.

(1985). Finally, cranial suture closure was assessed based on the rubric designed by Meindl and Lovejoy (1985). As above, the pelvis was considered the most reliable indicator of age, with cranial suture closure used when a pelvis was not available. Of the 74 adults whose age was estimated, 66 (89%) presented a pubic symphysis, 56 (76%) an auricular surface, and 35 (47%) a cranium for age estimation. I estimated the age of 66 out of 74 adults (89%) based on multiple methods. Adults were placed into the following age categories: 16-20; 21-30; 31-40; 41-50; 51-60; 61-70.

Note that for the purpose of biological classification, the 16-20 age range is necessarily a 5-year one, as it represents the earliest post-pubescent category but includes individuals whose age can be narrowed down on the basis of dental development and epiphyseal closure. In Roman culture, however, individuals in this age range would generally have been considered adults. Roman males and females could marry at ages 14 and 12, respectively. Although marriage was the rite of passage for a female into adult life, that moment for males was at the end of the 17th year, when a male was able to enter public life and join the army (Wiedemann, 1989). As such, an individual in the 16-20 age category should be considered culturally an adult, even if the person was still developing biologically.[8]

Subadult age at death was estimated primarily using tooth formation and eruption and secondarily by epiphyseal closure and long bone length of the postcranial skeleton. Tooth formation for both deciduous and permanent teeth was recorded using the charts in *Standards* after Moorees and colleagues (1963a,b). The approximate age of the subadult was then estimated using White (2005, fig. 19.2) based on work by Gustafson and Koch (1974) and Anderson and colleagues (1976). Epiphyseal closure of all available elements of the postcranial skeleton was scored as unfused, partially fused, or fully fused and compared with tables by Baker and colleagues (2005, tables 10.1-5). In rare cases, subadult age was estimated using the length of long bones (Johnston, 1962). Subadults were placed into the following age categories: fetal;

[8]An argument can, of course, be made for females in the 11-15-year age range to be considered adults in the Roman world. However, because puberty is the prime mover in creating sexual dimorphism in adults, it is very difficult to accurately estimate sex from remains of peri-pubescent individuals.

0-5; 6-10; 11-15. Whenever possible, more precise age estimates were made and noted per individual.

4.2.3 Stature Estimation

Adult stature was estimated as another metric with which to compare the present samples with other published Imperial skeletal populations. Long bone measurements were input into FORDISC 2.0, which uses formulae from Trotter and Gleser (1952) and Ousley (1995) to approximate living height from the postcranial skeleton. The formulae for whites from Trotter and Gleser (1952) were used in order to compare stature at the study sites with published data from other Imperial sites. For individuals with multiple long bones, leg bones were favored over arm bones where possible. The stature of every adult individual whose epiphyses were fully fused was estimated based on the available long bone whose regression formula presented the lowest standard error. The stature formulae can be thus ranked as follows, from those with the lowest to the highest error. For females: fibula, femur, radius, ulna, and humerus. For males: femur, fibula, humerus, radius, and ulna. Individuals over the age of 30 were subjected to a correction factor (Trotter, 1970) to account for age-related stature loss. The stature estimates presented below, therefore, approximate individuals' standing height at death.

4.3 Casal Bertone

The first skeletal population examined comes from a site called Casal Bertone, named for the modern Roman neighborhood in which it was discovered. Less than two kilometers from the walls and three kilometers from the city center, the site of Casal Bertone was closely associated with Rome. Excavations in 1989, 2000, 2001, and 2003 were salvage in nature. Parts of a villa were found in 1989 dating to the Republican era, and associations were noted between the villa, the ancient Via Collatina, and the Aqua Virgo (Calci and Messineo, 1989). In 2000, during installation of a train line in the area, a mausoleum and necropolis came to light, and 109 skeletons were excavated and analyzed in the field by A. Nanni and L. Maffei (2004). Some 21 additional individuals were found in the summer of 2001, and one more in the fall of 2003. Several boxes of commingled remains were not sorted or analyzed previously.

Casal Bertone made international news in 2007, when the director of excavations at the site, Stefano Musco, announced the discovery of a large industrial complex and a residential villa with nymphaeum (figure 4.2), all just meters from the previously discovered burial sites.[9] The complex is larger than anything found in Rome to date and is threatened by railway construction, but Musco hopes to finish excavating the area or remove it from the path of the rail line. Because the size of this site has precluded full excavation and analysis to date, only a brief article has been published so far; the summary below comes from that publication (Musco et al., 2008).

Figure 4.2: Casal Bertone Fullery/Tannery, *Columbaria*, and Road
Photograph from Musco et al. (2008, p. 32).

[9]"Archaeologists in Rome dig up ancient tannery," International Herald Tribune, July 31, 2007.

The entire site at Casal Bertone is over 3,000 square meters. The eastern portion of the site held a residential area that was occupied from about the 1st century BC to its abandonment in the 5th-6th centuries AD. The villa indicates some amount of wealth of its occupants in terms of the high quality and abundant quantity of building materials. In the later Imperial period, the villa was expanded onto a lower terrace, where a *nymphaeum* was situated. This water monument necessitated additional infrastructure in the form of lead pipes and basins to supply the fountains with water. The northern portion of the site includes segments of an ancient road and seven funeral buildings, two of which have *cippi* inscribed with the names of slaves or freedmen of Greek ancestry: L. Cincius Nasta[10] and C. Ateius Epaphra.[11] Just to the south of the road was a large building of at least 1,000 square meters dating to the 2nd-3rd centuries AD. In the main room of the building, there were close to 100 giant tubs up to 1 m in diameter, and there were remains of pipes for filling the basins with water. The structure is interpreted as either a *fullonica* (a fullery) (Bradley, 2002) or an *officina coriarorum* (a tannery) by similarity to those found at Pompeii; in either case, this is the largest known in the Roman world.

4.3.1 Mausoleum and Necropolis

The burial contexts (figure 4.4), originally excavated in 2000, were found to the south of the fullery/tannery (Nanni and Maffei, 2004). The above-ground mausoleum dates to the 2nd-3rd centuries AD and was built partly on top of the open-air necropolis, which dates slightly earlier in the same time period based on pottery and coins found with the burials (Musco et al., 2008).

The mausoleum measured 14 by 11 m and consisted of three rooms, two of which had a black-and-white mosaic floor and one of which (figure 4.3) was a semi-underground burial chamber. This chamber had 13 niches (*forme*), several of which contained the remains of more than one individual. Although the mausoleum had mosaic floors and painted plaster walls, the burials within it had few grave goods. Only 10% of the individuals in the mausoleum had any

[10]This inscription can be found in *CIL* VI 37587, and information on the burial in *LTURS*, vol. II, p. 102.

[11]This inscription can be found in *CIL* VI 37576, and information on the burial in *LTURS*, vol. I, p. 162.

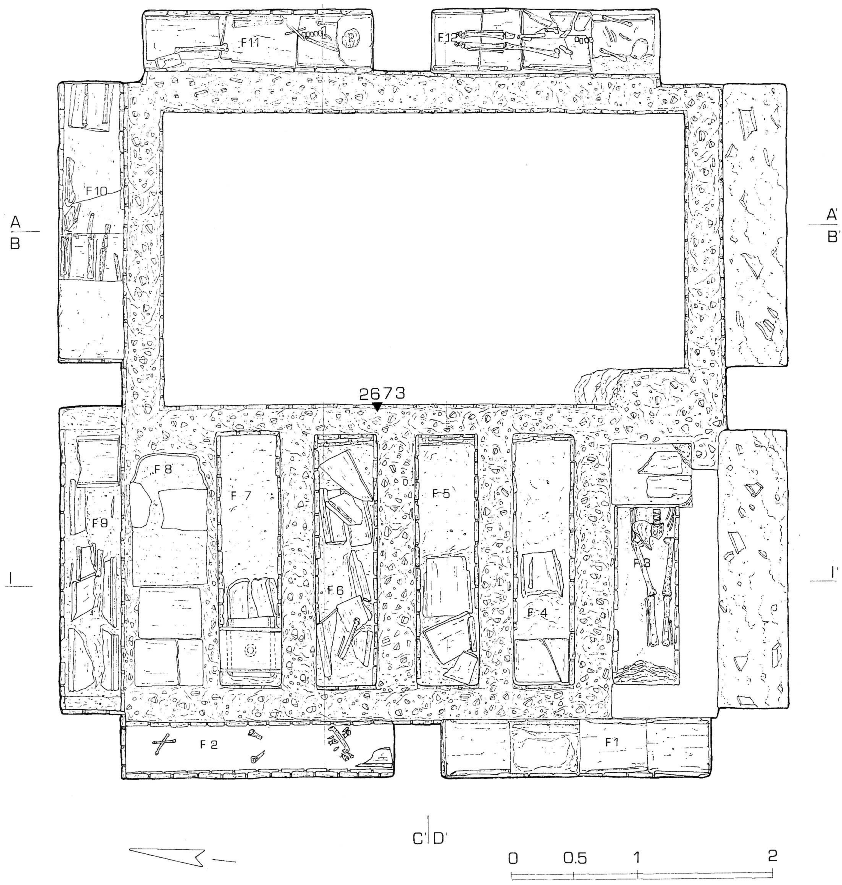


Figure 4.3: Plan of the Burial Area of the Casal Bertone Mausoleum
Drawing courtesy of the Soprintendenza Archeologica di Roma.

artifacts, and those that were present included coins, nails, and small vases such as *unguentaria* (Musco et al., 2008). In one case, a female in her late teens was buried with a necklace, and two additional females were buried with bronze rings (Nanni and Maffei, 2004). Individuals buried in the mausoleum therefore likely belonged to the upper echelons of the lower class and were possibly related to the guild of *fullones* or *coriarii* associated with the tannery/fullery (Musco et al., 2008). Nanni and Maffei (2004) note that they excavated 38 individuals from the mausoleum, whereas Musco and colleagues (2008) claim there were 74 individuals. I studied all the available skeletons from the earlier excavations, or 38 in all. Any additional skeletons uncovered since 2003 were not available for my study.

The necropolis (figure 4.4) consisted of approximately 70 graves haphazardly scattered in

Figure 4.4: Casal Bertone Necropolis and Mausoleum
Drawing courtesy of the Soprintendenza Archeologica di Roma.

a central area. Remains of additional individuals were collected from secondary interments and disturbed primary graves. Although Musco and colleagues (2008) note the presence of 84 people from the necropolis, I examined 100 individuals in total.[12] Some individuals from the Nanni and Maffei excavation were not available for my study, and additional burials were expected to be found in the 2008 field season. Of the graves I studied that could be typed, 57% had tile coverings in the *cappuccina* or *piana* style; 35% had no covering and were simple pit burials, and 8% were burials in amphorae (*enchytrismos*), all of whom were children. Similar to the mausoleum, the burials in the necropolis included few artifacts, with only 22% of burials having any grave goods.

Artifacts from the mausoleum and necropolis were not furnished for my study and were curated separately from the osteological remains. In some cases, a note was made in the excavation record listing the materials found with the skeleton. Because of the lack of grave goods and the *cappuccina* style burials, the excavators have assumed that individuals buried in the necropolis were of the lower social strata, and that individuals in the mausoleum had slightly higher status and/or wealth (Musco et al., 2008). There is no epigraphical evidence, however, that could confirm either the social class or identities of the individuals buried at Casal Bertone.

4.3.2 Sex, Age, and Stature

As noted, for the purposes of this study, I analyzed 38 individuals from the mausoleum and 100 from the necropolis, for a total of 138 individuals from Casal Bertone. The basic demographic information collected from these skeletons included an estimation of the age of every individual, as well as the sex and height of post-pubescent individuals.

Table 4.1 presents the estimated age at death of the individuals buried at Casal Bertone,

[12] Skeletons from the necropolis were labeled with their "tomba" numbers in the field, and skeletons from the mausoleum were labeled with their "forma" number. I shorten these to, respectively, T and F followed by the number. Some graves contained the remains of more than one person. In the case of multiple burials, I append a letter. Each skeleton therefore has a unique identifying letter-number combination.

broken down by context. In the mausoleum population, there is a definite spike in the 6-15-year-old age categories, and the curve tapers off towards adulthood. Similarly in the necropolis population, a high number of deaths in the subadult years declines in the teens and twenties, to rise again from 31-50. The individuals who lived past 50 are fewer at Casal Bertone than in the modern world, as expected from preindustrial populations in general (Parkin, 1992; Storey, 1992; Chamberlain, 2006). The histogram in figure 4.5 is unsurprising given the work of historical demographers in Rome (Parkin, 1992; Frier, 2001; Scheidel, 2001), with the exception of the 11-15 age category. Individuals of this age were generally at a lower risk of mortality than infants (Parkin, 1992). In the Roman world, however, it was not uncommon for females to marry in this age range (Wiedemann, 1989), and high mortality could represent complications in pregnancy and childbirth owing to the immature nature of the female pelvic bones.[13] On the other hand, males in this age range might have begun an apprenticeship or occupation at this time, possibly leading to work-related deaths.

It is, of course, likely that there is an underrepresentation of very young children, as the infant mortality rate in Rome for infants under one year of age was high (Parkin, 1992, p. 94) and infant bones are subject to lack of recovery and other taphonomic processes (Wood et al., 1992). According to Parkin (1992, p. 93), the infant mortality rate in Rome was about 300 per 1,000 per year, whereas the modern infant mortality rate is less than 10 per 1,000 per year. This means that about 30% of the Roman population likely died before the age of one, and 50% before the age of 5. Once this age was reached, however, over 80% of the remaining individuals could be expected to survive until 20 and 30% to 60 and above (Parkin, 1992, p. 94).

Of the 138 individuals examined, 78 could be estimated for sex (table 4.2). In both the

[13] Parkin (1992, p. 104-5) does not think that maternity was a large contributor to premature death among Roman women. The data he cites, however, place the youngest maternal age at 15. If Roman females were marrying and becoming pregnant as young teenagers, it is not unreasonable to think early pregnancy could have affected the average female age at death, as even modern statistics of teenage pregnancies involve poor obstetric outcomes (Gilbert et al., 2004). Research on the age at menarche of Roman females, however, puts it around 14-15 for the average (Hopkins, 1965; Amundsen and Diers, 1969), with fertility lagging behind until about 16-17. This would mean that, for much of the economically stressed Roman population, the time of first birth would not occur until 17-19 years of age. It is currently unclear, therefore, if the early age at marriage for Roman girls would have contributed to early pregnancy and complications therefrom.

	Maus #	Maus %	Nec #	Nec %	Total #	Total %
fetal	-	-	-	-	-	-
0-5	3	7.9	11	11.0	14	10.1
6-10	6	15.8	9	9.0	15	10.9
11-15	6	15.8	14	14.0	20	14.5
16-20	4	10.5	8	8.0	12	8.7
21-30	2	5.3	9	9.0	11	8.0
31-40	4	10.5	13	13.0	17	12.3
41-50	2	5.3	11	11.0	13	9.4
51-60	4	10.5	2	2.0	6	4.4
61-70	-	-	2	2.0	2	1.4
Adult	7	18.4	21	21.0	28	20.3
Total	38	100%	100	100%	138	100%

Table 4.1: Estimated Age at Death of Casal Bertone Population

	Maus M	Maus F	Nec M	Nec F	Total M	Total F
11-15	-	1	-	-	-	1
16-20	3	1	4	3	7	4
21-30	1	1	6	3	7	4
31-40	3	1	10	2	13	3
41-50	1	1	8	2	9	3
51-60	1	3	1	1	2	4
61-70	-	-	1	1	1	1
Adult	4	-	11	4	15	4
Total	13	8	41	16	54	24
Sex Ratio	61.9%	38.1%	71.9%	28.1%	69.2%	30.8%

Table 4.2: Sex Estimates of Casal Bertone Adults and Age at Death

mausoleum and necropolis contexts, there is an underrepresentation of females as evidenced in the sex ratios. The skewed sex ratio at Casal Bertone is not unexpected, as a lack of females in an osteological population can be related either to differential burial practices or to taphonomic processes affecting the usually less dense female bones (Trotter et al., 1960). Additionally, it is possible that the abundance of males is not an error but rather related to the association of the burials with the fullery/tannery, as adolescent and adult males rather than females were usually employed as *fullones* and *coriarii*.

Finally, average height was calculated for adult males and females. Table 4.3 presents the

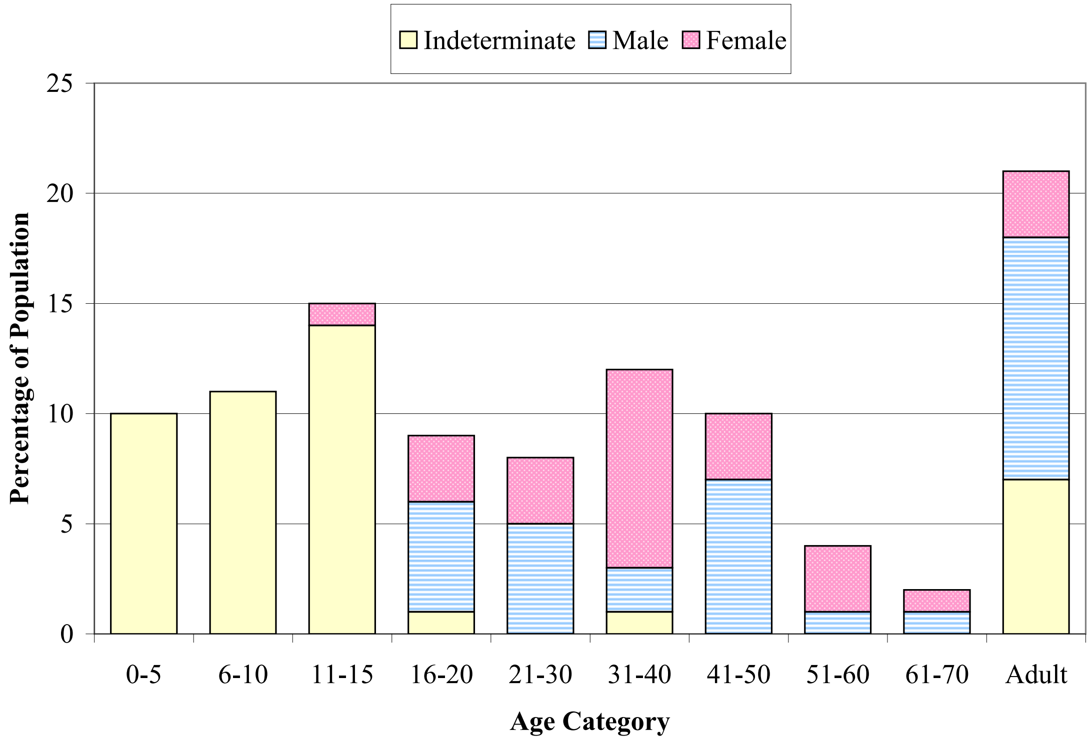


Figure 4.5: Estimated Age at Death and Sex of the Casal Bertone Population

average stature estimates broken down by sex and age category. As expected, females from Casal Bertone are shorter on average than males, a difference of about 10 cm.

	Females	Males
21-30	155 (n=1)	167 (n=4)
31-40	158 (n=3)	165 (n=12)
41-50	156 (n=2)	166 (n=8)
51-60	151 (n=4)	163 (n=1)
Adult*	170 (n=1)	168 (n=5)
Mean	157 (n=11)	167 (n=30)

Table 4.3: Average Height (in cm) of Casal Bertone Population by Sex and Age
*The age correction factor was not used on these stature estimates.

(a) General Plan, from Buccellato et al. (2008, p. 15).

(b) Necropolis Plan, from Buccellato et al. (2008, p. 16).

Figure 4.6: Castellaccio Europarco Maps

4.4 Castellaccio Europarco

The second skeletal population comes from the site of Castellaccio Europarco, which was located 11.5 km from Rome in the *suburbium*.[14] In 2003, excavations along the ancient Via Laurentina revealed a villa, a number of burials, and hydraulic infrastructure dating from the 4th century BC to the 2nd century AD (figure 4.6a). Excavation continued through 2007, but little has been published about this site so far.

Buccellato (2007) and Buccellato and colleagues (2008) report on the work from 2003–2007. All summary information in this section and in section 4.4.1 comes from those reports unless otherwise cited. From the earliest occupation, 4th-3rd centuries BC, archaeologists found remains of a rustic building that measured about 280 m^2 and had 12 medium-sized

[14] An entry on this area of the *suburbium*, namely the early finds along the Via Laurentina related to Castellaccio Europarco, can be found in *LTURS*, vol. III, p. 218-9.

rooms. In one room, the remains of a large *opus signinum* tub indicates the area was used as a *torcularium*, a room for pressing grapes or olives for wine or oil. This building, which was located off a side street of the Via Laurentina, was abandoned in the 2nd century BC. During this time, the ancient Via Laurentina was turned from a beaten path into a paved road, and there are various levels of road construction throughout the use of Castellaccio Europarco. By 177 AD, as dated by epigraphical evidence, an arched bridge and levees in *opus lateritium* were in place over the Via Laurentina. A second building dating to the 2nd to 4th centuries AD was found in the northern area of the site. This building could be accessed by carts and contained areas for storage, thus suggesting a multi-functional area, possibly for the protection of draught animals and for storage. To the south of the site were found nearly 100 burials, all placed along the Via Laurentina. Stratigraphy and artifacts from the graves indicate there were at least three phases of use of this area as a necropolis.

4.4.1 Phases of Burial

Coinciding with the first phase of built architecture at the site, Phase 1 burials from Castellaccio Europarco date to the 4th-3rd century BC (figure 4.6b). In an area about 24 by 5 m, there were 14 inhumations, 1 *bustum* (in-situ cremation), and 3 pits with no human remains. All were simple pit burials with the exception of tomb 64, which contained a child under 2 years of age whose grave had a basalt block covering and included faunal remains from a chicken and a pig, possibly indicating the rites of *silicernium* and *porca praesentanea* (Toynbee, 1971; Lindsay, 2000; Grandi and Pantano, 2007). Osteological analysis in the field led researchers to conclude that Phase 1 adults, almost all of whom were men, had skeletal indications of hard labor. In Phase 1, I studied 17 individuals, which represents the number the excavators identified in the field plus commingled remains of an additional three individuals in two graves. These extra skeletal remains were likely too small (in the case of a fetal skeleton) or too few for the excavators to calculate a proper MNI in the field.

Phase 2 burials date to the 2nd-1st centuries BC, when the Via Laurentina was covered with

(a) ET70, 41-50-year-old female. Photograph from Buccellato et al. (2008, p. 18).

(b) ET31, 3-4-year-old child. Photograph from Grandi and Pantano (2007).

Figure 4.7: Anomalous Castellaccio Europarco Burials

gravel and lined with walls of *opus incertum*. During this phase, the cemetery area, located between the Via Laurentina and its side street, was about 53 by 14 m and held 11 cremations (two of which were *busta*) and 14 burials (nine adults, four children, and one unknown), for a total of 25 individuals (figure 4.6b). Most burials in this phase are simple, but there were two *enchytrismos* infant burials, and one adult woman was buried with her arm partially inserted into a libation tube (Toynbee, 1971, p. 51) (figure 4.7a). Researchers noted trauma, infections, and metabolic issues in their palaeopathological examination of the skeletons in the field (Grandi and Pantano, 2007). Of the 14 burials recorded, one was devoid of skeletal remains, and one was not available for my study. By my count, there were 12 cremations rather than 11, likely a typographical error in the field report. From Phase 2, then, I studied 11 skeletons.

The number of individuals examined in the two earlier phases is quite small, particularly once the groups are sampled for chemical analysis, and there are no published comparanda for these time periods. Although individuals from these pre-Imperial time periods were thoroughly studied, the data obtained do not contribute significantly to the main thrust of this project on mobility and migration to the Imperial capital. As such, the basic demographic and isotope information gathered from the skeletons from Phases 1 and 2 at Castellaccio Europarco is presented separately in appendix B.

The Imperial burial context dates to the second half of the 1st to the last quarter of the 2nd century, or about 50-175 AD. The cemetery area still measured about 53 by 14 m and was more intensively used in the western part, as Imperial-period graves were superimposed on previous ones, either accidentally or intentionally. Of the 50 burials in this phase, 45 were inhumations, 3 were cremations (two *busta*), and 2 had no human remains (figure 4.6b). In large part, the inhumations were simple pit graves, but there were a few cases of *cappuccina* style, *enchytrismos*, and basalt block graves. Artifacts were few and included common pottery, *unguentaria*, personal objects such as *fibulae*, and bronze coins placed in the mouths of several individuals. Of the 45 inhumations, three individuals were buried prone, a child and a male and a female both in their late teens.[15] The burial of the child is especially noteworthy as he or she holds a chicken egg in the left hand, possibly as a symbol of rebirth (figure 4.7b).[16] I studied all 45 available skeletons from this phase.[17]

There is no historical or epigraphical evidence naming the individuals buried at Castellaccio Europarco. Because of the simple grave types and the lack of numerous grave goods, excavators interpret this necropolis as containing individuals from the lower classes. Phase 1 of this rural cemetery was possibly associated with the rustic building, as the *torcularium* would

[15]Buccellato and colleagues (2008) note that the male had evidence of tuberculosis on his skeleton. My data do not support this conclusion, however.

[16]Only one similar burial has been found in Rome, that of a child in the necropolis under St. Peter's, although it does not seem to have been published academically. See, however, the Associated Press story, "Newly excavated Roman necropolis is like a 'Pompeii of cemeteries'," October 9, 2006.

[17]Skeletons from this site were also labeled with their "tomba" numbers in the field. In order to distinguish these from individuals at Casal Bertone, I use the abbreviation ET followed by the grave number. Some graves contained the remains of more than one person. In the case of multiple burials, I append a letter. Each skeleton therefore has a unique identifying letter-number combination.

have necessitated laborers to process the grapes or olives. It is unclear, however, if the other phases of burial were associated with any other architecture in the area.

4.4.2 Sex, Age, and Stature

The minimum number of individuals at Castellaccio Europarco thus totals 45 from the Imperial time period. The basic demographic information that was collected from these skeletons included an estimation of the age of every individual, as well as the sex and height of post-pubescent individuals.

Figure 4.8 displays the estimated age at death of the Castellaccio Europarco population. Significant infant and child mortality is not unexpected, and those who made it to adulthood did not live past 50. This pattern is not unusual for Rome (Parkin, 1992). Surprisingly, Castellaccio Europarco presented more evidence of infant mortality in the 0-5-year age range than did Casal Bertone, but it is unclear if this is related to excavation and recovery methods, burial context, or taphonomic processes.

	Male	Female
11-15	1	-
16-20	3	-
21-30	5	1
31-40	8	2
41-50	4	4
51-60	-	-
61-70	-	-
Adult	3	-
Total	24	7
Sex Ratio	77.4%	22.6%

Table 4.4: Sex of Castellaccio Europarco Adults and Age at Death

Table 4.4 shows the number of individuals of either sex and the sex ratio for each phase. Males outnumber females 3 to 1, a statistically significant difference ($\chi^2 = 29.16, p < 0.0001$). As with Casal Bertone, it is unclear if this underrepresentation of females is related to the cultural context of burial or to taphonomic processes affecting female skeletons.

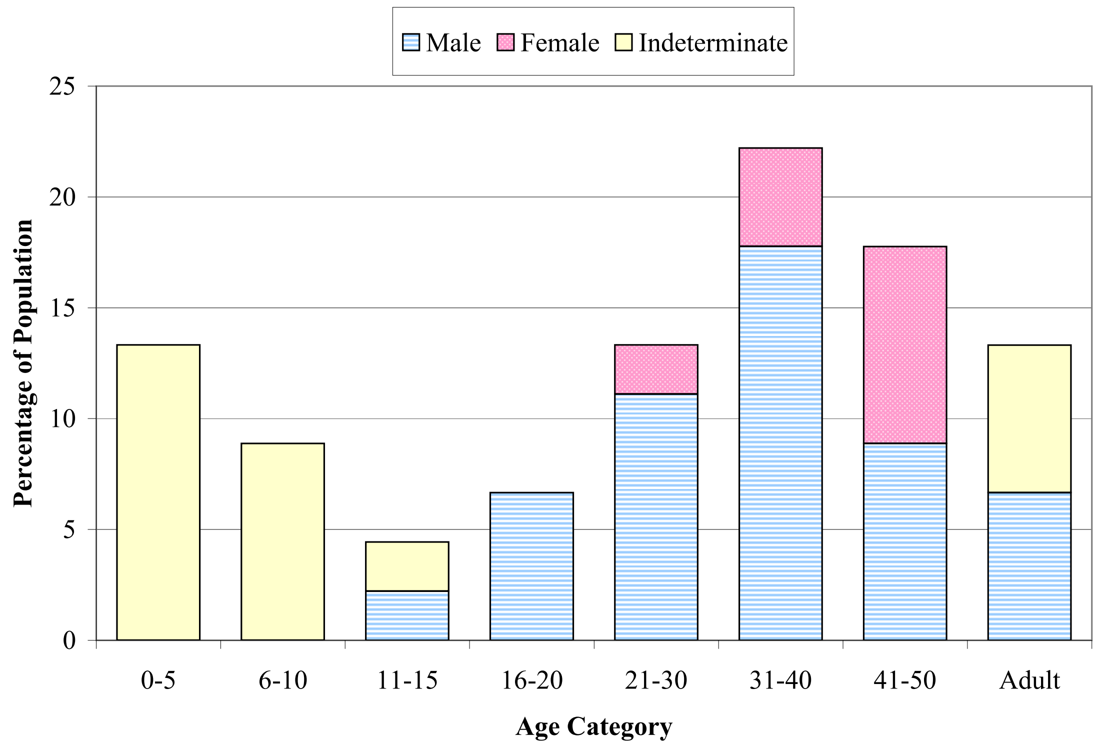


Figure 4.8: Estimated Age at Death and Sex of the Castellaccio Europarco Population

Finally, the average height was calculated for those adults whose sex could be determined and who presented at least one intact long bone. There were 19 males and 7 females whose height could be estimated. Average stature estimates are broken down by sex and age category in table 4.5.

Males from Castellaccio Europarco had the same average stature as males from Casal Bertone, 167 cm. Females from the suburban site, however, had a stature average 7 cm shorter than the females from the periurban site. The difference in stature between the sexes at Castellaccio Europarco is 17 cm. This dissimilarity will be further investigated below in comparison with other Imperial skeletal populations.

	Females	Males
21-30	139 (n=1)	169 (n=5)
31-40	144 (n=2)	164 (n=8)
41-50	154 (n=4)	165 (n=4)
Adult*	—	173 (n=2)
Mean	150 (n=7)	167 (n=19)

Table 4.5: Average Height (in cm) of Castellaccio Europarco Population by Sex and Age
*The age correction factor was not used on these stature estimates.

4.5 Comparative Samples

In spite of the immense number of skeletons that have been found in the Roman *suburbium* (Filippi, 2001), few populations have been fully analyzed. Figure 4.9 maps the sites that have been at least partially published to date. These sites can be classified into three different categories based on their proximity to Rome.

The periurban sites represent those that were found in the *suburbium* but are within 5 km of the city walls. Casal Bertone is the cemetery closest to Rome whose skeletons have been analyzed. An extremely large necropolis was found one kilometer west of this site, named after the two major nearby roads: Viale della Serenissima and Via Basiliano (Catalano et al., 2001a,b; Buccellato et al., 2003). Well over 2,000 skeletons were uncovered dating primarily to the 2nd century AD. To date, however, only 142 of these individuals have been analyzed in the laboratory and published (Buccellato et al., 2003).[18] Two additional periurban sites that date to the 2nd century AD are Quadraro and Tomba Barberini, which are located close to one another about 5 km southeast of the center of Rome. Neither site has been published on its own, but summary data from them exist in two different articles (Catalano et al., 2001a,b). The number of individuals examined is 34 from Tomba Barberini and 36 from Quadraro.

The suburban sites represent those that were found in the ancient *suburbium*, about 12 km from the city, where population density started to decrease and the landscape was dotted with

[18]This cemetery is also known as the necropolis of Collatina in a recent article (Buccellato et al., 2008a). See chapter 5 for additional information, particularly regarding pathology frequencies.

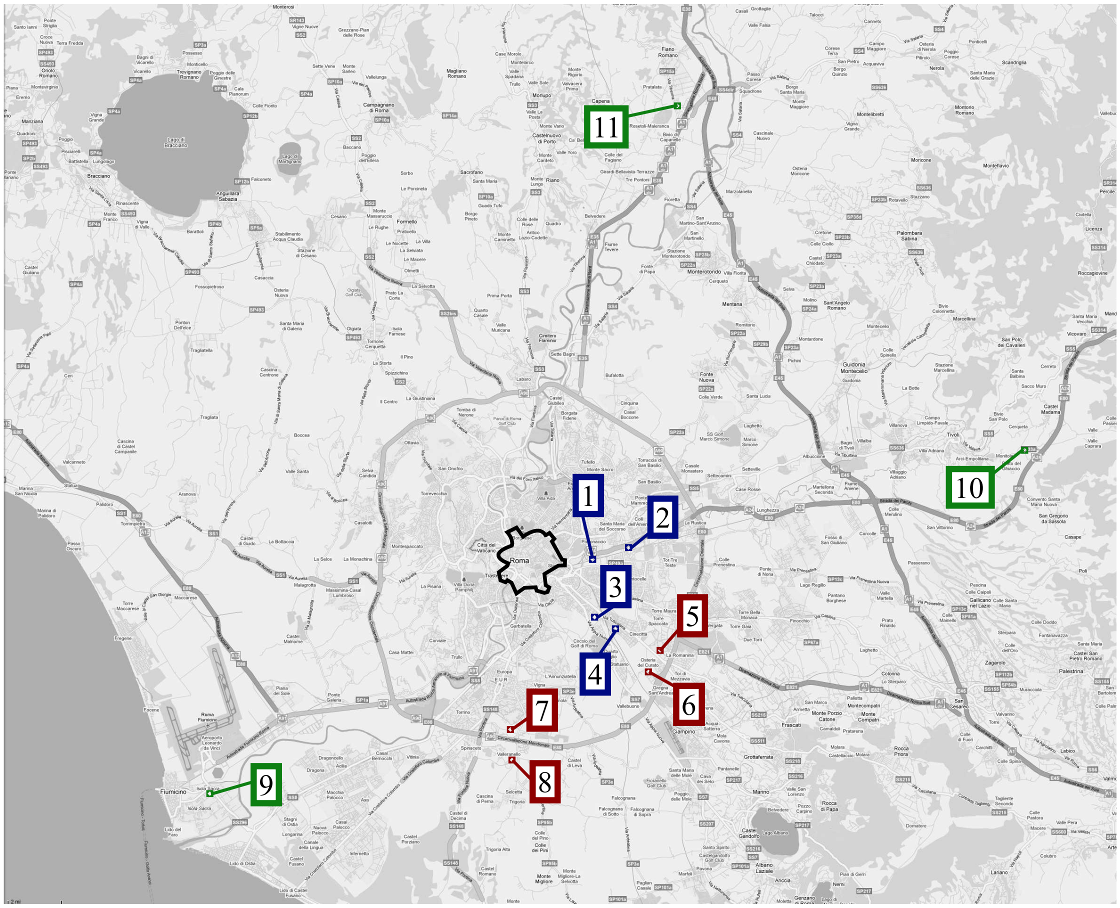


Figure 4.9: Map of Imperial Skeletal Populations
1 = Casal Bertone. 2 = Basiliano/Serenissima/Collatina.
3 = Quadraro. 4 = Tomba Barberini. 5 = Casal Ferranti.
6 = Osteria del Curato. 7 = Castellaccio Europarco. 8 = Vallerano.
9 = Isola Sacra. 10 = San Vittorino. 11 = Lucus Feroniae.

villas and other agricultural production (Champlin, 1982; Purcell, 1987). Directly south of Rome was Castellaccio Europarco, and about 1 km from that site was the necropolis at Vallerano. An average-sized 2nd-3rd century AD cemetery of just over 100 individuals, Vallerano has been published fairly extensively in both Italian- and English-language journals (Ricci et al., 1997; Catalano et al., 2001a,b; Cucina et al., 2006). About 12 km southeast of Rome were two additional necropoleis, Osteria del Curato (1st-3rd centuries AD) and Casal Ferranti (2nd century AD). While the entire population of Osteria del Curato is listed as an appendix in the back of Egidi et al. (2003), this publication primarily deals with the material culture, and only a sample of 61 individuals has been published elsewhere (Catalano et al., 2001a,b). Similarly,

Context	Site	Distance from Rome (km)	Sample Size
Periurban			
	Casal Bertone	1.6	138
	Via Basiliano[1,2]	3.6	142
	Quadraro[3,4]	3.6	36
	Tomba Barberini[3,4]	3.6	34
Suburban			
	Castellaccio Europarco	11.5	45
	Vallerano[5,6]	12.0	103
	Osteria del Curato[3,4,7]	11.0	61
	Casal Ferranti[3,4,7]	11.5	71

Table 4.6: Comparative Imperial Sites
1 = Buccellato et al. (2003). 2 = Buccellato et al. (2008a). 3 = Catalano et al. (2001a).
4 = Catalano et al. (2001b). 5 = Cucina et al. (2006). 6 = Ricci et al. (1997). 7 = Egidi et al. (2003).

Casal Ferranti offered at least 71 individuals for analysis, but the data are often combined with those from Osteria del Curato (Catalano et al., 2001b).

Other published Imperial sites within the larger periphery of Rome include Lucus Feroniae (Manzi et al., 1999), San Vittorino (Catalano et al., 2001b), and Isola Sacra (Prowse, 2001; Prowse et al., 2004, 2005, 2007), all about 25-30 km from the city. San Vittorino and Lucus Feroniae were both rural sites, making them more difficult to compare to Casal Bertone and Castellaccio Europarco. Isola Sacra was the cemetery for Portus Romae, the cosmopolitan port city of Rome (hereafter referred to simply as Portus). Comparisons between Casal Bertone and the nearby urban site of Isola Sacra will be dealt with further in chapters 5, 6, and 9.

4.5.1 Age at Death

Historical demographers have used primarily epigraphical evidence from tombstones to reconstruct the average age at death and life expectancy of the Romans (MacDonnell, 1913; Acsádi and Nemeskéri, 1970; Parkin, 1992; Storey, 1997a,b; Frier, 2001; Scheidel, 2001). Surprisingly, the estimates for average Roman life expectancy are similar: at birth, a person is expected to live into his or her mid-20s. Acsádi and Nemeskéri (1970) break this estimate down further into social classes; slaves had a life expectancy under 18 years, tradesmen 35, and professionals 40. In all cases, though, these numbers refer to males; females had a lower life expectancy in general owing to the significant risk of death during parturition and the immediate post-partum period. This does not mean, however, that the average Roman died at 25; rather, the high infant mortality dramatically decreases the life expectancy at birth. As noted above, in a population of individuals who had attained the age of 5, half of them would survive to at least 40 (Parkin, 1992, p. 94), and about one-third of them would reach 60.

The age distribution of the Roman population was affected by a number of variables in antiquity, including epidemic diseases, migration, and living conditions. These issues will be touched upon further in later chapters, but on the assumption that life was different for those living close to the city than for those who lived on the edge of a rural area (MacDonnell, 1913), age at death can be depicted for people buried in periurban and suburban sites. Figure 4.10 compares Casal Bertone to the periurban sites Tomba Barberini, Via Basiliano, and Quadraro, and figure 4.11 compares the Phase 3 burials from Castellaccio Europarco to the suburban sites Vallerano, Casal Ferranti, and Osteria del Curato.[19]

Estimated age at death at urban sites does not present any sort of unified distribution. Whereas Casal Bertone has a spike in the 7-12 age range, with 20% of the population dying in this range, Via Basiliano and Quadraro have fairly high infant mortality. These two sites also have a large number of people dying at or after age 40, whereas at Casal Bertone and Tomba Barberini, there are a fair number of 20-40-year-old individuals. Still, at all sites, the childhood death rate is significant, dropping off throughout the teen years (with the exception of Casal Bertone), and then increasing again by age 20. All four sites date roughly to the same time period, the 2nd century AD, and none of them had burial styles indicative of the upper class. The main differences between these sites are geography and archaeological context, the

[19]I reclassified subadult individuals at my two study sites into slightly different age categories in order to directly compare them with the data from the six other published Imperial sites.

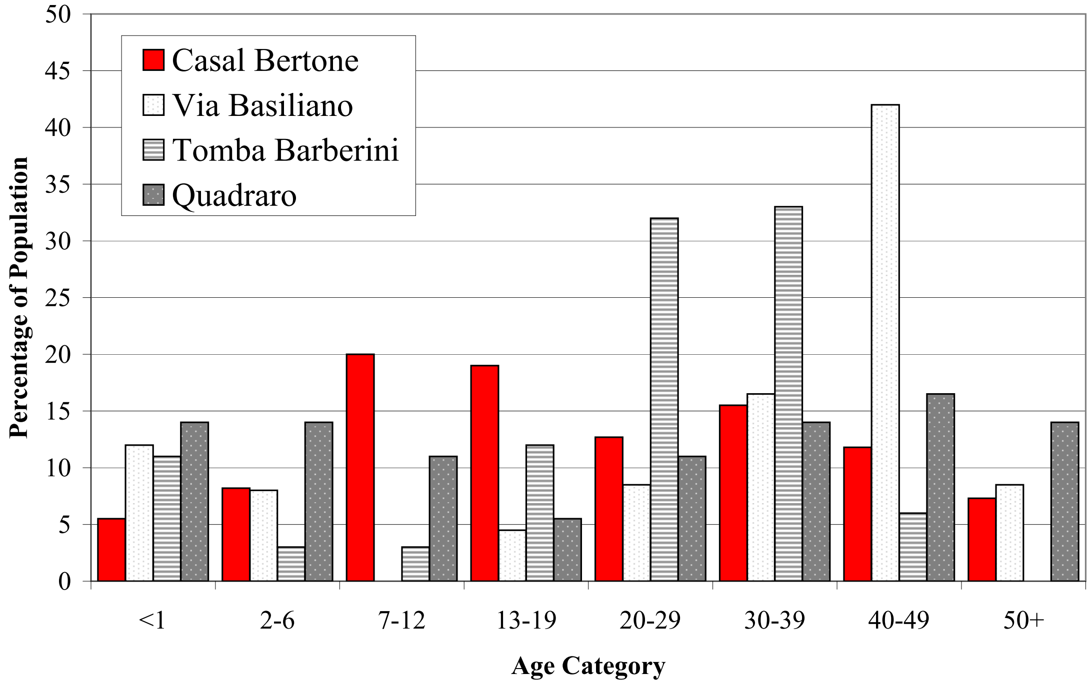


Figure 4.10: Estimated Age at Death - Periurban Cemeteries

latter of which has not been fully published for any site. The geography of Rome and its *suburbium* boasts hills and valleys, volcanoes and rivers, all of which likely contributed to different ecological niches that could have influenced the disease load of each population. In addition, fresh water from aqueducts was not available to every person living in the periurban and suburban areas, but Casal Bertone was located along the path of the Aqua Virgo, a major aqueduct that supplied numerous fountains and baths in Rome. Finally, the Casal Bertone burials could have been related to the large industrial complex. It is possible that employment of younger individuals led to some work-related accidental deaths. Palaeopathology of the Casal Bertone population, however, will be further examined in chapter 5.

The estimated age at death distributions among the four suburban cemeteries are more similar to one another than are the distributions of the urban cemeteries (figures 4.10 and 4.11). For the most part, a relatively low infant mortality rate decreases further by age 7-12 and then starts increasing, with much of the population dying in the 20-50 age range. An exception to this general trend is Casal Ferranti, which has a higher percentage of the deceased population in

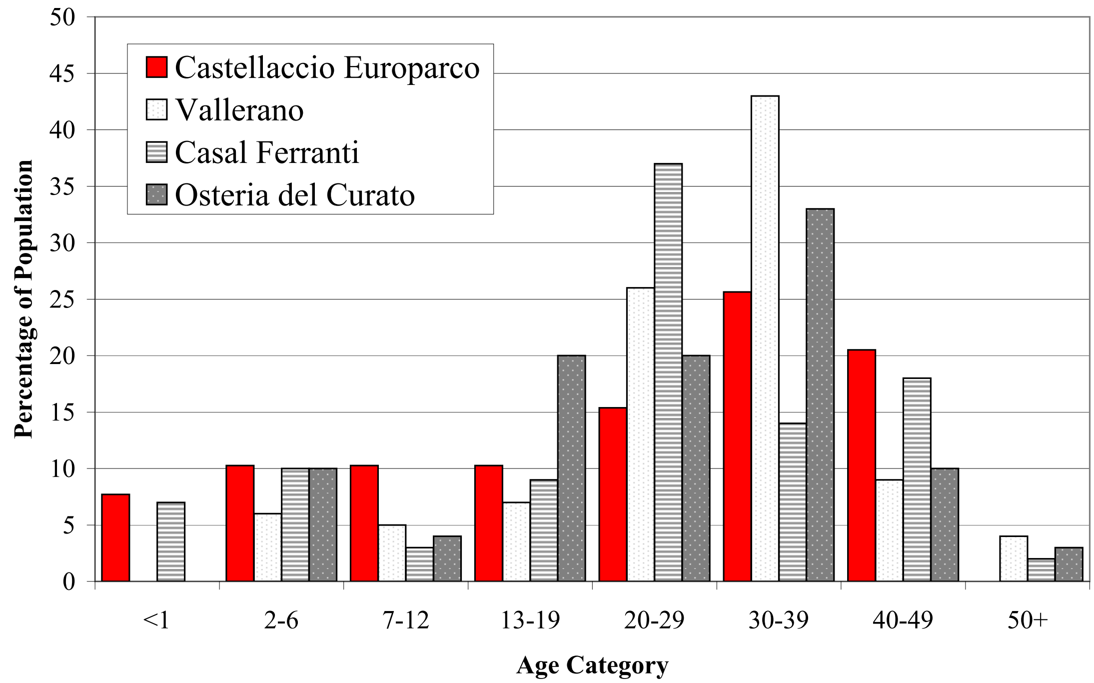


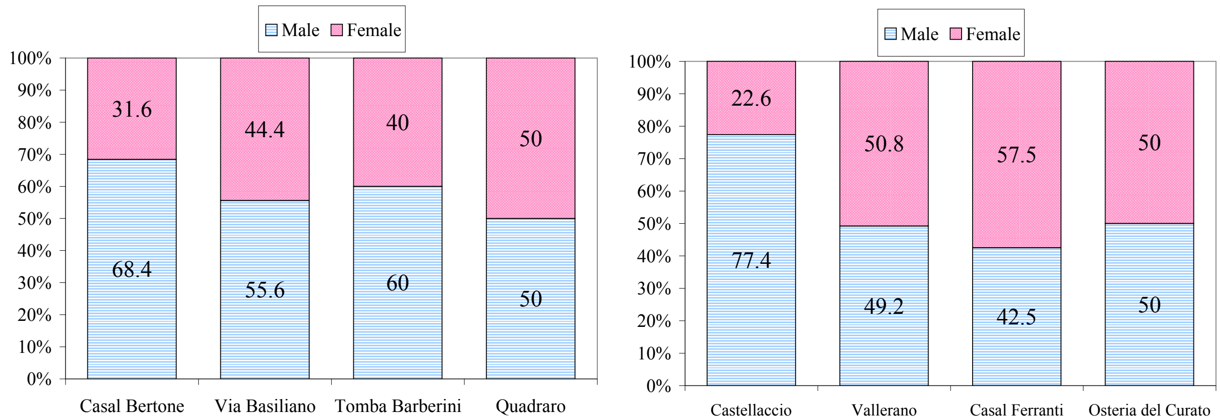
Figure 4.11: Estimated Age at Death - Suburban Cemeteries

the 20-29 age range. It is interesting that, although the relative percentages differ, the shape of the histogram for each site is nearly identical. As above, it is likely that these individuals lived in a more homogeneous geographical or cultural context, probably engaging in small-scale farming on the periphery of the suburban area as at nearby Vallerano (Cucina et al., 2006). The relative health of Castellaccio Europarco and the other suburban populations will be further examined in chapter 5.

4.5.2 Sex Ratio

Although other published sites do not usually include a breakdown of age at death by sex, the sex ratio at each site is used for comparative purposes. Figure 4.12a displays the sex ratios at periurban Roman sites, and figure 4.12b displays the ratios at suburban sites.

At Quadraro, equal numbers of male and female skeletons were found. The other periurban sites present more males, and Casal Bertone has the highest male-to-female ratio. As mentioned above, it is not unusual for skeletal populations to be skewed towards male. It is



(a) Periurban Sites (b) Suburban Sites

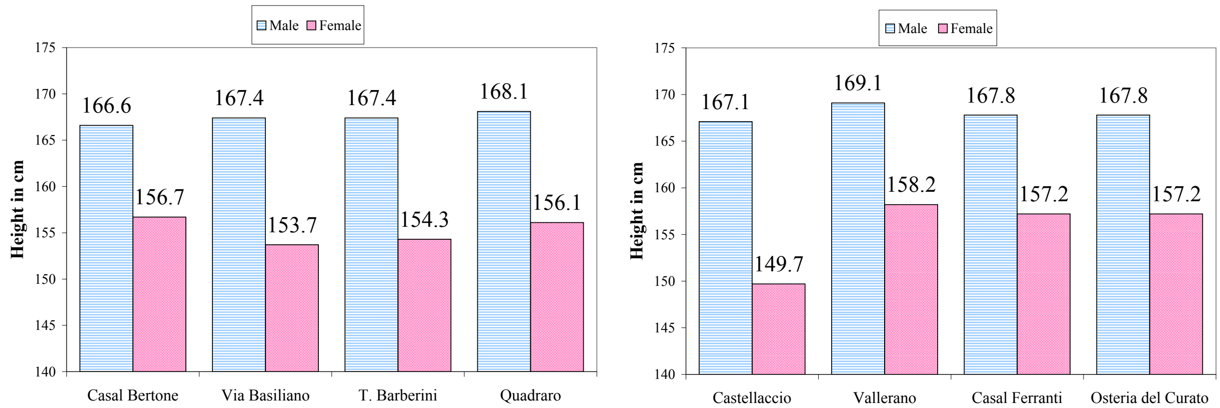
Figure 4.12: Sex Ratios of Imperial Cemeteries

interesting, however, that at all suburban sites except Castellaccio Europarco, the sex ratio is equal or is slightly in favor of females. Castellaccio Europarco and Vallerano date to the same time period and were less than 1 km from one another, yet Vallerano has a much more equal sex ratio. Without archaeological background on any of these sites, however, it is impossible to know if cultural factors led to the disparities in sex ratio between periurban and suburban sites or why Casal Bertone and Castellaccio Europarco are different than the comparative sites. It is also possible that differences in methods of sex estimation among bioarchaeologists in the field and in the lab contributed to the varying sex ratios.

4.5.3 Stature

It is standard practice for Italian bioarchaeologists to calculate living stature from maximum length of the long bones using formulae developed by Trotter and Gleser (1952) for American war dead. Applying these formulae to ancient Romans likely does not yield accurate stature estimates, but comparing the results obtained between the sexes and between sites provides interesting information on the relative magnitude of height differences.

As can be seen in figure 4.13, at the periurban sites of Via Basiliano, Tomba Barberini, and Quadraro, females are about 12 cm shorter than males, and at Casal Bertone they are 10 cm shorter. The sex-related stature difference at the suburban sites of Vallerano, Casal Ferranti,



(a) Periurban Sites (b) Suburban Sites

Figure 4.13: Stature of Individuals from Imperial Cemeteries

and Osteria del Curato is also about 10 cm, whereas at Castellaccio Europarco the difference is 17 cm. Females tend to be shorter in the periurban contexts and taller in suburban, although the study populations do not fit into this trend, particularly Castellaccio Europarco on account of the small sample size. On the other hand, males from the suburban contexts are on average slightly taller than males from the periurban contexts. Interestingly, Casal Bertone has the greatest average female stature of the published periurban sites.

In general, then, males and females from the suburban sites are less sexually dimorphic in stature than populations from periurban contexts, and males and females in the suburbs were taller on average than people from periurban contexts. Females from Casal Bertone are taller than their counterparts at the other periurban sites, with numbers closer to females from the suburban populations. The high average stature of Casal Bertone females in particular is likely related to better diet and health of this population, the latter of which is possibly the result of good access to clean water (Killgrove, 2008). The relative health of the Casal Bertone and Castellaccio Europarco populations and comparisons with other Imperial populations will be further examined in chapter 5, where palaeopathology data will be presented, and dietary differences between the two sites are investigated in chapter 6.

4.5.4 Discussion

The basic demographic data published for other Imperial sites allows only superficial comparisons of age at death, sex, and stature. Comparisons largely raise additional questions rather than generating explanations.

In general, there is moderate infant and childhood mortality in the Imperial Roman samples, and those individuals who survived to adulthood did not often live past 50. In the suburban populations, the age-at-death histograms look relatively similar, but the histograms for the periurban populations are quite varied (figures 4.10 and 4.11). It does appear that there were more individuals of an advanced age in the periurban contexts. Two explanations for this variation could be found in: archaeological context, if social status, gender, ethnicity, or other variables factored into the decision of burial location; or geographical location, if the particular ecology of the area, including access to clean water, population density, or other factors affected a population's susceptibility to disease and death. Unfortunately, archaeological context is not published for the majority of these skeletal populations. Further work to investigate the ecology of Latium is necessary, as very little has been done in this regard (Nutton, 2000; Morley, 2005).

The sex ratio of suburban sites is slightly skewed towards females, whereas the sex ratio at periurban sites is skewed towards males (figure 4.12). This makes it unlikely that females were merely underrepresented in the periurban contexts. A better explanation might be that males tended to live and work in the city, as Rome was a major preindustrial center with scores of professional guilds. Further, more males migrated to Rome than females (see chapter 10), likely in search of work, and this influx could have swayed the balance in favor of males. The fact that the Casal Bertone male population is twice that of the female population could be explained by the cemetery's association with the large industrial complex, which would have employed a number of men and boys. The overwhelming number of males buried at Castellaccio Europarco, however, is not as easily explained. The archaeological context of this site is not well understood at this point, though, which precludes drawing conclusions as to the male-favored sex ratio.

Finally, it does appear that individuals in suburban contexts were taller than those in periurban contexts (figure 4.13). Stature is often viewed as an index of health (Steckel, 1995), yet the suburban populations had fewer individuals who lived past 50 years of age. A number of plausible scenarios can be constructed to explain this phenomenon, such as the possibility that conditions of diet and disease ecology during subadult growth and development favored maximal expression of stature in the *suburbium* but that an epidemic disease common in Imperial Rome ravaged the population as adults. This difference in stature between periurban and suburban contexts is interesting, but at this point raises many additional questions, some of which will be dealt with in chapter 5.

4.6 Conclusions

This study involves osteological and chemical analysis of the skeletal remains of 183 individuals who were buried at two sites in the ancient Roman *suburbium* for the purpose of identifying immigrants and discussing their contributions to Roman society. Casal Bertone was chosen as a study site based on the number of individuals, its proximity to the walls of Rome, and the two different burial contexts. Its probable association with a large fullery or tannery was discovered during laboratory analysis and makes the cemetery population extremely interesting in that it might have contained individuals who worked in the industry. Castellaccio Europarco was chosen based on the multi-phase burial area and its location as a suburban site. Further excavation in this area has produced more skeletons and more information about the buildings and infrastructure in the area, but the archaeological data have not been published. Both populations presented an age-at-death structure within the norm for a preindustrial society and within the bounds of the predictions of historical demographers. There were more males than females at both sites, probably related to the male-dominated occupational sphere rather than to female underenumeration or gendered burial practices. The population at Casal Bertone was taller on average than was the population at other periurban cemeteries, but in general the suburban dwellers had a higher stature than those who lived near the city. These findings raise questions about diet, disease, migration, and occupation, which will be discussed in the following chapters.

Chapter 5

Disease in Imperial Rome

Life in Imperial Rome was by all accounts crowded, unsanitary, violent, and impoverished (Champlin, 1982; Scobie, 1986; Parkin, 1992; Scheidel, 2003; Morley, 2005). In an often-cited article on sanitation in the Roman world, Scobie (1986) concluded from a textual and archaeological assessment of lower class Roman living conditions that high frequencies of diseases such as cholera, typhoid, dysentery, gastroenteritis, leptospirosis, and infectious hepatitis could be attributed to food and water contamination by fecal material, open latrines in the kitchen, and defecation and urination in the streets. There is also ample historical evidence from such ancient authors as Celsus and Pliny the Younger attesting to the presence of diseases like malaria, leprosy, and tuberculosis in the population (Meinecke, 1927; Patrick, 1967; Grmek, 1989), but little evidence has been found in the scant skeletal record to indicate the prevalence of these conditions in ancient Italy. Malaria is assumed to have been endemic from skeletal indications of anemia (Angel, 1966; Sallares, 2002); leprosy is found as early as the 4th century BC (Mariotti et al., 2005); and tuberculosis is known from a handful of sites (Ricci et al., 1997; Roberts and Buikstra, 2003; Canci et al., 2005). In spite of the lack of skeletal evidence, it is reasonable to begin looking at archaeological populations from Rome with the assumption that "ancient empires with high population density and highly developed trading systems were ideal for the cultivation of such diseases and the ravages of epidemics" (Acsádi and Nemeskéri, 1970, p. 217).

Analysis of human skeletal populations from Casal Bertone and Castellaccio Europarco provides evidence of pathologies from a bioarchaeological perspective, broadening our understanding of communicable and nutritional diseases, dental pathology indicative of stress and diet, as well as patterns of trauma and osteoarthritis among the lower classes buried in the Roman *suburbium*. Both skeletal and dental pathologies from the two study sites are presented in this chapter. Where appropriate, inter-site and inter-sex variation in disease frequency are assessed, and comparisons are made between the study sites and other published Imperial Roman cemeteries. In studying palaeopathological indicators of disease, trauma, and stress, a better picture of the quality of life of the lower classes in Rome comes into focus.

5.1 Skeletal Pathology

The populations buried at Casal Bertone and Castellaccio Europarco produced few occurrences and low frequencies of most skeletal pathologies. Identification of these pathologies was made based primarily on Ortner (2003). The different categories of disease are introduced in terms of Ortner's classification, and the pathological conditions are presented more or less in order of those with high frequencies in the populations to the more rare issues. Interpretation in terms of what the osteological pathologies indicate about past populations is based on both Ortner (2003) and Larsen (1997).

5.1.1 Hematopoietic

The main pathological condition that most bioarchaeologists who work in the Italian peninsula are interested in is porotic hyperostosis, a gross indication of the stress placed on a population (Larsen, 1997). Porotic hyperostosis can affect the eye orbits, where it is often termed cribra orbitalia (figure 5.1), or it can be found on the flat bones of the cranial vault, where it is termed cribra cranii. A variety of causes have been put forth to explain the frequency of porotic lesions in populations around the world, but in general the lesions are an indication of

	Casal Bertone		Castellaccio Europarco	
	Orbits	Individuals	Orbits	Individuals
Male	6/60 (10%)	4/33 (12.1%)	2/21 (9.5%)	1/12 (8.3%)
Female	0/17 (0%)	0/11 (0%)	0/6 (0%)	0/3 (0%)
Subadult	10/33 (30.3%)	7/19 (36.8%)	4/12 (33.3%)	2/7 (28.6%)
Total	16/110 (14.5%)	11/63 (17.5%)	6/39 (15.4%)	3/22 (13.6%)

Table 5.1: Cribra Orbitalia Frequencies

iron-deficiency anemia. Hereditary hemolytic anemias (e.g., sickle cell anemia, thalassemia, and favism) are assumed to have existed in the Mediterranean, as individuals heterozygous for these conditions would have had an advantage in areas of endemic malaria. Bioarchaeologists in the Roman world are therefore quite interested in the frequency of porotic hyperostosis in ancient populations.

Skulls from Casal Bertone and Castellaccio Europarco were examined for evidence of porotic hyperostosis in the eye orbits (hereafter, cribra orbitalia) and on the parietal and occipital areas of the skull (hereafter, cribra cranii). Each lesion that was found was given two severity scores: one according to the methods presented in *Standards* (Buikstra and Ubelaker, 1994), and one according to the work of Hengen (1971), which is most often used by Roman bioarchaeologists. The results of this analysis are presented in table 5.1, which lists the frequencies of cribra orbitalia by number of orbits affected and number of individuals affected out of total orbits and individuals examined.

Figure 5.1: Cribra Orbitalia
Casal Bertone F10B, 6-10 years old

The total frequencies for cribra orbitalia in the two populations are similar. Neither population has any evidence of the disease process in females, although this sex is underrepresented in the sample. Hengen scores for the orbital lesions range from 1 (shallow furrows with tiny holes) to 3 (deeper holes and grooves up to 2 mm diameter), which means they were likely inactive at the time of the individual's death. Only individual F10B had a Hengen score of 5 (confluent holes, beginning of osteophytes) (figure 5.1), indicating the possibility that this subadult had an active hyperostotic lesion at death. The scores for lesions based on the method in *Standards* are nearly the same values as the Hengen scale, with the exception of F10B, who had a *Standards* score of 4 (coalescing pores with expansive changes).

Cribra cranii was found less often in both populations. Only one individual from Casal Bertone, F7B, had cranial lesions out of a total of 83 individuals examined, or a frequency of 1%. At Castellaccio Europarco, three individuals (ET63, ET31, and ET69) had cranial involvement indicative of porotic hyperostosis out of 32 individuals examined, for a frequency of 9%. Both ET63 and ET69 also presented evidence of cribra orbitalia, but the severity of the cribra cranii in all individuals examined was only a 2 on the Hengen scale, indicative of healed or healing lesions at the time of death.

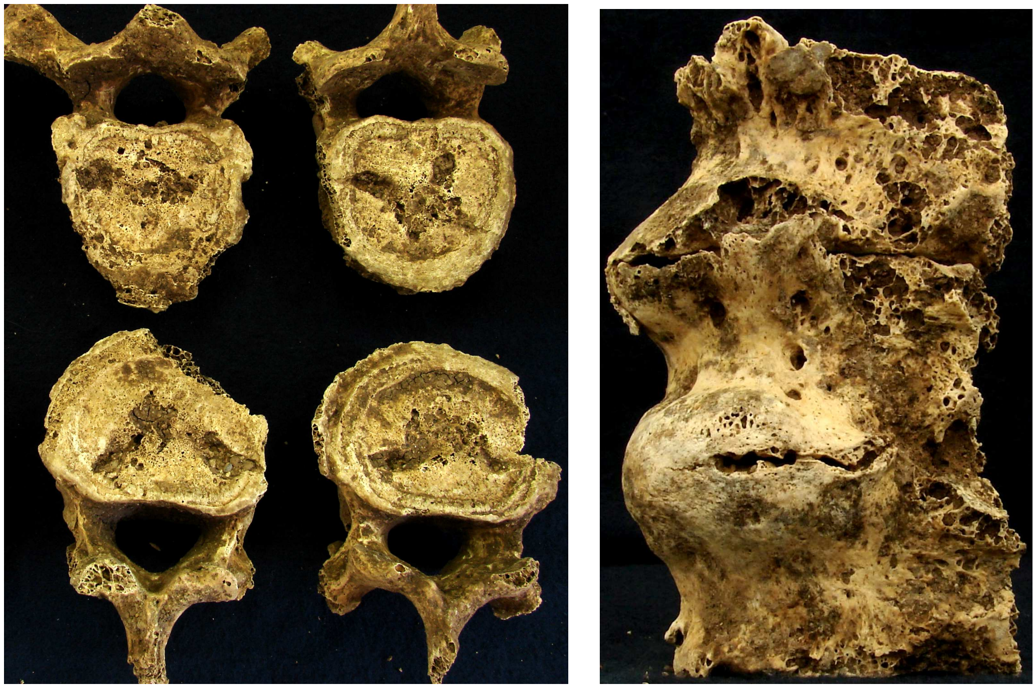
The populations at Casal Bertone and Castellaccio Europarco had relatively low frequencies of porotic hyperostosis of the cranium and orbits, which is surprising given their location in an area of the world with endemic malaria in the past. There is evidence that several individuals suffered from iron-deficiency anemia of sufficient severity to cause bone involvement, but the cause of the anemia is unknown. The frequencies of this disease process will be discussed below with reference to other skeletal populations from the *suburbium* of Rome.

5.1.2 Osteoarthritis and Disc Herniation

Osteoarthritis is an extremely common joint disease, particularly affecting people past middle age. In the contemporary Western world, osteoarthritis is rarely found before the age of 30, but about half of all individuals over the age of 60 have some form of the condition (Larsen, 1997; Ortner, 2003). Evidence of osteoarthritis can therefore be expected to be found in the ancient skeletal record.

Stress to the joint during repeated physical activity is the primary cause of osteoarthritis. However, frequencies of osteoarthritis in a population can be affected by a range of causes, such as age, sex, weight, nutrition, hormones, infection, heredity, etc. (Larsen, 1997, p. 163). While the exact etiology of osteoarthritis and the relationship between changes in cartilage and changes in bone are not entirely clear, the skeletal manifestations of osteoarthritis are easily identifiable. The five main bone responses to osteoarthritis are: eburnation (a polished area resulting from bone-on-bone contact), osteophytosis (growth of new bone), joint contour change/lipping, porosity, and subchondral cysts (porosity of bone beneath the surface) (Rogers and Waldron, 1995). Following Rogers and Waldron (1995), a skeletal element was recorded as having evidence of osteoarthritis if it: a) showed eburnation; or b) presented any two of the other four bony responses: osteophytes, lipping, porosity, or subchondral cysts. Skeletal elements with only one of the four changes are assumed to be the result of degenerative changes or possible precursors to full-fledged osteoarthritis. Because osteoarthritis is found in populations all over the world, the patterns seen in the distribution of lesions in the body and throughout the population can indicate the effects of aging and stress (Larsen, 1997, p. 166).

Two conditions found in the study populations that are also related to mechanical stress on the body are disc herniation (Schmorl's node) and ankylosis (fusion of marginal osteophytes of the vertebrae). Herniation of the intervertebral discs of the spine can cause the discs to bulge; when the bone of the vertebral body remodels to accommodate this, what is known as a Schmorl's node is formed (figure 5.2a). Ankylosis occurs when new bone formation along the margins of two or more vertebral bodies (osteophytes) connect and fuse (figure 5.2b); this condition limits an individual's range of motion, particularly if it occurs in the more mobile cervical or lumbar spines.



(a) Schmorl's Nodes - Castellaccio Europarco ET102, male, 41-50 years old

(b) Ankylosis - Castellaccio Europarco ET41, older adult

Figure 5.2: Osteoarthritis

Summary results of the study of osteoarthritis in the Casal Bertone and Castellaccio Europarco populations are presented in table 5.2. There is a distinct lack of osteoarthritis information in the bioarchaeological literature of ancient Rome. Researchers occasionally publish frequencies of arthritis in the vertebral column, but there is never an indication of the methods used for data collection or analysis (e.g., Ottini et al., 2001). That is, the data published may be a mixture of age-related skeletal degeneration and the pathological condition of osteoarthritis. In order for my data to be comparable to other studies now and in the future, I provide both the number of individuals who presented at least one degenerative bony response (i.e., one of: osteophytes, lipping, porosity, subchondral cysts) and the number of individuals with osteoarthritis (i.e., eburnation and/or two or more of the above responses).

The total frequencies from the two Roman sites indicate a very similar prevalence of osteoarthritis as well as responses to mechanical stress on bone. At Casal Bertone, there is a slightly higher frequency of males with bony responses than at Castellaccio Europarco, but

	Casal Bertone		Castellaccio Europarco	
	Bony Response ≥ 1	Osteoarthritis	Bony Response ≥ 1	Osteoarthritis
Males	41/54 (75.9%)	18/54 (33.3%)	15/24 (62.5%)	9/24 (37.5%)
Females	15/24 (62.5%)	8/24 (33.3%)	6/7 (85.7%)	1/7 (14.3%)
Total	56/78 (71.8%)	26/78 (33.3%)	21/31 (67.7%)	10/31 (32.3%)

Table 5.2: Osteoarthritis Frequencies

the frequencies of osteoarthritis in the male groups at the two sites is similar. At Castellaccio Europarco, almost all of the females had at least one skeletal element that showed evidence of a bony response to stress, but only one of them met the criteria of osteoarthritis. On the other hand, there was a higher frequency of females at Casal Bertone who suffered from osteoarthritis than at Castellaccio Europarco. In both populations, males outnumber females about two to one in presenting evidence of degenerative changes to joints. This is not unusual, as cross-culturally, males tend to have higher frequencies of arthritis than females (Larsen, 1997, p. 176-8).[1]

The distribution of osteoarthritis is slightly different in the two populations. In both, arthritis of the thoracic portion of the spine is the most commonly occurring issue, making up 32% of arthritis sites at Casal Bertone and 52% at Castellaccio Europarco. Whereas arthritis of the cervical and lumbar vertebrae and legs follows thoracic vertebrae in frequency at Casal Bertone (17%, 17%, and 9%, respectively), at Castellaccio Europarco, issues with the feet and the shoulder girdle (scapula and clavicle) are more common than issues with the cervical and lumbar spine (12%, 12%, 6%, and 7%, respectively). Other areas of the body (e.g., hands, arms, knees, pelvis) are infrequently affected at both sites. Based on this small sample, it would appear that people at Castellaccio Europarco were putting more stress on their feet and upper bodies than the people at Casal Bertone, who were mainly stressing their spines and legs. However, it is possible that the generally poor preservation at Castellaccio Europarco prevented

[1]Larsen (1997, p. 176) further notes that this generality holds no matter the subsistence strategy or sociopolitical complexity. Still, he cites archaeological populations in which neither sex has a higher frequency of osteoarthritis (177).

identification of arthritic conditions, particularly in the fragile vertebral bodies.

Additionally, at Casal Bertone, Schmorl's nodes (figure 5.2a) were found in 12 males and 2 females, or about 18% of the population examined. At Castellaccio Europarco, Schmorl's nodes were found in three of the 31 individuals examined, for a frequency of 10%. The greater frequency of assumed disc herniations in the Casal Bertone population could represent greater mechanical loading of the spine, but it could also be related to the fact that these skeletons were better preserved than those from Castellaccio Europarco.

Ankylosis of the vertebrae was noted in two individuals, a middle-aged male from Casal Bertone (T76) and an adult of unknown sex from Castellaccio Europarco (ET41) (figure 5.2b). Little additional is known about ET41, as it was a partially complete skeleton that was fairly poorly preserved. T76, on the other hand, presented numerous Schmorl's nodes indicative of disc herniation, had multiple sites of osteophytosis particularly in the foot and shoulder areas, and had numerous indications of strong muscle attachments in his long bones. This individual therefore likely placed a great deal of repeated mechanical stress on his body.

One additional individual, F10A from the Casal Bertone mausoleum, seems to be a special case of arthritis (figure 5.3). This individual was probably a male and was in his 50s when he died, making him on the older end of the demographic distribution of the population. Nearly every bone in his body had some amount of degenerative change. The changes were especially marked in the hands and feet, particularly the phalanges and the short bones. Additionally, he presented a Schmorl's node, a healed rib fracture, significant muscle markers along the linea aspera of both femora, and periostitis of the tibia. Although some of the bony responses, particularly in the fingers, are suggestive of leprosy, there is no facial involvement. It is most likely that this individual suffered from rheumatoid arthritis, in addition to a host of other issues. Rheumatoid arthritis is an erosive arthropathy, a type of arthritis that results in bone destruction rather than bone growth. The cause of this condition is still unknown, but it could be a combination of environmental, infectious, and genetic issues. Rheumatoid arthritis generally strikes females more often than males, but a study found that about 4% of males over the age of

(a) Right Metatarsals. Healthy bones from T73 on top, arthritic ones from F10A on bottom.

(b) Hand Phalanges, Palmar Aspect.

Casal Bertone F10A, 51-60-year-old male

Figure 5.3: Rheumatoid Arthritis

65 in northern Europe had this condition (Ortner, 2003, p. 561-2). Like other forms of arthritis, rheumatoid arthritis can cause pain, swelling, and stiffness in joints and can eventually lead to deformities of the hands and feet. It is likely that individual F10A was often in pain from his rheumatoid arthritis, and his body had been stressed by other conditions as well, such as fracture and disc herniation.

5.1.3 Infectious Diseases

Infectious diseases that can be diagnosed from skeletal material include treponematoses (including syphilis), leprosy, and tuberculosis but also lesser known diseases such as osteomyelitis, periostitis, and mycotic, viral, and parasitic conditions. Although there were some vertebrae in the study populations that might be indicative of tuberculosis, there was no conclusive evidence at either Casal Bertone or Castellaccio Europarco for infectious diseases other than

	Casal Bertone	Castellaccio Europarco
Male	19/54 (35.2%)	12/24 (50%)
Female	7/24 (29.2%)	3/7 (42.9%)
Subadult	4/48 (8.3%)	1/14 (7.1%)
Total	30/126 (23.8%)	16/45 (35.5%)

Table 5.3: Periosteal Reaction - Individual Frequencies

osteomyelitis and periostitis. Osteomyelitis is a pyogenic (pus-producing) infection of bone marrow. Bacteria, usually *Staphylococcus aureus*, are introduced into the bone through direct trauma or indirectly from soft tissue injuries. Osteomyelitis can be identified on bone primarily through endosteal bone changes, the formation of cloacae (holes through which pus drains), and the development of sequestra (small pieces of dead bone) (Ortner, 2003, p. 181).

Anything that breaks, tears, stretches, or touches the periosteum, or outer layer of a bone, causes it to create new bone, a condition known as periostitis or, more appropriately, periosteal reaction. Generation of new periosteum is easy to spot on skeletal elements because of its woven appearance, but the cause of the apposition is nearly always impossible to figure out, as it could result from anything from shin splits to infectious disease to serious skin burns. Because of the multifarious causes of periosteal reaction, it is quite commonly seen in skeletal populations. Like osteoarthritis, periosteal reaction is usually examined in terms of the skeletal elements that it affects in an individual and in a population. It remains, however, a nonspecific indicator of skeletal pathology.

Periosteal reactions are not widely reported in the Roman bioarchaeological literature. For this study, I calculated the frequency in a manner similar to osteoarthritis: by counting the number of individuals with at least one occurrence of periosteal reaction and dividing it by the total number of individuals examined. Results can be seen in table 5.3.

Slightly more males than females have indications of periosteal reaction, probably the result of the fact that males tended to engage in more activities than females in Roman society, and a low number of subadults is affected. The total frequency of periosteal reaction at Casal Bertone is lower than that of Castellaccio Europarco, indicating the latter population was more stressed or more prone to trauma. Unsurprisingly, 73% of the periosteal lesions at Casal Bertone were on the legs, and 87% of the reactions at Castellaccio Europarco affected the legs, many of which were likely the result of clumsiness as people accidentally banged their shins and ankles.

Only one individual presented evidence of osteomyelitis, a male in his late teens from the Casal Bertone mausoleum (individual F4C). There was definite osteomyelitis of the left fifth metacarpal (figure 5.4) and the right radius, each of which presented with obvious cloacae, and possible osteomyelitic lesions of the left tibia, left fourth metacarpal, left hamate, and both calcanei. Because of the distribution of the lesions, it is possible this individual suffered from chronic osteomyelitis, which involves localized foci of infection that recur through time when triggered by physical stress (Larsen, 1997, p. 84).

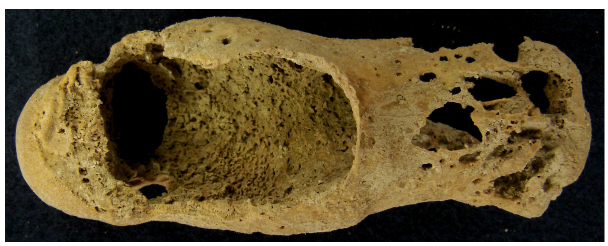


Figure 5.4: Osteomyelitis
Left fifth metacarpal; Casal Bertone F4C, male, 16-20 years old

Osteomyelitis is not necessarily fatal, although the pyogenic bacteria can compromise other organ systems if they do not remain localized. The expansion of the diaphysis of the left fifth metacarpal of F4C indicates an active or recently active disease process, as there is no indication of healing or remodeling of this bone. There was no further evidence, however, of this young man's possible cause of death.

5.1.4 Trauma

Evidence of trauma to bone, namely fractures and dislocations, was collected from both skeletal populations primarily as a way to assess whether people living in and near a major urban center were prone to problems of interpersonal violence. As with all other pathologies,

Skeleton	Sex	Age	Trauma	Side	Bone(s) Affected
ET68	F	41-50	Fracture	L	rib, medial
ET43	M	31-40	Fracture	R	fibula
ET41	I	Adult	Compression	L	L1
F10A	PM	51-60	Fracture	L	rib 2, medial
F11B	M	31-40	Fracture	L	rib, anterior
F1C	F	51-60	Spondylolysis		L5
F4B	F	51-60	Fracture	L	nasal
F6E	F	51-60	Fracture	R	humeral neck
			Fracture	R	rib 3-10, anterior
			Fracture	L	rib 3-10, anterior
F7B	M	16-20	Fracture	R	parietal
T10	M	31-40	Spondylolysis		L5
T18	PM	31-40	Dislocation	L	TMJ
T21	M	16-20	Fracture	R	MC 4
T24	M	51-60	Fracture	R	MC 5
T28	F	51-60	Fracture	L	clavicle
T40	M	21-30	Fracture	R	MC 1
T51A	F	61-70	Fracture	R	radius
T51B	I	0-5	Fracture		two ribs, medial
T56	I	11-15	Fracture	L	clavicle
T59	M	Adult	Compression		C vert
T61	PM	Adult	Fracture		fibula
T69A	M	41-50	Fracture		rib, medial
			Fracture	L	ulna
T9	I	0-5	Fracture	R	rib, medial

Table 5.4: Traumatic Injuries

comparatively few instances of trauma were discovered on the skeletons.

A fracture is simply a discontinuity of skeletal tissue, and it can range in severity from a minor, partial (greenstick) break to a traumatic, complete (comminuted) break. The fractures identified in the populations were almost all well-healed based on visual examination of the skeletal elements. A dislocation is the displacement of the two bones that form a joint. If the bones are not properly realigned following the injury, changes occur to the subchondral bone or to the bone adjacent to the joint (Ortner, 2003, p. 159). One individual suffered a dislocation of the left temporomandibular joint (TMJ), but otherwise no evidence of dislocations was found in the skeletal populations.

There were 24 instances of fractures in the populations of Castellaccio Europarco and Casal Bertone and a total of 21 individuals who suffered at least one traumatic injury. Individuals of both sexes and all ages present evidence of fracture, although it is unknown at what age each individual suffered the trauma. At Castellaccio Europarco, only three individuals suffered trauma out of a total of 45 individuals, or 7% of the population. At Casal Bertone, on the other hand, 19 individuals out of 126 (15%) presented evidence of trauma, over twice the frequency as at Castellaccio Europarco. Nevertheless, analysis of the proportions with Fisher's exact test of a two-by-two contingency table did not show statistical significance of the two proportions ($p = 0.20$). At Casal Bertone, 11 males suffered trauma, or a total of 20% of the male population. Five females suffered trauma out of 24 examined, or 21% of the female population. Out of 48 subadults, three had evidence of trauma, or 6% of the subadult sample.

In terms of body parts most affected by trauma, ribs accounted for eight of the fractures and vertebrae for four, followed by arm and hand bones (three each) and the clavicle, leg, and head (at two each). Ribs are easily fractured during physical activity, so it is not uncommon to see healed rib fractures in a skeletal population. Two of the vertebral fractures were likely compression in nature, and two were a special case known as spondylolysis, when the inferior portion of the vertebral arch is fractured through mechanical stress on the spine and the bone does not knit back together (figure 5.5a). All of these fractures could relate to heavy use of the body in activities that require lifting, bending, or jumping, and advancing age can be a contributing factor. Fractures of the arms and clavicles might reflect use of the upper body in physical activity, and fractures of the metacarpals could present evidence of use of the hands in physical confrontation, as they are often broken in hand-to-hand combat. The two leg fractures were to fibulae, which are long, thin bones that can be broken during falls or other activities that place stress on the lateral lower leg.

The two fractures of the skull that were found could be related to interpersonal violence rather than to accidents. F7B was a young male who had evidence of a depression fracture of his right parietal. The fracture was well-healed and showed no indication of what kind of object

(a) Spondylolysis of L5 - Casal Bertone T10, male, 31-40 years old

(b) Nasal Fracture - Casal Bertone F4B, female, 51-60 years old

Figure 5.5: Fractures

struck his head. This injury could have resulted from trauma inflicted by another individual or could have resulted from an accident: a trip-and-fall episode, or an object falling onto his head from a height. The other instance of cranial trauma comes from F4B, an older woman with a healed fracture on the left lateral border of her nasal aperture (figure 5.5b). This kind of nasal fracture generally results from a forceful blow that pushes the nose to the side rather than from an impact to the bridge of the nose (Walker, 1997, p. 154). Although it is possible that F4B accidentally broke her nose, her left nasal bone could have been fractured by a severe trauma to the face (i.e., a hard punch) by a right-handed assailant. The multiple injuries sustained by F6E, particularly the ribs, might add to evidence of violence against women, but the locations of the fractures and the possible mechanics of the trauma are not as clear as F4B's nasal injury. Finally, there is evidence that young children sustained fractures to the ribs. Although ribs can be fractured during a traumatic birth, rib fractures sustained by infants are predominantly caused by intentional injury (Bulloch et al., 2000).

Most of the fractures seen in the populations of Casal Bertone and Castellaccio Europarco can be attributed to accidental injury based on the location of the traumas and the possible mechanics behind them. Reliable identification of interpersonal violence based on healed fractures, however, is difficult to make. In a cross-cultural study of nonlethal cranial injuries, Phil Walker (1997) found a number of trends. Nasal fractures were the most common injury he found, followed by frontal and parietal injuries. Males were more often affected by cranial trauma than females. The left side of the cranium was twice as likely to be affected by trauma as the right side. In comparing the two major causes of cranial fractures - interpersonal violence and accidental injuries - among contemporary people, Walker (1997, p. 163) found that young and middle-aged individuals (15 to 50 years old) suffered cranial trauma largely from interpersonal violence. Individuals younger and older than this range more often suffered trauma because of falls. The cranial fractures suffered by F7B and F4B are therefore consistent with interpersonal violence; of course, accidental injury cannot be ruled out. The rib fractures on the female F6E and the children T9 and T51B could also have been inflicted by another person, although accidental falls are equally plausible. Finally, three males presented fractured right metacarpals (T21, T34, and T40). These fractures were all at approximately midshaft and healed with slight angulation of the bone, which are characteristics of so-called "boxer's fractures" (Rogers, 1992) resulting from landing a blow with a clenched fist. Whether these men fractured their hands in punching another person, however, cannot be determined.

Several male individuals present plausible evidence of having inflicted trauma, and several females and children present plausible evidence of having had trauma inflicted on them. However, more research involving identification of traumatic injuries, particularly in women and children, is needed before making blanket statements about violence in ancient Rome. Given the fact that a large percentage of the male population at Rome was likely to have been involved in the military at some point in their lives, it is surprising that there are so few traumatic injuries seen. Trauma has not been studied comprehensively in the published literature of Roman bioarchaeology, so it is unknown how the populations of Casal Bertone and Castellaccio Europarco compare to other urban and suburban sites.

5.1.5 Congenital Issues

The congenital pathologies identified on the skeletons were mostly related to the spine (spina bifida and scoliosis), but there was also one case of possible clubfoot (table 5.5). The cases of spina bifida are straightforward, an example of which can be seen in figure 5.6a. Spina bifida, a common defect of the fusion of the vertebral arches that leaves the spinal cord unprotected, was found in three younger individuals. Modern clinical evidence indicates that a deficiency of folic acid in the gestating mother can lead to spina bifida in the fetus. It is difficult to tell the severity of this defect in the absence of connective tissue, which can mask the vertebral arch deficiency, but all three individuals do not seem to have suffered any serious complications, such as paraplegia.

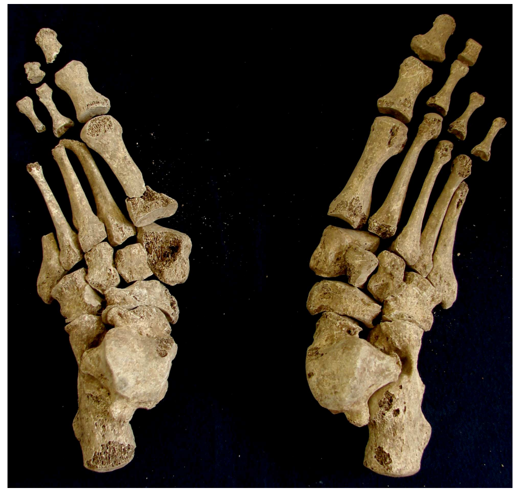
Skeleton	Sex	Age	Pathology	Bone(s) Affected
ET69	M	21-30	scoliosis	vertebrae
ET27	PM	16-20	bilateral clubfoot	fibulae, tarsals, MTs, phalanges
ET18	F	21-30	spina bifida	sacrum
F1A	F	16-20	spina bifida	sacrum
T53	PM	21-30	spina bifida	sacrum

Table 5.5: Congenital Pathologies

Scoliosis, an abnormal lateral curve in the spine, is harder to recognize than spina bifida in the ancient skeleton because slight deformities might not be seen in disarticulated vertebrae. Only one individual from Castellaccio Europarco presented a lumbar spine whose anterior view resembled a lateral curve. As the thoracic and cervical spine appeared normal and there was no indication of asymmetrical development of, for example, the ribs, it is possible that this individual suffered instead from compression of the lumbar spine.

Individual ET27 from Castellaccio Europarco might have suffered from the congenital condition of bilateral clubfoot. It is difficult to distinguish between congenital conditions and those that were caused by a paralytic condition later in childhood, such as polio or multiple sclerosis. ET27's condition was noticed first in the tarsals of each foot, five of which (calcanei, tali, naviculars, cuboids, and third cuneiforms) have significantly enlarged articular facets that show evidence of lipping and osteophyte formation. Both tibiae and fibulae have areas of periostitis, and the metatarsals and phalanges are all very lightweight with thinner than normal shafts. The vertebrae and pelvis appeared to be unaffected. Archaeological notes indicate this individual

(a) Spina Bifida - Castellaccio Europarco ET18, female, 21-30 years old



(b) Possible Clubfoot - Castellaccio Europarco ET27, probable male, 16-20 years old

Figure 5.6: Congenital Pathologies

was found with rows of nails at his feet, likely the remains of a type of tall Roman sandal. This individual's gait was probably different than normal, likely affected by supination of the feet. The cause of this foot problem is unknown, but a congenital issue or a disease in childhood are possible explanations.

5.1.6 Tumors

Tumors in the human skeleton are usually the result of abnormal proliferation of bone, cartilage, or fibrous tissue. When a tumor is localized and consists of mature bone, it is considered benign, but when its growth is unchecked by the body, it can affect other bones and is called malignant (Ortner, 2003, p. 503). Only benign tumors were found in the skeletal populations from Rome (table 5.6).

Osteomata are commonly found on skeletal remains, almost always on the skull bones, and are sometimes called button osteomata because of their shape and size. Individual T14 had an osteoma on the endocranial surface of his frontal bone. Auditory exostoses are osteomata of the external auditory meatus, the ear canal, often found in archaeological skeletons (figure 5.7a). In a study of auditory exostoses from the population at Portus and Lucus Feroniae, Manzi

Skeleton	Sex	Age	Pathology	Bone(s) Affected
ET43	M	31-40	auditory exostosis	left temporal
T10	M	31-40	auditory exostosis	both temporals
T14	M	21-30	osteoma	frontal, endocranially
T37	PM	31-40	auditory exostosis	right temporal
T7	M	41-50	osteochondroma	left tibia

Table 5.6: Benign Tumors in the Imperial Populations

(a) External Auditory Exostosis - Casal Bertone T10, 31-40-year-old male

(b) Osteochondroma - Casal Bertone T7, 41-50-year-old male

Figure 5.7: Benign Tumors

and colleagues (1991) found a lack of exostoses in females but a high frequency in males from Portus. They suggest that men's habit of using public baths could have contributed to the differential development of the exostoses in the two sexes. A more recent analysis (Crowe et al., 2010) has suggested that individuals with exostoses at the Tyrrhenian coastal cities of Portus and Velia were engaged in water-related occupations, as higher than average consumption of seafood was found in a dietary analysis of these individuals.[2]

The three individuals with auditory exostoses from Rome were all middle-aged males. Analysis of skeletons from the cemetery at Basiliano just east of Casal Bertone indicated that

[2]Exposure to cold water cannot be seen as the exclusive etiology for auditory exostoses, however, as several pathological conditions that affect the ear canal could result in an exostosis (Hutchinson et al., 1997).

6% of the population examined had auditory exostoses, but no criteria were provided for how this figure was calculated nor the sex ratio of the presence of the tumor (Buccellato et al., 2003). Additional analysis of skeletons from Rome is needed in order to investigate sex bias in the development of this condition.

Individual T7 presented a probable osteochondroma of the proximal tibia. An osteochondroma is an exostosis of cartilage rather than bone, likely the result of overproduction of cartilage during growth, and is a benign tumor. These lesions are typically found at the metaphyses of long bones, most commonly the distal femur and proximal tibia (Ortner, 2003, p. 508). The tibia of T7 was badly damaged, by either taphonomic processes or intra vitam erosion of the bone, but the location and appearance of the growth is consistent with osteochondroma (figure 5.7b). Because the left leg bones were fragmentary, it is unclear if the osteochondroma affected this individual's gait.

5.1.7 Miscellaneous Pathologies

A few additional pathologies could be identified in the two study populations, including occurrences of myostitis ossificans, abnormal fusion of the sternum, and hyperostosis of the cranium. Five individuals presented evidence of myostitis ossificans, a condition characterized by excessive bone formation by muscle tissue, often secondary to trauma. The most often affected skeletal locales are the insertion and origin points of the extensor and adductor muscles of the upper leg (Ortner, 2003, p. 134). The extra bone formation on the leg bones of F11B, T73, and ET43 are consistent with myostitis ossificans of the thigh muscles. ET57 has extraneous bone on the clavicle at the origin of the deltoid muscle. One additional individual, F7B, appears to have the condition on the inferior aspect of his occipital (figure 5.8a), at the origin of the digastric muscle.[3]

Three individuals, two males from Castellaccio Europarco and one male from Casal Bertone,

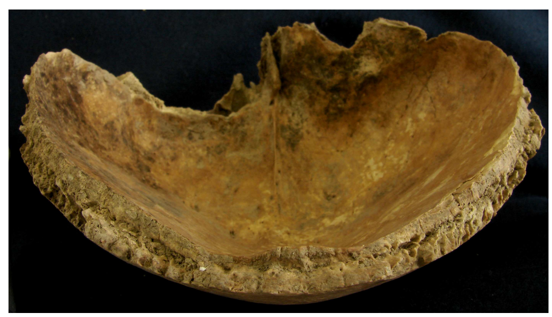
[3]Interestingly, individual ET82, a middle-aged male from Phase 1 at Castellaccio Europarco, presented an identical pillar of bone on the inferior occipital.

Skeleton	Sex	Age	Pathology	Bone(s) Affected
F7B	M	16-20	myostitis ossificans	occipital
F11B	M	31-40	myostitis ossificans	right tibia
T73	M	31-40	myostitis ossificans	right femur
ET57	PM	41-50	myostitis ossificans	right clavicle
ET43	M	31-40	myostitis ossificans	left femur
ET103	PM	31-40	abnormal fusion	sternum
ET52	PM	21-30	abnormal fusion	sternum
F7B	M	16-20	abnormal fusion	sternum
T53	PM	21-30	abnormal fusion	disto-lateral humeral epiphysis
F13C	F	41-50	internal frontal hyperostosis	frontal and parietals

Table 5.7: Miscellaneous Pathologies

had abnormally fused sterna. A variety of conditions can affect the shape and the size of the sternum (Ortner, 2003, p. 471), so the etiology of these fused sterna is unclear. One individual had a misfused disto-lateral humeral epiphysis, which was either congenital or the result of physiological stress on the bone during growth.

(a) Myostitis Ossificans - Casal Bertone F7B, 16-20-year-old male. Cranial base is up.



(b) Internal Frontal Hyperostosis - Casal Bertone F13C, 41-50-year-old female. Endocranial is up.

Figure 5.8: Miscellaneous Pathologies

A thickening of the endocranial surface of the frontal bone is found most often in post-menopausal women as a result of hormonal changes (Ortner, 2003, p. 416). This condition is known as internal frontal hyperostosis, and it does not appear to adversely affect a person. Individual F13C from Casal Bertone, a female in her early 40s, appears to have had this condition (figure 5.8b), which likely would not have been noticed had her cranium not been disarticulated.

5.2 Dental Pathology

This section reports the analysis of pathological conditions of teeth at Casal Bertone and Castellaccio Europarco. Each tooth present was assessed for evidence of calculus, carious lesions, and enamel hypoplasias, and each tooth socket was assessed for dental abscesses and tooth loss.

In all, 2,995 teeth and 3,480 sockets were examined from the two populations. Teeth were given a code for presence or absence based on *Standards* (Buikstra and Ubelaker, 1994). The number of individuals analyzed from each sample was generated by adding individuals with at least one tooth that could be scored as 1 (present, not in occlusion), 2 (present, in occlusion), 4 (antemortem loss), 5 (postmortem loss), 7 (present but damaged), and 8 (present but unobservable), for a total of 109 individuals at Casal Bertone and 34 individuals at Castellaccio Europarco. The number of teeth in each sample was calculated by adding teeth with scores of 1, 2, 7, and 8: 2,279 at Casal Bertone and 716 at Castellaccio Europarco. Finally, the number of observable sockets was calculated by summing all teeth with scores 1, 2, 4, 5, 7, and 8: 2,618 at Casal Bertone and 862 at Castellaccio Europarco. Frequency data for some of the dental pathologies deviates from the totals above. A tooth that has a large, destructive carious lesion, for example, can be scored for caries but not for calculus. For overall counts and percentages, subadult and adult teeth were added together in order to provide a clearer picture of the pathology load of the entire population. Deciduous teeth are treated separately at the end of the chapter, however. Table 5.8 shows the age and sex distribution for the individuals from both Casal Bertone and Castellaccio Europarco included in this dental pathology study.

5.2.1 Demographics of the Samples

There were 109 individuals from Casal Bertone for whom at least one tooth was present. Of these, 80 had one or more adult teeth, 26 had mixed dentition, and 3 had only deciduous teeth. In terms of age and sex, there were 46 males, 20 females, 6 adults of indeterminate sex, and 37 subadults. The underrepresentation of females compared to males in this population is statistically significant ($\chi^2 = 10.242, p = 0.0014$). Only in the 31-40 age category, however, is there a significant difference in the number of male and female individuals ($\chi^2 = 8.067, p = 0.0045$).

	Casal Bertone				Castellaccio Europarco			
Age Range	Male	Female	Unknown	Total	Male	Female	Unknown	Total
0-10			23	23			8	8
11-20	7	4	14	25	4	0	1	5
21-30	6	4	0	10	3	1	0	4
31-40	13	2	1	16	6	0	0	6
41-50	8	4	0	12	3	3	0	6
51+	3	4	0	7	0	0	0	0
Adult	9	2	5	16	2	0	3	5
Totals	46	20	43	109	18	4	12	34

Table 5.8: Age and Sex Distribution of Dental Series

Of the 45 individuals examined from Castellaccio Europarco, 34 (76%) had at least one tooth present. There were 26 individuals with adult teeth, 1 with all deciduous teeth, and 7 with mixed dentition. This can be broken down into 18 males, 4 females, 4 adults of indeterminate sex, and 8 subadults. Females represent only 12% of the population, and there is a significant difference in the number of males and females ($\chi^2 = 8.909, p = 0.0028$). The lack of adult females in this population, with zero in four of the age categories, means that analysis of dental data based on sex will not yield significant results.

Both Casal Bertone and Castellaccio Europarco suffer from an underrepresentation of females, not only in terms of teeth available for study but also in terms of individuals represented by skeletal material (see chapter 4). It is difficult to further compare the demographic structure of Castellaccio Europarco with that of Casal Bertone because of the small size of the sample.

5.2.2 Dental Calculus

Plaque that mineralizes on a tooth is called calculus (figure 5.9a). Calculus is composed of a variety of minerals and can trap phytoliths and food particles. Since saliva contains the minerals involved in plaque formation, calculus tends to affect teeth situated near the salivary glands of the mouth. The lingual surface of the incisors and canines and the buccal surfaces of the molars are thus the most likely to be affected (Hillson, 1996). Each tooth was scored for the presence or absence of calculus based on *Standards* (Buikstra and Ubelaker, 1994): small, moderate, or large amounts. On account of the small sample sizes, however, the results reported here group the three calculus categories into a single presence variable to compare with complete absence of calculus.

At Casal Bertone, 515 of the 1,459 adult teeth analyzed (35%) had some degree of calculus formation. The type of tooth most affected by calculus was the incisor, followed by the canine, with 45% of all incisors and 39% of all canines showing some evidence of calculus. Although there was no preference for left- or right-sided calculus, the mandibular arcade was more often affected (41% of mandibular teeth affected) than the maxillary arcade (27% of maxillary teeth affected), with a statistically significant difference in prevalence ($\chi^2 = 40.018, p < 0.0001$).

Overall, within the population of Casal Bertone, 76 individuals had calculus on their teeth, or 70% of the population. Table 5.9 shows the distribution of calculus based on age and sex. There is a clear increase through time, with older individuals generally being more often affected by calculus than younger individuals. In modern populations, men tend to have higher frequencies of calculus than women (Hillson, 1996, p. 260), but males and females were equally affected at Casal Bertone.

Castellaccio Europarco presented a higher percentage of teeth with calculus (51%) and a higher frequency of individuals affected by calculus (85%) than Casal Bertone. Although right-sided teeth were more often affected (55%) than left-sided teeth (47%), this is not a statistically significant difference. As expected, incisors and canines have a higher frequency of calculus (69% and 54% respectively) than premolars and molars. Mandibular teeth (57%) were

Age	Casal Bertone Male	Female	Unknown	Total	Castellaccio Europarco Male	Female	Unknown	Total
0-10			34.8	34.8			50	50
11-20	85.7	25	71.4	68	100	-	100	100
21-30	100	75	-	90	100	100	-	100
31-40	92.3	100	0	87.5	100	-	-	100
41-50	87.5	100	-	91.6	100	100	-	100
51+	66.7	100	-	85.7	-	-	-	-
Adult	66.7	50	0	43.8	100	-	33.3	60
Totals	84.8	75	41.9	69.7	100	100	62.5	85.3

Dashes indicate that no individuals were examined in that age and sex category.

Table 5.9: Frequency (%) of Individuals with Calculus

significantly more likely to have calculus than maxillary teeth (45%) ($\chi^2 = 6.154, p = 0.0131$). Out of the 34 individuals examined, 29 (85%) had some amount of calculus on their teeth. The small sample size makes it impossible to note trends in terms of sex or age.

At both sites, the frequency of calculus among adults was quite high. Castellaccio Europarco appears to have a somewhat higher overall frequency of calculus within the population as all adult individuals are affected, and subadults had higher frequencies of calculus. The mandibular incisors and canines were the teeth most affected by calculus, as shown in table 5.10. This table also demonstrates the consistently higher frequency of calculus at Castellaccio Europarco in all tooth types.

The small sample size makes hypothesizing about the differences between the two populations difficult. It is possible that the two groups were eating different food, or biological and morphological variation could account for the differences in calculus formation.

5.2.3 Carious Lesions

The disease process of dental caries results in demineralization of tooth enamel (see figure 5.9b) and is caused by a variety of factors, including bacteria, saliva, and plaque in the mouth as well as dietary practices (Larsen, 1997). A total of 2,542 teeth from 143 individuals were examined for the presence of dental caries based on the guidelines in *Standards* (Buikstra

Arcade	Tooth	Casal Bertone affected	Casal Bertone examined	Casal Bertone % affected	Castellaccio Europarco affected	Castellaccio Europarco examined	Castellaccio Europarco % affected
Maxilla							
	Incisors	33	171	19.3	25	55	45.5
	Canine	28	90	31.1	15	36	41.7
	Premolars	49	168	29.2	28	70	40
	Molars	74	250	29.6	42	85	49.4
Mandible							
	Incisors	125	184	67.9	54	60	90
	Canine	49	96	46.9	23	35	65.7
	Premolars	74	214	34.6	36	71	50.7
	Molars	83	286	29.0	37	90	41.1
Total		515	1459	35.3	260	502	51.8

Table 5.10: Calculus Frequency (%) by Tooth

(a) Calculus - Casal Bertone F1C, 21-30-year-old female

(b) Caries - Castellaccio Europarco ET18, 21-30-year-old female

Figure 5.9: Dental Pathologies - Calculus and Caries

and Ubelaker, 1994). Lesions were recorded based on location: occlusal surface, interproximal surface, smooth surface, cervical lesion, root lesion, large lesion, and noncarious pulp exposure. In this analysis, root lesions are omitted because of their different etiology (Hillson, 1996), and noncarious pulp exposure is omitted because it is not a true lesion (Buikstra and Ubelaker, 1994).

Researchers have used a variety of techniques to report dental caries in skeletal samples. The method most often used in the past to report dental caries frequencies is calculated by dividing the number of teeth with carious lesions by the number of teeth observed in the sample

(Larsen et al., 1991). This statistic, however, can over-represent dental caries within a population if a small number of individuals have numerous lesions. Frequencies of carious lesions were also calculated for individuals, and this statistic is not affected by the degree of caries in any one individual (Hutchinson, 2002). These calculations do not account for antemortem tooth loss (AMTL) that might have resulted from carious lesions. At least three different researchers have proposed methods to correct this. The diseased missing index (DMI), also called the decayed, missing, filled index (DMF), involves adding the carious teeth and the teeth lost antemortem and dividing that by the sum of observable teeth and teeth lost antemortem (Klein et al., 1938). This index, however, assumes that all teeth lost antemortem were the result of dental caries, when in reality periodontal disease can also cause AMTL (Hillson, 1996). The caries correction factor created by Lukacs (1995) uses AMTL and carious pulp exposure. Because this study did not collect information on carious pulp exposure, the caries correction factor cannot be applied. Hillson (1996) notes that because carious lesions are more common in molars, which tend to be less affected by postmortem loss, a population with a large number of anterior teeth lost postmortem will have an inflated carious lesion frequency. Erdal and Duyar (1999) developed a proportional correction factor for samples that deviate from the expected ratio of incisors to canines to premolars to molars. In a normal quadrant of the mouth, there are 3 anterior and 5 posterior teeth, which produces a ratio of 0.6. At Casal Bertone and Castellaccio Europarco, of the teeth examined for carious lesions, the ratios of anterior to posterior teeth were 62% and 61% respectively, so the proportional correction factor should not change the frequency of carious lesions in either population. Therefore, no caries correction factors were used in this study. Reported in this section are tooth frequency (number of teeth affected) in table 5.11 and individual frequency (individuals affected) in table 5.12. In both tables, the first line in an age category is the count and the second line is the frequency. For these tables, subadults are included for the purpose of generating a carious lesion frequency for the entire population. The deciduous dentition will be further broken down in a subsequent section.

	Casal Bertone				Castellaccio Europarco			
Age	Male	Female	Unknown	Total	Male	Female	Unknown	Total
0-10			7/219	7/219			0/95	0/95
			3.2	3.2			0	0
11-20	7/182	2/68	7/304	16/554	2/95	-	0/26	2/121
	3.9	2.9	2.3	2.9	2.1	-	0	1.7
21-30	4/151	1/59	-	5/210	2/87	3/26	-	5/113
	2.7	1.7	-	2.4	2.3	11.5	-	4.4
31-40	15/341	0/34	1/21	16/396	29/116	-	-	29/116
	4.4	0	4.8	4.0	25	-	-	25
41-50	10/180	17/112	-	27/292	4/46	7/79	-	11/125
	5.6	15.2	-	9.3	8.7	8.9	-	8.8
51+	6/55	5/82	-	11/137	-	-	-	-
	10.9	6.1	-	8.0	-	-	-	-
Adult	8/49	1/35	2/25	11/109	2/27	-	3/28	5/55
	16.3	2.9	8.0	10.1	7.4	-	10.7	9.1
Overall #	50/958	26/390	17/569	93/1917	39/371	10/105	3/149	52/625
Overall %	5.2	6.7	3.0	4.9	10.5	9.5	2.0	8.3

Dashes indicate that no individuals were examined in that age and sex category.

Table 5.11: Dental Caries - Number and Frequency of Teeth Affected

The Casal Bertone population had an overall carious lesion frequency of 4.9%. This number is relatively low for an agricultural population. Larsen (1997) calculated total carious lesion percentages based on data from Turner (1979) and found that foraging populations averaged a carious lesion frequency of 1.7%, mixed foraging and agricultural populations were 4.4%, and agricultural populations had a frequency of 8.6%.[4] The high frequency of carious lesions in agricultural populations in the Americas has been attributed to the rise in consumption of maize, a cariogenic food. In Europe, high carious lesion frequencies have been linked to eating honey and sweet sticky fruits (Larsen, 1997, p. 71). The low Casal Bertone carious lesion frequency, however, needs a different explanation. The most likely causes include a diet low in cariogenic foods or good dental hygiene. Both of these explanations will be explored further below and in chapter 6. As expected, the majority of carious lesions were found in molars,

[4]Nevertheless, other studies have shown that populations do not necessarily conform to these expected carious lesion frequencies. Hutchinson (2002), for example, found high frequencies of teeth affected by caries, 17-19%, in non-agricultural Native American populations on the North Carolina coast.

Age	Casal Bertone				Castellaccio Europarco			
	Male	Female	Unknown	Total	Male	Female	Unknown	Total
0-10			7/23	7/23			0/8	0/8
			30.4	30.4			0	0
11-20	3/7	2/4	4/14	9/25	1/4	-	0/1	1/5
	42.9	50	28.6	36	25	-	0	20
21-30	3/6	1/4	-	4/10	1/3	1/1	-	2/4
	50	25	-	40	33.3	100	-	50
31-40	8/13	0/2	1/1	9/16	4/6	-	-	4/6
	61.5	0	100	56.3	66.7	-	-	66.7
41-50	3/8	4/4	-	7/12	1/3	3/3	-	4/6
	37.5	100	-	58.3	33.3	100	-	66.7
51+	2/3	3/4	-	5/7	-	-	-	-
	66.7	75	-	71.4	-	-	-	-
Adult	3/9	1/2	2/5	6/16	1/2	-	1/3	2/5
	33.3	50	40	37.5	50	-	33.3	40
Overall #	22/46	11/20	14/43	47/109	8/18	4/4	1/12	13/34
Overall %	47.8	55	32.6	43.1	44.4	100	8.3	38.2

Dashes indicate that no individuals were examined in that age and sex category.

Table 5.12: Dental Caries - Number and Frequency of Individuals Affected

with a decreasing prevalence towards the anterior teeth. The mandibular teeth were slightly more affected by carious lesions (5.3% of teeth) than the maxillary teeth (4.5%), but this result is not statistically significant. Carious lesions affected left-sided teeth (5.3% of teeth) more than right-sided (4.6%), but there is no statistical significance to this difference. Of the 93 lesions, the most common were interproximal lesions (61.1% of all lesions), followed by occlusal (16.7%), large (14.4%), cervical (4.4%), and root (3.3%). No instances of noncarious pulp exposure were noted in this population.

Males and females had slightly different frequencies of carious lesions, with 5.1% of male teeth and 6.7% of female teeth having a lesion. This difference was tested using the Mann-Whitney U statistic and found not to be significant. When carious lesions are examined by individual, 47.8% of males suffered from at least one lesion and 55% of females did. It appears that females had slightly more carious lesions than males did, both in terms of teeth affected (degree) and in terms of individuals affected. This is not unusual, as there is often a greater caries prevalence in females in a population (Larsen, 1997, p. 72). There is a slight increase in carious lesion prevalence based on increasing age, particularly in the number of male teeth affected. Interestingly, females age 41-50 have a 15% carious lesion frequency by teeth. However, these 112 teeth come from only 4 individuals. These females could have had a different diet or could have lacked the dental hygiene that other adults in the population had.

The population from Castellaccio Europarco had an overall carious lesion frequency of 8.3%, which is reasonable for a population that subsisted on a largely agricultural diet. This frequency could be influenced by diet, such as the consumption of sticky, carbohydrate-based foods, or by dental hygiene. The majority of the 52 lesions noted were discovered on molars, with 13.7% of all molars in the sample affected by caries. Surprisingly, there is a higher frequency of carious lesions on the incisors (n=7, 4.9% of all incisors) than on the canines (n=2, 2.7% of all canines). This could be related to the small sample size or to the degree of wear on the anterior teeth of this population. The maxillary teeth (10.9%) were more often affected by carious lesions than the mandibular teeth (7.4%), and left-sided teeth (9.8%) were more affected than right-sided teeth (8.3%). Neither of these results is statistically significant, however. Of the 52 lesions, the majority were interproximal lesions (53.9%), followed by large carious lesions (15.4%), cervical lesions (11.5%), occlusal lesions (9.6%), and root lesions (1.9%). There were four instances of noncarious pulp exposure noted, but these were not tabulated with the data for this analysis.

Within the Castellaccio Europarco population, male teeth were more often affected than female teeth (10.5% and 9.5% of teeth, respectively); however, 44% of males had at least one carious lesion whereas 100% of females did. The difference in individuals is most likely due to the very small sample, as only four female adults had teeth that could be examined. Three of these were in the 41-50 age category, which is an advanced age for a Roman woman. The paucity of adult individuals in general means that no statistically significant results can be obtained in terms of age and sex differences. No deciduous teeth from this population had carious lesions.

The two sites in this study are contemporaneous but were located about 12 km apart in antiquity: Casal Bertone was just outside the city walls of Rome, while Castellaccio Europarco was located in the *suburbium*. The archaeological context of Casal Bertone implies that this was an agricultural and industrial area as indicated by the presence of a villa and a fullery or tannery, whereas Castellaccio Europarco had only a villa and was likely a largely agricultural area in the suburbs. The overall carious lesion frequency for Casal Bertone (4.9%) is significantly lower than that of Castellaccio Europarco (8.3%). The two most likely explanations for this difference are diet and dental hygiene. The population at the more intensely agricultural Castellaccio Europarco might have been eating more cariogenic foods, while the population at Casal Bertone might have had more access to meat. In general, individuals who practiced a skilled trade in Rome, whether slave or free, were of a higher status and had more income than farmers (Bradley, 1994; Garnsey, 1988), which could explain more access to meat and the consumption of a different diet at Casal Bertone. Dental hygiene could also have contributed to the frequency of carious lesions. Some Romans did clean their teeth, with a variety of substances, and higher status individuals were more likely to do so (Cruse, 2004). Dietary differences between Casal Bertone and Castellaccio Europarco will be discussed in more detail in chapter 6.

5.2.4 Dental Abscesses

Untreated caries or other inflammatory processes can lead to a dental abscess, which is the accumulation and eventual drainage of pus through the jawbone (see figure 5.10a). Most abscesses create a tunnel or fistula on the buccal side of the jaw because of the thin bone in this area, but they can also appear lingually (Hillson, 1996). Few abscesses were found in either population: 23 at Casal Bertone and 16 at Castellaccio Europarco. This number could be artificially low because abscesses were only scored when there was a fistula in the bone. The jaws were not examined for abscesses that did not break through the bone.

There were 1,950 adult tooth sockets observed from the Casal Bertone population and

29 abscesses, for a frequency of 1.5% of all sockets that were affected by an abscess. The majority of these abscesses were located on the buccal/labial side of the mouth (n=15, 65%) and in the maxillary arcade (n=14, 61%). Molars were most affected, with 65% of abscesses being associated with that tooth type, followed by incisors (22%), premolars (9%), and canines (4%). In terms of sex, 1% of all male sockets had an abscess, while 2% of all female sockets were affected. This difference is not statistically significant, however. Of the 86 individuals from Casal Bertone who presented sockets that could be assessed for an abscess, 20 had at least one abscess (23%).

There were 16 abscesses found in 702 observable sockets at Castellaccio Europarco, for a frequency of 2% of sockets affected by abscesses. Of these, 12 (75%) were located buccally/labially. Maxillary and mandibular sockets were equally affected (50%). Eight of the 16 abscesses were found on molars (50%), followed by incisors (31%), premolars (13%), and canines (6%). In this population, male sockets had a slightly higher frequency of abscesses (3%) than female sockets (2%), although the difference is not statistically significant. Of the 25 individuals from Castellaccio Europarco who presented sockets that could be assessed for an abscess, 9 had at least one abscess (36%).

Because of the small number of abscesses present in these populations, further breakdown based on age and sex categories was not done. Castellaccio Europarco does have a slightly higher frequency of abscesses than Casal Bertone, which is not unexpected considering the higher frequencies of calculus and carious lesions in this population as well.

5.2.5 Tooth Loss

Postmortem Tooth Loss. Teeth are often lost after death in an archaeological context as the soft tissue structures that help anchor teeth to the jaw during life disintegrate. Poor archaeological recovery techniques also contribute to the phenomenon of missing teeth. The most frequently lost teeth are the single-rooted incisors and canines, and molars are often retained on account of their numerous splayed roots. All teeth were given a presence/absence score

(a) Abscess - Casal Bertone T13, 61-70-year-old male

(b) AMTL - Castellaccio Europarco ET40, 41-50-year-old female

Figure 5.10: Dental Pathologies - Abscess and AMTL

based on *Standards*, with one code specifically denoting "missing, with no alveolar resorption: postmortem loss" (Buikstra and Ubelaker, 1994, p. 49).

At Casal Bertone, there were 219 teeth recorded as missing postmortem out of 2,618 observed sockets, a frequency of 8% teeth missing. Predictably, the incisors were lost most often, accounting for 47% of all teeth lost postmortem, followed by canines (21%), premolars (17%), and molars (15%). The frequency of postmortem loss was a bit higher at Castellaccio Europarco, with 100 teeth lost out of 862 sockets (12%). Out of these 100 lost teeth, 54% were incisors, 18% canines, 14% premolars, and 14% molars.

Antemortem Tooth Loss. Diseased and decayed teeth can fall out of the mouth during an individual's life, and the alveolus will heal, leaving a smooth, flat area where a tooth once was (see figure 5.10b). Although periodontal disease, which involves a loss of alveolar bone, can lead to tooth loss, it is not always possible to attribute antemortem tooth loss (AMTL) to caries, periodontitis, dental hygiene, or diet (Larsen, 1997, p. 77-8). There does, however, seem to be a correlation between the frequencies of carious lesions and AMTL in many populations (ibid.). In the Roman world, ancient authors such as Celsus (*de Medicina* VII.12) attest to the extraction of painful or decayed teeth, although it was more common for a physician to prescribe a poultice for healing the tooth and gums (Cruse, 2004). Some skeletal evidence exists of dental surgery in ancient Italy (Robb, 1997). Antemortem loss was noted based on *Standards* (Buikstra and Ubelaker, 1994, p. 49): tooth "missing, with alveolus resorbing or fully resorbed: premortem loss."

AMTL frequencies in both populations were relatively low, with 4.6% of teeth (120 out of 2,618) lost antemortem at Casal Bertone and 5.3% (46 out of 862) at Castellaccio Europarco. Table 5.13 breaks down the frequency of loss by age and sex categories.

	Casal Bertone				Castellaccio Europarco			
Age	Male	Female	Unknown	Total	Male	Female	Unknown	Total
0-10			1/23	1/23			0/8	0/8
			4.4	4.4			0	0
11-20	0/7	0/4	0/14	0/25	1/4	-	0/1	1/5
	0	0	0	0	25	-	0	20
21-30	0/6	0/4	-	0/10	2/3	1/1	-	3/4
	0	0	-	0	66.7	100	-	75
31-40	9/13	1/2	1/1	11/16	6/6	-	-	6/6
	69.2	50	0	68.8	100	-	-	100
41-50	6/8	2/4	-	8/12	1/3	1/3	-	2/6
	75	50	-	66.7	33.3	33.3	-	33.3
51+	3/3	3/4	-	5/7	-	-	-	-
	100	75	-	71.4	-	-	-	-
Adult	2/9	0/2	0/5	2/16	0/2	-	1/3	1/5
	22.2	0	0	12.5	0	-	33.3	20
Overall #	20/46	6/20	2/43	27/109	10/18	2/4	1/12	13/34
Overall %	43.5	30	4.7	24.8	55.6	50	8.3	38.2

Dashes indicate that no individuals were examined in that age and sex category.

Table 5.13: AMTL - Number and Frequency of Individuals Affected

Molars were lost most frequently at Casal Bertone, with 58% of all AMTL affecting this tooth type, followed by premolars (23%), incisors (15%), and canines (4%). Of the male individuals present, 44% lost at least one tooth prior to death, and 30% of females lost one or more teeth. This difference is not, however, statistically significant. The frequency of AMTL appears to increase with an individual's age. At Castellaccio Europarco, the AMTL frequency is 5.3%, or 46 teeth lost from 862 observable sockets. Of the 46 lost teeth, 27 were molars (59%), while incisors accounted for 24% of teeth lost (n=11), premolars for 13% (n=6), and canines for 4% (n=2). Males and females were affected relatively equally, with 56% of males and 50% of females suffering at least one instance of AMTL (see table 5.13). Because of the scattered data available for this population, no conclusions about age differences can be made. The patterns of tooth loss at both Casal Bertone and Castellaccio Europarco are similar. The overall frequency is very close, molars were most affected at both sites, and males were affected slightly more often than females.

5.2.6 Enamel Hypoplasias

Hypoplasias are macrodefects in dental enamel, usually in the form of a line or a pit, and are thought to represent non-specific, systemic metabolic stress that lasts from several weeks to months and concomitantly disrupts amelogenesis (enamel development) (Larsen, 1997, p. 47). Anterior teeth (incisors and canines) are more often affected by hypoplasias than posterior teeth (premolars and molars). By measuring the distance between the center of the hypoplasia and the cementoenamel junction, it is possible to calculate the approximate age in an individual's life at which the disruption occurred (Martin et al., 2008). Many researchers have found that hypoplasias in the anterior teeth peak in a population between two and four years of age, and weaning is a plausible explanation for the chronology of the disruption (Larsen, 1997, p. 48). Blakey and colleagues (1994), however, found that the peak of hypoplasia frequencies in a Southern U.S. slave population was between 1.5-4.5 years of age, leading them to look into other explanations, such as disease and malnutrition.

In this study, each tooth was studied for evidence of enamel hypoplasias and recorded following the methods in *Standards* (Buikstra and Ubelaker, 1994). All hypoplasias were recorded, no matter the form (e.g., linear, pit) or tooth (e.g., anterior or posterior). Surprisingly few hypoplasias of any type were found in the two Roman cemetery populations. In order to present data that are comparable to the findings at other Roman area cemeteries, however, the remainder of the discussion specifically addresses linear enamel hypoplasias (LEH), or enamel macrodefects that present as a line or band on the tooth surface.

At Casal Bertone, 52 adult teeth out of 1,962 examined (2.2%) had evidence of LEH, and there were no deciduous teeth with hypoplasias. Out of the 95 individuals who presented at least one adult tooth, 18 (19%) had at least one hypoplasia. Summing the adult and deciduous dentitions gives 2.5% of all teeth with hypoplasia and 18 out of 113 individuals (16%). There were hypoplasias in 40 out of 739 (5%) anterior permanent teeth in this population.

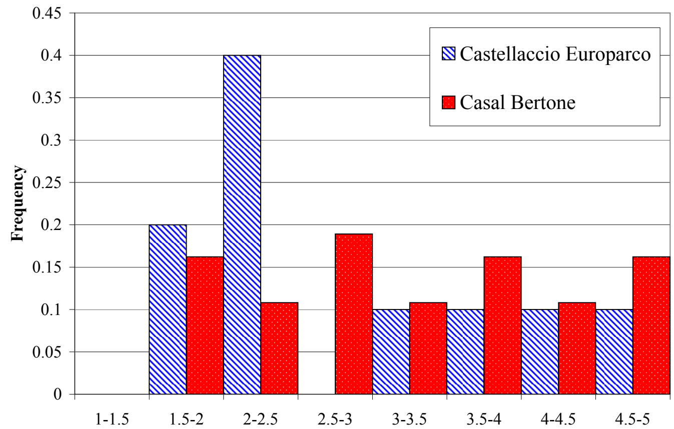
At Castellaccio Europarco, 14 adult teeth out of 563 examined (2.5%) presented a linear enamel hypoplasia, and 4 out of 25 people with adult teeth (16%) had at least one hypoplasia. In the subadult population, there was one hypoplasia in a sample of 73 teeth (1.4%), and one subadult out of seven examined (14%) had a hypoplasia. In total, 15 out of 636 adult and deciduous teeth examined from this site (2.4%) had a hypoplasia, and 5 out of 26 individuals (19%) had at least one hypoplasia. In terms of anterior permanent teeth, out of 218 examined, 10 had a linear enamel hypoplasia (5%).

There are too few individuals with hypoplasias to investigate meaningful sex or age differences in their frequency. Individual T10 from Casal Bertone, however, accounted for 12 out of the 52 LEHs found, roughly one-quarter of the hypoplastic lesions (figure 5.11a). As LEH is indicative of systemic metabolic stress, multiple instances of LEH are often found on individuals who were stressed for long periods of time in childhood. As noted above, this individual also presented additional issues, such as bilateral auditory exostoses, spondylolysis of the fifth lumbar vertebra, and other dental issues. Only two females were found to have linear enamel hypoplasias on the anterior teeth, both of them at Casal Bertone, but it is unclear if this is related to an underrepresentation of females in the skeletal record or the result of less physiological stress. The age at which these enamel disturbances occurred is different in the two populations. The distance in millimeters between the center of the hypoplasia and the cementoenamel junction was measured for all teeth using vernier calipers. For the anterior teeth, age at which the disturbance occurred was calculated based on the regression equations of Swärdstedt (1966) as presented in table 2 of Martin et al. (2008). The results for Casal Bertone and Castellaccio Europarco are provided in table 5.14.

Skeleton	Sex	Age	LNC	LNI2	LNI1	LXC	LXI2	LXI1	RNC	RNI2	RNI1	RXC	RXI2	RXI1
ET17	I	6-10					1.9					2.0	2.3	
ET27	PM	16-20	3.2				2.5		3.6				2.6	
ET103	PM	31-40	4.3	2.5	1.9				4.7	2.2	2.2			
T63A	I	6-10	3.9											
T72	I	11-15	3.8			3.8			3.9			3.2		
T11	I	11-15	4.9						5.0					
T32	I	11-15		1.7	1.9			2.7	2.7	2.1	1.7			2.8
F1A	F	16-20	3.1											
T23	M	21-30										3.5		
F1B	M	31-40	4.0						4.3					
T76	PM	31-40	4.8						4.6					
T10	M	31-40	5.0			3.0	3.7	2.7	4.5			3.6	3.0	2.6
T30	PF	41-50							4.3					
F3C	M	41-50				2.3								
T63B	I	Adult		1.8	1.9					2.1	2.1			
T61	PM	Adult							4.5					
F3B	I	Adult				2.5		1.6						

Table 5.14: Age in Years at Linear Enamel Hypoplasia Occurrence, by Tooth

(a) LEH - Casal Bertone T10, 31-40-year-old male



(b) Age in Years at Formation of LEH

Figure 5.11: Linear Enamel Hypoplasias

Although the sample populations with enamel hypoplasias are small, there is a clear difference between the two sites as indicated in figure 5.11b. At suburban Castellaccio Europarco, there is a peak in hypoplasia frequency between the ages of 1.5 and 2.5. This peak could represent the time at which these individuals were weaned, as Roman women nursed (or contracted another woman to nurse) their children for anywhere from 6 months to 3 years (see chapters 6 and 7). At urban Casal Bertone, on the other hand, there is no clear distribution of the ages at which hypoplasias occurred. A number of individuals suffered disruption of enamel growth in the 1.5-to-2.5-year period, but a fair fraction of the population with hypoplasias got them in later childhood, long after weaning likely took place. It would appear that, once the initial period of physiological stress from 1.5 to 2.5 years occurred in people from suburban Castellaccio Europarco, there was no other significant time of stress. Physiological stress at Casal Bertone, however, was more constant through the formative years of childhood.

5.2.7 Deciduous Dentition

The deciduous dentition, in addition to being included in overall population counts above, was investigated separately based on additional age categories. Very few subadult teeth were found at Castellaccio Europarco, with no evidence of caries, abscesses, or AMTL in the deciduous dentition in this population. Table 5.15 shows the breakdown of dental pathologies based on two subadult age categories: 0-5 and 6-10. There was only one deciduous tooth found in the 11-15 age range at either site, and it did not have any evidence of dental disease. Calculus and carious lesion frequencies are based on number of observable teeth, while abscesses and AMTL are based on the observability of specific dental alveoli.

	Casal Bertone				Castellaccio Europarco			
Age	Calculus	Caries	Abscess	AMTL	Calculus	Caries	Abscess	AMTL
0-5	2/69	2/69	0/63	0/173	0/27	0/27	0/36	0/78
	2.9	2.9	0	0	0	0	0	0
6-11	11/80	3/80	1/65	2/114	4/36	0/36	0/32	0/42
	13.8	3.8	1.5	1.8	11.1	0	0	0
Overall #	13/149	5/149	1/128	2/287	4/63	0/63	0/68	0/120
Overall %	8.7	3.4	0.8	0.7	6.3	0	0	0

Table 5.15: Deciduous Dentition - Number and Percentage of Dental Pathologies

The results of the pathology analysis of the deciduous dentition are not surprising. The frequency of carious lesions in both subadult populations is low but increases from the earlier to later age groups at Casal Bertone. Calculus also shows a trend towards more prevalence with increasing age. At Casal Bertone, 0-5-year-olds had a calculus frequency of 3%, which increased to 14% at age 6-10, 68% at 11-20, and nearly 100% in individuals over 21. The frequencies of AMTL and abscesses in children are too low to be indicative of trends in either population. In general, subadults in these populations have healthy teeth.

5.3 Discussion

Comparing the results of the pathology analysis of the populations at Casal Bertone and Castellaccio Europarco is problematic owing to: a) the lack of published data on Imperial Roman cemeteries; b) different methodologies for collecting and reporting pathology frequencies owing to different academic traditions that led to the practice of bioarchaeology; and c) the fact that the methodology used is rarely published in the summary articles from which much of the comparative pathology data are drawn. The closest Roman cemetery that has been published in depth is Isola Sacra from Portus (Manzi et al., 1991, 1999; Prowse, 2001; Prowse et al., 2004, 2005, 2007). Numerous sites from the Roman *suburbium*, however, have been partially published, usually in articles that summarize several sites at once in terms of demography and pathology. As noted above, in this study, pathologies were identified based primarily on Ortner (2003) and were recorded largely based on the methods put forth in *Standards* (Buikstra and Ubelaker, 1994). Because of these differences, it is impossible to make direct comparisons among the data generated in this study and the data published from other sites. Nevertheless, broad trends in the skeletal and dental pathologies can be investigated in populations from sites in the Imperial Roman *suburbium* and rural Latium, and these trends can be compared with what is historically known about disease in ancient Rome.

5.3.1 Skeletal Pathology

No published Imperial cemeteries list frequencies of osteomyelitis, nor did any report the presence of infectious diseases such as tuberculosis, leprosy, or treponemal disease, or nutritional diseases such as scurvy and rickets. The skeletal pathologies collected in this study that could be compared with at least one other published Imperial site include porotic hyperostosis, trauma, auditory exostoses, osteoarthritis, Schmorl's nodes, and periosteal reaction. The Imperial sites in table 5.16 are arranged based on increasing distance from the city walls of Rome, with the study sites highlighted in bold. All sites were located in the southeast quadrant of the *suburbium* or the wider region of Lazio.

Of the comparative pathologies presented in table 5.16, only porotic hyperostosis is regularly reported with respect to both frequencies and methods used to collect the data. Porotic hyperostosis frequencies are calculated as number of individuals with at least one orbit affected by cribra orbitalia divided by the total number of individuals with at least one orbit examined; and the number of individuals with at least one area of cribra cranii divided by the total number

	Cribra Orbitalia	Cribra Cranii	Trauma	Auditory Exostoses	Osteo-arthritis	Schmorl's Nodes	Periosteal Reaction
Casal Bertone	**17.5**	**1.2**	**15.1**	**2.4**	**33.3**	**17.9**	**23.8**
Basiliano/Collatina[1]	65	50	32	5.7	—	—	—
Quadraro[2,3]	8	—	0	—	80	30	7.7
Castellaccio Europarco	**13.6**	**9.4**	**6.7**	**3**	**32.3**	**9.7**	**35.5**
Osteria del Curato[4]	79.2	53.6	—	—	—	—	—
Vallerano[2,3,5]	69.2	26.8	21-27	—	60	6	2.7
Gabii[2]	0	—	—	—	50	—	—
Lucus Feroniae[6,7,8]	49.5	10.7	30.2	2.8	72.1	—	—
San Vittorino[2,3]	0	—	21-27	—	70	18	33.3

[1]Buccellato et al. (2003). [2]Ottini et al. (2001). [3]Catalano et al. (2001a). [4]Egidi et al. (2003). [5]Cucina et al. (2006). [6]Salvadei et al. (2001). [7]Sperduti (1997). [8]Manzi et al. (1991).

Table 5.16: Comparative Imperial Populations - Skeletal Pathology Frequencies (%)

of individuals for whom at least one-third of the cranium could be examined. There appears to be no clear pattern to the frequency data on porotic hyperostosis, however. The sites of Basiliano (Buccellato et al., 2003),[5] Osteria del Curato (Egidi et al., 2003), Vallerano (Cucina et al., 2006), and Lucus Feroniae (Salvadei et al., 2001) have been reasonably well published and all present high frequencies of cribra orbitalia in the populations. Lucus Feroniae, however, has a comparatively low frequency of cribra cranii, similar to that of Castellaccio Europarco. Of the well-studied sites, Casal Bertone and Castellaccio Europarco present the lowest frequencies of both porotic hyperostosis conditions. Interestingly, one sentence found in a rather obscure Italian article (Ottini et al., 2001) offhandedly notes that Quadraro, about midway between the two study sites geographically, had a cribra orbitalia frequency of 8%. These researchers further note that Gabii and San Vittorino, located a few dozen kilometers past Rome in the *suburbium*, had absolutely no indication of cribra orbitalia. These vast differences could be related to observer method, bias, or the taphonomy of the sample, or the disease ecology of Latium could have been as strikingly varied as the geology (see chapter 8).

The frequency of trauma at the published Imperial Roman cemeteries varies, but not quite

[5]As noted in chapter 4, this cemetery, which held over 2,000 individuals, was initially published as the necropolis of Via Basiliano (Buccellato et al., 2003), but a recent article calls it the necropolis of Collatina (Buccellato et al., 2008a). In the latter, only brief, summary frequencies were reported for the skeletal remains, but they differed from the original report. There is no information as to the composition of the sample population(s) studied, however, so it is unclear which are the correct numbers.

as widely as porotic hyperostosis or osteoarthritis. Casal Bertone and Castellaccio Europarco are the populations with the lowest frequencies of trauma. At both periurban Basiliano and rural Lucus Feroniae, trauma affected about one-third of the population, while at suburban Vallerano, only around one-quarter of the population had evidence of trauma. The types of trauma and sex ratios were not collected in all comparative studies, but some reported higher frequencies of males affected by trauma (e.g., Buccellato et al. (2003)).

Osteoarthritis is similarly low at Casal Bertone and Castellaccio Europarco, with one out of every three individuals studied having evidence of osteoarthritis, whereas the other published sites range from 50-80% of the population affected. These data, however, are likely to be affected by different collection methodologies. The reported numbers for Casal Bertone and Castellaccio Europarco are for osteoarthritis alone and do not include degenerative changes; if the latter numbers are reported for each site, the frequency increases to 72% for Casal Bertone and 68% for Castellaccio Europarco, well within the range of the other Imperial sites. Additionally, at least two of the comparative sites appear to be reporting osteoarthritis frequencies for just the vertebral column (Ottini et al., 2001). For only three other populations have frequencies of Schmorl's nodes been reported. Suburban Vallerano has a slightly lower frequency than Castellaccio Europarco, which was about 1 km away, and individuals at periurban Casal Bertone were affected more often than either of these suburban populations. It is unfortunate that there is currently no published information on degenerative issues at Basiliano, which was located close to Casal Bertone.

Although no researchers have published any information on osteomyelitis, a few note the frequency of periosteal reaction within the population. Quadraro and Vallerano, both suburban sites, have very low frequencies of this condition, particularly when compared with Casal Bertone and Castellaccio Europarco. San Vittorino, located in the eastern rural countryside of Lazio, however, has a frequency of individuals affected by periosteal reaction similar to the study sites. With such a low frequency of porotic hyperostosis at Quadraro, the low frequency of periostitis is not surprising. However, the high frequencies of pathologies at Vallerano lead me to suspect the validity of the extremely low frequency of periosteal reaction in the population.

Finally, the analyzed sample from the skeletal population at Basiliano had a frequency of 6% auditory exostoses, which researchers compared with the finding of 31% at Isola Sacra at Portus (Manzi et al., 1991). Based on a correlation between external auditory exostosis presence and increased consumption of seafood at Portus and coastal Velia, researchers hypothesize that the people at Isola Sacra, particularly the men, were either frequenting public baths or working in water-related occupations (Crowe et al., 2010). A low frequency of these lesions was also found at rural Lucus Feroniae. Based on the low frequency of auditory exostoses from the periurban populations at Casal Bertone and Castellaccio Europarco, it is not clear what their etiology is. The individuals with exostoses are all middle-aged males, however, so more research needs to be done on the frequency with which these tumors are found in Imperial populations around the city and in other areas of the Empire with a culture of public baths.

In terms of comparative measures of health of populations around the Roman *suburbium* based on the bony skeleton, only porotic hyperostosis is reported widely enough to provide data from different locations. It is currently unclear, however, what caused these anemic reactions, making it impossible to draw conclusions about the relative health of the populations based on this single marker of nonspecific disease. Comparing the data published from periurban Basiliano with that from periurban Casal Bertone indicates that the latter population was healthier using the metrics of porotic hyperostosis and trauma. Suburban Castellaccio Europarco similarly appears to be a healthier population than the suburban sites of Osteria del Curato and Vallerano. The latter, however, has lower frequencies of Schmorl's nodes and periosteal reaction than Castellaccio Europarco, possibly indicating a slightly less physically active population.

The figures in table 5.16 clearly indicate that much more work needs to be done and many more suburban and periurban Roman cemetery populations need to be published.[6] It is unfortunate that cemeteries such as Quadraro and Gabii are not published individually, as their surprisingly low frequencies of skeletal pathologies indicate that the Roman *suburbium* was not a homogeneous place. Whether the heterogeneity relates to the populations themselves or to their geographical locations, however, is currently unknown. In order to understand what the varying frequencies of skeletal pathologies at different sites indicate about the Roman population and the disease ecology of Lazio, additional data are needed.

5.3.2 Dental Pathology

The majority of bioarchaeological investigations of dental pathology in the Roman world have focused on populations that lived in the provinces of the Roman Empire. Older reports that do focus on Rome and Italy are not thoroughly published, with only scattered references to statistics such as total percent caries. For example, Macchiarelli et al. (1988) note that two samples from the Iron Age have "percent of decayed teeth" of 19.9% and 8.6%, while another Imperial sample has a frequency of 11.9%. The Soprintendenza Archeologica di Roma has started a large-scale synthesis of dental data from sites throughout Italy from a variety of time periods. Data from the present project will be added to this study. Carious lesion information from these two sites and several other Imperial sites from Rome will be joined with data from other time periods and other locations on the peninsula into a synthetic study of caries, including trends through time and space. Until that publication, however, comparisons can be made with the only Imperial sites from the city and outskirts of Rome that have been published with both methods and results: Vallerano (Cucina et al., 2006) and Isola Sacra (Prowse, 2001; Manzi et al., 1999).[7]

---

[6] See also the forthcoming article by Gowland and Garnsey (2010).

[7] Additional, partial data have been published from the necropolis of Via Basiliano. With the caveat footnoted on page 138, 10% of all teeth have at least one carious lesion, 42% of teeth have LEH, 7.7% of all alveoli were affected by AMTL, and 3.2% of alveoli were affected by abscesses, all higher than the data presented in table 5.17 (Buccellato et al., 2003).

Table 5.17 presents the comparative data. All values are percentages, and all were calculated based on the frequency of teeth rather than individuals.

	Casal Bertone	Castellaccio	Vallerano	Isola Sacra
Caries				
Maxilla	4.5	10.9	2.6	-
Mandible	5.3	7.4	2.4	-
Males	5.1	10.5	2.3	6.0
Females	6.7	9.5	2.8	5.5
Total	4.9	8.4	2.5	5.4
AMTL				
Total	4.6	5.3	3.4	6.3
Abscesses				
Total	1.3	2.3	1.1	0.9
Calculus				
Maxilla	27.1	44.7	-	66.3
Mandible	41.9	56.8	-	78.4
Total	35.3	51	-	72.9
Hypoplasia				
Total	2.2	2.5	63.5	35.5

Table 5.17: Dental Pathology Frequencies (%) in Comparative Samples

The overall frequency of antemortem tooth loss at Vallerano is 3.4%, whereas both sites in this study are higher, with Casal Bertone at 4.6% and Castellaccio Europarco at 5.3%. Isola Sacra has the highest frequency, at 6.3% of all observed sockets having AMTL. The carious lesion frequency at Vallerano, 2.5% of all teeth, is also significantly lower than the other three sites. Casal Bertone is 4.9%, and Castellaccio is 8.4%; Isola Sacra is close to Casal Bertone, with 5.4% of all teeth affected. At all sites, males and females are more or less equally affected, and the differences are not statistically significant in any of the populations. Isola Sacra has the lowest amount of abscesses, with less than 1% of all sockets affected. Casal Bertone and Vallerano are close in value, at 1.3% and 1.1% respectively. Castellaccio Europarco is slightly higher at 2.3%. Although Cucina and coworkers did not record calculus at Vallerano, Prowse did at Isola Sacra. The frequencies of calculus at Isola Sacra were higher than at Casal Bertone and Castellaccio Europarco, with nearly three-quarters of the Isola Sacra population having some amount of calculus. Prowse found that this level of calculus was low for preindustrial populations, and her isotope study (Prowse et al., 2004) uncovered the fact that males were consuming more marine resources, while women and children were eating more grains and vegetables. Finally, the frequencies of enamel hypoplasias at Vallerano and Isola Sacra are shockingly higher than the ones from Casal Bertone and Castellaccio Europarco. In spite of the fact that the Casal Bertone population seems to have undergone more consistent physiological stress than the one at Castellaccio Europarco, it was still far less stressed than the populations at suburban Vallerano or urban Portus based on this single metric. Interestingly, Cucina and colleagues (2006) found that hypoplasias in the anterior teeth peaked twice, at 3-3.4 years old and at 4.5-4.9 years old. Neither Casal Bertone nor Castellaccio Europarco seems to follow this pattern (figure 5.11b). It is possible that differences in inter-observer identification or recording practices for LEH contributed to these numbers, but it is also possible that a variety of factors, such as nutrition, water sources, and disease ecology, contributed to the differential enamel hypoplasia frequencies at these four Rome-area sites.

Whereas Casal Bertone is close in value to both Vallerano and Isola Sacra in terms of frequency of carious lesions, there is a higher frequency at Castellaccio Europarco in all carious lesion categories. This difference will be explored further in chapter 6.[8] AMTL and abscesses are relatively low in all four populations, and Isola Sacra has a slightly higher calculus frequency than Casal Bertone or Castellaccio Europarco. Enamel hypoplasia, however, is found far less frequently at Casal Bertone and Castellaccio Europarco than at Vallerano and Isola Sacra. Comparisons are made in chapter 6 between the dietary information gathered in this

[8]An additional unexplored possibility for differences in carious lesion frequencies is the presence of fluorine in the water sources available to different parts of the *suburbium*. An analysis of fluorine concentrations in dental enamel of people from Herculaneum (79 AD) found much higher than normal values (Torino et al., 1995). Coupled with high frequencies of enamel hypoplasias and low frequencies of carious lesions (3.8% of teeth examined), the authors suspect endemic dental fluorosis. As volcanic activity can lead to high levels of fluorine in the environment (D'Alessandro, 2006) and as Rome was situated between two dormant volcanic complexes (see chapter 8), it would not be unusual to find natural fluorine present in the water supply. Vallerano, for example, has a very low frequency of carious lesions but a high frequency of enamel hypoplasia, similar to Herculaneum. A study of the fluorine available to Rome and the *suburbium*, though, would need to be accomplished in order to identify whether this element could be related to the relatively low frequencies of carious lesions in the suburban and periurban populations of Rome.

study and that generated by Prowse from Isola Sacra to investigate whether Romans on the coast and those living inland were consuming the same foods.

5.4 Conclusions

Data were presented for the frequencies of calculus, carious lesions, abscesses, enamel hypoplasias, and antemortem tooth loss in the populations from Casal Bertone and Castellaccio Europarco. Dental calculus affected the majority of adults from both sites, and there appears to be a trend of increasing frequency with increasing age. Caries affected more males than females at Casal Bertone, but the reverse was true at Castellaccio Europarco. The frequency of teeth with carious lesions at Casal Bertone was significantly lower than that of Castellaccio Europarco. A low frequency of abscesses was found at both sites, and the frequency of AMTL at the two sites was low as well. The age at which enamel hypoplasias occurred was more or less continuous at Casal Bertone, whereas it peaked around 1.5-3 years at Castellaccio Europarco. Both sites, however, have significantly lower LEH frequencies than nearby populations. Deciduous teeth were seldom affected by dental disease, and subadults appear to have had good dental health. A comparison with contemporaneous populations from Rome indicates differences in carious lesion frequency, AMTL, abscesses, enamel hypoplasia, and calculus.

In terms of skeletal pathology, data were collected on porotic hyperostosis, trauma, tumors, osteoarthritis, disc herniation, periostitis, and osteomyelitis. There was no obvious, macroscopic evidence of any common metabolic diseases (e.g., scurvy or rickets) or well-known infectious diseases (e.g., leprosy, tuberculosis, syphilis) in either population. Porotic hyperostosis affected subadults more than adults in both populations, and no females were found to have suffered from these lesions. Osteoarthritis was present in a significant fraction of the individuals studied. While the frequencies in the sexes were equal at Casal Bertone, over twice as many males as females at Castellaccio Europarco suffered from osteoarthritis. Periosteal reactions were found mostly on the lower leg bones. Males and females were more or less equally affected by periostitis at each site, although the frequencies in both sexes are higher at Castellaccio Europarco. Evidence of trauma (i.e., fractures) was found over twice as often at Casal Bertone as at Castellaccio Europarco, indicating a slightly rougher life for individuals who were buried in the periurban cemetery. Both cemetery populations studied, however, have lower frequencies of skeletal pathology than nearly every other published Imperial Roman cemetery. It is not clear, however, why individuals from Casal Bertone and Castellaccio Europarco are, on the whole, healthier than other individuals from the same geographical area.

In summary, the populations buried at Casal Bertone and Castellaccio Europarco appear to have lived relatively healthy lives based on the pathologies examined. Granted, they likely succumbed to a disease that left no bony trace. One of the most famous plagues of antiquity, the Antonine Plague, lasted from about 165-180 AD and could have been a pandemic of smallpox or measles. Both cemeteries were in use during the Antonine period, but the possible diseases that caused the plague are highly unlikely to cause pathognomic changes (i.e., lesions that positively identify a specific disease process) to bone. People at Casal Bertone and Castellaccio Europarco did die at a much younger age than by modern standards, and there was a high frequency of infant mortality (see chapter 4). Their dental health, however, was about average for agriculturally-reliant populations. Although the frequencies of carious lesions, antemortem tooth loss, and abscesses at the two sites point to worse dental health than nearby Vallerano and Isola Sacra, the frequency of linear enamel hypoplasias at Casal Bertone and Castellaccio Europarco is extremely low. A possible explanation for these findings is a diet that was slightly more cariogenic but possibly healthier or more abundant, leading to a population that was less metabolically stressed during the formative years of amelogenesis. This explanation will be pursued further in chapter 6 with the presentation of dietary information from Casal Bertone and Castellaccio Europarco. Additionally, the populations from the study sites have dramatically lower frequencies of porotic hyperostosis than most other Imperial Roman cemetery populations, providing further evidence of the salubriousness of the people buried at Casal Bertone and Castellaccio Europarco.

Scobie (1986, p. 433) concludes his assessment of Roman sanitation by saying that, “High density living in insanitary urban dwellings and surroundings can have only one major consequence in a preindustrial society which lacks effective and cheap medical care: a short, often violent life. That this was the common lot of the millions of people in the Roman world who lived on or below subsistence level can hardly be doubted.” The palaeopathological and demographic assessment of individuals from Casal Bertone and Castellaccio Europarco has shown that some people did live short lives, some suffered significant amounts of trauma, disease, and violence, but some lived into their 60s and others had seemingly good health until their death. It is likely that many of the people examined, particularly from Casal Bertone, lived in the urban area of Rome at some point in their lives. As presumably lower-class individuals, their accommodations might have been in slums or other poor housing conditions. The possibility of geographical movement in Rome and its *suburbium*, however, is extremely important in creating the skeletal assemblages we see in the bioarchaeological record. Immigrants to Rome might bring in new diseases to the city or might succumb easily to endemic conditions upon arrival. Movement around the city likely included visits to public baths and other sanitary conveniences not enjoyed by most preindustrial societies. The less-crowded *suburbium* might have promised a better quality of life compared to the city, or its creation as an area of heavy industry disallowed within the city walls could conversely have made it a worse place to live. Analysis of ancient skeletal material is the best way to start investigating the intertwined issues of disease, diet, and demographic change that come with urbanization in the Imperial period. As such, following chapter 6 on the ancient diet, the remainder of this dissertation deals with identifying and understanding types of mobility in Imperial Rome and the consequences of urban living on the bodies of both immigrants and locals.

Chapter 6

Dietary Practices in Rome

While the general diet of people in Imperial Rome is known to have consisted primarily of grain, olives, and wine, historical information indicates that dietary practices varied based on age, sex, social class, and occupation. Recent palaeodietary work at Portus and a late Imperial Christian necropolis in the Roman *suburbium* shows that different food webs were being utilized in spite of the relatively short distance between Rome and the sea. A dietary analysis of the human skeletal remains from Casal Bertone and Castellaccio Europarco provides additional data on diet in the periurban and urban contexts of the Imperial capital and further addresses the characterization of the ancient diet in the greater Rome area.

This isotope study of skeletons of Imperial Rome, however, has also provided information about the dietary practices of immigrants to Rome (see chapter 11). Given the assumption that individuals living in the Roman Empire exploited local resources for the majority of their diet, those people with anomalous carbon and nitrogen isotope ratios are likely to have come to Rome from elsewhere. Further, investigating intraindividual isotope ratios can yield additional information about age at migration, change in diet, or even maintenance of traditional foodways. This study is therefore the first to evaluate the diet of not only lower-class Romans in a periurban versus a suburban context but also immigrants to Rome. Carbon and nitrogen isotope analysis results for all individuals tested from Casal Bertone and Castellaccio Europarco are presented in this chapter, and interpretation of the diets of immigrants is provided in chapter 11.

6.1 The Ancient Roman Diet

A complete discussion of the ancient Roman diet from primary sources can be found in a variety of places (Garnsey, 1999; Prowse, 2001; Alcock, 2006; Cool, 2006), and additional works discuss the problem of understanding the average diet on account of authors' biases as well as the probability that diet varied based on factors such as sex, age, occupation, and social class (Garnsey, 1999; Purcell, 2003; Wilkins and Hill, 2006). In light of these thorough publications, the current understanding of the ancient Roman diet will be only briefly summarized here along with expectations with respect to the diet of individuals at Castellaccio Europarco and Casal Bertone.

The extant primary source material on the ancient diet was written by upper-class Roman authors: agricultural methods were detailed by Cato (*de re Agricultura*) and Varro (*de re Rustica*) in the Republican period and by Columella (*de re Rustica*) at the beginning of the Empire. By the fourth century AD, a cookbook of recipes had been compiled, *de re Coquinaria*, often attributed to Apicius but likely a collection by a variety of people. These recipes have been used to understand what cooking was like in this area of the world before the introduction of tomatoes and the invention of pasta, which have been heavily associated with Italian cooking for centuries. The cookbook includes numerous recipes involving meat (from birds, mammals, and fish), legumes, and fruit and vegetables. Many recipes, however, were quite exotic and probably do not characterize the diet of the lower-class individuals investigated in this study. Similarly, feasts and banqueting depicted in such works as Petronius' *Satyricon* and visual representations of food from mosaics and frescoes in upper-class houses at Pompeii might not be representative of the diet of the average Roman. There is little textual evidence of the diet of lower-class and poor Romans, although Cato suggests that slaveholders provide each of their male slaves with certain rations: four *modii* of wheat and half a liter of olive oil each month; olives, salt, or fish pickle as a condiment; and plenty of wine - 42 gallons per annum (White, 1976).

In general, scholars discuss the basic Roman diet as a "Mediterranean triad" composed of cereals, wine, and olives (ibid.). Both wheat and barley were cultivated by the Romans, although the latter was considered substandard grain in comparison to the range of foods that could be made with wheat (Garnsey, 1999). Millet is also known to have been cultivated in ancient Rome, but it is almost always mentioned in reference to famines and food shortages (Evans, 1980; Spurr, 1983). Nevertheless, it would have been easy to grow, with the climate of Italy being able to yield up to three plantings per year (Spurr, 1986). In spite of a lack of archaeobotanical evidence possibly owing to the small size of millet grains, Spurr (1983, p. 10-11) concludes that millet was likely utilized by the poorer classes at Rome who could not afford the more expensive wheat and barley. Nenci (1999), on the other hand, believes that our modern perception of millet and over-reliance on the elite-biased historical record has contributed to the assumption that millet was not often consumed. Further, millet did have commercial value as evidenced by the Edict of Diocletian (301 AD), which set a similar maximum price for all three major cereals, but it might have been used for animal fodder, to leaven bread, and as birdseed for hens and pigeons rather than directly consumed by humans (Spurr, 1983).

A wide variety of vegetables, fruits, and nuts were eaten by ancient Romans. The aforementioned Edict of Diocletian, which set the maximum prices for comestibles in the early 4th century AD, lists 96 fruits and vegetables, and Pliny's *Historia Naturalis* notes 70 garden plants that can be cultivated for cooking (Prowse, 2001). Legumes were also important to the Roman diet in the form of lentils, chickpeas, broad beans, and garden peas (Faas, 1994; Garnsey, 1999). Particularly popular in rural areas according to historical sources like Pliny, legumes could be eaten on their own or in a mixture with millet and other beans (Evans, 1980; Spurr, 1983). The relative contribution of legumes to the Roman diet, however, is still being debated. Garnsey (1991, 1999) in particular argues that legumes should be added to the Mediterranean triad, most notably for the lower-class and rural populations, as a significant contribution to the protein portion of the diet in the absence of affordable meat.

Grain is thought to have composed roughly three-quarters of the average Roman's caloric intake (Rickman, 1980; Garnsey, 1983; White, 1988). However, had the Romans subsisted primarily on cereals and carbohydrates, they would have been at increased risk for nutritional problems such as protein-calorie malnutrition (known in modern times as *kwashiorkor*, the acute childhood form of the deficiency) (White, 1976; Prowse et al., 2004, 2005). Our knowledge of the kind and amount of meat consumed by the average Roman is sparse, in spite of the fact that pigs, cows, goats, and sheep were quite important to the Roman economy. By the 3rd century AD, the grain dole, which allotted free grain to adult men, began to include rations of pork as well (White, 1976; Brothwell, 1988). Other sources of meat included goat/sheep, poultry, and fish, but probably little beef. Some archaeological evidence seems to indicate that, although goats and sheep were primarily raised for milk and wool, their flesh and cheese from their milk were often eaten and could make up about one-third of the meat component of the Roman diet (Brothwell, 1988; Garnsey, 1999). Chickens could be found on most farms but were primarily used as egg producers, as the Romans were fond of eating eggs (Brothwell and Brothwell, 1998). Small birds such as hens and pigeons were likely eaten by even the lower classes, whereas pheasant and geese, among other exotic birds, were more likely consumed by the elite (Frayn, 1993). Finally, the patterns of fish consumption by the ancient Romans are quite unclear, as this category of animal was alternately seen as a threat (to seafaring) and as a common food, sometimes expensive and sometimes easy to procure, a luxury item in the form of *garum* (fish sauce) and a food of the common fisherman, all depending on the time period in history, social status, occupation, and a variety of other contextual factors (Purcell, 1995). Analysis of bioarchaeological remains at Portus provide information on the Romans' complex relationship with fish (Prowse, 2001; Prowse et al., 2004, 2005), but it is unclear to what extent people living inland at Rome relied on fish in their diets.

It is therefore expected that the lower-class individuals from Casal Bertone and Castellaccio Europarco consumed a diet that consisted primarily of cereals, olive oil, wine, and legumes. Depending on their levels of wealth, social class, and access to resources, they might have consumed wheat, barley, and/or millet as the primary grain in their diets. As these sites were located inland, people likely had less access to seafood than people from, for example, nearby

Portus. However, the Tiber River had some freshwater fish, and it is possible that the Romans exploited that resource. Faunal remains recovered from both sites (chapter 4) indicate the presence of cows, sheep/goats, pigs, and chickens. As these are cemetery sites rather than households, it is unclear if these animals are representative of those that were eaten by the occupants of the tombs. Roman burial rituals are known to include all four of these species, so direct correlations between faunal remains at the site and comestibles cannot be definitively drawn. Nevertheless, based on the available historical, archaeological, and zoological evidence, the individuals from Casal Bertone and Castellaccio Europarco are hypothesized to have consumed a diet composed of cereals, carbohydrates from fruits and vegetables, fats from olives and olive oil, and protein from meat and legumes.

6.2 Methods

6.2.1 Isotopic Analysis of Diet

The human diet comes from a variety of sources, mainly foodstuffs containing protein and carbohydrates. Stable isotope analysis of carbon and nitrogen has been used for decades to characterize human diets in the past because it provides a way to generalize the types and amounts of proteins and plant matter in an individual's diet (Katzenberg, 2008). Carbon and nitrogen isotope measurements of several individuals can thus provide general information on subsistence practices within a population, which might differ based on sex, age, or status.

Carbon exists in three naturally occurring isotopes, ^{12}C (about 99% of the world's C) (Katzenberg, 2008), ^{13}C, and ^{14}C. The latter of these is radioactive and decays over time into ^{14}N, but the relative amounts of the other two isotopes in organic matter stay the same through time. Carbon enters the food chain during photosynthesis, and the amounts of the two naturally-occurring stable isotopes of this element vary relative to carbon dioxide in the atmosphere. Stable isotope analysis thus measures the relative abundance of these two isotopes of carbon (^{13}C/^{12}C) and compares them to a known standard, Vienna Pee Dee Belemnite (VPDB).

Results are presented in delta notation:

$$\delta^{13}C(‰) = \left(\frac{^{13}C/^{12}C_{sample} - ^{13}C/^{12}C_{VPDB}}{^{13}C/^{12}C_{VPDB}}\right) \times 1000$$

There are two major photosynthetic pathways, C_3 and C_4. In the C_3 pathway, atoms of ^{13}C are discriminated against in favor of ^{12}C, and vice versa for C_4, in a process that is known as fractionation. This means that plants that use a C_3 pathway for photosynthesis will have more negative δ^{13}C values than C_4 plants. C_3 plants include temperate grasses such as wheat and barley, which range from about -35 to -20‰, whereas C_4 plants include corn, millet, and sorghum and range from about -14 to -9‰ (Katzenberg, 2008). The non-overlapping δ^{13}C ranges of the photosynthetic pathways are important in reconstructing the carbohydrate and protein portions of past diet. Bone collagen is about 5‰ enriched relative to the diet, and there is an additional 1‰ fractionation factor between herbivores and carnivores related to trophic position (see below) (Ambrose and Norr, 1993). Therefore, an individual who ate a diet composed only of foods with a C_3 contribution would have a δ^{13}C value around -20‰, whereas an individual who consumed mainly C_4 foods would have a δ^{13}C value around -10‰.

Analysis of carbon isotope ratios derived from bone collagen (δ^{13}C) mainly indicates the protein component of the diet (Krueger and Sullivan, 1984), that is, whether an individual ate more terrestrial or more marine foods. The measurement of carbon isotopes in bone or enamel apatite ($\delta^{13}C_{ap}$) provides a better picture of the whole diet, including both proteins and carbohydrates (Katzenberg, 2008). Apatite, however, is more prone to issues of diagenesis than collagen, and the fractionation factor between it and the human diet is currently unknown, although it has been approximated at -12‰ (Prowse et al., 2004). This means that a low $\delta^{13}C_{ap}$ value of -12‰ is approximately equal to what would be expected from a C_3 plant based diet of -25‰. A comparatively heavy $\delta^{13}C_{ap}$ value of -1‰ would thus equate to a diet composed mostly of C_4 plants. Therefore, a midrange $\delta^{13}C_{ap}$ value of -6‰ would similarly be expected from a diet composed of contributions from both C_3 and C_4 plants.

A comparison of the apatite and collagen carbon ratios ($\Delta^{13}C_{ap-co}$) by Krueger and Sullivan (1984) was found to be smaller in carnivores than in herbivores, likely indicative of the contribution of meat to the diet. The calculation of $\Delta^{13}C_{ap-co}$ thus provides information about the relationship between dietary proteins and other components (i.e., carbohydrates). A $\Delta^{13}C_{ap-co}$ range of 0-2‰ indicates a diet of marine protein and C_3 carbohydrates; a range of 5-7‰ is representative of an omnivorous (monoisotopic) diet; and a range of 10-12‰ shows a diet composed of terrestrial protein and C_4 plants.

Individuals who ate terrestrial protein have lower $\delta^{13}C_{co}$ values than those who ate marine protein, and individuals who consumed C_3 plants have lower $\delta^{13}C_{ap}$ values than those who consumed C_4 plants. In environments where a population is utilizing both marine resources and C_4 plants, however, it can be difficult to understand the diet based on carbon isotopes alone (Larsen et al., 1992). Stable isotopes of nitrogen ($^{15}N/^{14}N$) better discriminate between marine and terrestrial protein, and the combination of carbon and nitrogen isotopes is therefore the best way to characterize the ancient diet (Schoeninger et al., 1983; Katzenberg, 2008).

Almost all of the nitrogen on Earth exists as N_2 in the atmosphere and dissolved in the oceans. Nitrogen in the human diet is therefore obtained through consumption of other organisms, mainly plants and animals. There are only two naturally-occurring isotopes of nitrogen, ^{14}N and ^{15}N, both of which are stable. Nitrogen isotope analysis thus measures the relative abundance of these two isotopes and compares them to a standard, atmospheric N_2 (AIR). The result ($\delta^{15}N$) is presented in delta notation similar to carbon:

$$\delta^{15}N(‰) = \left(\frac{^{15}N/^{14}N_{sample} - ^{15}N/^{14}N_{AIR}}{^{15}N/^{14}N_{AIR}}\right) \times 1000$$

Understanding nitrogen isotopes involves knowledge of an organism's trophic position in the food chain - that is, what it eats and what eats it. Plants that directly fix atmospheric N_2, such as legumes, occupy the lowest trophic position and therefore have a $\delta^{15}N$ value close to zero (Katzenberg, 2008). Nonleguminous terrestrial plants are slightly enriched with respect to δ^{15}N and thus have slightly higher values, around 1-5‰. At the next trophic level are herbivores that consume plants, followed by carnivores that consume herbivore meat. The nitrogen isotopes in body tissues of herbivores have been calculated to be about 3‰ more enriched than the plants they consume; similarly, the body tissue of carnivores is 3‰ more enriched than the flesh of consumed herbivores (Schoeninger and DeNiro, 1984). An increase in trophic level thus correlates with an increase in δ^{15}N value because of the amplification of nitrogen isotopes as they are passed up the food chain.

Values of δ^{15}N in the range of 5-12‰ can therefore indicate that a human consumed a terrestrial diet of plants and the flesh of herbivores. The marine ecosystem is a bit more complicated than the terrestrial one, as its longer food chain creates additional trophic levels, meaning that the δ^{15}N of marine organisms can become more enriched than terrestrial organisms (Katzenberg, 2008). Individuals enriched with respect to nitrogen are assumed to have consumed marine foods. A human diet composed mostly of marine sources would be much higher than a terrestrial diet, with δ^{15}N values in the range of 12-22‰.

Measurement of δ^{15}N values has also been used to understand breastfeeding and weaning in past populations (Katzenberg et al., 1996; Katzenberg, 2008). Breastfeeding infants consume the product of their mothers' body tissues and therefore occupy a higher trophic level than adults and weaned children. The δ^{15}N values of nursing infants are thus expected to be enriched relative to those of adult females in the population, by about 2.4‰ (Fogel et al., 1989). The δ^{15}N enrichment decreases as an infant ages because of the process of weaning and the introduction of supplementary foods. An infant's measured δ^{15}N value will eventually decrease to that of the adult population after complete cessation of breastfeeding. Bone deposition and turnover rates in subadults, however, are not systematically understood, so it is not possible to isolate the exact time at which breastfeeding stopped and weaning began (Herring et al., 1998).

6.2.2 Roman Diet and Stable Isotope Expectations

As noted, I would expect the individuals at Casal Bertone and Castellaccio Europarco to have eaten a diet composed of cereals, fruit and vegetables, and legumes, with a variable contribution from meat (primarily pork and mutton) and fish. It is impossible to rule out the presence of C_4 foods in the Roman diet because the C_4 grain millet was known to be directly consumed and to be used for the foddering of meat and milk animals. Based on the location of these two sites, it is also impossible to rule out the presence of seafood and freshwater fish in the diet, thus necessitating investigation of both δ^{13}C and δ^{15}N values.

If the protein component of the diet of individuals at Castellaccio Europarco and Casal Bertone was drawn primarily from the flesh and milk of herbivores (i.e., cows, sheep/goats, and pigs), I would expect the δ^{13}C values of humans to be enriched about 1‰ compared to the average δ^{13}C of herbivores from the area and a δ^{15}N value about 3‰ higher owing to the trophic level effect (Prowse et al., 2004). Significant enrichment above these general values would thus indicate the inclusion of additional foods in the diet: some C_4 plants and some marine resources. Depletion of δ^{13}C and δ^{15}N, in comparison, could indicate the consumption of mostly C_3 plants and foods at low trophic levels, like legumes, with basically no marine or C_4 contribution.

As the individuals at the two study sites are thought to be among the lower classes of Rome, I would expect them to have inconsistent access to high-quality and high-status food. Individuals with more wealth could have eaten a more consistent diet composed of higher-status foods, which would mean less variation in their long-term diet. A population of poor Romans would likely have eaten whatever they were able to find and afford, though, which would lead to significant variation in the diet. The fact that wild game could be caught and eaten in the *suburbium* raises the additional possibility that the protein portion of the diet was quite variable. The populations at Casal Bertone and Castellaccio Europarco were thus subjected to stable isotope analysis of carbon and nitrogen in order to investigate the general parameters of the lower-class diet, to look for sex-, age-, and status-related differences in overall diet, and to understand the variation in diet at periurban and suburban contexts. The dietary evidence will further be used in chapter 11 to characterize the lives of immigrants to Rome.

6.2.3 Sample Selection and Demographics

As the goal of this dietary study was to characterize both the adult and subadult diet of Romans at Casal Bertone and Castellaccio Europarco, bone samples were chosen over enamel for analysis because this tissue yields information about the long-term, cumulative diet of an individual over a period of years before death. During data collection, femoral mid-shaft sections were taken from adult and teenage individuals from whom a first molar was also taken, and rib samples were taken from subadults under 10 years of age who possessed at least one rib. Not every individual could be subjected to dietary analysis, so a stratified sample of individuals from the populations at Casal Bertone and Castellaccio Europarco was taken for carbon and nitrogen isotope analysis. Bones from a total of 48 individuals from the Imperial period (1st-3rd centuries AD) were tested,[1] 12 from Castellaccio Europarco and 36 from Casal Bertone, the latter of which included 12 individuals from the mausoleum and 24 from the necropolis context. All individuals in this stratified sample were also subjected to strontium (chapter 8) and oxygen (chapter 9) isotope analyses with the goal of understanding as much as possible about this presumably representative subsample of the bioarchaeological populations.[2]

Not every sample produced reliable isotope results. From the Casal Bertone sample (n=36), information on δ^{15}N, $\delta^{13}C_{co}$, and $\delta^{13}C_{ap}$ was obtained from 26 individuals; only $\delta^{13}C_{co}$ and δ^{15}N were obtained from 6 individuals; 3 individuals yielded no $\delta^{13}C_{co}$, δ^{15}N, or $\delta^{13}C_{ap}$ data; and 1 individual produced only $\delta^{13}C_{ap}$ data. From the Castellaccio Europarco sample (n=12), information about δ^{15}N, $\delta^{13}C_{co}$, and $\delta^{13}C_{ap}$ was gathered from 7 individuals; no isotope data could be measured from 3 individuals; and only $\delta^{13}C_{ap}$ data could be gotten from 2 individuals. In total, of the 48 samples sent from the two populations, 33 could be assessed for δ^{15}N, $\delta^{13}C_{co}$,

[1]See appendix B for the results of the four individuals from the earlier periods who were tested.

[2]See appendix A for a full list of individuals with demographic information and all isotope measurements.

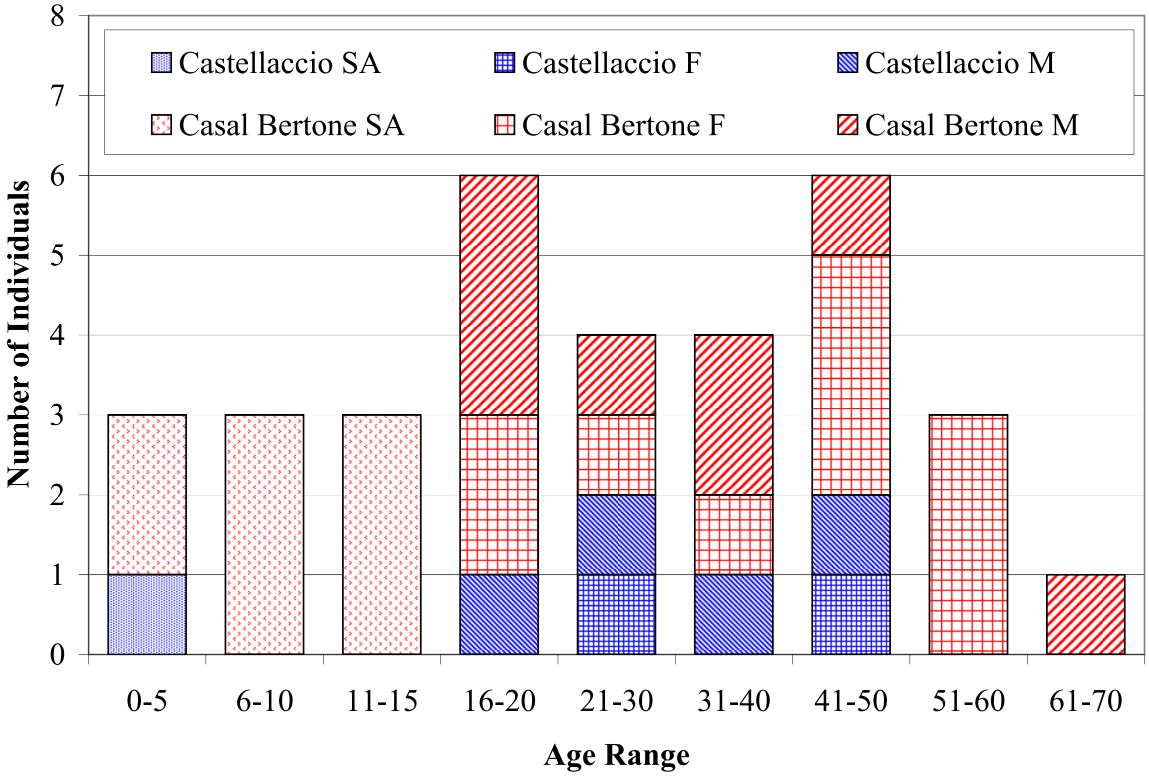


Figure 6.1: Demographics of Population That Yielded $\delta^{13}C_{co}$, $\delta^{15}N$, and $\delta^{13}C_{ap}$ Data

and $\delta^{13}C_{ap}$, which included 28 femur and 5 rib samples.[3] The demographics of the individuals for the 33 individuals from whom complete dietary information could be extracted are provided in figure 6.1. Only one subadult from Castellaccio Europarco presented usable carbon and nitrogen isotope information. Although the skeletal population at this site suffers from an underrepresentation of females (chapter 4), three females and five males were assessed for palaeodietary information. Casal Bertone subadult skeletons produced more reliable results than those of Castellaccio Europarco, likely because of the better preservation in the former site. In all, eight subadults could be examined: two under 5 years of age, three between 6-10 years old, and three between 11-15 years old. Of the adult individuals whose bones yielded reliable carbon and nitrogen isotope results at Casal Bertone, 10 were females and eight were males. The total Imperial sample that produced reliable isotope results thus includes three

[3]Ribs were tested from: ET31 and ET67 from Castellaccio Europarco, as well as T29, T71, T20, and T70 from Casal Bertone. No collagen could be obtained from ET67, however.

individuals in each of the subadult age categories, and 12 each of male and female adults of various ages.

6.2.4 Laboratory Analysis

Owing to the absence of equipment on campus dedicated to processing ancient skeletal remains for carbon and nitrogen isotopes, samples were analyzed on my behalf by Dr. Robert Tykot in the anthropology department of the University of South Florida. The procedures followed in his lab for extracting collagen from bone are based on those of Ambrose (1990) and can be summarized as follows (see also Tykot, 2004 and similar). Bone is first placed in 2% HCl to demineralize, after which contaminants are removed from the mixture with 0.1 M NaOH and with a 2:1:0.8 mixture of CH_3OH, $CHCl_3$, and water. The freeze-dried samples are then analyzed with a Finnigan MAT stable isotope mass spectrometer for δ^{13}C and δ^{15}N. The reliability of the samples is confirmed through measurement of collagen yields and C:N ratios.

The methods used for extracting carbon information from bone apatite are modified from Koch and colleagues (1997). Bones are first cleaned, and about 10 mg of powder is drilled from each sample. The bone sample is dissolved in 2% NaOCl, and non-biogenic carbonates are removed from the sample with 1.0 M buffered acetic acid. Samples are processed by a Finnigan MAT mass spectrometer with a Kiel III individual acid bath carbonate system. The reliability of samples is confirmed through assessment of apatite yields during the pretreatment process. Analytical precision of the δ^{13}C values is $\pm$ 0.1‰, and all values are reported with respect to the VPDB standard. For δ^{15}N, the precision is $\pm$ 0.2‰, reported with respect to AIR.

Additional $\delta^{13}C_{ap}$ data were supplied by Dr. Janet Montgomery at the University of Bradford, who processed 60 teeth for oxygen isotope analysis (chapter 9), all of which were from individuals subjected to strontium, carbon, and nitrogen isotope analysis. It is standard practice when measuring δ^{18}O values to measure carbon isotopes as well, and the methods of processing the enamel for analysis can be found in chapter 9. Analytical precision of the $\delta^{13}C_{ap}$

measurements from dental enamel is $\pm$ 0.06‰. The 37 individuals for whom there is available dietary information from bone apatite thus also provided enamel apatite ($\delta^{13}C_{ap}$) information from their first molars. Measurement of one individual's diet at two different times - from birth to about 3 years old and during the last several years or decades of life - can provide a significant amount of information about intraindividual dietary changes through time in the Roman population. The enamel data are presented below in comparison with the $\delta^{13}C_{ap}$ measurements from bone.

6.3 Results

Tables 6.1, 6.2, and 6.3 present the results of the analysis of both bone and enamel for carbon and nitrogen isotopes. The C:N ratio and percent collagen yield are listed as an indication of the reliability of the sample measurements. The values of $\Delta^{13}C_{ap-co}$ (bone) and $\Delta^{13}C_{ap}$ (bone-enamel) were calculated for all possible bone samples and are presented in the tables, as are the measured values of $\delta^{13}C_{ap}$ from enamel. Calculated mean values and standard deviations of all measurements are listed in the last rows of each table. Much of this information is also listed in appendix A.

Isotope values of individuals from both sites are plotted in figure 6.2. In order to provide a picture of the $\delta^{13}C$ and $\delta^{15}N$ values of domestic and wild animals in the area with which to assess trophic effects, it is customary to plot analyzed faunal remains. Unfortunately, in spite of the presence of animal bone at both cemeteries, none was provided for my analysis (see chapter 8, however, for strontium isotope information on pig teeth collected). A variety of faunal remains found in the context of the Isola Sacra cemetery at Portus were tested by Tracy Prowse (2001), who assumed they were representative of the local domesticates. This Imperial site was only about 25 km from Rome; however, it is not known whether geographical or ecological differences between Portus and Rome influenced the $\delta^{13}C$ and $\delta^{15}N$ values of herbivorous animals. Prowse's data are plotted in figure 6.2 as the best approximation of the

Skeleton	Sex	Age	δ^{13}C (‰ VPDB)	δ^{15}N (‰ AIR)	C:N	% Yield	$\delta^{13}C_{ap}$ (bone)	$\Delta^{13}C_{ap-co}$ (bone)	$\delta^{13}C_{ap}$ (enamel)	$\Delta^{13}C_{ap}$ (bone-enamel)
ET69	M	21-30	-19.5	7.8	3.2	2.2	-10.7	8.8	-13.11	2.4
ET44	M	16-20	-19.1	8.5	3.3	2.3	-9.3	9.8	-13.52	4.2
ET18	F	21-30	-18.8	11.0	3.3	2.6	-10.4	8.4	-12.52	2.1
ET38	M	41-50	-18.4	8.8	3.2	1.3	-9.8	8.6	-7.64	-2.2
ET31	I	0-5	-18.3	11.8	3.2	1.0	-10.9	7.4	-12.35	1.5
ET58	F	41-50	-17.9	9.5	3.3	2.2	-10.8	7.1	-11.74	0.9
ET72	M	31-40	-17.8	9.1	3.3	5.7	-10.9	6.9	-12.12	1.2
ET20	M	31-40	-12.5	8.3	3.2	2.0	—	—	-4.00	—
ET68	F	41-50	-18.1	11.5	3.3	0.4	—	—	-12.45	—
ET67[1]	I	11-15	—	—	—	0	-12.2	—	-12.45	0.3
ET27[1]	PM	16-20	—	—	—	0	-10.2	—	-12.09	1.9
ET36[1]	I	6-10	—	—	—	0	—	—	-12.78	—
ET45[2]	M	16-20	—	—	—	—	—	—	-12.63	—
ET42[2]	PM	Adult	—	—	—	—	—	—	-13.80	—
		Mean	*-18.5*	*9.8*			*-10.6*	*8.1*	*-12.2*	*1.4*
		StDev	*0.6*	*1.5*			*0.8*	*1.0*	*1.5*	*1.7*

[1] = No collagen yield. [2] = Only enamel tested. All delta values are reported in permil.

Table 6.1: Castellaccio Europarco δ^{13}C and δ^{15}N Results

domesticated animals available to the people at Casal Bertone and Castellaccio Europarco.

As noted above, if the individuals from the two Roman sites were consuming a diet composed primarily of wheat/barley (C_3 plants) and herbivorous animals and their milk (cow, sheep/goat, pig), we would expect their δ^{13}C values to be 1‰ enriched above the animals' and their δ^{15}N values to be 3‰ enriched. The average δ^{13}C and δ^{15}N of the humans tested is -18.2‰ and 10‰, respectively, whereas the values for the herbivores are -20.6‰ and 5.3‰, respectively. It would appear that the ancient Romans had average enrichments of 2.4‰ in δ^{13}C and 4.7‰ in δ^{15}N over the animals. Both human populations thus ate a diet that was largely based on C_3 plants and herbivores, with some contribution from marine protein and C_4 plants.

Based on the data plot in figure 6.2, there are two obvious outliers in the data set. One individual from the Casal Bertone necropolis has a high δ^{15}N value; as this was a subadult, it is likely this individual was not fully weaned. See section 6.4.3 for further discussion. One individual from Castellaccio Europarco (ET20, a male in his late 30s) has a δ^{13}C value significantly more enriched than any other individual's coupled with a relatively low δ^{15}N value,

Skeleton	Sex	Age	δ^{13}C (‰ VPDB)	δ^{15}N (‰ AIR)	C:N	% Yield	$\delta^{13}C_{ap}$ (bone)	$\Delta^{13}C_{ap-co}$ (bone)	$\delta^{13}C_{ap}$ (enamel)	$\Delta^{13}C_{ap}$ (bone-enamel)
F4B	F	51-60	-19.4	7.1	3.1	6.2	-13.3	6.1	-13.24	-0.1
F11A	F	31-40	-18.7	7.0	3.3	4.0	—	—	-12.95	—
F9B	I	0-5	-18.6	11.0	3.2	10.8	—	—	—	—
F3C	M	41-50	-18.6	10.1	3.2	6.2	-12.9	5.7	-12.47	-0.4
F12A	M	31-40	-18.1	11.2	3.2	1.0	-12.8	5.3	-14.22	1.4
F10D	I	11-15	-18.1	10.7	3.2	8.8	-12.7	5.4	-12.05	-0.6
F10C	I	6-10	-18.1	8.6	3.2	11.2	-12.3	5.8	-10.42	-1.9
F6E	F	51-60	-18.1	10.3	3.2	6.8	-13.2	4.9	-12.37	-0.8
F1A	F	16-20	-18.1	11.3	3.1	9.3	-12.9	5.2	-11.96	-0.9
F13C	F	41-50	-17.7	11.0	3.2	3.6	-12.8	4.9	-12.49	-0.3
F7B	M	16-20	-17.7	10.8	3.1	5.0	-12.6	5.1	-12.32	-0.3
F5A	M	21-30	-17.5	9.3	3.3	2.9	—	—	-11.72	—
		Mean	*-18.2*	*9.9*			*-12.8*	*5.4*	*-12.4*	-0.4
		StDev	*0.5*	*1.5*			*0.3*	*0.4*	*1.0*	*0.9*

All delta values are reported in permil.

Table 6.2: Casal Bertone Mausoleum δ^{13}C and δ^{15}N Results

indicating a much greater than average contribution of C_4 plants. Unfortunately, no $\delta^{13}C_{ap}$ information from his bone was obtained; however, his enamel produced a $\delta^{13}C_{ap}$ value of -4.0‰, the most enriched of all enamel measurements. As noted above, millet was likely consumed either directly or indirectly at Rome, but not to such an extent as seen in ET20's $\delta^{13}C_{co}$ and $\delta^{13}C_{ap}$ isotope ratios. Individual ET20 therefore consumed a very aberrant diet compared to the typical Roman diet, perhaps one composed of large quantities of millet and beans. Pliny notes that these two foods were eaten together by people in rural Italy (Evans, 1980; Spurr, 1983).[4] Further discussion of this individual can be found in chapter 11.

The δ^{13}C values presented alone, however, provide an indication of the carbon isotopes in only the collagen component of bone. By comparing the measurement of carbon in collagen and apatite, it is possible to get a better picture of the whole diet. Figure 6.3 is a scatterplot of $\Delta^{13}C_{ap-co}$ versus δ^{15}N. An omnivorous diet is represented by a $\Delta^{13}C_{ap-co}$ range of about

[4] It does not seem, however, that millet was consumed in great enough quantities to affect the δ^{13}C value this dramatically anywhere else in the Roman Empire. Fewer than a dozen isotopic dietary studies have been published from Imperial populations, but none have any δ^{13}C values this high. As noted in section 6.4.6 on page 174 below, the highest δ^{13}C values around Rome do not even reach -18‰ (Prowse, 2001). The highest δ^{13}C value I could find from an Imperial Mediterranean context is about -16.5‰ at Leptiminus in Tunisia (Keenleyside et al., 2009). Although a δ^{13}C value of -12‰ is not unusual in the maize-consuming peoples of the Americas, this value is astoundingly high for the Old World and reflects abnormal consumption of C_4 plants.

Skeleton	Sex	Age	δ^{13}C (‰ VPDB)	δ^{15}N (‰ AIR)	C:N	% Yield	$\delta^{13}C_{ap}$ (bone)	$\Delta^{13}C_{ap-co}$ (bone)	$\delta^{13}C_{ap}$ (enamel)	$\Delta^{13}C_{ap}$ (bone-enamel)
T20	I	6-10	-19.6	7.2	3.2	6.5	-12.9	6.7	-13.45	0.5
T83B	M	16-20	-19.5	8.4	3.1	7.8	-12.6	6.9	-13.43	0.8
T82A	F	41-50	-19.1	7.6	3.2	7.4	-12.9	6.2	-12.82	-0.1
T80	I	11-15	-19.0	9.5	3.2	10.2	-13.1	5.9	-14.78	1.7
T21	M	16-20	-19.0	8.0	3.2	3.4	-11.3	7.7	-13.45	2.2
T28	F	51-60	-18.6	11.3	3.2	2.7	-11.7	6.9	-11.78	0.1
T70	I	6-10	-18.5	10.2	3.2	2.2	-12.2	6.3	-12.62	0.4
T7	M	41-50	-18.2	11.0	3.3	2.6	—	—	-12.48	—
T39	PF	16-20	-18.2	11.8	3.1	8.7	-11.7	6.5	-10.90	-0.8
T13	M	61-70	-18.2	11.1	3.2	4.2	-12.7	5.5	-12.04	-0.7
T34	M	31-40	-18.1	11.6	3.2	4.7	-11.7	6.4	-12.16	0.5
T42	F	31-40	-18.1	9.8	3.2	2.0	-12.5	5.6	-12.61	0.1
T36	I	11-15	-18.1	10.8	3.2	3.8	-10.4	7.7	-6.76	-3.6
T24	M	51-60	-18.1	9.6	3.2	5.8	—	—	-10.87	—
T23	M	21-30	-18.1	11.6	3.2	3.5	-11.4	6.7	-11.25	-0.2
T50	PF	21-30	-18.0	10.8	3.2	2.6	-12.2	5.8	-12.93	0.7
T30	PF	41-50	-17.8	11.0	3.2	4.8	-12.1	5.7	-12.29	0.2
T29	I	0-5	-17.5	13.2	3.2	5.2	-12.2	5.3	-12.35	0.2
T71	I	0-5	-17.4	10.2	3.2	3.6	-12.8	4.6	-13.05	0.3
T33	M	41-50	-17.2	9.7	3.2	7.6	—	—	-12.74	—
T18[1]	PM	31-40	—	—	—	0	-13.7	—	-12.75	-0.9
T14[2]	M	21-30	—	—	—	—	—	—	-13.15	—
T81[1]	M	21-30	—	—	—	0	—	—	-12.86	—
T76[1]	PM	31-40	—	—	—	0	—	—	-12.44	—
T32[2]	I	11-15	—	—	—	—	—	—	-12.37	—
T15[2]	PM	31-40	—	—	—	—	—	—	-12.32	—
T10[1]	M	31-40	—	—	—	0	—	—	-12.12	—
T72[2]	I	11-15	—	—	—	—	—	—	-11.91	—
T8[2]	I	6-10	—	—	—	—	—	—	-10.91	—
T19[2]	M	41-50	—	—	—	—	—	—	-10.91	—
		Mean	*-18.4*	*10.1*			*-12.2*	*6.3*	*-12.2*	*0.1*
		StDev	*0.6*	*1.4*			*0.9*	*0.8*	*1.4*	*1.2*

[1] = No collagen yield. [2] = Only enamel tested. All delta values are reported in permil.

Table 6.3: Casal Bertone Necropolis δ^{13}C and δ^{15}N Results

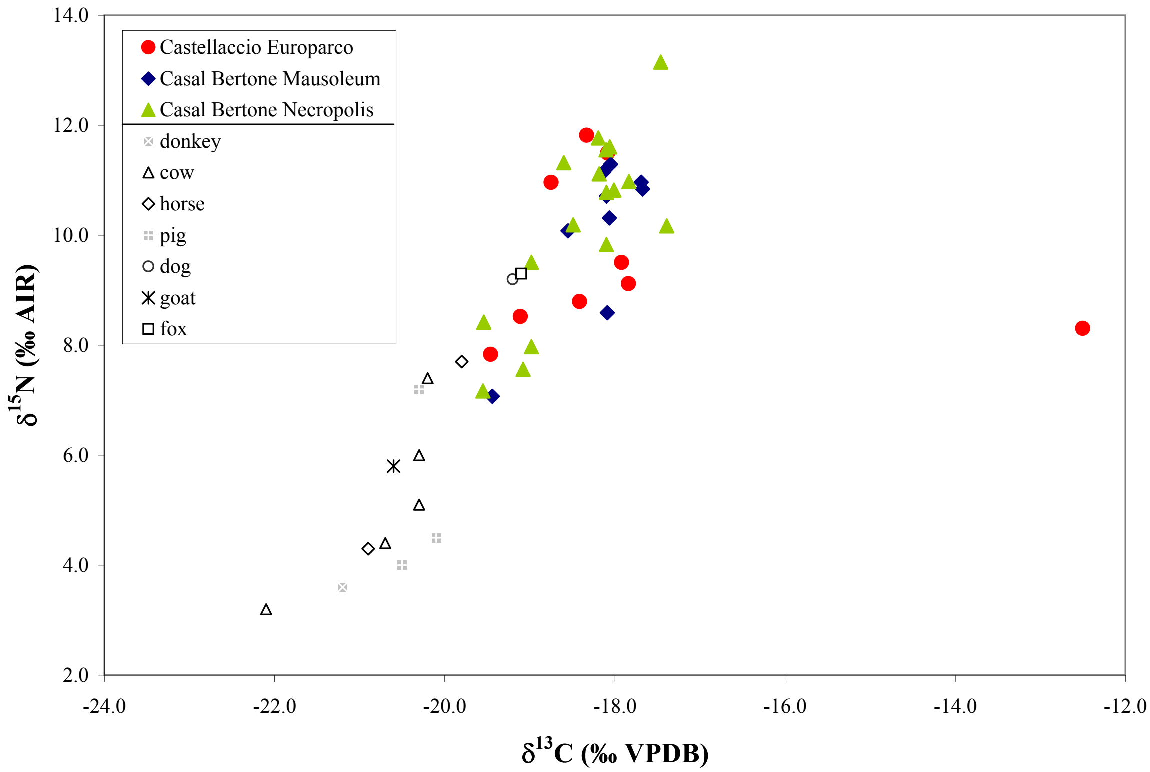


Figure 6.2: δ^{13}C and δ^{15}N with Fauna from Portus
Faunal data are from Prowse 2001.

5-7‰. The majority of the individuals studied fall within this range, but over half of the individuals sampled from Castellaccio Europarco are much higher than this, in the range of 8-10‰. The higher $\Delta^{13}C_{ap-co}$ value and low δ^{15}N for these individuals suggests they were consuming more terrestrial protein and C_4 foods than the individuals from Casal Bertone.

By graphing the $\delta^{13}C_{co}$ values versus $\delta^{13}C_{ap}$, it is further possible to investigate the general composition of the diet. Figure 6.4 presents theoretical ranges for eight different human diets based on the carbon isotopes in apatite and collagen (Krueger and Sullivan, 1984). Most of the individuals fall within the range of a diet composed of C_3 plants and marine protein, which would not be unusual for people living a few kilometers from the Tiber River and only about half a day's walk to the Tyrrhenian Sea. There are, however, several people who seem to have had a diet dominated by C_3 plants and meat, with basically no marine component. Interestingly, figure 6.4 provides further evidence that the people of Castellaccio Europarco were eating a diet

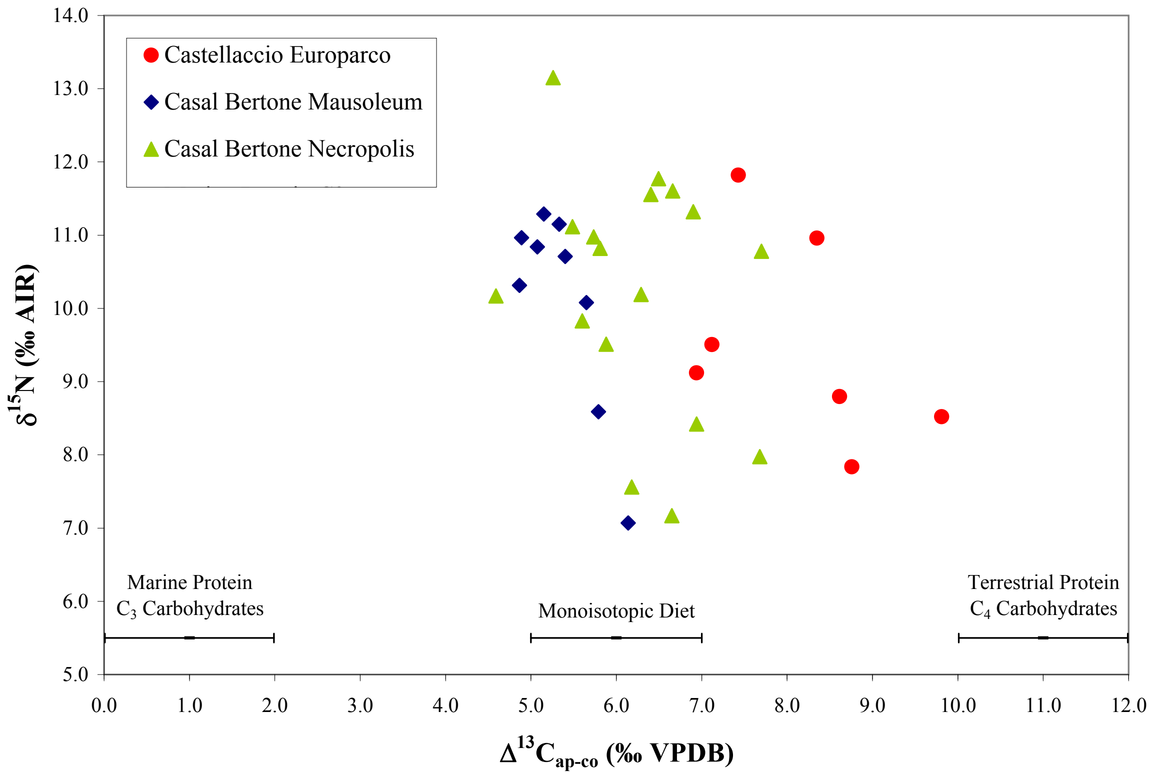


Figure 6.3: $\Delta^{13}C_{ap-co}$ versus $\delta^{15}N$

composed of foodstuffs more enriched in $\delta^{13}C$ than the diet of the people of Casal Bertone. As the $\delta^{15}N$ values in figure 6.2 are within the same range for all people, the differences seen at Castellaccio Europarco, particularly in the $\delta^{13}C_{ap}$ values, are likely related to consumption of C_4 foods, either directly or indirectly.

Although the general diet of the people from Casal Bertone and Castellaccio Europarco can be reconstructed as one composed of cereals and fish, figures 6.3 and 6.4 clearly show that the average diet at the suburban and periurban sites differs, particularly in the $\delta^{13}C_{ap}$ measurements. The differences between the two sites are further investigated below, as are intracemetery variations in age and sex, and interregional variation in diet at other published Imperial-era sites.

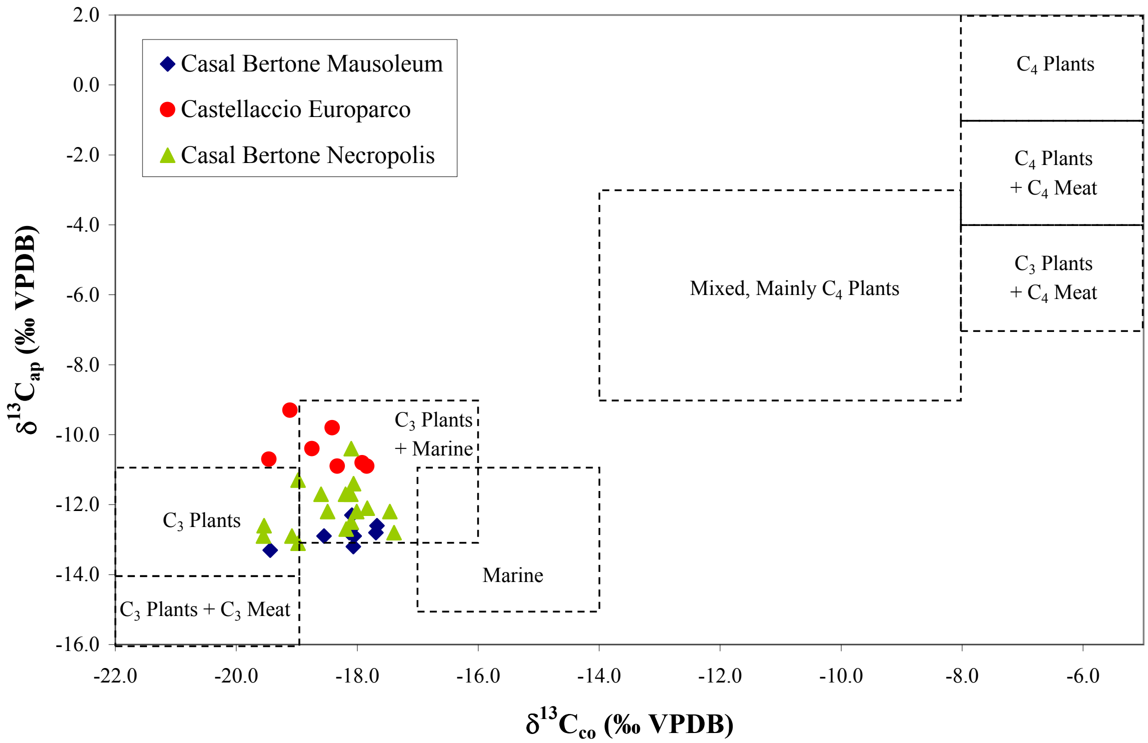


Figure 6.4: $\delta^{13}C_{co}$ versus $\delta^{13}C_{ap}$
Approximate human dietary ranges are from Krueger and Sullivan (1984, Fig. 5).

6.4 Discussion

Although palaeodietary isotope analysis is still a new methodology in the Roman world, the few studies that have been done illustrate a general Mediterranean diet composed of cereals and marine resources with regional variation. This study of two cemetery populations from the city of Rome itself represents only the second dietary study of individuals who lived in the Imperial capital. By analyzing people from two different contexts - urban and suburban - this project is the first to investigate variation in the Roman diet at a small geographical scale. Additionally, this dietary analysis is the first in the Roman world to be linked with a study of immigration and yields information on the dietary adaptation of foreigners at Rome (chapter 11). This discussion centers on differences in diet between Casal Bertone and Castellaccio Europarco, along with information on intracemetery variation in age and sex. Both populations are compared with published dietary analyses from sites along the Italian peninsula.

6.4.1 Periurban versus Rural Diet

Casal Bertone and Castellaccio Europarco were both located in the *suburbium* of Rome, about 12 km apart. Whereas the former cemetery was likely associated with a periurban site just outside the city walls, the latter cemetery was found in what was probably a largely agricultural area. These facts combined with known topographical and ecological variations in the Alban Hills area of Italy mean that differences in food resources consumed by individuals buried at these two sites would not be unusual.

Figures 6.3 and 6.4 show that there are clear clusters of individuals from the necropolis and mausoleum at Casal Bertone and from Castellaccio Europarco, particularly in terms of $\delta^{13}C_{ap}$ measurements. Table 6.4 presents the means and standard deviations for all measured and calculated isotope values at Casal Bertone and Castellaccio Europarco. Note that these values were calculated after removal of both ET20, whose $\delta^{13}C_{co}$ was significantly different from the remainder of the population (see section 6.4.4), and T29, whose $\delta^{15}N$ value indicates this subadult was not yet fully weaned (see section 6.4.3).

The average $\delta^{13}C_{co}$ values from each site are statistically very similar (two-tailed t test: $t = 0.81; p = 0.44$): within the range of -18.5 to -18.2‰ with a low standard deviation. In terms of $\delta^{15}N$, Castellaccio Europarco has the lowest average values. The mausoleum and necropolis samples from Casal Bertone are not statistically different from one another ($t = 0.40; p = 0.70$). However, a two-tailed t test comparison between the means of the pooled Casal Bertone sample and Castellaccio Europarco is statistically significant ($t = 2.41; p = 0.04$). The comparatively lower average $\delta^{15}N$ value at Castellaccio Europarco suggests consumption

	$\delta^{13}C$ (bone)	$\delta^{15}N$ (bone)	$\delta^{13}C_{ap}$ (bone)	$\Delta^{13}C_{ap-co}$ (bone)	$\delta^{13}C_{ap}$ (enamel)	$\Delta^{13}C_{ap}$ (bone-enamel)
Casal Bertone Maus	-18.2 ± 0.5	9.9 ± 1.5	-12.8 ± 0.3	5.4 ± 0.4	-12.4 ± 1.0	-0.4 ± 0.9
Casal Bertone Nec	-18.4 ± 0.6	10.1 ± 1.4	-12.2 ± 0.8	6.3 ± 0.8	-12.2 ± 1.4	0.3 ± 0.8
Castellaccio Europarco	-18.5 ± 0.6	9.8 ± 1.5	-10.6 ± 0.8	8.1 ± 1.0	-12.2 ± 1.5	1.8 ± 1.2

All delta values are reported in permil.

Table 6.4: Mean $\delta^{13}C$ and $\delta^{15}N$ Results - Imperial Cemeteries

of more terrestrial protein such as herbivores or legumes, whereas the slightly higher values at Casal Bertone could be interpreted as consumption of more marine protein. The δ^{15}N averages at the two sites, while statistically different, are still within range of other Imperial Roman populations (see section 6.4.6) and indicate a typical Mediterranean diet composed of both terrestrial and marine protein. The statistically significant variation in δ^{15}N, however, shows that there were slight intraregional differences in diet.

The $\delta^{13}C_{ap}$ measurements from bone, on the other hand, are strikingly different between the periurban and suburban sites. A two-tailed t test of the $\delta^{13}C_{ap}$ means from the two sites is statistically significant ($t = 5.57; p = 0.0005$). Average $\delta^{13}C_{ap}$ measurements of $-12.5‰$ at Casal Bertone and -10.6‰ at Castellaccio Europarco put both populations within the range of consumers of C_3 plants and marine resources. It is likely, however, that the people of Castellaccio Europarco were obtaining a diet that produced a higher average $\delta^{13}C_{ap}$ value from consuming, either directly or indirectly, more C_4 foods than the people at Casal Bertone. The cemetery at Castellaccio Europarco was associated with a villa and other indications of an agricultural lifestyle, so it is likely that these individuals were consuming either millet or domesticated animals that were fed millet to a much greater extent than the people buried at periurban Casal Bertone. Both the $\delta^{13}C_{ap}$ measurements and the frequencies of carious lesions at the two sites (8.3% at Castellaccio Europarco and 4.9% at Casal Bertone) indicate a strikingly different diet consumed by the respective populations.

Further evidence of a different diet at Castellaccio Europarco is provided by the change in the measurements of $\delta^{13}C_{ap}$ from first molar enamel and bone that can be seen in table 6.4 and figure 6.6. With only one exception (individual ET38), the $\delta^{13}C_{ap}$ values of individuals at this site increase after infancy an average of almost 2‰. This increase is in stark contrast to the average difference at the Casal Bertone mausoleum (a decrease of 0.4‰) and necropolis (an increase of 0.3‰). The average diet of infants from both sites was not significantly different ($t = 1.24; p = 0.24$) and likely included mostly terrestrial and C_3 foods. The diet of older subadults and adults from Castellaccio Europarco, on the other hand, is significantly enriched with respect to $\delta^{13}C_{ap}$. Because the $\delta^{15}N$ values at Castellaccio Europarco are actually lower than those at Casal Bertone, the increase in $\delta^{13}C_{ap}$ values more than likely relates to an increased consumption of C_4 plants or animal tissue after infancy. These $\delta^{13}C_{ap}$ values are the highest of any comparative site (see section 6.4.6); however, all other published isotope analyses of diet in ancient Italy are of coastal or periurban populations. The study of Castellaccio Europarco lends credence to the historical assessment that the diet of many rural people in Roman Italy included millet and beans.

6.4.2 Age and Sex Differences in Adult Diet

Although some researchers have found differences in diet related to age and sex among ancient Roman populations (Prowse et al., 2004, 2005; Dupras et al., 2001), others have found no differences (Craig et al., 2009; Keenleyside et al., 2006, 2009). The number of individuals in this study is comparatively small, so an analysis of age and sex differences must be viewed with caution. Figure 6.5 presents the $\delta^{13}C$ and $\delta^{15}N$ data with males, females, and subadults from each site indicated by different symbols.

An investigation of comparisons and differences with respect to age in these populations is not possible because of the small number of individuals: only two subadults from Castellaccio Europarco yielded both $\delta^{13}C$ and $\delta^{15}N$ information. Eight subadults from Casal Bertone were tested and all of them except T29, an unweaned infant, are scattered within the adult range of both $\delta^{13}C$ and $\delta^{15}N$.

Whereas both sex categories and both age groups from Casal Bertone are equally widely dispersed on both axes, the female and male groups from Castellaccio Europarco form distinct clusters on the $\delta^{15}N$ axis that do not overlap. Nevertheless, a two-tailed t test of the sex-segregated means of $\delta^{15}N$ is not statistically significant ($t = 3.45; p = 0.08$). Perhaps females at Castellaccio Europarco were consuming a bit more marine protein than males; or perhaps males and females were consuming different kinds of marine resources. For instance, the popular fish sauce *garum* was made of small fish such as anchovies and as such was found to

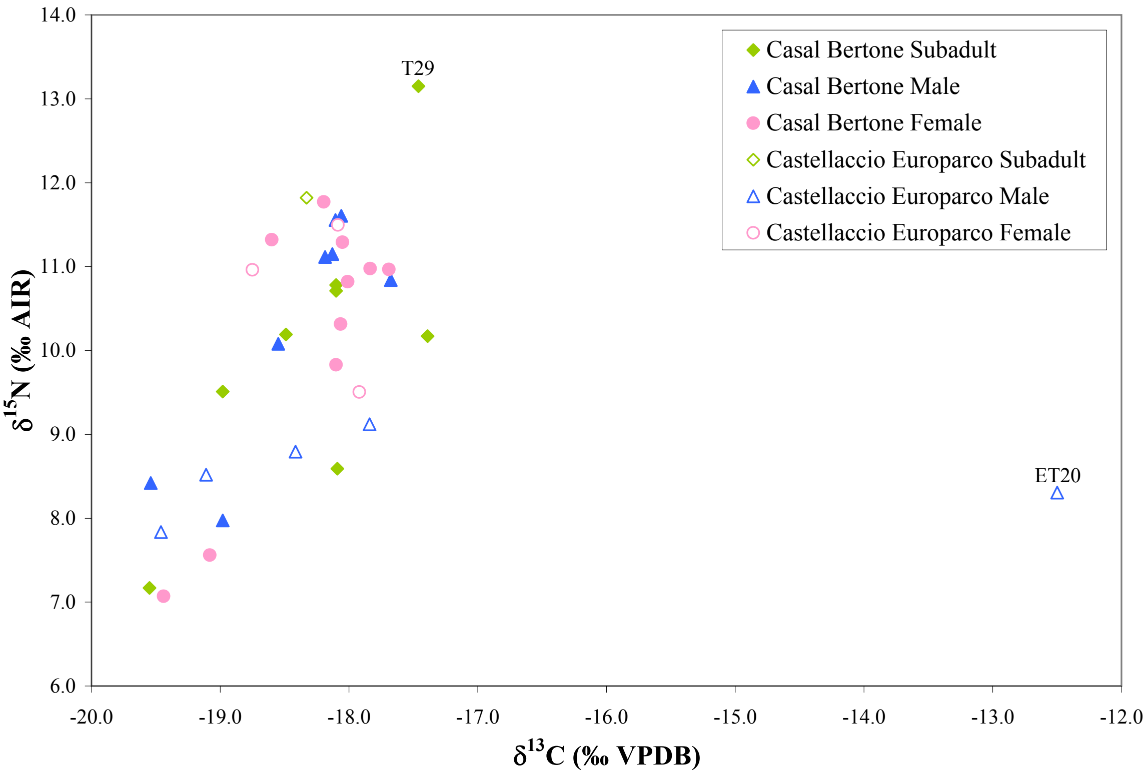


Figure 6.5: δ^{13}C and δ^{15}N by Sex and Age

have a lower (depleted) δ^{15}N value compared with fish from the Mediterranean (Prowse, 2001; Prowse et al., 2004, 2005). Further analysis of individuals and faunal material from this site might be able to provide a reason for this perceived difference.

6.4.3 Evidence of Infant Feeding Practices

As noted above, individual T29 has a comparatively high δ^{15}N value. This subadult was about 3 years old at death based on dental development, although long bone measurements provided a lower estimate, around 18-30 months. Dental age is usually a better approximation of actual age than long bone lengths, as the latter are more plastic in a population owing to vagaries of osteoclastic activity, which is influenced to a greater degree by pathology and nutritional issues than is amelogenesis. T29's δ^{15}N value of 13.2‰ is a full 3‰ enriched compared to the average adult female δ^{15}N value at the site of 10.2‰, and the child's δ^{13}C value was a little less than 1‰ more enriched than the average female value, indicating this subadult was likely still obtaining the majority of his or her nutritional needs from breastmilk.

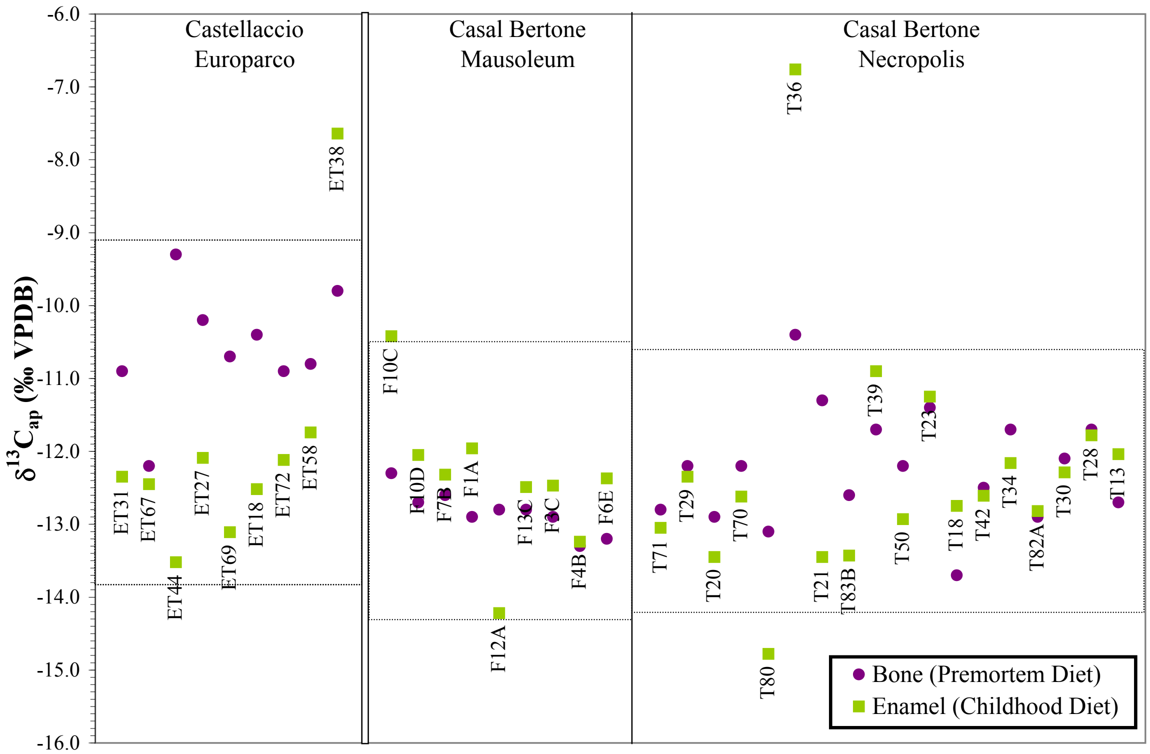
As further discussed in chapter 7, section 7.4, Roman authors and physicians recommended children be breastfed for at least six months before the introduction of weaning foods such as cow or goat milk, wine mixed with water, honey, and cereals (porridge). Direct evidence of breastfeeding and weaning in the ancient Roman world, however, comes from bioarchaeological analysis of diet. Prowse (2001) found a significant difference in both δ^{13}C and δ^{15}N in infants under 2 years of age at the Isola Sacra cemetery of Portus and suggested that weaning occurred in this population some time between 3 months and 2 years of age. An additional study of Christian burials from Rome dating to about 250-400 AD found one subadult whose δ^{13}C and δ^{15}N values were enriched over the adult female sample (Rutgers et al., 2009). Rutgers and colleagues concluded that this two-year-old was still being breastfed.

The other two young children from Rome who were under the age of five at the time of death (ET31 and T71) were both older than three. Given historical documents and bioarchaeological findings at other sites, it is unsurprising that their δ^{13}C and δ^{15}N values are not significantly enriched. Bone turnover rate in subadults is not precisely known, however, so the only conclusion to be drawn from the data is that ET31 and T71 were weaned at some point prior to three years of age.

6.4.4 Dietary Differences in Childhood

The combination of $\delta^{13}C_{ap}$ values from enamel and bone is unusual in palaeodietary analysis and has not been done before in the Roman world. The carbon isotope values measured from apatite of tissues that formed at different times in a person's life allow me to investigate age-related variation in diet at the intra-individual level.

Figure 6.6 presents the results of all individuals for whom paired $\delta^{13}C_{ap}$ values from enamel and bone were obtained. Individuals along the x axis are grouped based on burial context and sorted left to right from youngest age group to oldest (0-5 ... 61-70). The $\delta^{13}C_{ap}$ data



Dotted lines represent 2σ ranges for bone and enamel values.

Figure 6.6: $\delta^{13}C_{ap}$ of Bone Versus $\delta^{13}C_{ap}$ of Enamel

from first molar enamel effectively provides a window into the childhood diet of individuals from both sites. It is difficult to interpret $\delta^{13}C_{ap}$ without concomitant data on $\delta^{13}C_{co}$ and $\delta^{15}N$. Nevertheless, figure 6.6 indicates that the childhood diet for individuals assumed to have grown up near Casal Bertone and Castellaccio Europarco was the same within statistical limits ($t = 1.24; p = 0.24$). Although the precise relationship between $\delta^{13}C_{ap}$ and diet is unknown, it has been approximated at -12‰ (Prowse et al., 2004, 2005). The average $\delta^{13}C_{ap}$ from enamel at both sites is about -12‰, meaning dietary $\delta^{13}C_{ap}$ was likely around -24‰, which is consistent with a terrestrial, C_3 based diet.

The Casal Bertone mausoleum and necropolis populations have fairly consistent $\delta^{13}C_{ap}$ measurements between bone and enamel, but Castellaccio Europarco shows a significant increase in $\delta^{13}C_{ap}$ after childhood (table 6.4 and figure 6.6). Interestingly, at Isola Sacra, Prowse and colleagues (2005) found that $\delta^{13}C_{ap}$ from bone generally decreased with age (see table 6.5).

These researchers hypothesized that individuals in older age groups tended to consume proportionally more meat and fish than younger individuals; alternatively, those individuals who consumed greater amounts of maritime protein lived longer than people who did not. Age-related variation within individuals at Castellaccio Europarco indicates the opposite trend: as adults, people were likely eating more C_4-enriched foods than they were as children. The lack of age-related variation at Casal Bertone could indicate a less variable diet for people living just outside the city of Rome compared to the diets of individuals in the *suburbium* and at Portus. Further analysis of infants from both Casal Bertone and Castellaccio Europarco therefore could add to our growing knowledge about infant feeding and weaning practices in ancient Rome.

Individuals whose enamel $\delta^{13}C_{ap}$ values are strikingly different from the average include ET38 at Castellaccio Europarco, the only individual from that site whose enamel is more enriched than the bone, and T36 at Casal Bertone, whose bone is similarly more enriched than the rest of the population. The extremely high $\delta^{13}C_{ap}$ values of these two individuals most likely represent higher consumption of C_4 foods as children than the remainder of the population. Also shown in figure 6.6 are dotted lines representing a two standard deviation range of the average bone and enamel values for each context. Individuals who fall outside of this range, F10C from the mausoleum and T80 from the necropolis, are statistically different than the remainder of the population. F10C has slightly higher than expected $\delta^{13}C_{ap}$ values indicative of a childhood diet with a significant C_4 plant component, and T80 has a lower than expected $\delta^{13}C_{ap}$ value suggesting a childhood diet composed of primarily C_3 plants.

Carbon and nitrogen isotopes measured from skeletal material from archaeological sites are expected to vary within the population, sometimes along age and sex lines, as different individuals exploit different food resources. Comparing the $\delta^{13}C_{ap}$ measurements from dental enamel, however, removes some of this variation because these ratios are formed during amelogenesis and thus represent a snapshot in time rather than the cumulative diet over decades. People whose $\delta^{13}C_{ap}$ childhood isotope ratios differ significantly from the remainder of the population, then, were either purposefully being fed an abnormal diet or were being fed foods characteristic of their local ecosystem or cultural background. These explanations will be addressed further in chapter 11.

6.4.5 Status Differences - Casal Bertone

Although measurements of δ^{13}C and δ^{15}N in individuals from the Casal Bertone mausoleum and necropolis are similar in range, the $\delta^{13}C_{ap}$ values in bone from the two contexts are significantly different (two-tailed t test: $t = 3.26, p = 0.02$). The differences can be seen in figure 6.6 and table 6.4 along with paired $\delta^{13}C_{ap}$ data from first molar enamel. The measurements of $\delta^{13}C_{ap}$ from bone at the mausoleum of Casal Bertone are very similar to the measurements of $\delta^{13}C_{ap}$ from enamel, indicating the diet of an individual changed little following childhood. On the other hand, the $\delta^{13}C_{ap}$ values of bone from the people buried in the necropolis vary widely, particularly in the younger adult individuals (16-20 years and 21-30 years old, or individuals T21 through T18 in figure 6.6). Individuals on the older end of the necropolis age range in turn have smaller $\Delta^{13}C_{ap}$ differences. These data are few but could indicate a more varied diet during young adulthood followed by a less varied diet in senescence.

It is clear from the closer investigation of the burial contexts at Casal Bertone that, if anomalous individuals are excepted (see section 6.4.4), the diet of those interred in the mausoleum is consistent no matter age at death, whereas the adult diet of those interred in the necropolis is quite variable. Mausoleum burial is often assumed to indicate a higher social status than simple burial in the ground. In the Roman world, even if mausoleum construction was financially impossible for poorer individuals, membership in a guild (*collegium*) put mausoleum burial within the reach of the working class of society. Although very few grave goods were found at Casal Bertone to indicate social status, excavators assumed that the people in the mausoleum were of higher status than the necropolis people and hypothesized a relationship in which the former were the owners or managers of the fullery/tannery and the latter were workers or slaves (Musco et al., 2008). The available bioarchaeological evidence does not allow us to test this assumption directly. However, the differences in diet between the two contexts could indicate that the people buried in the mausoleum had better or at least more consistent access to food over the course of their lives, whereas those in the necropolis obtained a more varied diet from whatever food sources they could find. The poorer classes of Rome were eligible for a grain dole of 5 *modii* of wheat per month (equal to about 5 pecks), but citizenship was a requirement (Garnsey and Rathbone, 1985). The low $\delta^{13}C_{ap}$ values of the mausoleum people are consistent with a diet composed mostly of C_3 plants such as wheat; therefore, they could have taken advantage of the dole to a greater degree than individuals in the necropolis. Although this variation in diet, combined with archaeological and historical information, suggests a status difference between the mausoleum and necropolis burials at Casal Bertone, it is far from conclusive proof.

6.4.6 Dietary Comparisons - Other Imperial Sites

Only a handful of palaeodiet studies have been done on populations from Imperial Italy. The best comparative study for individuals from Casal Bertone and Castellaccio Europarco is Prowse and colleagues' analysis of skeletons from the Imperial necropolis at Portus (Prowse, 2001; Prowse et al., 2004, 2005). Recently, a small dietary analysis was published from the Christian (3rd-5th century AD) necropolis of St. Callixtus, which was located about 3 km from the city walls of Rome and less than 5 km from Casal Bertone (Rutgers et al., 2009). Although this site is as likely to represent a periurban population as Casal Bertone is, the fact that these individuals were early Christians raises the issue of differences in diet due to asceticism. Prowse (2001) published additional sample data from the cemetery known simply as ANAS, which was located halfway between Portus and Rome. Further south on the Italian peninsula, a dietary study of people from early Imperial Velia (modern Elea) was undertaken by Craig and colleagues (2009).

Table 6.5 lists the mean and 1σ standard deviations of $\delta^{13}C$ and $\delta^{15}N$ from the Italic populations, and figure 6.7 displays these data in graphical form. As noted above, the mean and standard deviation for $\delta^{13}C$ and $\delta^{15}N$ from the study sites were calculated following removal

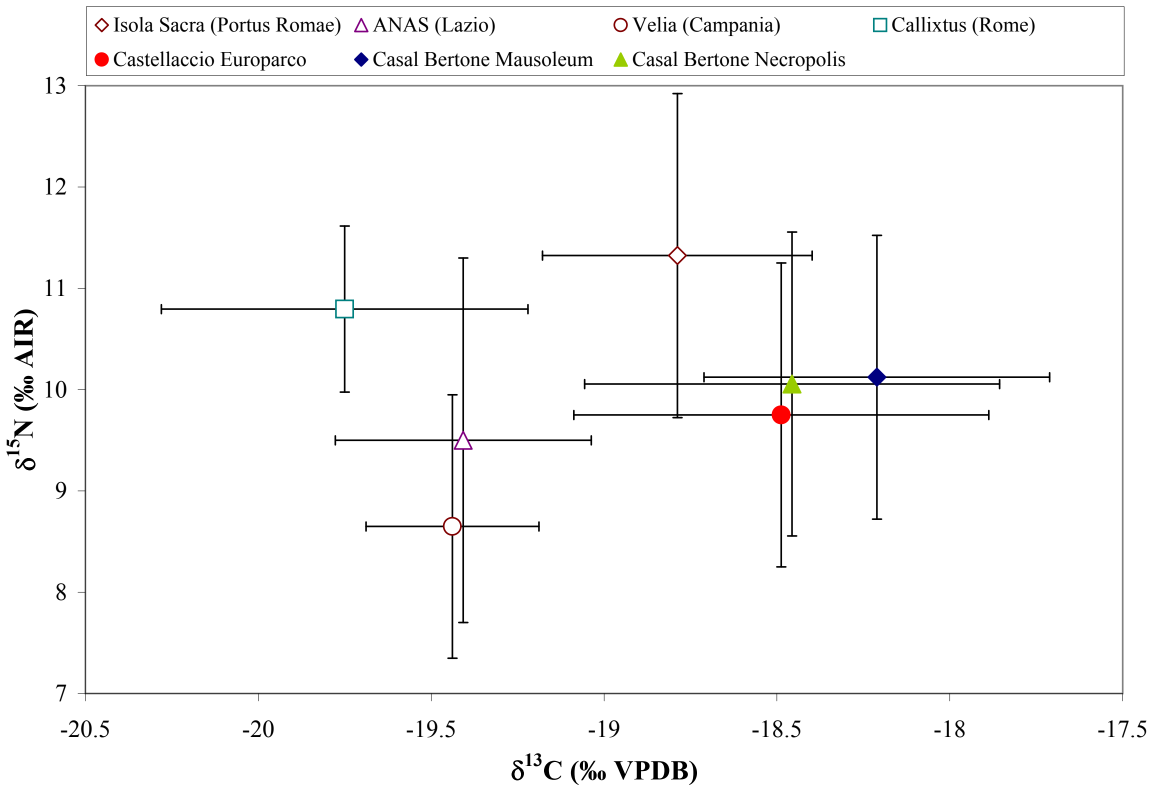


Figure 6.7: δ^{13}C and δ^{15}N Averages from Comparative Sites

of ET20 and T29. Because of differing ecological niches and available flora and fauna, it is currently unknown whether the actual δ^{13}C and δ^{15}N numbers of the other peninsular sites are directly comparable to the values at Casal Bertone and Castellaccio Europarco. It is reasonable to assume, however, that people living at Rome had access to many of the same resources that individuals at Portus did. Prowse (2001) assumed that the people buried at ANAS could be interpreted with reference to the Portus faunal data. Rutgers and colleagues (2009) also employed these faunal data in interpreting the diet of late Imperial Christians. The same must be done here owing to a lack of testable faunal remains from Casal Bertone and Castellaccio Europarco.

The two study sites have average δ^{13}C values very close to those of Isola Sacra at Portus. Still, the average δ^{13}C measurements from the two study populations are more enriched than

	$\delta^{13}C$ (bone)	$\delta^{15}N$ (bone)	$\delta^{13}C_{ap}$ (bone)	$\Delta^{13}C_{ap-co}$ (bone)
Casal Bertone Mausoleum	-18.2 ± 0.5	9.9 ± 1.5	-12.8 ± 0.3	5.4 ± 0.4
Casal Bertone Necropolis	-18.4 ± 0.6	10.1 ± 1.4	-12.2 ± 0.8	6.3 ± 0.8
Castellaccio Europarco	-18.5 ± 0.6	9.8 ± 1.5	-10.6 ± 0.8	8.1 ± 1.0
Callixtus	-19.8 ± 0.5	10.8 ± 0.8	—	—
ANAS	-19.4 ± 0.4	9.5 ± 1.8	—	—
Isola Sacra	-18.8 ± 0.4	11.3 ± 1.6	-11.4 ± 1.1	7.4 ± 1.3
Velia	-19.4 ± 0.3	8.6 ± 1.3	—	—

Table 6.5: Mean $\delta^{13}C$ and $\delta^{15}N$ Results - Comparative Sites on the Italian Peninsula

the average measurements at the other peninsular sites, likely indicating a slightly higher consumption of C_4 plants. Nitrogen isotope values range more widely, but they are predictably higher at the Tyrrhenian coastal city of Portus than at the inland Roman sites (Casal Bertone, Castellaccio Europarco, and Callixtus). Surprisingly, however, the southern coastal site of Velia has a comparatively depleted average nitrogen ratio.

Prowse and colleagues (2004) interpret the ANAS isotope values as indicative of a terrestrial diet, as the $\delta^{13}C$ and $\delta^{15}N$ values are not enriched more than expected based on trophic level. As ANAS was an inland site outside the *suburbium*, this conclusion is not unusual. At Portus, on the other hand, individuals were comparatively enriched in both $\delta^{15}N$ and, to a lesser degree, in $\delta^{13}C$. As Portus was located on the Tyrrhenian coast, it is not unexpected to find that its people were consuming nitrogen-enriched marine protein. The Roman Christians buried in the necropolis at Callixtus have average $\delta^{15}N$ values midway between Isola Sacra and ANAS, indicating more marine protein consumption than the latter but less than the former. This necropolis was located about 3 km from the Tiber River, meaning people living in the area could have had access to marine resources. Rutgers and colleagues (2009) note the comparatively low (depleted) $\delta^{13}C$ values from individuals in the Callixtus necropolis and interpret them as evidence of consumption of freshwater fish. Finally, at Velia, a site in Campania on the Tyrrhenian sea, Craig and colleagues (2009) undertook a large dietary analysis of human and faunal remains. They concluded that their average δ^{13}C and δ^{15}N values were consistent with a largely terrestrial diet of cereals with a small contribution from meat and marine resources. These researchers further note, however, that there was substantial variation within the population at Velia, suggesting that the diet of individuals buried there was not uniform.

The average δ^{15}N values of populations from Casal Bertone and Castellaccio Europarco fall between the diet of people at Portus and Callixtus, with moderate marine protein components, and the diet of people at ANAS in the countryside of Latium and Velia in Campania, who consumed a diet composed mostly of terrestrial protein. It does not appear that legumes constituted the bulk of the protein component of the diet at any of the Italian sites. The average δ^{13}C values from Casal Bertone and Castellaccio Europarco, on the other hand, are higher than those at Portus and quite a bit more enriched than those of Velia, ANAS, and Callixtus. A more enriched δ^{13}C signature coupled with a δ^{15}N average on par with surrounding contemporaneous sites indicates the consumption of more C_4 foods, either directly or indirectly, by the people at Casal Bertone and Castellaccio Europarco. Nevertheless, both of these sites have quite wide ranges of δ^{13}C values, and neither is similar to the average values at nearby Callixtus, indicating there was no standard Roman diet.

No comparative data were found on $\delta^{13}C_{ap}$ from dental enamel against which to interpret the results from Casal Bertone and Castellaccio Europarco. The significant enrichment in $\delta^{13}C_{ap}$ from childhood to adult diet at Castellaccio Europarco was unexpected considering the age-related dietary variation discovered by Prowse and colleagues (2005) at Portus, where $\delta^{13}C_{ap}$ was lower in adult bones than in subadult bones. The isotope study of a population from Roman-period Egypt by Dupras and colleagues (2001), however, helps generate a hypothesis for the discovered $\delta^{13}C_{ap}$ increase at Castellaccio Europarco. Dupras and colleagues (2001) found that infants in their sample who were being breastfed or in the process of weaning displayed a distinctive δ^{13}C enrichment, which they believe was related to the practice of giving infants cow or goat milk from animals that had been foddered on millet. Millet was well-known in the Roman world as fodder for dairy- and egg-producing herbivores, but its low nutritional value for humans meant it was unlikely to be consumed directly except in times of food shortage and famine (Jasny, 1942; Garnsey, 1999; Nenci, 1999; Purcell, 2003).[5] The low $\delta^{13}C_{ap}$ values in the enamel of individuals from Castellaccio Europarco indicate that the C_4 enriched foods were not given to infants in the process of weaning, meaning goat or cow milk might not have made up a large part of the weaning foods offered a Roman infant. Rather, the fact that the adult diet is enriched with respect to $\delta^{13}C_{ap}$ indicates that people were likely eating food produced by animals foddered on the grain: mutton, poultry, beef, milk, or eggs. Of these, mutton is the most likely candidate, as there is archaeological evidence to attest to about one-quarter of the protein component of the Roman diet being composed of sheep or goat meat, with beef and poultry less often consumed (Brothwell, 1988; Garnsey, 1999). Further analysis would be necessary, of course, to confirm this hypothesis, particularly testing faunal remains from the site of Castellaccio Europarco to determine if any herbivores were enriched with respect to $\delta^{13}C$.

Comparative analysis of the $\delta^{13}C$ and $\delta^{15}N$ values of skeletal populations from nearby sites indicates that terrestrial meat and C_3 plants such as wheat made up a large portion of the average diet. Beyond this, however, there is significant variation between sites, as some populations consumed fresh- and/or salt-water marine resources and some consumed C_4 plants directly or indirectly. There is also variation within populations; the three populations from the Roman *suburbium* have substantial, yet non-overlapping, $\delta^{13}C$ ranges. Additional research is needed into dietary practices in Rome, the Italian peninsula, and the Empire in general in order to better understand the diversity of foodways and exploitation of local resources that have been largely glossed over in surviving historical sources.

[5]Nevertheless, both direct and indirect evidence of consumption of C_4 plants has been found in earlier time periods of Roman history in northern Italy (Pals and Voorrips, 1979; Murray and Schoeninger, 1988; Tafuri et al., 2009) and at Pompeii (Robinson, 2002), although Motta (2002) found no evidence of millet in a palaeobotanical study of the Palatine in 8th-6th century BC Rome.

6.5 Conclusions

Results of the dietary analysis from periurban Casal Bertone and suburban Castellaccio Europarco indicate the two populations were utilizing different resources to comprise the part of their diet that differed from the standard ancient Mediterranean diet. Whereas individuals living closer to the city of Rome were consuming some marine resources, those in the *suburbium* made greater use of millet. Within the population from each site, there is no significant evidence of sex-related variation. A change in the type of food consumed after infancy can be seen at Castellaccio Europarco, where a dramatic increase in $\delta^{13}C_{ap}$ between enamel and bone is indicative of increased C_4 consumption starting perhaps in later childhood. Casal Bertone, on the other hand, provides evidence of a relatively static diet between childhood and maturity. The individuals from mausoleum burials presented $\delta^{13}C_{ap}$ enamel and bone values that were very close together, suggesting these individuals had the most consistent access to resources and could thus have been of a higher social class than individuals from the necropolis. Evidence of one breastfeeding child was found from Casal Bertone, demonstrating a lengthier period of nursing than the minimum advocated by ancient physicians.

The dietary study of individuals from Casal Bertone and Castellaccio Europarco was initially undertaken in order to provide contextual information about the diet of individuals living in periurban and suburban Rome. The unexpected availability of $\delta^{13}C_{ap}$ data from enamel, however, provided a way to compare an individual's diet at two different points in his or her life. In the sample of 36 individuals for whom $\delta^{13}C_{ap}$ data from both bone and enamel were gathered, four were found to deviate from a 2σ range of $\delta^{13}C_{ap}$ values calculated for each site, indicating a childhood diet different from the typical Roman diet. These findings will be discussed in more depth in chapter 11.

Comparisons between the diets of individuals at Casal Bertone and Castellaccio Europarco with Imperial-period sites from the Italian peninsula show that there was no singular Roman diet. To a base of cereals, olives, and wine were added terrestrial meat, legumes, fish, and millet in different proportions and from different sources. Although copious amounts of food were imported from various areas of the Empire - grain from north Africa, olive oil from Greece, wine from France - the diet of the average lower-class Roman was likely contingent on food-stuffs available in the immediate area. This palaeodietary analysis of two sites in the Roman *suburbium* demonstrates the variation that existed in the diet of the common people. More stable isotope research is needed on populations from Rome and Imperial Italy, in addition to zooarchaeological and palaeobotanical studies, in order to more fully understand the variety of natural resources available for both human and animal consumption in this important historical time period.

Part III

Human Mobility in Imperial Rome - A Multipronged Approach

Chapter 7

Methods of Assessing Mobility

This project on migration and mobility in the Roman Empire rests primarily on the assumption that it is possible to identify nonlocal individuals based on their skeletal remains. Although there are examples in Rome of foreigners commemorating themselves or their families in death (e.g., the aforementioned Eurysaces), the vast majority of the lower class was buried outside the city walls in simple graves with few goods that would indicate a connection with a different homeland or ethnicity. Assessing mobility from bioarchaeological remains of lower class Romans thus necessitates chemical analyses of the skeletal tissue itself. Part III of this dissertation presents the methods most often used to understand mobility in the past from human skeletal remains. The methodological background for two chemical analyses are given in this chapter, as well as examples of studies in the Roman world that utilize these methods. Results of the chemical analyses of the Casal Bertone and Castellaccio Europarco populations are presented in the next three chapters, followed by a discussion of locals and nonlocals in Part IV.

7.1 Archaeological Mobility Studies in Brief

From investigating hunter-gatherer food procurement patterns to understanding contemporary transnational immigrants, mobility studies in anthropology have several questions in common: What was the impetus to move? How can we characterize communities with nonlocal members? What was the quality of life like for the individual who moved? Like many researchers who engage in archaeological mobility studies, I tackle mainly the latter two questions, as push and pull factors of immigration are notoriously difficult to deal with in ancient populations (Anthony, 1997). The quality of life of the lower class of Rome is not well-known from historical texts, and there is a gap in palaeodemographical information on immigrants to the city. As noted in chapter 4, there are no distinguishing characteristics, either biological or cultural, that would suggest that any of the individuals from Casal Bertone or Castellaccio Europarco originated somewhere other than Rome. Identification of nonlocal individuals is thus critical to my research, which employs a multipronged approach to characterize mobility among the cemetery populations at Casal Bertone and Castellaccio Europarco.

Prior to the 1990s, investigations of mobility used quantitative statistics to demonstrate, for example, exogamous marriage patterns and population origin: Relethford and Lees (1982) laid out ways of understanding human population structure from skeletal traits and Kennedy (1981) used biological distance statistics to survey marriage patterns in Newfoundland based on skeletal remains. The processualist focus on anthropometry as an objective method for understanding past population dynamics has largely been subsumed by chemical techniques for studying ancient human tissue.[1] A recent review of statistical methodology by Stojanowski and Schillaci (2006), however, is indispensable for its coverage of questions that can be answered using anthropometry and its demonstration that this technique can yield important information about past group mobility. The skeletal material available for this study was not particularly well-preserved, and a craniometric analysis could not be performed to investigate migration. Statistical analyses of nonmetric cranial traits were performed on data recorded from adult skulls from Casal Bertone and Castellaccio Europarco. These analyses, however, are inconclusive because nonmetric data are better suited to uncovering differences in a population rather than between individuals. The nonmetric trait analysis is presented in its entirety in appendix C.

[1]A quick review of the *American Journal of Physical Anthropology* for the year 2009, for example, finds just two articles that used only anthropometric data to investigate questions of migration in modern humans (Schillaci et al., 2009; Hanihara and Ishida, 2009). On the other hand, four articles used only chemical analyses to understand migration (Mitchell and Millard, 2009; Perry et al., 2009; Schroeder et al., 2009; Knudson and Torres-Rouff, 2009), and one additional article combined chemical and statistical methods (Leach et al., 2009).

Much more common in mobility studies today is the employment of chemical analyses of human bone and teeth. Starting in the 1990s, archaeologists realized that, whereas cranial and dental metrics worked best to characterize groups of people, isotope analyses had the potential to identify anomalous individuals. The first applications of strontium isotope analysis of human tissue were done by Ericson (1989) and Sealy (1989). Both studies sought to identify individuals who grew up on the coast versus inland, the former in prehistoric California and the latter in South Africa. Shortly thereafter, Price and colleagues (1994a,b) used this technique on the Bell Beaker people in ancient Bavaria and the Native Americans at Grasshopper Pueblo in Arizona. The vast majority of strontium isotope analyses done by anthropologists today address questions of human mobility (Knudson and Price, 2007, p. 25). Analysis of oxygen isotope ratios became popular in the early 2000s. Following work by geologists who demonstrated the possibility of reconstructing past conditions from mammal bone in spite of fractionation effects (Longinelli, 1984), one of the first uses of this analysis to investigate human mobility in the past was at Teotihuacan (White et al., 1998). Scholars in various geographical areas began to undertake oxygen analysis, as in Egypt (Dupras et al., 2001) and Britain (Budd et al., 2003a), in order to characterize mobility in the past. Oxygen isotope analyses are thus being used today to understand the ancient climate, water sources available to humans in the past, and human and animal mobility.

Two elements that are sometimes studied in order to provide direct evidence of ancient migration of individuals are lead and sulfur. The use of lead isotopes is not widespread and has been primarily used in Roman Britain (Montgomery et al., 2000; Montgomery, 2002; Montgomery et al., 2005). Lead isotopes are similar to strontium isotopes in that they vary with respect to the geology of the region and are incorporated into the human body mainly through diet in preindustrial societies. Anthropogenic lead, however, does seem to have had an effect on the lead isotopes measured from the skeletons of a Romano-British population (Montgomery et al., 2005). Although individuals from Casal Bertone and Castellaccio Europarco were not buried in lead coffins, it is well known from ancient sources such as Pliny's *Historia Naturalis* and Columella's *de re Rustica* that lead was used and consumed in many everyday items, from eating utensils to sweetened wine to water pipes. Because of the assumed prevalence of anthropogenic lead in Imperial Rome, this element was not chosen as a method of characterizing the mobility of individuals in this study. Much more recently, some scholars have advocated using sulfur isotope analysis to investigate migration (Richards et al., 2001; Vika, 2009). Like strontium and lead, sulfur is linked to geology and, like carbon and nitrogen, it is also linked to diet. Sulfur is most useful in distinguishing between people who lived near and ate food from the coast and those who are characterized more by an inland signature. Because of the geography of Italy, oxygen and sulfur isotope analyses are likely to produce similar information. For this reason, sulfur isotope analysis of the skeletal remains from Rome was not undertaken.

The most recent trend in archaeological mobility studies is employing a variety of techniques to characterize past movement, including isotopes, trace elements, and morphometrics (Knudson and Price, 2007; Schwarcz et al., 2010). Researchers have most often combined strontium and oxygen isotope analyses (Bentley and Knipper, 2005; Evans et al., 2006a,b; Schroeder et al., 2009), but there are examples of combinations of strontium with lead (Montgomery et al., 2000; Montgomery, 2002) and of the inclusion of morphometrics (Leach et al., 2009). Statistical analyses of nonmetric cranial traits were employed at the outset of this project in order to gain a broad understanding of the characteristics of and possible relationships between the people at Casal Bertone and Castellaccio Europarco (appendix C). Strontium and oxygen isotope analyses were then undertaken on subsets of the populations in order to specifically identify nonlocal individuals.

7.2 Strontium Isotope Analysis

Although some researchers have used trace elements to recognize mobility, heavy and light isotopes are the most useful for understanding ancient migration. The frequently utilized elements of strontium and oxygen form independent systems that reflect their consumption by plants, animals, and humans in the food chain. Individuals local to an area should have an isotope signature characteristic of the water, soil, and rocks in the region. Nonlocal individuals will present anomalous ratios compared to the locally-defined signature. By comparing the isotope ratios of Sr and O in human tissue with published geology and climatology data, it becomes possible to predict the homelands of nonlocal individuals (Pollard et al., 2007, p. 191).

The fundamental idea behind strontium isotope analysis is that the relative abundance of strontium isotopes is related to bedrock and to the geological peculiarities of a particular region. As bedrock weathers, it releases strontium into groundwater and surrounding soil, and this element enters the food chain and is incorporated unfractionated into the human body during tissue formation. Chemical analysis of bone or enamel can thus indicate whether an individual moved during her lifetime and potentially whence the person emigrated.

Strontium has four isotopes that occur in nature with different abundances: ^{88}Sr, ^{87}Sr, ^{86}Sr, and ^{84}Sr. Whereas ^{88}Sr, ^{86}Sr, and ^{84}Sr do not vary over time, ^{87}Sr increases with time because of the decay of ^{87}Rb. This radioactive decay is an extraordinarily slow process, however, as ^{87}Rb has a half-life of about 47 billion years (Pollard et al., 2007). Although this isotope system is not technically stable, the minuscule increase in strontium from the decay of rubidium during the Holocene means that ^{87}Sr/^{86}Sr can be treated as a stable isotope system for archaeological populations. ^{87}Sr is measured in relation to ^{86}Sr because these isotopes are similar in abundance (7.04% and 9.87%, respectively), whereas ^{88}Sr and ^{84}Sr are the highest and lowest, respectively.

The strontium isotope ratio of any specific rock reflects the relative amounts of rubidium and strontium present during its formation, as well as post-formation processes such as mixing or metamorphic activity (Montgomery, 2002). Measured ^{87}Sr/^{86}Sr ratios are related to both the age and the isotopic composition of the rock; thus, older rocks have more radiogenic ^{87}Sr than younger rocks. The geology of our planet has not changed significantly in the time since modern humans evolved, and the ^{87}Sr/^{86}Sr ratio of Earth ranges from about 0.703 in young volcanic rock to 0.740 in older, crustal rocks (Faure, 1986; Montgomery, 2002; Pollard et al., 2007). The differences in strontium isotope ratios within this range are small, but with the advent of thermal ionization mass spectrometers (TIMS), they can be measured to a precision of ± 0.000007 (Montgomery, 2002).

Strontium enters the biosphere through the weathering of rocks. This heavy element does not significantly fractionate like the light isotopes (oxygen, carbon, and nitrogen - see chapter 6 and below), and thus strontium passes into groundwater, soil, plants, animals, and humans basically unchanged from its original geological ratio. Nevertheless, strontium isotope ratios are said to be *characteristic* of a geological area rather than a direct reflection of it because strontium ratios can be modified by the mixing of sources with different strontium ratios and concentrations (Montgomery, 2002, p. 24-5). If local water from the volcanic geology of Rome, for example, is mixed with a large amount of seawater with a low Sr concentration, the concentration of the mixture will decrease significantly, but the Sr ratio should only decrease slightly. Strontium isotope ratios are thus often plotted compared to strontium concentrations on a mixing line with two endpoints, the local and the introduced ratios (Montgomery, 2002, p. 25).

Humans obtain strontium primarily from their diet. The water we drink and the plants and animals we consume all possess strontium isotope ratios characteristic of the geology in which these food items were produced. As the atomic radius of strontium is similar to that of calcium, strontium can substitute for calcium in certain minerals, including apatite and phosphate. Almost all of the strontium in the human body is found in skeletal tissues (Underwood and Mertz, 1977). Bioavailable strontium thus moves unchanged from rocks through the food chain to the human body, where it is incorporated through passive substitution for calcium into the mineral phase of tissue development (Montgomery, 2002, p. 34). The geological provenance of an individual from his hard tissue is made possible by analysis of the $^{87}Sr/^{86}Sr$ ratio, which provides a link between humans and geology through the intermediary of diet.

Similarly, the strontium concentration in tissue is related to both the diet and the amount of strontium available in the geological environment, so strontium concentrations also vary geographically and with trophic level. Herbivores, for example, have higher strontium concentrations than carnivores, as meat has low levels of strontium and plants have high levels; modern humans typically range between 50-300 ppm (Montgomery, 2002, p. 37). It is therefore possible that excessive consumption of one dietary product could change an individual's $^{87}Sr/^{86}Sr$ ratio. Both the concentration of strontium and the ratio between ^{87}Sr and ^{86}Sr can be measured from the hard tissue of ancient human remains.

Strontium isotope analysis tends to be expensive, as the process of extracting, cleaning, and analyzing strontium from ancient human remains is labor-intensive and slow. Until very recently, all strontium analyses were done via thermal ionization mass spectrometry (TIMS) (Pollard et al., 2007). TIMS is an extremely accurate and precise way to measure isotope ratios in samples with very small elemental concentrations. As mentioned, all strontium ratios on Earth fall within a very small range, necessitating high precision in their measurement. Some researchers have investigated the use of inductively coupled plasma mass spectrometry (ICP-MS), but the accuracy of the resulting measurements is unclear for archaeological samples (Pollard et al., 2007). This project used the TIMS method because of its availability at the Isotope Geochemistry Laboratory in the Department of Geological Sciences at UNC.

Previous studies of migration and mobility within the Roman Empire using strontium isotopes have only been undertaken in Late Roman Bavaria (Schweissing and Grupe, 2003), Britain (Evans et al., 2006b), Greece (Nafplioti, 2008), and northeastern Africa (Buzon and Bowen, 2010). The countries of Germany and the United Kingdom have been fairly well studied in terms of strontium bioavailability in the Imperial period, but there have been no comparable studies in Italy. Only two strontium studies on biological remains in Italy have been accomplished, both on prehistoric faunal materials. These studies will be discussed in more depth in chapter 8, along with the results of the strontium isotope analysis of samples from Casal Bertone and Castellaccio Europarco. The strontium analysis in this project therefore serves to both understand mobility in the Roman Empire and to generate baseline and comparative data to aid future studies of migration.

7.3 Oxygen Isotope Analysis

Oxygen isotope analysis has been used for many years in palaeoclimate studies. Its application to questions of past human mobility, however, became popular only in the last decade. Oxygen isotopes are related to various climatological factors that affect the elemental composition of water. Because the oxygen isotopic composition of body water is related to the isotopic composition of environmental water (Longinelli, 1984), it stands to reason that measuring the oxygen incorporated into human tissue during development will yield a ratio characteristic of the local area in which a person lived.

Whereas strontium is a heavy element and passes through the food chain unfractionated, oxygen, carbon, and nitrogen (see chapter 6), are light elements. Oxygen occurs naturally in more than one stable isotopic form. The most abundant is ^{16}O (99.76%), with the heavier isotopes of ^{18}O (0.2%) and ^{17}O (0.04%) making up a fraction of all available oxygen (Pollard et al., 2007). Unlike radioactive isotopes such as ^{87}Rb or ^{14}C, stable isotopes of an element do not decay over time (Katzenberg, 2008).

The amount of ^{18}O versus the amount of ^{16}O in a sample can therefore be directly measured by an isotope ratio mass spectrometer (IRMS). The measured ^{18}O/^{16}O ratio is usually presented in delta notation:

$$\delta^{18}O(\text{‰}) = \left(\frac{^{18}O/^{16}O_{sample} -^{18} O/^{16}O_{standard}}{^{18}O/^{16}O_{standard}} \right) \times 1000$$

where the delta value is given in per mil (‰) and measured with respect to a standard. Oxygen isotope ratios are typically measured with respect to the VSMOW (Vienna Standard Mean Ocean Water) standard, although it is also possible to measure them with respect to VPDB (Vienna Pee Dee Belemnite). The latter standard is often used for measuring oxygen isotope ratios from carbonates. A conversion exists to compare data obtained relative to each standard. In this study, measurements were taken with respect to VSMOW.

The δ^{18}O of both meteoric (rain, snow) and environmental water (rivers, springs, lakes) varies by region in relation to factors such as temperature, humidity, distance from the coast, latitude, rainfall, and elevation (Craig, 1961; Gat, 1996). Measurement of δ^{18}O of a sample can thus provide an indication of the climate of the area in which the sample was formed. The oxygen found in the human body comes primarily from three sources: drinking water, water in consumed plants and animals, and inhaled molecular oxygen. Oxygen also leaves the body in the form of sweat, urine, and exhaled carbon dioxide. Body water is thus a balance between incoming and outgoing oxygen. Longinelli (1984) was the first to suggest that measurement of δ^{18}O in mammalian tissue could answer palaeohydrological and palaeoclimatological questions. He (1984, p. 385) reasoned that the mean isotopic composition of environmental water is one of the main variables controlling the oxygen isotope composition of mammalian body water. His study of the isotopic composition of the body water of rats, domestic pigs, and humans demonstrated a direct relationship (equilibration) between the δ^{18}O of ingested water and body water. The oxygen isotope signature of environmental water can thus be measured from both hydroxyapatite carbonate and phosphate in human dental enamel and bone (Longinelli, 1984; Luz et al., 1984). If the majority of the oxygen that a person ingested or inspired while his teeth and bones were forming came from local water sources, the measured δ^{18}O value from his hard tissue would be characteristic of the geographical peculiarities of that water, taking into account metabolic fractionation between enamel and body water (Levinson et al., 1987; Iacumin et al., 1996; Daux et al., 2008). It is therefore possible to identify individuals who accessed either local or nonlocal water sources and, by inference, locals and immigrants.

It is not often straightforward, however, to compare the δ^{18}O measured from human tissue to that of the environment, as ^{18}O is preferentially retained compared to ^{16}O during evaporation, condensation, and precipitation (Bentley and Knipper, 2005). The amount of ^{18}O in food can be significantly higher than that of local environmental water, particularly for herbivores (Daux et al., 2008). The majority of humans' δ^{18}O phosphate and carbonate signatures, however, is related to the composition of drinking water (Longinelli, 1984; Luz et al., 1984; Levinson et al., 1987; Iacumin et al., 1996). Various linear relationships have been obtained by researchers between the δ^{18}O of the phosphate or carbonate in mammalian tissue and the δ^{18}O of local meteoric water. Using these equations, which differ slightly in terms of both slope and y-intercept value, it is possible to approximate the δ^{18}O value of a person's drinking water from his enamel or bone.

Carbonate in human tissues can be more susceptible to diagenetic alteration in the post-burial environment than phosphate, but dental enamel is highly resistant to diagenesis. Multiple studies have shown the lack of diagenesis of both the carbonate and the phosphate components of dental enamel, even in samples submerged in water for tens of thousands of years (Lee-Thorp and Sponheimer, 2003; Zazzo et al., 2004). The analysis of the δ^{18}O of carbonate is faster and easier to perform than the δ^{18}O of phosphate and is growing in popularity, although more researchers still measure the phosphate component of teeth. The one comparative study of δ^{18}O from ancient Rome by Prowse and colleagues (2007) was performed on carbonate. For ease of comparison and ease of analysis, in this study, δ^{18}O values were measured from the hydroxyapatite carbonate portion of human dental enamel, usually represented as $\delta^{18}O_{ap}$.

As measurement of the carbonate portion of the human tooth for oxygen isotopes is done less often than measurement of the phosphate portion, there is currently no equation for humans that directly relates carbonate values to drinking water. A calibration equation that relates enamel carbonate values to drinking water values exists but is species-specific (Longinelli, 1984; Luz et al., 1984). Iacumin and colleagues' (1996) linear regression equation 1, which calculated oxygen isotope drinking water values based on oxygen isotopes measured from the carbonate portion of deer teeth, is thus not directly applicable in this study In order to compare measured human oxygen isotope values to a map of drinking water isotope values to track migration, therefore, it is necessary to convert the carbonate values to phosphate. The relationship between the carbonate and phosphate portions of mammalian teeth is constant and can be accurately predicted 1) given the assumption that the enamel was formed at normal human body temperature of 37°C; and 2) by employing a fractionation factor (α). The conversion from carbonate to phosphate is as follows, based on Bryant and colleagues' (1996) equation 1:

$$\delta^{18}O_p = \frac{1000 + \delta^{18}O_{ap}}{\alpha} - 1000$$

The value of α has been found to be 1.009 $\pm$ 0.0007 by Iacumin and colleagues (1996) and 1.0086 $\pm$ 0.0007 by Bryant and colleagues (1996). In this study, I follow the lead of Millard and Schroeder (2009), who derive a weighted average of these values of α = 1.0088 $\pm$ 0.0005.

A significant amount of work has been done on the relationship between the δ^{18}O of phosphate and drinking water in humans (Longinelli, 1984; Luz et al., 1984; Levinson et al., 1987; Iacumin et al., 1996; Daux et al., 2008). Each of these researchers calculated a regression equation to relate measured human enamel phosphate values ($\delta^{18}O_p$) directly to drinking water ($\delta^{18}O_{dw}$), and each equation differs slightly in its slope and y-intercept value. Recent work by Daux and colleagues (2008) synthesized these previously published studies and added new data to generate the best linear relationship calculated to date, with an r^2 correlation of 0.87 and a p value of 2×10^{-19}:

$$\delta^{18}O_{dw} = 1.54(\pm 0.09) \times \delta^{18}O_p - 33.72(\pm 1.51)$$

The direct linear relationship presented in Daux et al. (2008), however, does not perfectly relate the oxygen composition of an individual's enamel to the published map of precipitation values in Italy (Longinelli and Selmo, 2003). Further discussion of the measured and converted δ^{18}O values in regard to Roman drinking water will be presented in chapter 9 along with the results of this analysis.

Only a handful of oxygen isotope studies have been done to investigate migration in the Roman Empire. Dupras and Schwarcz (2001) investigated a 3rd century AD cemetery in Egypt and found that males were more enriched in δ^{18}O than females, indicating the former were more mobile. In Britain, where the majority of the Old World isotope studies are currently being done, Evans and colleagues (2006) studied a Romano-British (4th century AD) population from Winchester and used oxygen isotope analysis to identify “exotic” individuals with significantly lower δ^{18}O values than the remainder of the population. A more recent study on additional individuals from the same site by Eckardt and colleagues (2009) found that some of the immigrants likely originated in the Hungarian basin or the southern Mediterranean. In Roman-period York, Leach and colleagues (2009) used oxygen isotope analysis to find four nonlocal individuals and hypothesize that one came from a warmer area and three from continental Europe.

The study of Prowse and colleagues (2007) deserves thorough consideration, as it is the only oxygen isotope study of past human behavior that has been done in central Italy and provides a comparable data set for the δ^{18}O values obtained from individuals at Casal Bertone and Castellaccio Europarco. Tracy Prowse (2001) studied dental remains of individuals from Isola Sacra, the 1st-2nd century AD cemetery associated with Portus. Prowse hypothesized that many of the individuals buried at Isola Sacra were associated with the grain trade, as Portus acted as a way station before grain was transported inland to Rome. The dietary analysis by Prowse and her colleagues mentioned in chapter 6 indicated the people at Portus were consuming a significant amount of marine resources (Prowse, 2001; Prowse et al., 2004, 2005). Prowse and colleagues decided to undertake an oxygen isotope analysis of first molars from individuals buried in the Isola Sacra cemetery in order to understand patterns of migration within the population. Oxygen was chosen both because of the availability of data on the δ^{18}O of meteoric precipitation in Italy and because the researchers felt that ^{87}Sr/^{86}Sr isotope analysis would be compromised by the amount of marine foods consumed by people living near the sea (Prowse et al., 2007, p. 511-2).

In order to characterize the local δ^{18}O signature, Prowse and colleagues (2007) measured the oxygen isotope signatures of 24 deciduous teeth collected from 19 children who were born in the city of Rome in the late 1980s. They also tested paired first and third molars from 61 individuals from the Isola Sacra cemetery population. They found a continuum of δ^{18}O values in the ancient population, which they interpreted as evidence of people coming to Portus from gradually further distances (518). Additionally, they found statistically significant differences between the first and third molars of numerous individuals, which they interpreted as evidence of movement during childhood (517). These researchers note their plan to undertake a strontium study to support and clarify the results of the oxygen (518). The oxygen isotope analysis of Prowse and colleagues (2007) clearly demonstrates that males, females, and children were mobile during the Roman Empire, an important finding that underscores the need for chemical analysis of skeletons in addition to the study of historical texts and epigraphical inscriptions from tombstones in order to reconstruct population dynamics and palaeodemography in Rome.

Results from the present study of individuals from the periurban context of Rome are compared directly with the $\delta^{18}O_{ap}$ data from Prowse et al. (2007) in chapter 9. A local range for Rome will be refined, and the data will be compared to drinking water values in Italy. Individuals whose $\delta^{18}O$ values significantly differ from that of the local water range will be treated as consumers of nonlocal water and inferred to be immigrants. Finally, where possible, the place of origin of nonlocal individuals is hypothesized based on the calculated $\delta^{18}O$ values of their drinking water and maps of the average annual $\delta^{18}O$ of meteoric water in Italy and the rest of the Empire (Longinelli and Selmo, 2003; Bowen and Revenaugh, 2003).

7.4 Sample Selection

Osseous tissue remodels and regenerates through the lifetime of an individual, and bone turnover takes between two and twenty years depending on the size of the bone and the amount of cortical versus trabecular bone. This means that chemical analysis of the femur, for example, represents about the last 5-10 years of an individual's life (Larsen, 1997). Dental enamel, however, does not remodel following amelogenesis and eruption, it only wears down. Because we know the age at which teeth form, chemical analysis of teeth allows us windows into several different times in an individual's life: the crown of the first permanent molar is complete by age 3; the incisors and third premolar between 4-6; the second molar, fourth premolar and canines by 6-8; and the third molar between 12-16. An often-cited study by Sealy et al. (1995) demonstrates that it is possible to track the movement of one individual throughout her lifetime by testing different teeth as well as bone.

During data collection in Rome, samples were taken from as many individuals as possible. First molars, third molars, and femoral midshaft sections were obtained for use in destructive chemical analyses. A debate exists in the literature about whether a study of mobility should use dental enamel, bone, or both. Price and colleagues (2000, p. 911) write that, "Measurement of dental enamel provides a signal of place of birth and measurement of bone indicates the place of death." Price and Bentley are the most strident advocates for the use of bone to create, in particular, a local baseline of strontium values (Price et al., 2002; Bentley et al., 2004; Bentley, 2006). In their view, bone values from humans or animals in a particular geological area can be used to represent the expected strontium ratio of that area. On the other hand, Janet Montgomery (2002, p. 409) points out that "information about the place of death can be obtained far more easily, cheaply and reliably in the vast majority of cases just by recording the place of burial, particularly as adult cortical bone ratios represent the last $\sim$ 20 years of life and not perimortem values." Measuring strontium and oxygen ratios from bone tends to yield data consistent with local geology and climate. Bone from Casal Bertone and Castellaccio Europarco skeletons was therefore not subjected to chemical analysis to characterize migration.

Isotope ratios preserved in the teeth, on the other hand, represent the individual's intake of those elements averaged throughout the duration of crown formation. Dental enamel is a static tissue and is extremely resistant to diagenetic alteration in the post-burial environment. Some researchers undertaking isotope studies specifically test for the effects of diagenesis by analyzing multiple teeth from the same individual and by comparing the crystallinity index between the sample and modern enamel (Montgomery, 2002; Prowse et al., 2007). It was not possible to assess diagenetic factors in the present study; however, care was taken in both strontium and oxygen isotope analyses to avoid the possibly contaminated enamel on the outer surface of the crown as well as the enamel close to the dentoenamel junction, where elemental exchange is known to occur (Pollard et al., 2007; Boushell et al., 2007). For both strontium and oxygen isotope analyses, therefore, dental enamel was used. Out of the 183 total skeletons studied from the two Imperial sites, first molars were obtained from 105 and third molars from 67. First molars rather than third were chosen as the data set for this initial project on mobility primarily because the structure of migration in the Roman Empire is not well known. If only third molars had been tested, evidence of young children (under 8 years of age) who immigrated to Rome would have been overlooked.

Although numerous researchers have tested first molars in order to assess the origin of an individual, there are a couple of caveats with this method related to ontogeny and lactation. In terms of strontium, Janet Montgomery (2002, p. 43-4) argues that it is best to sample teeth that are formed post-weaning in order for an individual's $^{87}Sr/^{86}Sr$ ratio to accurately reflect the food and water that he or she consumed. It has been demonstrated that lead (Pb) stored for several years within the skeleton can be released into the blood in response to an insufficient calcium intake, particularly in pregnant and lactating women. Lead can cross the placental barrier, and in studies of rats, it can pass from mother to child through milk. Montgomery (2002, p. 44) argues that strontium could be mobilized in the same way as lead in response to high calcium demands. Therefore, a mother who has recently immigrated to Rome might have the $^{87}Sr/^{86}Sr$ ratio of her old home in her skeleton, which can then affect her child's isotope signature through the child's consumption of breastmilk, making him or her appear to be an immigrant. First molars thus may inherit isotope signatures that relate more to the mother's years before pregnancy than to a child's birth locale. It is therefore possible that individuals with anomalous strontium signatures are first-generation Romans with immigrant mothers. Montgomery (2002) suggests testing premolars, which start forming around the age of four and which have a simple cusp formation but plenty of enamel for sampling. Premolars were not available for this study. However, strontium testing of third molars from a subset of the population is planned for the future. By comparing the data obtained from first and third molars of the same individual and comparing that to the $^{87}Sr/^{86}Sr$ ratio of Rome, it should be possible to obviate some of the problems associated with possible strontium transference during pregnancy and lactation.

In terms of oxygen, it has similarly been suggested that the duration of nursing commonly found in preindustrial societies can affect the $\delta^{18}O$ of the teeth formed while a child is breast-feeding (Wong et al., 1987; White et al., 2004a; Evans et al., 2006b; Buzon et al., 2010). A child's teeth that form before weaning are influenced by the water consumed by his or her mother provided that child is breastfeeding when amelogenesis occurs (Evans et al., 2006b). Breastmilk has been shown to be enriched in $\delta^{18}O$ relative to drinking water, leading some researchers to conclude that there is a "nursing effect" on the $\delta^{18}O$ of teeth formed during breastfeeding (Wong et al., 1987). Most notably, White and colleagues (1994a,b) found a trophic increase in $\delta^{18}O$ among ancient populations in the Old and New World, at Teotihuacan and in Nilotic Nubia. These researchers compared the $\delta^{18}O_p$ of bone from nursing children with that of post-weaning children and found that, at Teotihuacan, nurslings had a 0.7‰ increase over weaned children and adults and, in Nubia, a 2‰ increase over weaned children. However, when White and colleagues compared the $\delta^{18}O_p$ of enamel from Nubian teeth formed pre-weaning, such as the first molar, to those formed post-weaning, they found a nearly 1‰ decrease, which they attribute to possible seasonal fluctuations in food and water sources. As the studies by White and colleagues show, the effect that a trophic increase in ^{18}O has on the oxygen ratio measured from a human first molar is still unclear. Additionally, as seen in the different numbers found at Teotihuacan and Nubia, factors such as duration of breastfeeding, access to food and water resources for the breastfeeding mother, and seasonality of water sources likely affect the $\delta^{18}O$ of breastmilk and therefore the $\delta^{18}O$ of enamel formed prior to weaning. Therefore, it is important to address evidence of breastfeeding duration on a site-by-site basis when considering oxygen isotope ratios from early forming teeth.

In the late 1st and early 2nd centuries AD, the Greek physician Soranus' *Gynaecology* instructed about both women's health and the care of newborns, and remained the standard text until the 16th century. Soranus begins his discussion on when and how to wean an infant (Book II, Chapter XXI, Article 46) with a complaint that some women start feeding their babies cereal after 40 days. He recommends nursing for six months, followed by gradual introduction of weaning foods, such as cereals, milk, wine, and honey, and complete weaning around 18 to 24 months. It is unknown, however, to what extent women, particularly lower-class women who would not have had access to literature or doctors, did or did not follow these recommendations. Additionally, female slaves and lower-class women could be used as wet-nurses (Garnsey, 1989). Contracts for wet-nurses tended to range from 6 to 18 months (Fildes, 1986; Lefkowitz and Fant, 2005), but it is unclear what the duration of exclusive breastfeeding was. It would appear that upper-class Roman women in particular did not breastfeed their infants for very long if at all, and that they routinely contracted out the nutritional needs of their offspring, particularly in the highly urbanized society of Imperial Rome (Garnsey, 1989).

Direct evidence of breastfeeding from middle- and lower-class individuals comes from the bioarchaeological record. A carbon and nitrogen isotope study of skeletal remains from Late Roman Britain (Fuller et al., 2006) indicates that breastfeeding had completely ceased by 3-4 years and that special weaning foods were introduced by 2-4 years. This study, however, did not test skeletal remains of individuals under the age of 18 months. In her carbon and nitrogen isotope study of individuals from Imperial Portus, Tracy Prowse (2001) found a significant difference in δ^{13}C and δ^{15}N in infants under 2 years of age, although her sample was admittedly small (n=6). She suggests that weaning occurred in this population some time between 3 months and 2 years of age. As reported in chapter 6, carbon and nitrogen isotope analysis was undertaken on a subset of the Casal Bertone and Castellaccio Europarco skeletons in order to characterize the ancient Roman diet. Only four children under the age of 5 were tested. Three of them showed no sign of trophic increase explicable by nursing, but one (T29, a child of about 30 to 36 months) had a high δ^{15}N value. Further testing of these populations would be necessary in order to estimate the duration of breastfeeding among the lower-class individuals buried at Casal Bertone and Castellaccio Europarco. It is likely, however, that cessation of lactation and commencement of weaning varied based on both the mother's physiology and social class. The available historical and biological evidence indicates that, in general, Roman women nursed their children or nurslings exclusively for 3 to 6 months, with the introduction of weaning foods composed of cereal, milk, and wine at some point after that time (Garnsey, 1999). Weaning can be a lengthy process, and it is currently unclear whether observed trophic increases in δ^{18}O are seen only in exclusively breastfed babies or also in those who both nursed and ate solid food.

The data on a possible nursing effect on the δ^{18}O of teeth formed pre-weaning are spotty at this time. Although evidence of the δ^{18}O of bone phosphate shows an increase in breast-fed children in both the Old and New Worlds, δ^{18}O of enamel phosphate shows a decrease in breastfed children. Duration of breastfeeding is different in the Roman Empire than in other preindustrial societies, with upper- and middle-class women deciding not to nurse their own infants. There is no information in the historical record on lower-class women and breastfeeding, other than that they and slaves sometimes contracted themselves out as wet-nurses to the wealthy (Lefkowitz and Fant, 2005). The limited evidence from skeletons from Casal Bertone and Castellaccio Europarco shows that one child was still nursing or was being weaned around 2 years of age, but a second child of about 18 months had likely already been weaned. Finally, studies by White and colleagues that have shown a trophic difference in pre-weaning individuals have all tested the phosphate component of skeletal tissue. This study investigates δ^{18}O through carbonate, and it is unknown if a nursing effect would affect carbonate in the same way as phosphate. For all of these reasons, no adjustments were made in the δ^{18}O ratios of first molars sampled from Casal Bertone or Castellaccio Europarco. In the future, however, I plan to examine third molars from a subset of the population for strontium and oxygen, which should help me understand whether or not breastfeeding affected the ratios of isotopes in the first molars.

7.5 Multipronged Approach

Because this is an exploratory study of understanding migration to Imperial Rome, it was not known beforehand which, if any, methods of isolating immigrants would work. A preliminary assessment of nonmetric cranial traits was performed in order to identify a sample population to subject to stable isotope analysis. The results of this study are presented in appendix C because nonmetric analysis was not found to be a good predictor of immigrant status. Oxygen isotope analysis of individuals at Portus provides a comparative data set for the populations in this study, but no such research has been done previously using strontium isotopes. In order to maximize the amount of information gleaned about mobility and migration in the Empire, this study employs chemical isotope analysis of both strontium and oxygen. Many recent studies in other parts of the world have combined information derived from oxygen isotope analysis, which relates to hydrology, with strontium isotope analysis, which relates to geology, because together these two elements can provide independent sources of data to confirm an individual's nonlocal origin (Bentley and Knipper, 2005). Statistical analysis of morphometric properties of skeletons are less often used today than in the past, although researchers in Britain are at the forefront of combining multiple techniques to assess ancient mobility (Leach et al., 2009).

Each technique, however, was applied to slightly different population subsets from Casal Bertone and Castellaccio Europarco. Cranial nonmetric analysis can only be performed on adult crania, so this method cannot characterize the mobility of subadults. In ancient Rome, the age of majority was 12-16, and it is reasonable to assume that some of these biological subadults were culturally adults and moved around the Empire. Strontium isotope analysis was undertaken on every individual who presented a non-pathological first molar. Using this technique stands to miss individuals who were edentulous or whose teeth could not be found owing to taphonomic processes. Finally, oxygen isotope analysis was undertaken on a stratified sample of the population subjected to strontium isotope analysis. The reality of funding precluded testing every individual for δ^{18}O, and those individuals not tested could possibly have been explicated using this technique. By combining the three analytical avenues available, however, this multipronged approach contributes a wealth of information to the phenomena of migration and mobility in Imperial Rome. Results of the isotope analyses are presented separately in chapters 8 and 9, followed by a synthesis of the mobility data in chapter 10.

Chapter 8

Strontium Analysis

This study employs strontium isotope analysis in an attempt to identify immigrants to Rome and characterize their lives. Strontium was chosen as the primary element by which to assess mobility for several reasons: 1) strontium analysis yields extremely precise data; 2) the ability to isolate an immigrant's homeland based on strontium signature; and 3) greater control over the samples and the data by undertaking the analysis myself at the Isotope Geochemistry Laboratory at UNC.

The Italian region of Lazio contains four mountain groups of volcanic origin. Its geology has been well-studied by volcanologists, and the strontium isotope ratios of the lava around Rome are distinct from the other major volcanic areas in peninsular Italy and from the older rock that forms the Apennines and the Alps. In spite of the well-published geological data from various regions of Italy, strontium isotope analysis is a technique that has never before been applied to questions of mobility in Rome. There are thus no comparative data on the biological availability of strontium from samples of human dental enamel.

This chapter presents the methods used to gather strontium isotope data, from processing the enamel to extracting the strontium. Results from 105 individuals from Imperial-period Casal Bertone and Castellaccio Europarco are presented, along with the results from two archaeological faunal samples. The human ratios are interpreted by creation of a model of the available strontium range in the city and suburbs of Rome. Both strontium and oxygen isotope analyses of archaeological populations generally rely on the assumption that people were drinking local water and thus that the strontium isotope signature of local individuals reflects that of the local water and geology. The model presented in this study, however, takes into account the fact that the city of Rome was supplied by several aqueducts. Nonlocal individuals are identified as those whose origins are outside of the greater Rome area. The possible homelands of nonlocals will be further discussed in chapter 10 following presentation of complementary oxygen isotope data in chapter 9.

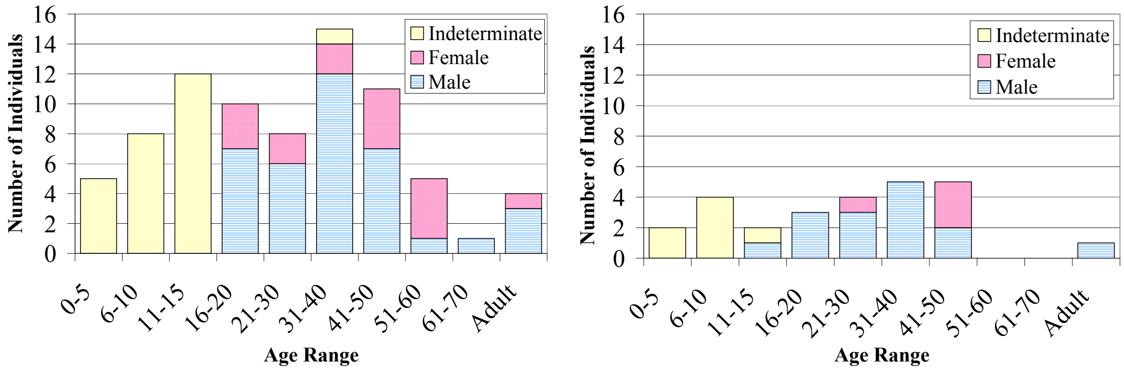
8.1 Methods

The cultural context of immigrants to Rome is unknown, as the vast number of graves uncovered in the last decade do not indicate that people individualized their identities in death in a material way that would identify them as nonlocals. Because of a lack of material culture, historical evidence, or macroscopic biological variability, it was impossible to select a sample of the population to subject to strontium isotope analysis. If Rome consisted of only about 5-10% immigrants (Noy, 2000), and if slaves were buried separately, testing a random sample of individuals could easily miss all the nonlocals. In order to maximize my chances of finding an immigrant using strontium isotope analysis, I tested all individuals from whom I collected at least one tooth.

One first molar, either maxillary or mandibular, was extracted from every individual who possessed at least one of these teeth. Criteria used for choosing which molar to extract included: a) identification of the M1 that was the easiest to remove without damaging the alveolar bone; and b) identification of an M1 that lacked carious lesions, enamel hypoplasias, and significant calculus, per the request of the Soprintendenza Archeologica di Roma.[1] Also per their request, each tooth was measured in situ using the mesiodistal, buccolingual, and crown height measurements published in *Standards* (Buikstra and Ubelaker, 1994, p. 61-3).

First molars were extracted from 79 individuals from Casal Bertone and 23 individuals

[1]Information on dental pathology can be found in chapter 5.



(a) Casal Bertone (b) Castellaccio Europarco

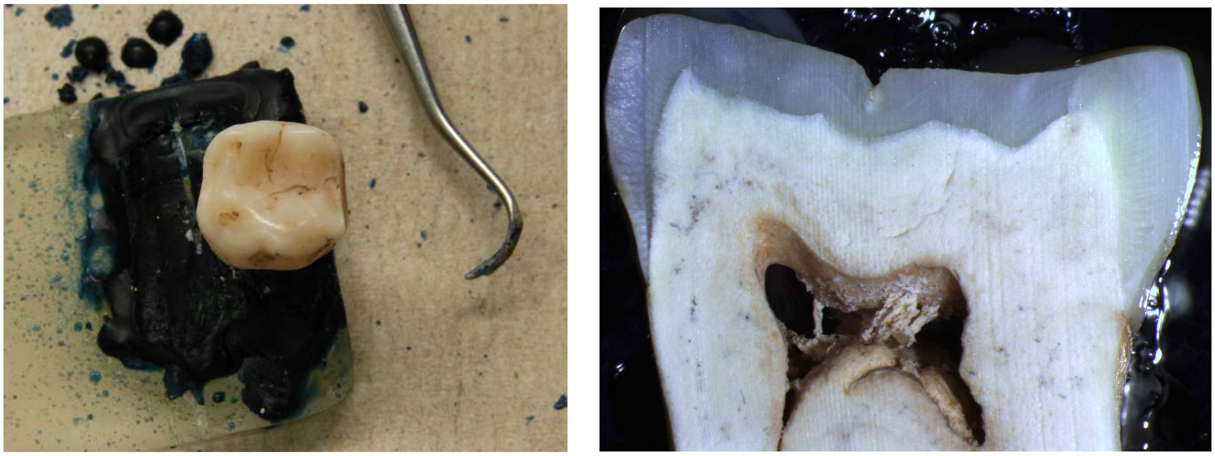
Figure 8.1: Demographics of Individuals Subjected to Strontium Isotope Analysis

from Castellaccio Europarco,[2] and an additional three canines were extracted from individuals from Castellaccio Europarco. Skeletons ET33 and ET43 presented an M1 with carious lesions, and ET37 had a large hypoplasia on the only first molar in the mouth. The canines from those individuals were selected because: a) crown mineralization begins at about 4 months of age, close to the time the first molar begins to form (Gustafson and Koch, 1974); and b) canine crowns are larger, have more enamel, and are more likely to be found in the jaw than incisor crowns, which also begin to form just after birth.

Demographic information on the 105 Imperial period individuals subjected to strontium isotope analysis is presented in figure 8.1. By comparing these graphs with the overall demographic graphs from each site (figures 4.5 and 4.8), the similar distributions indicate the negligible effect of sex- and age-related taphonomic processes on the sample of teeth. An additional two teeth from *Sus scrofa* found in the archaeological context of each site were processed in order to gain a better understanding of the bioavailability of strontium in the region of Rome. Further discussion of the faunal remains is presented in section 8.3.

The first step in processing each tooth was sectioning it for easy extraction of powdered enamel. The tooth was secured by means of blue (modeling) dental paraffin to a 1.5 cm-thick

[2] In Phases 1 and 2 from Castellaccio Europarco, only six individuals presented teeth for strontium isotope analysis. Because of the small sample size and the difference in time period, the results of all analyses on the earlier individuals at Castellaccio Europarco and a discussion of the same are presented in appendix B.



(a) Preparing Tooth to Be Sectioned (b) Tooth Section Under Microscope

Figure 8.2: Sectioning Teeth

acrylic pad (figure 8.2a) in order to cut the tooth along its mesiodistal axis using a Buehler Isomet 1000 precision saw at the Bioarchaeology Laboratory at UNC. The 15.25 cm by 0.5 mm diamond wafering blade was lubricated with distilled water, and the tooth was cut into three parts. When the paraffin was removed, each tooth yielded one 3 mm-thick midsection slice. Research has shown that dentine is more porous than enamel and thus is more prone to diagenesis and postmortem change, particularly strontium uptake (Budd et al., 2000). Researchers interested in studying immigration based on strontium isotope ratios therefore concentrate on testing enamel (Price et al., 2002; Bentley, 2006), which is formed at very predictable ages. But whereas some researchers opt to test any enamel obtained from a tooth (Montgomery et al., 1999), others suggest that the outermost layer of enamel has a minor amount of strontium uptake that could lead to incorrectly identifying a nonlocal individual as local (Grupe et al., 1999). In order to obviate this issue, research dentist Dr. Lee Boushell at UNC suggested extracting enamel that would be least likely to have experienced any extraneous strontium uptake, namely, the enamel between the external surface of the tooth and the dentoenamel junction, the interface between the dentine and enamel that has a high protein content (Boushell et al., 2007).

Tooth sections, once obtained, were ultrasonically cleaned in deionized water and secured to glass microscope slides using Duco cement, chosen because this adhesive is easily removable with acetone. Enamel was extracted from the first 15 samples using a Merchantek MicroMill (figure 8.3a), a device that allows for precision microsampling of a specimen, in Dr. Drew Coleman's Isotope Geochemistry Laboratory at UNC. It quickly became obvious that microsampling was both unnecessary as well as time-consuming. In order to extract enamel more efficiently, Dr. Donna Surge allowed me access to a Brasseler dental drill and Olympus digital microscope in the Palaeoclimate and Palaeoecology Lab at UNC. Sectioned teeth were similarly affixed to glass slides and viewed under the microscope (figure 8.2b) in order to obtain enamel from between the occlusal surface and the dentoenamel junction. Between 5-10 mg of dental enamel was extracted from the remaining teeth using a Brasseler hand-held dental drill fitted with a 0.3 mm round tungsten carbide bit, weighed on a Sartorius microbalance, and stored in 5 mL Savillex vials with deionized water until it could be processed.

In preparing the enamel sample for chemical analysis, the water was first evaporated by placing the vials on a laboratory hotplate. Strontium was extracted from the remaining powdered enamel by dissolving it in 500 μL of 7 M HNO_3, then evaporating and redissolving it in 500 μL of 3.5 M HNO_3. Sr-Spec™ columns were cleaned and loaded with approximately 50-100 μL of EiChrom SR-B100-S resin, and the enamel sample was centrifuged to avoid putting large chunks of enamel in the columns. The sample was loaded by pipette from the centrifuge vial and subjected to dropwise and bulk sample rinses with HNO_3. Strontium was eluted into a clean Savillex vial with water, 25 μL of H_3PO_4 was added, and the water was allowed to evaporate on a hotplate (figure 8.3b). The sample was redissolved with 2 μL of $TaCl_5$. Half of the strontium was loaded onto a rhenium filament, and the $^{87}Sr/^{86}Sr$ isotope ratio was measured on a fully automated VG Micromass Sector 54 TIMS spectrometer in reference to a standard[3] at the Isotope Geochemistry Laboratory at UNC.

[3]Values for $^{87}Sr/^{86}Sr$ are reported relative to standard NBS-987, which has a value of 0.710270 $\pm$ 0.000014 (2σ). The internal precision for strontium runs is typically $\pm$ 0.0012 to 0.0018% (2μ) standard error based on 100 dynamic cycles of data collection.

(a) MicroMilling enamel (b) Eluted Sr in Savillex Vials

Figure 8.3: Extracting and Processing Enamel

8.2 Human Results

The measured strontium ratios from human dental enamel are presented in tables 8.1, 8.2, and 8.3. In order to visualize the distribution of strontium ratios, a dot histogram of all 105 Imperial samples was constructed (figure 8.4). It is clear from the histogram that the values cluster around 0.7090 and that there is a more or less normal distribution of the strontium ratios. At least six individuals (shown as black dots) appear to have strontium signatures that deviate from the mean. Comparing the results from the Casal Bertone skeletons with those from Castellaccio Europarco, as in figure 8.5, yields an interesting difference.

At Casal Bertone, although the mausoleum slightly post-dates the necropolis, a pairwise comparison of the mean of the two groups is not statistically significant, indicating the two contexts can be treated as the same population. The average strontium ratio from the Imperial era Castellaccio Europarco teeth (0.709289), however, is higher than the mean at Casal Bertone (0.709077), which can be seen in the mirror histogram. Although the difference between the two means appears small, strontium ratios are measured extremely precisely, and differences in the fourth decimal place are significant (Faure and Powell, 1972). A two-tailed t test run on these data confirms that the difference in the means is statistically significant ($t = 8.57$, $p \leq 0.0001$). It is therefore important to treat the individuals interred at these two sites as

Burial	Age	Sex	$^{87}Sr/^{86}Sr$ Ratio	Burial	Age	Sex	$^{87}Sr/^{86}Sr$ Ratio
T29	0-5	I	0.709327	T53	21-30	PM	0.708500
T60B	0-5	I	0.708843	T50	21-30	PF	0.709312
T71	0-5	I	0.709039	T42	31-40	F	0.709280
T9	0-5	I	0.709302	T10	31-40	M	0.709566
T20	6-10	I	0.709089	T34	31-40	M	0.709071
T55	6-10	I	0.708933	T47	31-40	M	0.708652
T62	6-10	I	0.709155	T73	31-40	M	0.709134
T70	6-10	I	0.708984	T15	31-40	PM	0.713980
T8	6-10	I	0.710647	T18	31-40	PM	0.709485
T11	11-15	I	0.709325	T37	31-40	PM	0.709183
T32	11-15	I	0.709178	T76	31-40	PM	0.709415
T36	11-15	I	0.707191	T77	31-40	PM	0.709142
T45	11-15	I	0.709237	T49	31-40	U	0.709153
T56	11-15	I	0.709505	T82A	41-50	F	0.708617
T72	11-15	I	0.707914	T30	41-50	PF	0.709219
T75	11-15	I	0.708737	T38	41-50	PF	0.709323
T80	11-15	I	0.709064	T31	41-50	M	0.709181
T84	11-15	I	0.708898	T33	41-50	M	0.708155
T12	16-20	M	0.709546	T69A	41-50	M	0.710089
T21	16-20	M	0.708811	T7	41-50	M	0.709404
T83B	16-20	M	0.708780	T19	41-50	M	0.709153
T35	16-20	PM	0.709462	T67	41-50	PM	0.708354
T39	16-20	PF	0.708206	T28	51-60	F	0.708529
T41	16-20	PF	0.709172	T24	51-60	M	0.707351
T14	21-30	M	0.708986	T13	61-70	PM	0.708490
T22	21-30	M	0.709070	T48	Adult	PF	0.709508
T23	21-30	M	0.708424	T26	Adult	PM	0.709175
T81	21-30	M	0.708849	T66	Adult	PM	0.708730
				T59	Adult	M	0.708586

Table 8.1: Casal Bertone $^{87}Sr/^{86}Sr$ Ratios - Necropolis

Burial	Age	Sex	$^{87}Sr/^{86}Sr$ Ratio	Burial	Age	Sex	$^{87}Sr/^{86}Sr$ Ratio
F9B	0-5	I	0.709769	F5A	21-30	M	0.709945
F10B	6-10	I	0.709276	F9C	21-30	PF	0.709212
F10C	6-10	I	0.708251	F11A	31-40	F	0.709711
F13A	6-10	I	0.709425	F11B	31-40	M	0.709008
F10D	11-15	I	0.709885	F12A	31-40	M	0.709296
F11C	11-15	I	0.709576	F1B	31-40	M	0.709038
F4A	11-15	I	0.709845	F13C	41-50	F	0.709455
F1A	16-20	F	0.709299	F3C	41-50	M	0.708346
F7B	16-20	M	0.709457	F1C	51-60	F	0.709623
F1D	16-20	PM	0.708787	F4B	51-60	F	0.709821
F4C	16-20	PM	0.709189	F6E	51-60	F	0.708944

Table 8.2: Casal Bertone $^{87}Sr/^{86}Sr$ Ratios - Mausoleum

distinct Imperial populations. Further, after removal of the immigrants from these populations as noted below (section 8.6), the average strontium isotope ratio is still significantly different. Casal Bertone (n=74) presents an average strontium isotope ratio of 0.709128 with a standard deviation of 0.00043, and Castellaccio Europarco (n=24) a ratio of 0.709198 with a standard deviation of 0.00051. A two-tailed t test indicates the difference in the means is statistically significant at the $p \leq 0.001$ level.

8.3 Faunal Results

The results of the strontium analysis of two teeth from archaeologically recovered pigs are presented in table 8.4. It is impossible to draw conclusions based on one data point from each site; however, the pig tooth from Castellaccio Europarco has a higher strontium ratio than the one from Casal Bertone, which is not unexpected given the statistically significant differences in the mean human values mentioned above.

Burial	Age	Sex	$^{87}Sr/^{86}Sr$ Ratio	Burial	Age	Sex	$^{87}Sr/^{86}Sr$ Ratio
ET16	0-5	I	0.709661	ET69	21-30	M	0.708624
ET31	0-5	I	0.709848	ET52	21-30	PM	0.708716
ET17	6-10	I	0.708827	ET43	31-40	M	0.708126
ET63	6-10	I	0.709349	ET20	31-40	M	0.709631
ET36	6-10	I	0.709565	ET72	31-40	M	0.709996
ET37	6-10	I	0.709570	ET103	31-40	PM	0.709105
ET76	11-15	PM	0.710471	ET51	31-40	PM	0.709335
ET67	11-15	I	0.709173	ET68	41-50	F	0.708754
ET45	16-20	M	0.709397	ET58	41-50	F	0.709162
ET44	16-20	M	0.710150	ET40	41-50	F	0.709175
ET27	16-20	PM	0.709543	ET38	41-50	M	0.711934
ET18	21-30	F	0.708618	ET33	41-50	PM	0.708783
ET22B	21-30	M	0.708399	ET42	Adult	PM	0.709245

Table 8.3: Castellaccio Europarco $^{87}Sr/^{86}Sr$ Ratios

Site	Burial	Species	Tooth	$^{87}Sr/^{86}Sr$ value
Castellaccio Europarco	ET20	*Sus scrofa*	Max. P4	0.710313
Casal Bertone	US31	*Sus scrofa*	Max. M1	0.709326

Table 8.4: Faunal $^{87}Sr/^{86}Sr$ Ratios

8.4 Bioavailability of Strontium in Rome

Because this is the first strontium isotope study of human remains within the region of Lazio and, as of this writing, within the Italian peninsula, it is necessary to define the strontium signature of the local area of Rome in order to identify nonlocal individuals. Comparing the results from dental enamel directly with geological strontium signatures is not entirely straightforward; rather, it is important to compare strontium signatures from the human remains with the range of biologically available strontium at the burial location.

The majority of the strontium in the human body comes from the diet of the individual, as groundwater incorporates strontium from weathering rock and is ingested by humans directly as water and indirectly from the plants and animals that humans consume (Price et al., 2002). It is assumed that the strontium ratio present in the human first molar therefore reflects the strontium of the geological region in which that person was born. The problems with this

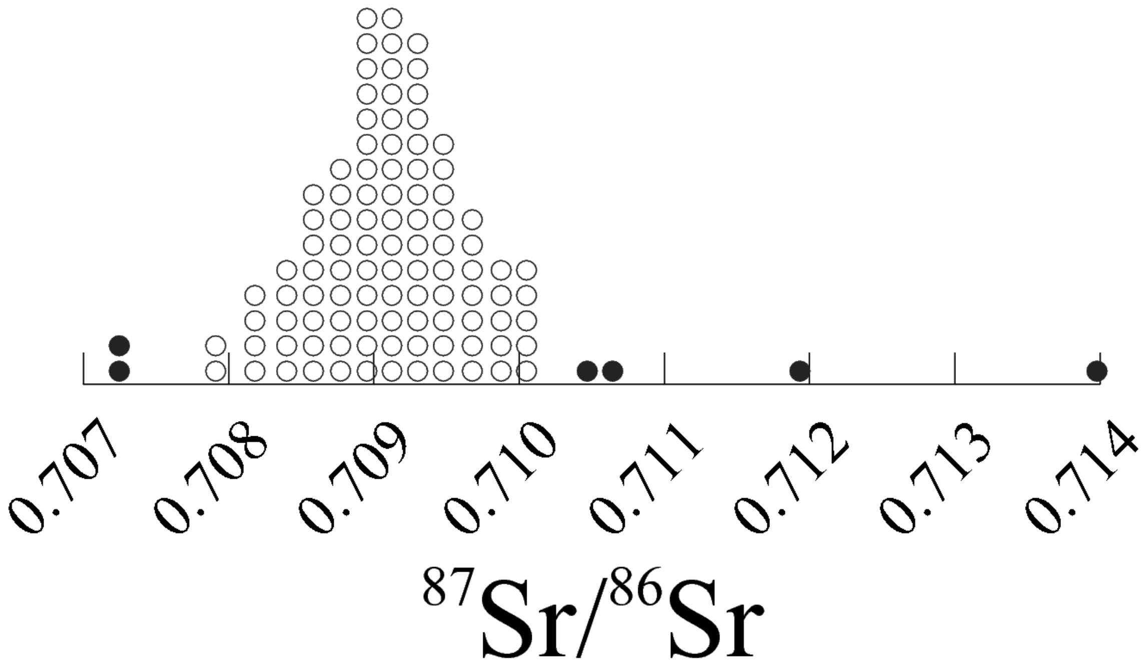


Figure 8.4: Dot Histogram of All $^{87}Sr/^{86}Sr$ Ratios

assumption include the fact that it is difficult to isolate a range of strontium ratios given an area with complex geology and the fact that the range of strontium values in humans reflects the biological availability of strontium - from bedrock, soil, water, and diet - rather than directly mapping to a geological range (Price et al., 2002, p. 119). Thus, identifying a local range necessitates knowledge of both the geology of the region and the availability of strontium to plants, animals, and humans.

There are two main methods for creating a local strontium baseline to reflect the biological availability of strontium. First, Bentley and colleagues (2004, p. 366) suggest defining a local enamel value as within two standard deviations of the average human bone value. Because bone reflects the last few years of an individual's life, analyzing bone should produce a range of strontium values that indicate the strontium availability in the area in which the individuals were buried. This approach is problematic because of the effects of diagenesis on human bone, which can be permeated by strontium in modern groundwater and skew the results, leaving a poor approximation of the past local range. At some archaeological sites, however, it may be

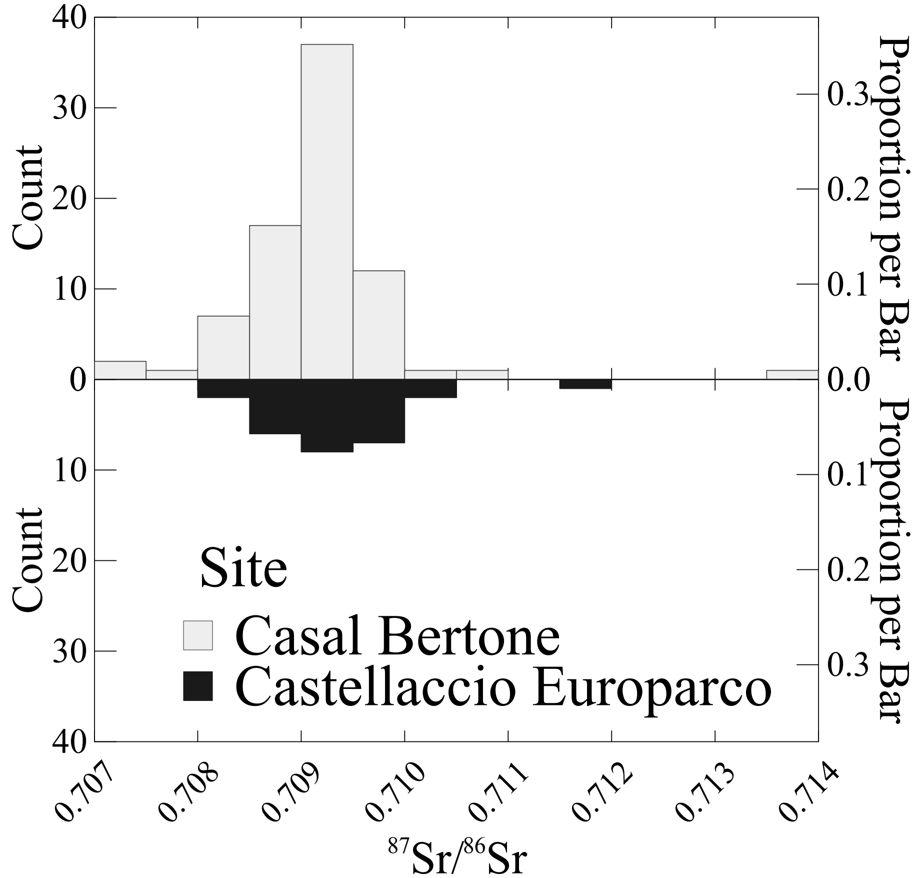


Figure 8.5: Mirror Histogram of Imperial $^{87}Sr/^{86}Sr$ Ratios

valid to consider the contamination from current groundwater to be reflective of conditions of the past (Grupe et al., 1997, 1999). Although bone samples from femora were available for this study, I did not subject any to strontium isotope analysis because of the unresolved issues with diagenesis. Many of the remains from Casal Bertone and all of the remains from Castellaccio Europarco were found in flooded areas, and there was no way to identify the source of the standing water nor the length of time the burials had been flooded. In addition, the availability of water and the sources of that water are different in modern Rome than they were in ancient Rome, although some of the same aqueduct channels remain in use today.

A second way to define the local area is to measure the strontium isotope signatures of the animal species that lived there in the past (Price et al., 2002; Bentley et al., 2004). Using zooarchaeological material obviates some of the issues presented above with diagenesis, modern contamination, and environmental variability. Price and colleagues (2002) suggest analyzing the dental enamel from species that have small home ranges. These researchers (ibid., p. 125) have obtained good results using species such as mice, guinea pigs, rabbits, squirrels, and snails, herbivores that eat a range of plant material from their home area. As diet is the proximate source of strontium in humans, testing an omnivorous species with moderate home range can also provide a picture of the strontium available to humans (ibid., p. 130). Two teeth from *Sus scrofa* were the only faunal remains available for analysis in this study.

Combining published information on the geology of Lazio and on archaeological faunal remains provides a starting point for understanding the strontium signatures of the human populations at Castellaccio Europarco and Casal Bertone. The information utilized to understand the available strontium in the area of Rome thus includes strontium ratios from: studies of the local geology; two archaeological faunal samples from Casal Bertone and Castellaccio Europarco; and samples of prehistoric elephants, deer, and horses.

8.4.1 Geology of Lazio

The geology of the region of Rome has long fascinated volcanologists, as the city is positioned along the Tiber River between two dormant volcanic complexes, the Colli Albani (Alban Hills) and the Monti Sabatini (Sabatini Mountains) (figure 8.6). Rome is therefore surrounded by Middle to Upper Pleistocene volcanic rock as well as some Plio-Quaternary sedimentary units along the Tiber, which extend westward to the Tiber Delta and end at the Tyrrhenian sea near Ostia. To the east of Rome are the Apennine Mountain foothills (sometimes called the Preapennines), which are composed of Meso-Cenozoic sandstones and limestones (Pellegrini et al., 2008; Vinciguerra et al., 2009).

A variety of strontium ratios for the geology of Lazio have been published (figure 8.7). The volcanic area of the Colli Albani has been sampled by Federico and colleagues (1994). Their analysis of nine samples of ejecta gives a strontium range of 0.7090 to 0.7103 for the volcanic material in the southeastern portion of the Roman *suburbium*. The average strontium ratio of

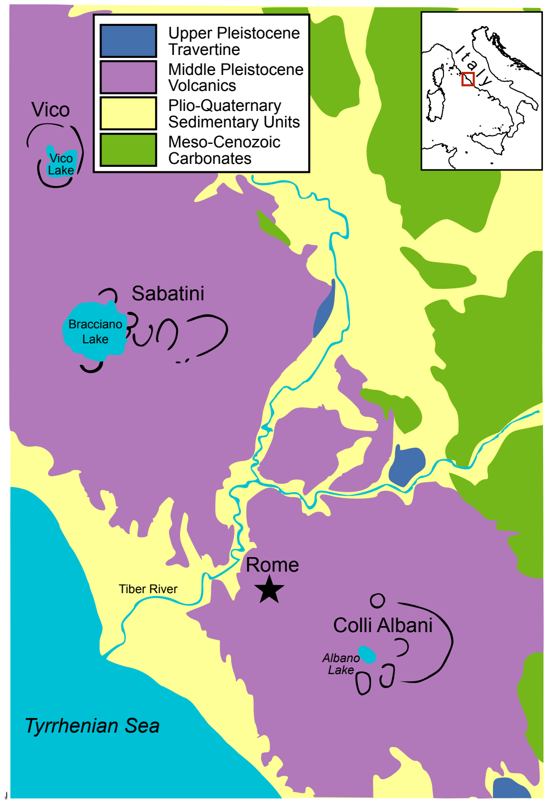


Figure 8.6: Simplified Geological Map of Rome
Modified from Vinciguerra et al. 2009.

the northwestern volcanic complex, Monti Sabatini, is 0.7107 and the average at Monti Vulsini, northwest of Sabatini, is 0.7104 according to Barbieri and colleagues (1979). The volcanic rock in central Lazio, then, has a range from 0.7090 to 0.7107, well within the expected range of young volcanic material (Faure and Powell, 1972). Although there are some outcroppings of travertine near Rome and Tivoli,[4] the abundant limestone in the Apennine foothills of the Monti Simbruini dominates the geology of numerous freshwater springs, which have strontium ratios of 0.7079 to 0.7080 (Barbieri and Sappa, 1997). In addition, the strontium ratio of seawater and rainwater, 0.7092 (Bentley, 2006, p. 146), likely contributed to the $^{87}Sr/^{86}Sr$ ratios of both humans and animals.

---

[4]Strontium ratios of travertine are lower than lavas, with published ratios of 0.7086 and 0.7079 at Rome and Tivoli, respectively (Minissale et al., 2002).

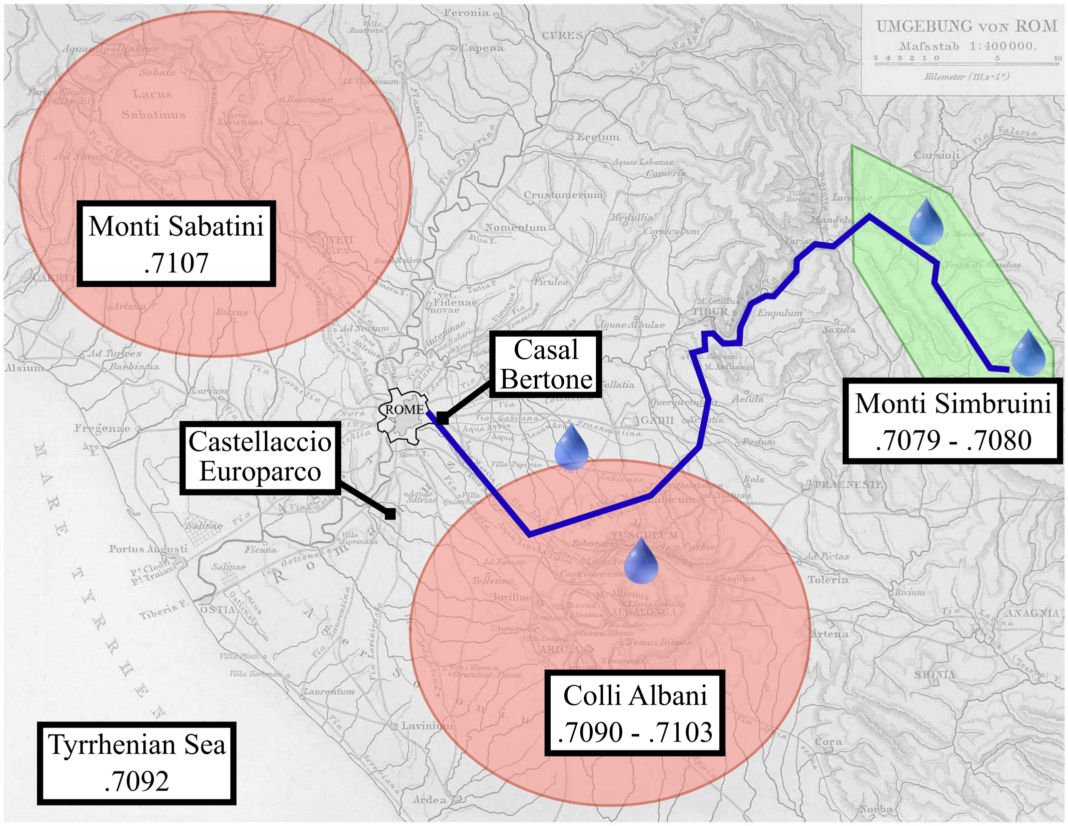


Figure 8.7: Simplified Strontium Map of Rome
Base map from Droysen 1886: *Umgebung Roms in Altertum*.

8.4.2 Strontium Analysis of Faunal Material

Two studies have reported strontium ratios from faunal material in the area of Rome. Palombo and colleagues (2005) studied both oxygen and strontium isotopes in the teeth of Middle Pleistocene *Elephas antiquus*. One sample population came from Casal de' Pazzi, in the eastern portion of the Roman *suburbium*, and the other from La Polledrara di Cecanibbio, near the base of the Sabatini volcanic area. The Casal de' Pazzi elephants produced an average strontium ratio of 0.7100 (n=19), and the La Polledrara elephants an average ratio of 0.7099 (n=20). The authors concluded that the elephants were likely local to the area based on the strontium ratios present in the Colli Albani (Federico et al., 1994). Recent work by Pellegrini and colleagues (2008) involved microsampling of Upper Palaeolithic *Cervus elaphus* and

Equus hydruntinus teeth from a cave in a travertine deposit between Rome and Tivoli. The mean of these strontium ratios is 0.7087. Variations within the layers of enamel sampled indicate the animals were migratory but that they ranged over a more narrow area than expected or in an area with relatively homogeneous strontium ratios.

The results of my analysis of dental enamel from *Sus scrofa* were presented in section 8.3. The pig from Casal Bertone has a lower strontium ratio than the one from Castellaccio Europarco, but the range they produce, 0.7093 to 0.7103, is reasonable for animals that lived on young volcanic rocks. With only two samples available, it is statistically invalid to produce a two standard deviation range with which to compare the human remains. In addition, there is a possibility that the pigs were imported or were fed imported foods, as grain and other foodstuffs were transported to Rome with great frequency during the Empire (Garnsey, 1988). Finally, although pigs are omnivores, they were not necessarily getting the majority of their water from the same place that humans were, as they were more likely to be watered from local sources.

Because of the small sample of faunal remains from the study sites, constructing a local range based on two teeth is spurious at best. Faunal data from Pleistocene elephants and Palaeolithic horses and deer also do not accurately reflect the water sources available to Romans during the Empire and cannot contribute to defining a local range of biologically available strontium.

8.5 Strontium Mixing Models

This strontium isotope study in ancient Rome is unlike published strontium studies of other archaeological sites. A typical sedentary agricultural population in the past would have ingested strontium from two main sources: rainwater and the geology on which the population farmed their food (Montgomery et al., 2007). Rome, however, is known for its innovative infrastructure of aqueducts that carried fresh water from sources dozens of kilometers away. The available strontium in the city of Rome, I hypothesized, would thus have been influenced by the geology of the water sources of the aqueducts. As can be seen in the reported strontium ratios in section 8.2, there is variation within the population that cannot be accounted for based solely on nonlocal individuals.

The disparate sources of water available to the city of Rome require constructing mixing models to approximate the bioavailability of strontium. Two methods have been most often used in the literature: 1) predicting the strontium ratio of a reservoir based on the relative contribution of individual inputs (Capo et al., 1998; Bentley, 2006); and 2) identifying the two geological end-members that affect strontium isotope ratios in a population by plotting those strontium ratios against the inverse of the measured strontium concentration (Montgomery et al., 2007). These two mixing models support the hypothesis that individuals who had access to aqueduct water could obtain a lower strontium isotope ratio than those who had little to no access to it.

8.5.1 Predicted Strontium Isotope Range of Roman City Water

Figure 8.8 shows the sources and paths of the aqueducts that supplied the city of Rome with water. By the time of the burials at Casal Bertone and Castellaccio Europarco, the city was served by nine aqueducts that carried a total of about 115 million gallons of water per day based on the volume data by Frontinus, the water commissioner of the aqueducts in the first century AD (Taylor, 2000). Frontinus gives the capacity of each aqueduct, and this has been converted to modern measurements in table 8.5.[5]

There were three main sources of the water that flowed into Rome: 1) the Aniene River and springs in the Monti Simbruini; 2) springs in the Colli Albani; and 3) the lake area of Monti Sabatini (Aicher, 1995). Further parsing Frontinus' data, water from the aqueducts Tepula and Alsietina was considered substandard and non-potable; the former was tepid and

[5]Disagreement exists as to the actual volume of water that flowed into Rome, as this calculation rests on the Roman measurement unit of *quinaria*, which is undefined in ancient texts. What matters for the mixing model, however, is the relative percentage of water carried to Rome from the various aqueducts, and these figures are generally agreed upon. See Taylor 2000 for further discussion of volume measurement.

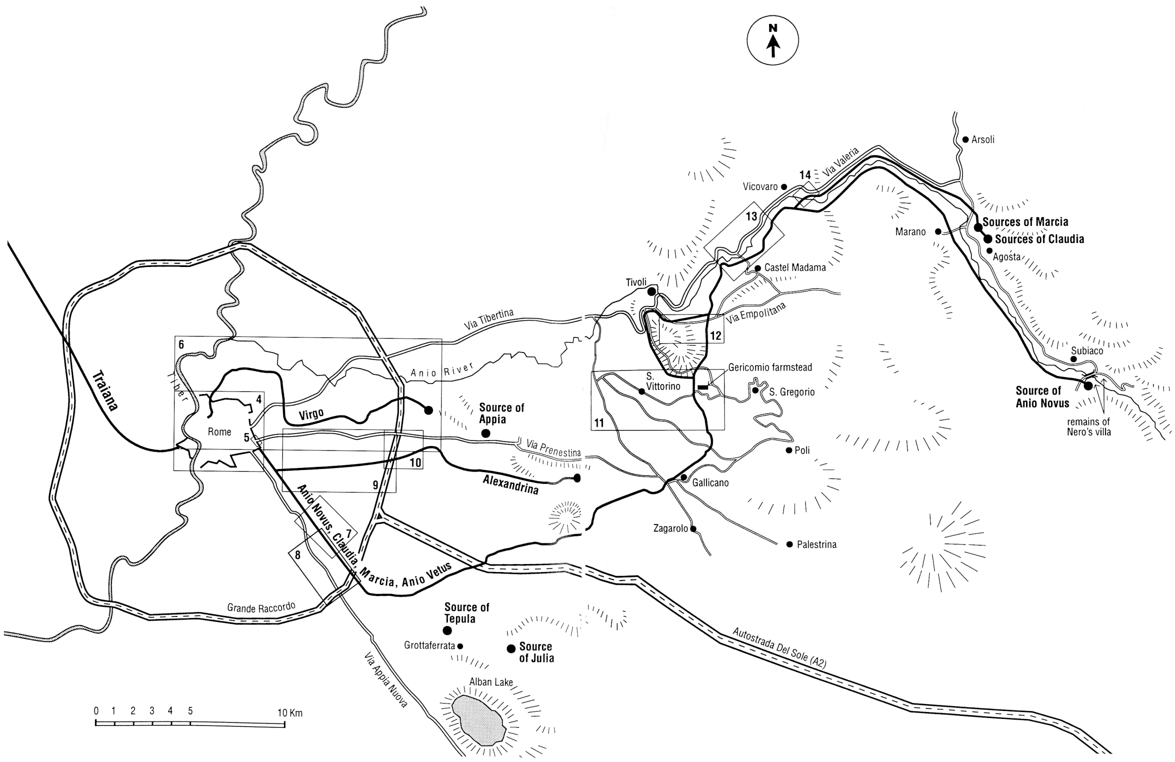


Figure 8.8: Map of Aqueducts of Rome
From Aicher 1995, Map 2.

the latter supposedly served only to fill Augustus' *naumachia* (Taylor, 2000). The authorized delivery of over 100 million gallons per day of potable water was meted out within the city to both private consumers and to public works (fountains, baths, basins, etc.) and was available to everyone: women as well as men, slaves as well as free citizens (Aicher, 1995). Some water was also piped into the *suburbium* to supply baths, fountains, and industries. Frontinus' statistics, however, only hold for government-regulated water usage. Taylor (2000, p. 39) suggests that unauthorized delivery in the countryside - through such methods as tapping the aqueduct along its route - included up to another 89 million gallons of water per day.

Individuals who lived in or frequented the city of Rome thus had access to water that came from two distinctly different geological sources. In order to model the strontium isotope signature of the mixture of potable water flowing into Rome, it is necessary to use a standard two-component mixing equation (Faure, 1986, p. 229):

Aqueduct	Date	Capacity (gal/day)		Potable Water
Marcia	144-140 BC	14,655,702		
Claudia/A. Novus	52 AD	41,519,558		
Anio Vetus	273 BC	17,597,834		
		Simbruini Mts.	*73,773,094*	*68.8%*
Virgo	19 BC	21,169,818		
Julia	33 BC	6,374,618		
Tepula	126 BC	[3,762,208]		
Appia	312 BC	5,951,898		
		Colli Albani	*33,496,334*	*31.2%*
Alsietina	2 BC	[3,314,125]		
Traiana	109 AD	Unknown		
		Monti Sabatini	*Unknown*	
		Total Water Volume	*107,269,428*	

Table 8.5: Authorized Water Delivery Volume of Imperial Aqueducts

Figures in brackets are non-potable water. Data are converted from Taylor (2000, p. 44), Table 1.

$$\left(\frac{^{87}Sr}{^{86}Sr}\right)_{mix} = \frac{\left(\frac{^{87}Sr}{^{86}Sr}\right)_{E1} \cdot f_{E1} \cdot [Sr]_{E1} + \left(\frac{^{87}Sr}{^{86}Sr}\right)_{E2} \cdot f_{E2} \cdot [Sr]_{E2}}{[Sr]_{E1} \cdot f_{E1} + [Sr]_{E2} \cdot f_{E2}}$$

in which E is the strontium isotope ratio of the end member (that is, the aqueduct source), f_{E1} is the fraction of the mixture that comes from the first end member, f_{E2} is defined as $1 - f_{E1}$, and $[Sr]$ is the strontium concentration in ppm.

In the Monti Simbruini, Sappa and Barbieri (1997) found several springs that originate in a deep aquifer near the Simbrivio River and feed into the Aniene River. These springs are therefore comparable in geographical location and water origin to those in antiquity that fed the eastern aqueducts around Subiaco. The strontium concentration of these springs ranges from 0.03 to 0.05 ppm (Barbieri and Sappa, 1997). In the Colli Albani, a multi-year study of the composition of water in the Lago Albano by Ellwood and colleagues (2009) revealed the strontium concentration to range from 0.5 to 0.8 ppm.

Given the ranges of strontium isotope ratios and concentrations, as well as the fraction of water coming from each source presented above, the two-component mixture of water in

Imperial-era Rome is predicted to have a strontium isotope range between 0.7089 and 0.7100. This range, it should be reiterated, represents the overall mixture of water from the two major sources that the Roman aqueducts tapped. In the southern, western, and northern *suburbium* of Rome, on the other hand, water was primarily drawn from local springs. People living in these parts of the greater Rome area would be expected to have strontium isotope ratios in the range of values for the Colli Albani: 0.7090 to 0.7103.

Water distribution in both Rome and the *suburbium* was complicated, however. Individual *castella* in Rome were distribution tanks or cisterns that were usually fed by the water of one aqueduct (Taylor, 2000). When the f values in the mixing equation above are changed to reflect a different proportion of water, the range of strontium isotope ratios can change. Most notably, as the proportion of water from the low-strontium Monti Simbruini reaches 100%, the lower limit of the modeled strontium isotope range of Rome decreases. For example, a child who lived a relatively stationary existence in Rome near the *Castellum Aqua Claudia*, built in 52 AD just inside the Porta Maggiore to hold water from the Aqua Claudia (Aicher, 1995), had the opportunity to obtain a first molar strontium isotope value as low as 0.7079. In other areas of Rome, multiple *castella* could be found in the same location. On the Quirinal Hill, three *castella* were found near the Porta Viminale dating to the first century BC, and each is thought to have held water from a different source: the Aquae Marcia, Tepula, and Julia (Ashby, 1935). In this example, a child who lived on the Quirinal could have obtained his water only from the low-strontium Marcia, only from the high-strontium Julia or Tepula, or from a combination of the waters. His strontium isotope ratio could fall anywhere within the range of .7079 to .7103.

Aqueduct water was distributed to the *suburbium*, and aqueducts were also tapped along their paths to Rome. It is likely that some individuals living in the eastern part of the *suburbium* had access to the low-strontium water of the Monti Simbruini. Given the mixing equation above, an individual would have to drink at least 70% of his water from the Monti Simbruini to have a strontium isotope ratio lower than the geology of the Colli Albani. If he drank any less than this from the lower strontium Monti Simbruini water, his ratio would be dominated by the higher strontium of water in the Colli Albani and thus indistinguishable from someone who drank only Colli Albani water.

Finally, it is possible that individuals whose strontium ratios indicate consumption of low-strontium water were immigrants. People who were born and raised in the Apennine foothills would have had direct access to the water that Rome imported and might therefore be considered short-distance migrants or mobile individuals. Other people with low strontium ratios might be from different geographical areas entirely, such as the volcanic area around Naples. This latter point will be further addressed in chapter 10 following investigation of the oxygen isotope range of Rome.

Based on both the predicted and known ranges of the two major sources of Roman water, the local range of strontium isotope ratios can be conservatively modeled as 0.7079 to 0.7103. Individuals with values either lower or higher than this range therefore represent immigrants to Rome.

8.5.2 Two End-Member Strontium Mixing Model

A small sample (n=17) of the populations from Casal Bertone and Castellaccio Europarco was analyzed for the concentration of lead and strontium in dental enamel in support of a project on migration in Roman Britain led by Dr. Janet Montgomery at the University of Bradford (Montgomery et al., 2010).[6] Seven individuals from Castellaccio Europarco were tested, and from Casal Bertone, three individuals from the mausoleum context and seven from the necropolis were tested.

[6]Anthropogenic lead was widely available in the Roman world, and people ingested it voluntarily as a seasoning and involuntarily as a byproduct of industry. Differential ingestion, however, depends on geographical area, status, dietary practices, occupation, and other factors. The combination of lead isotope and concentration data, therefore, can help isolate individuals with anomalous lead levels in a region with known lead values from human remains. The lead and strontium isotope ratios from a female burial from Spitalfields in London strongly suggest that she immigrated to Britain from Rome. This result represents the first isotopic evidence of a Roman emigrant in the Empire. In addition to the concentration data, lead isotopes were measured from three individuals (ET93, ET31, and F11A). For results from this study, see Montgomery et al. (2010). Publication of the lead concentration and isotope data from Casal Bertone and Castellaccio Europarco will be forthcoming, including one additional sample from the Republican period of Castellaccio Europarco.

Skeleton	Age	Sex	Sr ppm
ET27	16-20	PM	250
ET31	0-5	I	214
ET42	Adult	PM	162
ET58	41-50	F	260
ET67	11-15	I	118
ET69	21-30	M	194
ET72	31-40	M	477

Table 8.6: Strontium Concentration - Castellaccio Europarco Samples

Skeleton	Age	Sex	Sr ppm
F11A	31-40	F	340
F12A	31-40	M	57
F1A	16-20	F	156
T18	31-40	PM	254
T23	21-30	M	208
T30	41-50	PF	107
T32	11-15	I	225
T33	41-50	M	131
T36	11-15	I	111
T70	6-10	I	107

Table 8.7: Strontium Concentration - Casal Bertone Samples

The two end-member mixing equation cited in section 8.5.1 above demonstrates that, when two geological or hydrological sources with different strontium isotope ratios and concentrations are combined, substituting different values of f yields a hyperbolic curve of predicted strontium isotope values for the resulting mixture. Strontium isotope ratios from human dental enamel can also fall along a hyperbolic curve when plotted against the strontium concentration of the enamel if a population was obtaining dietary strontium from two distinct geological areas (Beard and Johnson, 2000; Bentley, 2006). Some researchers, however, have suggested plotting the enamel strontium ratios against the inverse of the enamel strontium concentration (1/Sr). In this type of graph, enamel samples that fall in a straight line suggest that two primary geological end-members contributed to the array of strontium isotope ratios seen. Montgomery and colleagues (2007, Fig. 2), for example, were able to separate two archaeological populations that appeared to be a disorganized cloud of data because the samples from the earlier time period demonstrated a direct linear relationship between two geological end-members.

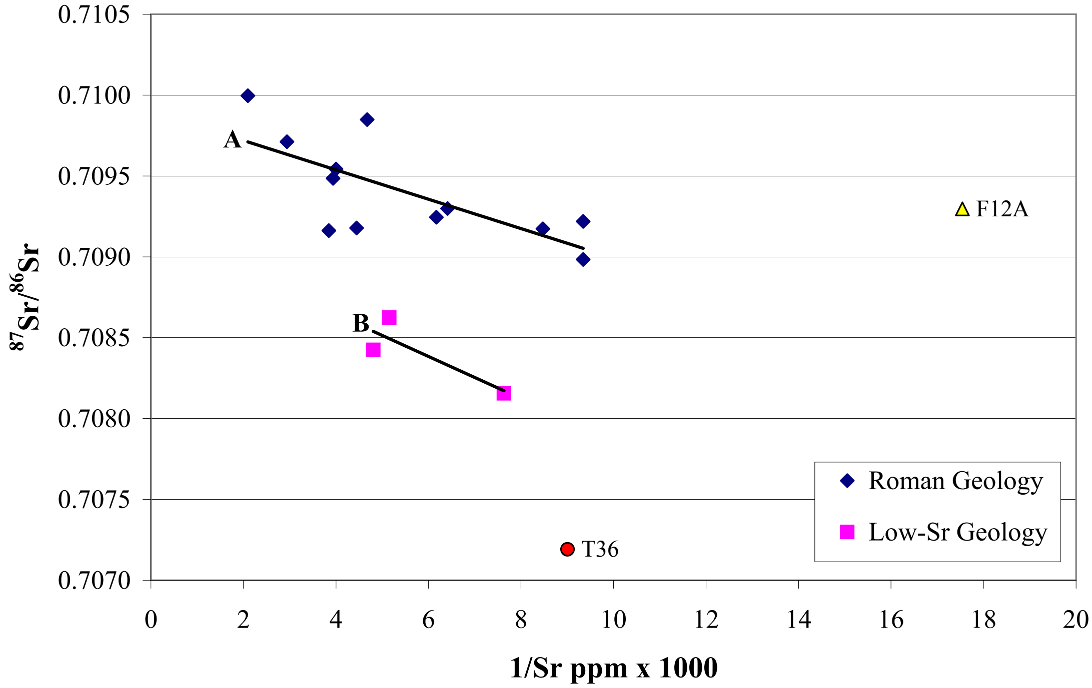


Figure 8.9: Strontium Mixing Lines from Roman Enamel Samples
Line A, mixing line for water from local geology, r^2 = -0.72.
Line B, mixing line for nonlocal water, r^2 = -0.85.
F12A and T36 are anomalous individuals.

The strontium concentration data from the 17 Imperial period samples from Casal Bertone and Castellaccio Europarco are plotted in figure 8.9. Individuals F12A and T36 are anomalous and will be discussed further in section 8.6.1. Two mixing lines can be fitted to this dataset. Line A is the best fit line for the cluster of individuals with higher strontium ratios; the Pearson correlation coefficient ($r^2 = -0.72$) indicates a moderate correlation. The end-members of line A therefore encompass geology comparable to measured strontium ratios in the Colli Albani and/or seawater.

Line B is the best fit line for the cluster of individuals with lower strontium ratios; the Pearson correlation coefficient ($r^2 = -0.85$) indicates a moderate correlation. The end-members of line B are lower than line A and are comparable to measured strontium ratios in the Monti Simbruini on the low end and either seawater or water from the Colli Albani on the high end. The data points from line B suggest that these individuals either: a) lived in the greater Rome area and consumed more than 70% of their water via aqueduct from the lower-strontium springs in the Monti Simbruini; or b) lived somewhere other than Rome where the strontium isotope range was similarly low. Only three data points fall along line B; additional measurements of strontium concentration in samples with low isotope ratios would be beneficial. Nevertheless, the linear relationships seen in figure 8.9 suggest that it is possible to distinguish individuals who consumed a high proportion of water from the eastern aqueducts from individuals who consumed local water or a mixture of local and eastern aqueduct water.

The correlation coefficients of these lines indicate that, although the two end-members contribute greatly to the strontium concentration of the water, people ingested more than two sources of water in both the city and *suburbium* of Rome. One possible candidate for an additional source of strontium is imported food or drink. As noted in chapter 6, Rome imported a large quantity of grain from northern Africa and distributed some of it through a grain dole to the lower classes (Garnsey, 1988). The water content of the imported food could have contributed an additional strontium source to the dental enamel of any individuals who were eating mostly non-local food. Without further evidence of the amount of imported food consumed or its strontium isotope ratio, it is impossible at this time to include this variable in a model of the biological availability of strontium in Rome.

8.5.3 Strontium Ratio of Rome and the *Suburbium*

Instituting criteria to separate populations into locals and nonlocals using strontium ratios is almost never straightforward, as it is unlikely a population's ratios will conform to a statistically normal distribution. A number of factors, including cultural practices, personal choice, and availability of food and water resources, affect an individual's strontium ratio (Montgomery et al., 2007, p. 1503).

For the purposes of this study, three different data sets were employed in order to approximate the range of biologically available strontium isotopes in Rome and the *suburbium*. The mixing equation took as inputs the range of strontium isotopes measured at the sources of the ancient aqueducts along with the relative percentage of water obtained from these sources. In this model, the strontium isotope range of Imperial Rome and the *suburbium* is 0.7089 to 0.7100. The two end-member mixing model took as inputs both the strontium isotope ratio and the strontium concentration of dental enamel, data that are not normally linearly related (Montgomery et al., 2007, p. 1504). The finding of two linear relationships within the data set indicates that, although there is variation among the individuals, the majority of their dietary strontium was coming from two geological end-members, likely rainwater and the geology of their drinking water sources: either the high-strontium Colli Albani or the low-strontium Monti Simbruini. Measuring the strontium content of additional samples would be useful in further understanding the isotope range of Rome.

At this point, it is impossible to rule out certain scenarios in which an individual born locally could have obtained a strontium ratio either higher or lower than the modeled range of 0.7089 to 0.7100. Someone living in Rome who drank only water from the eastern aqueducts could have obtained a strontium ratio lower than 0.7089, and someone living in the Colli Albani could have obtained a strontium ratio higher than 0.7100. A very conservative strontium isotope range for Rome, therefore, necessarily encompasses the geology of the major water sources in the area: 0.7079 to 0.7103.

8.6 Discussion

Figure 8.10 is a plot of the strontium ratios from all Imperial period individuals. Indicated on this chart and others that follow are the two major strontium isotope ranges that represent the local Roman range. The strontium isotope range of Rome and the *suburbium* based on the mixing models is indicated by the dotted red rectangle. The lower range of strontium isotope ratios that could be obtained by locals drinking most of their water (over 70%) from sources in the Monti Simbruini is indicated by the dashed yellow rectangle. The value of seawater is shown as a solid blue line.

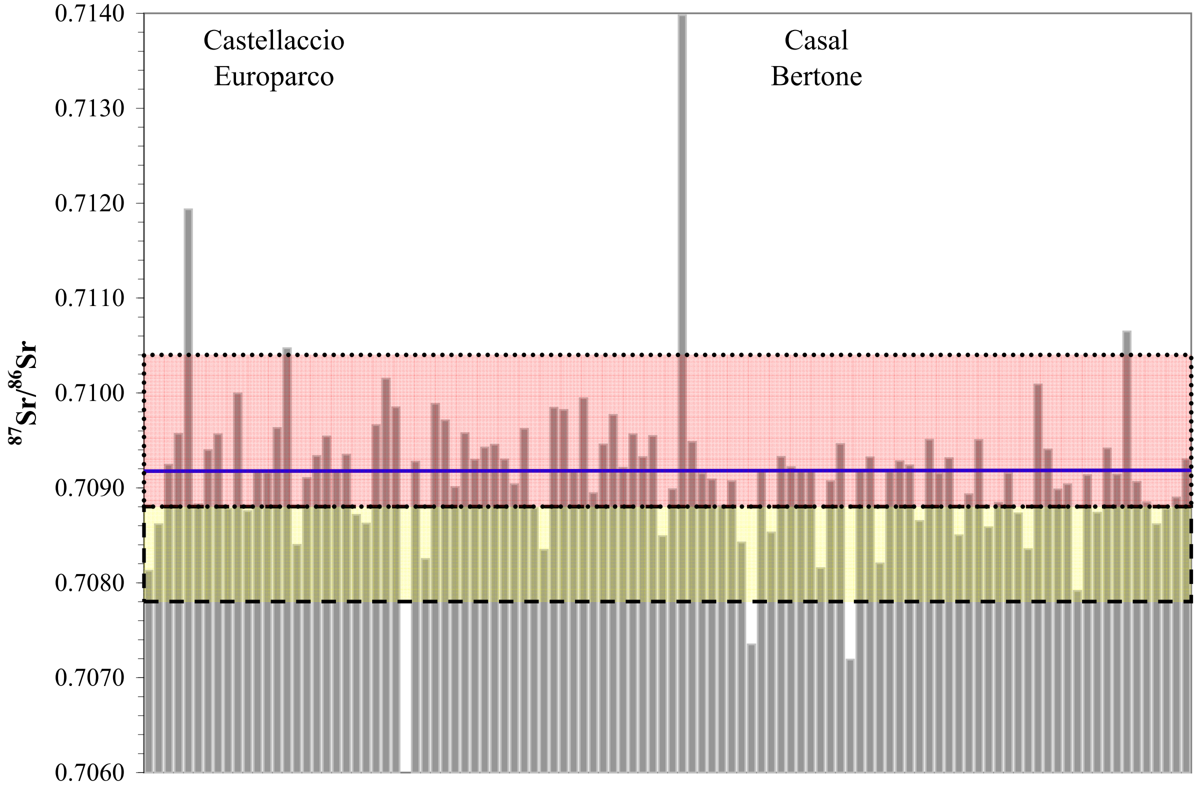


Figure 8.10: Strontium Ratios of All Imperial Period Individuals
Dotted red rectangle represents the likely local Roman range; dashed yellow rectangle represents the lower range of isotope ratios that could be obtained by locals drinking water from the Monti Simbruini; solid blue line represents seawater.

It is clear that there is a huge spread of strontium ratios at both sites. There are, however, some obvious outliers to the data, two from Castellaccio Europarco and five from Casal Bertone. These strontium ratios represent individuals who were not born within the vicinity of Rome and thus are nonlocals or immigrants to the Imperial capital.[7]

[7]The strontium isotope ratio of T72, 0.707914, falls on the lower limit of the possible strontium range of Rome. The next highest individual sampled from that site presents a strontium isotope ratio of 0.708155, a difference of over 0.0002. In terms of strontium isotope ratios, this is a significant difference, so I cautiously interpret T72 as an immigrant rather than as a local.

8.6.1 Immigrants

Demographic information on the individuals identified as nonlocal based on strontium isotope ratios is presented in table 8.8. All nonlocal adults are most likely male based on skeletal indicators, and two (ET38 and T24) are males older than the average age-at-death for these populations. The teeth tested, however, provide information about the first three years of life, so there is possibly no correlation between nonlocal status and longevity. The three remaining nonlocals are subadults whose sex could not be determined by biological remains nor predicted archaeologically because of the lack of grave goods. In the population at Castellaccio Europarco, two individuals were nonlocal out of a total of 26 individuals tested, or 7.7% of the population. Interestingly, at Casal Bertone, nonlocals appear only in the necropolis context. The nonlocal population at Casal Bertone as a whole amounts to 6.3% based on strontium signatures.

Site	**Sample**	**Age**	**Sex**	**Sr value**
Castellaccio	ET76	11-15	PM	0.710471
Castellaccio	ET38	41-50	M	0.711934
Casal Bertone	T36	11-15	I	0.707191
Casal Bertone	T24	51-60	M	0.707351
Casal Bertone	T72	11-15	I	0.707914
Casal Bertone	T8	6-10	I	0.710647
Casal Bertone	T15	31-40	PM	0.713980

Table 8.8: Individuals Not Local to Imperial Rome

In order to figure out where the nonlocal individuals originated, it is necessary to investigate the geology of Italy and attempt to define the lithologies in the area from which a person obtained his or her food and water. The anomalous strontium ratios in this study are both lower and higher than the local area of Rome. The higher individuals, ET38 and T15, likely lived in an area with older Paleozoic rock such as granite. This type of rock is sparse in the Italian peninsula, with the only large outcroppings in Calabria (the toe of the Italian boot) and just across the Strait of Messina in the northeastern part of Sicily (Servizio Geologico d'Italia, 2004). Older granitic rocks, however, are also found in the Alps (ibid.), where granites range from 0.712 to 0.714 in Germany and Switzerland (Faure and Powell, 1972), as well as in a large outcropping on the eastern coast of Corsica. Based on strontium signatures, all of these locations are possible homelands for ET38 and T15. The largest amount of granitic rock in Italy is in the Alps, and strontium isotope ratios generally decrease north-to-south (Turi and Taylor, 1976). Additionally, the data provided by oxygen isotope analysis in chapter 9 suggest that both individuals originated in areas north of Rome.

The two individuals whose strontium ratios are slightly higher than the local Roman signature, ET76 and T8, likely lived in an area with a geological signature higher than the volcanic area of Rome and thus somewhere to the north. Published strontium isotope data of the volcanic areas north of Rome (Monte Vico, Monti Sabatini, and the Tuscan magmatic area) all have ratios slightly higher than Rome, around 0.710 to 0.712 (Turi and Taylor, 1976; Avanzinelli et al., 2008). Both ET76 and T8 have statistically higher strontium ratios than the individuals identified as local, but are probably short-distance migrants to Rome.

Individuals with a lower strontium ratio than Rome include T36, T72, and T24. A lower strontium ratio means that an individual was obtaining water from young geology, probably volcanic basalts. Other volcanic areas in and around Italy include Mount Vesuvius near Naples, Monte Vulture in south-central Italy, Mount Etna in Sicily, and the western coast of Corsica. Measured strontium isotope ratios from most of these contexts demonstrate lower numbers than the Roman volcanic region. Monte Vulture, the only inland Italian volcanic area, measures around 0.705-0.706 (Barbieri and Morotti, 2003; Avanzinelli et al., 2008). Mount Vesuvius is around 0.707-0.708 (Turi and Taylor, 1976; Avanzinelli et al., 2008), while the nearby volcanic island of Ischia is 0.706-0.707 (Barberi et al., 1969; Avanzinelli et al., 2008). Water measured from springs in Mount Etna basalts are significantly lower than the peninsular basalts, around 0.703-0.704 (Pennisi et al., 2000). The people with lower strontium ratios than Rome are thus, conservatively, from another area of Italy with young geology, possibly the Naples area. Individual T36 has anomalous strontium and oxygen ratios and will be examined further in chapter 10.

Additionally, the strontium concentration data indicate that two individuals, F12A and ET72, both 31-40-year-old males, were different than the rest of the population. The strontium concentration of 57 ppm for F12A is markedly lower than the other measurements at Casal Bertone, which range from 107 to 340 (table 8.7), and this individual does not plot with the others in figure 8.9. This man's strontium isotope ratio, 0.709296, is within the range of the volcanic area of the Colli Albani, but it is also a reasonable strontium ratio for someone who lived near the sea. The concentration of 477 ppm for ET72 is markedly higher than the range at Castellaccio Europarco of 118-260 ppm (table 8.6). This individual's $^{87}Sr/^{86}Sr$ ratio, 0.709996, is also within the range of the Colli Albani. As noted in chapter 7, the strontium concentration in human tissue is related to both the geology of a person's area of origin and the trophic position of a person's diet. Individual F12A could have eaten a diet with large amounts of meat and dairy, or one high in calcium-poor staples, whereas individual ET72 could have consumed a diet with a lot of nuts, seeds, and legumes (Montgomery et al., 2003). Neither man's diet appeared to be anomalous based on carbon or nitrogen isotope analysis, however (see chapter 6). Alternatively, these individuals could have originated in an area with similar geology to Rome. Volcanic rocks with low $^{87}Sr/^{86}Sr$ ratios have high strontium concentrations, whereas volcanic rocks with high $^{87}Sr/^{86}Sr$ ratios have low strontium concentrations (Faure and Powell, 1972, p. 28-9). The fact that these individuals' first molars have anomalous strontium concentrations indicates they ate a different diet, were from another geographical area, or both. Unfortunately, there is no comparative data set of strontium concentrations for humans from the Italian peninsula. It is most likely that these individuals were consuming food from a slightly different geological area than Rome, probably a nearby volcanic area, such as the Monti Sabatini complex or the southern Tuscan magmatic province. These individuals were thus likely short-distance migrants. More work is needed, however, to characterize strontium concentrations in human remains from Rome, so these individuals are not included in further discussion of immigrants.

Using the criteria established to approximate the strontium range of Imperial Rome and the *suburbium*, seven out of 105 individuals were identified as nonlocal. Thus, 6.7% of the population at these two sites came to Imperial Rome from elsewhere. Pinpointing immigrants' homelands using only strontium is difficult, as the geology of the area does not necessarily translate directly to the strontium signature of a human tooth. Given the conservative assumption that most immigrants to Rome came from the Italian peninsula, it is likely that two individuals originated in southern Tuscany (ET76 and T8), two came from either the Naples area or the Monte Vulture area in the south-central part of the peninsula (T24 and T72), and two journeyed to Rome from Liguria or Tuscany (ET38 and T15). Although the strontium signature of T36 places this subadult's birth in an area with young volcanic basalts, the oxygen isotope ratio indicates an origin other than the Italian peninsula. All immigrants will be contextualized in terms of diet, disease, burial style, and demographics in chapter 11.

8.6.2 Variation in $^{87}Sr/^{86}Sr$ Ratios

Site Differences

As noted in section 8.2, the average strontium ratio from the local Castellaccio Europarco individuals was shown to be significantly higher than the mean at Casal Bertone. These results suggest that the individuals from periurban Casal Bertone had greater access to lower-strontium water than individuals from suburban Castellaccio Europarco.

Castellaccio Europarco was located in the *suburbium*, about 12 km from the city walls of Rome. This distance would have taken an adult nearly two hours on foot, so it is possible but unlikely that individuals living in this area would have commuted into the city on a daily basis. Measured strontium ratios, of course, are from the first molar and reflect the first few years of life. Infants who were born and raised in the countryside are unlikely to have journeyed into Rome often enough to have obtained a strontium signature reflective of eastern aqueduct water. There should, therefore, be two ranges of values: those individuals who had access to a great amount of lower-strontium water and those individuals who had access mostly to higher-strontium water.

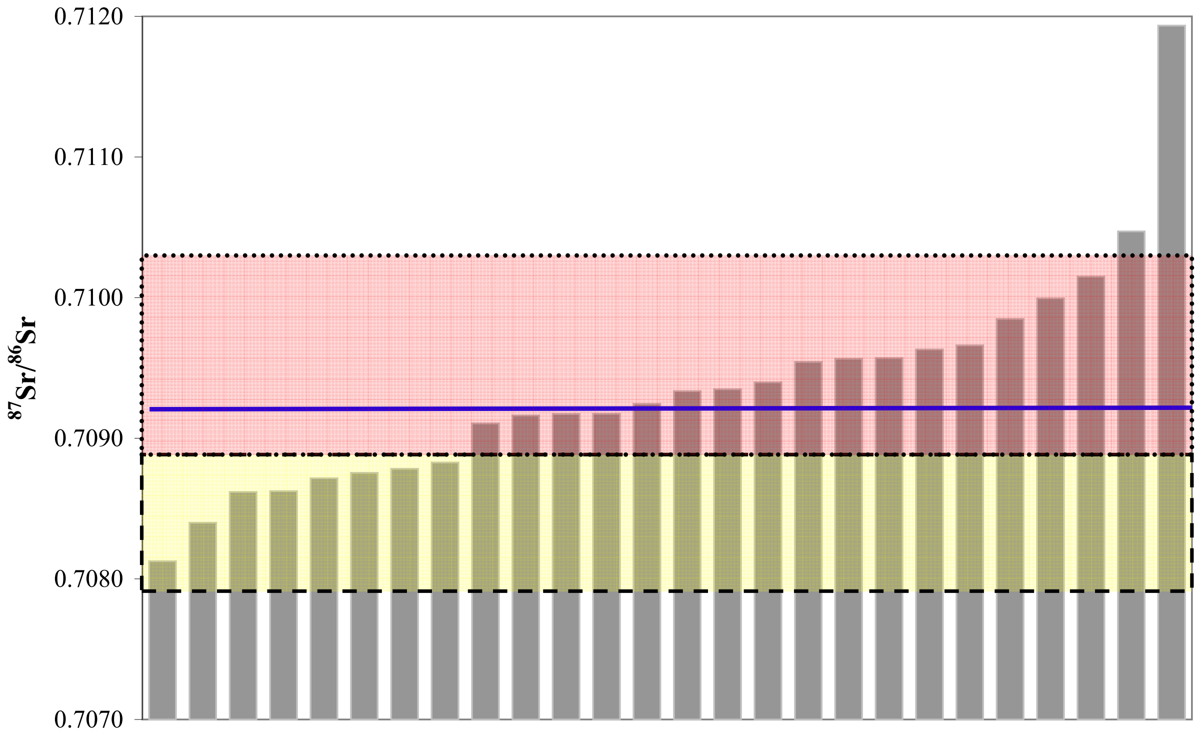


Figure 8.11: Castellaccio Europarco - Strontium Ratios
Dotted red rectangle represents the likely local Roman range; dashed yellow rectangle represents the lower range of isotope ratios that could be obtained by locals drinking water from the Monti Simbruini; solid blue line represents seawater.

Elimination of the two known nonlocals at Castellaccio Europarco whose strontium signatures are greater than 0.7103 leaves 24 individuals who have a continuum of local strontium signatures. There is, however, a clear discontinuity in the graph at about 0.7088. Individuals with a strontium isotope signature in the lower range likely ingested at least 70% of their water from lower-strontium sources, such as the eastern aqueducts. The separation in the graph into a group of individuals who drank mostly local water and a group of individuals who drank mostly nonlocal water bears out the assumption that Castellaccio Europarco was far enough from Rome that individuals were not regularly consuming water imported from the Monti Simbruini. Of the 24 people local to the area of Rome, one-third of the sampled individuals fall into the lower strontium range and two-thirds into the higher range. Those in the lower strontium range might have been born in another area of Rome with greater access to eastern aqueduct water, they might have been mobile enough as children to have obtained a low strontium isotope ratio from consumption of eastern aqueduct water, or they might have been immigrants from an area with similar strontium isotope ratios.

The site of Casal Bertone is located on the eastern side of the *suburbium*, within meters of the path of the Aqua Virgo. It is likely that, if the individuals buried there had lived nearby, they had regular access to water from that aqueduct. The source of the Virgo is rainfall in the *suburbium* (figure 8.8) and would have carried a strontium isotope signature similar to the geology of the Colli Albani. The archaeological context of Casal Bertone includes two large complexes that would have required abundant water: a *nymphaeum* and a tannery/fullery (see chapter 4). The source of the water that supplied these buildings is unfortunately unknown, but in all probability they were fed by aqueducts, either legally or illegally. It is therefore possible that water from the eastern aqueduct sources was meted out to the suburban bath and industrial complexes found at the site. Casal Bertone is also located just 1.6 km (1 mi) from the city walls of Imperial Rome and, more importantly, from the Porta Maggiore, which was not only an entry gate to the city of Rome but also a channel for both the Aquae Claudia and Anio Novus. Assuming that individuals buried at Casal Bertone lived in the area near the cemetery, a mere 15-minute walk would have taken them into the city. It is highly likely that individuals buried at Casal Bertone frequently traversed both the urban context of the city and the periurban context of the *suburbium* just outside the walls. If the assumptions about the source of water at the site and the mobility of the population buried at Casal Bertone are correct, the range of strontium ratios should be relatively continuous, as different individuals would have utilized resources differently by moving between contexts. The average strontium ratio at Casal Bertone is expected to be lower than that of Castellaccio Europarco, as people at Casal Bertone had easier access to lower-strontium water owing to their propinquity to the city and the path of the eastern aqueducts.

The strontium signatures from the people buried at Casal Bertone support the hypothesis that a continuum of water consumption exists. Figure 8.12 is a graph of strontium ratios from the site. There are five nonlocal individuals represented by the two signatures greater

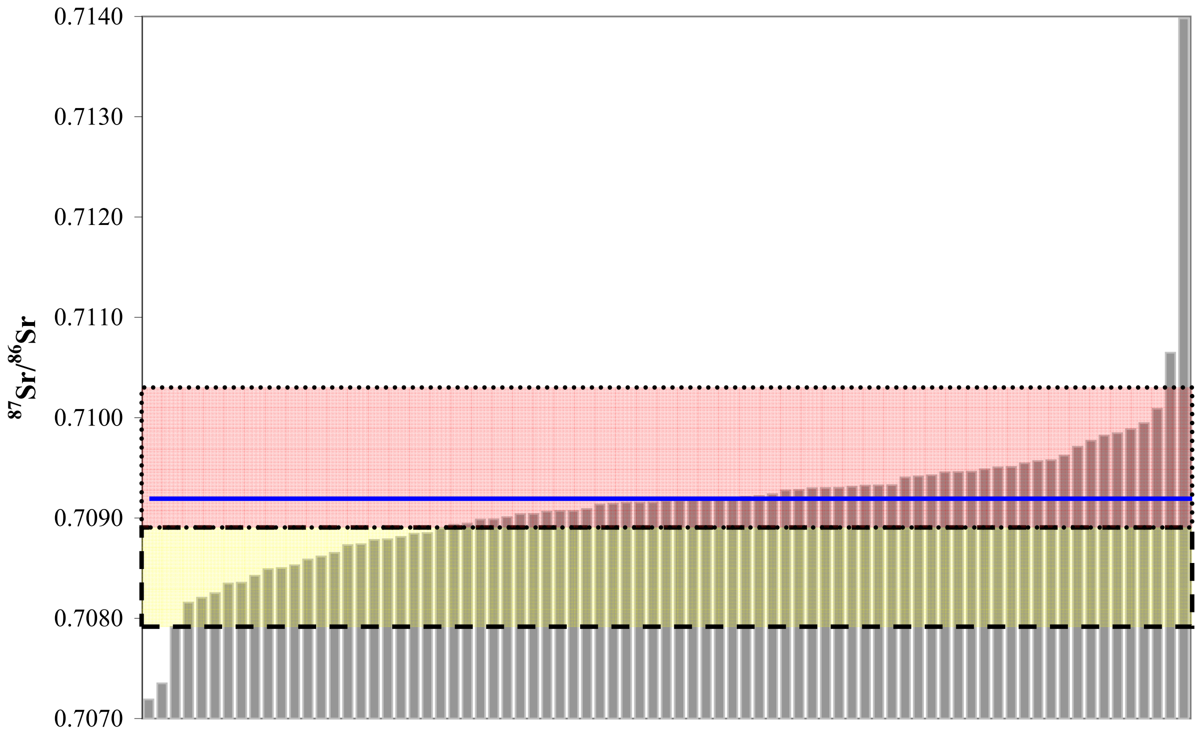
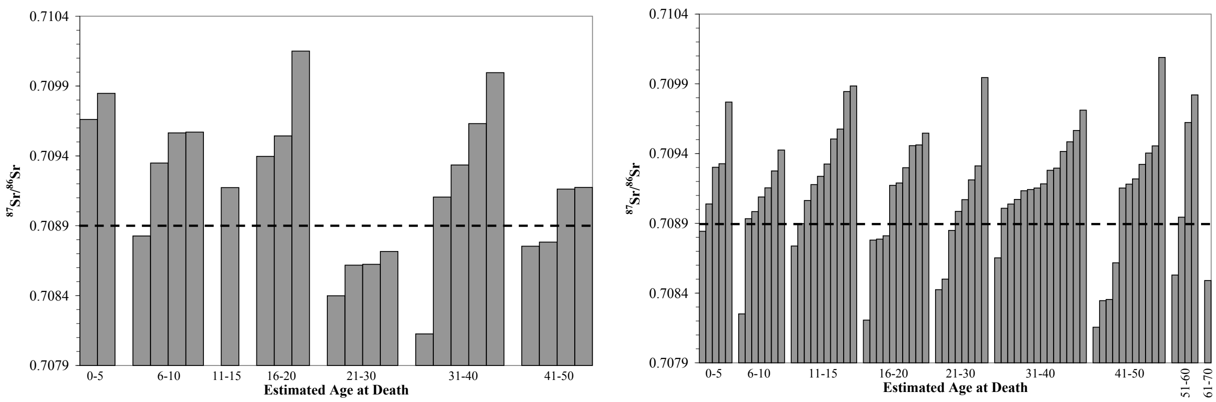


Figure 8.12: Casal Bertone - Strontium Ratios
Dotted red rectangle represents the likely local Roman range; dashed yellow rectangle represents the lower range of isotope ratios that could be obtained by locals drinking water from the Monti Simbruini; solid blue line represents seawater.

than 0.7103 and the three less than 0.7079 as reported in section 8.6.1. Unlike Castellaccio Europarco, however, Casal Bertone presents local ratios along the continuum of water values. The distinction between individuals who consumed mostly low-strontium water and those who consumed mostly high-strontium water at Casal Bertone is blurred, as individuals living in the periurban context of the *suburbium* likely had the opportunity to obtain the significant amount of nonlocal aqueduct water necessary to lower their strontium isotope ratios.

Age Differences

Variation in the strontium isotope ratios by estimated age-at-death was also investigated. The sample of the Castellaccio Europarco population whose strontium isotope ratios were measured could be broken down into six age categories. For the purpose of statistical analysis, the



(a) Castellaccio Europarco

(b) Casal Bertone

Figure 8.13: Local Strontium Isotope Ratios by Age

one individual in the 11-15 age category, ET72, was placed in the 6-10 age category. Additionally, one individual who could only be determined to be an adult was excluded from statistical analysis. In order to compare the means of the strontium isotope ratios of the age cohorts, a one-way ANOVA was calculated. The result indicated a statistically significant difference ($p \leq 0.05$) among the between-group means. Figure 8.13a presents the strontium isotope ratios of the locals at Castellaccio Europarco broken down into age categories. Individuals above the dashed line were consuming mostly local water, while those below were consuming mostly eastern aqueduct water. The four individuals who were in their 20s when they died have much lower values on average than any other group. As infants, these individuals were likely obtaining a large portion of their water from lower-strontium sources such as the Monti Simbruini. Nevertheless, there are few individuals in each age category; the small sample size of each age cohort could therefore be distorting the data.

The Casal Bertone population could be split into eight categories of estimated age-at-death. For the purposes of statistical analysis, the one individual in the 61-70 age group was included with the 51-60 age group, and the four individuals who could only be determined to be adults were excluded. The one-way ANOVA test of the between-group means was statistically insignificant ($p = 0.7$). Figure 8.13b presents the strontium isotope ratios of locals at Casal Bertone broken down into age categories. Individuals above the dashed line were consuming mostly local water, while those below were consuming mostly eastern aqueduct water. Each age cohort has a range of strontium isotope values. The variance in the ratios of individuals estimated to have been 31-40 years old at death is smaller than the other groups. Only one individual in this group appears to have been drinking a significant amount of lower-strontium water, such as from the Monti Simbruini. However, this age group has the most data points; it is possible that additional testing of individuals in other groups would produce more continuous ranges of strontium isotope ratios.

It is currently unclear what, if anything, the age-related differences in strontium isotope ratios means at Castellaccio Europarco or what the lack of differences means at Casal Bertone. Future studies of dental enamel from Imperial Rome could help explicate these data.

Sex Differences

By separating the populations into groups of males and females, sex differences in water consumption at both sites can be examined by investigating the variance within the populations (Bentley, 2006). At Castellaccio Europarco, the range of female strontium values is not significantly different from the range of male values. However, only four adult females from Castellaccio Europarco presented teeth for evaluation, so the underrepresentation of one sex could have affected this outcome.

At Casal Bertone (figure 8.14), the difference between male and female strontium ratios is statistically significant in a two-tailed t test ($t = 3.6162, p \leq 0.01$). Males averaged 0.709042 with a standard deviation of 0.00045 (n=35), while females averaged 0.709202 with a standard deviation of 0.00044 (n=16). Local males thus had greater access to lower-strontium water on average than did local females.

Various scenarios can explain why male children had greater access to aqueduct water than females. For example, perhaps male children were more likely to travel into Rome with their mobile fathers than were female children who grew up in the *suburbium*, thereby being able to obtain lower strontium isotope ratios than female. More chemical testing of teeth that form

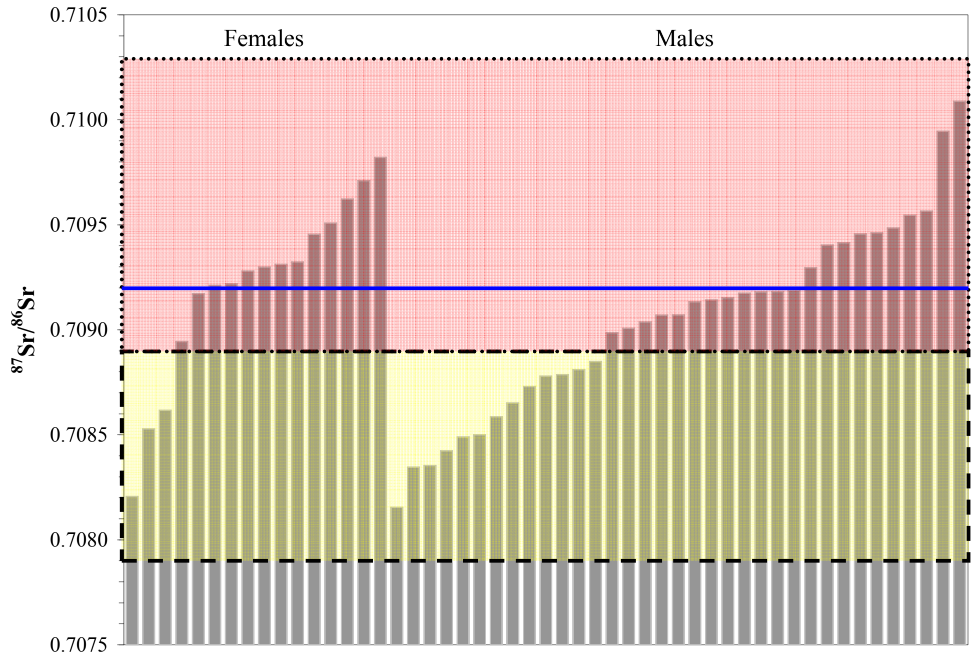


Figure 8.14: Casal Bertone - Female and Male Strontium Ratios
Dotted red rectangle represents the likely local Roman range; dashed yellow rectangle represents the lower range of isotope ratios that could be obtained by locals drinking water from the Monti Simbruini; solid blue line represents seawater.

at different age ranges, however, would be necessary before attempting to explain any possible sex-related differences in water consumption.

8.7 Conclusions

Strontium isotope analysis is not a flawless method for understanding mobility and migration in the past. Although water flowing over rocks takes on the strontium signature of the geology, humans usually consume water from a variety of sources. At best, measured human strontium isotope ratios will create a small range offset above or below the range of the local geology. Strontium ratios from human dental enamel might also reflect a simple mixing line between rainwater and the local geology (Montgomery et al., 2007). In many archaeological studies, however, it is necessary to create objective criteria by which the population can be judged to be either local or nonlocal. Finally, there is usually variation within a population's

$^{87}Sr/^{86}Sr$ ratios other than that contributed by nonlocal individuals (Bentley, 2006). It is often difficult therefore to assess how much variation exists and what contributes to the variation.

This study of strontium isotope ratios from Imperial Roman remains necessitated the creation of objective criteria to judge local and nonlocal individuals because no previous study of human strontium ratios has been done in Italy. In looking at the collected data from each site, the mean strontium ratios for the local populations are 0.709128 (Casal Bertone) and 0.709198 (Castellaccio Europarco). The two pig teeth tested are 0.709326 (Casal Bertone) and 0.710313 (Castellaccio Europarco). These results all suggest that the biological availability of strontium is within the lower end of the range of strontium values measured from the local geology of the Colli Albani.

In the Imperial period, however, it is known that the city of Rome imported about two-thirds of its water from springs and rivers to the east in the Monti Simbruini of the Preapennines. The geology of this area is composed of older rock and therefore has a significantly lower strontium signature than the volcanic area around Rome. Water piped into Rome from the east was available in addition to water from the *suburbium*. The $^{87}Sr/^{86}Sr$ ratio of different mixtures of these waters can be modeled by means of a mixing equation. Further, the moderate linear relationship found in a two end-member mixing model suggests the main sources of dietary strontium were rainwater or seawater and the geology from which drinking water was drawn.

Individuals who were nonlocal were identified based on strontium isotope ratios. There were seven individuals who fell outside of the local isotope range. All nonlocals were either adult males or subadults. A conservative interpretation of their homelands puts all but one coming from the Italian peninsula. A couple likely came to Rome from nearby Tuscany, but two more appear to have come from far southern Italy, over 700 km from Rome. Evidence of nonlocal individuals thus involves both short-distance and long-distance migration. It is currently unknown when in life these individuals immigrated, but the presence of a subadult who died around 8 years old (T8) among the short-distance immigrants suggests that children moved to Rome. Whether they moved with their families, by themselves, or as slaves cannot be determined from the data at hand.

Finally, variation both within and between the populations was investigated. Castellaccio Europarco, located about 12 km from the city, and Casal Bertone, located 1.6 km from Rome, have statistically different means and ranges in strontium isotope data. Individuals who were buried at Casal Bertone were drinking water with a lower strontium isotope ratio than the individuals from Castellaccio Europarco and thus likely had more frequent access to aqueduct water. Although there were no sex differences in strontium ratios at Castellaccio Europarco, the significant difference between males and females at Casal Bertone suggests that males obtained lower strontium values than females, possibly the result of higher mobility or better access to eastern aqueduct water.

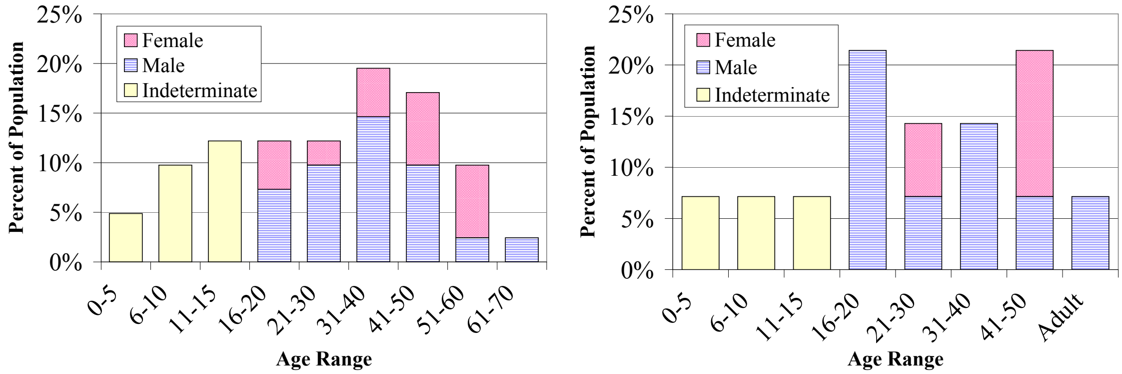
Rome's complex infrastructure of imported water and abundance of imported food significantly complicate the biological availability of strontium and make defining a local baseline difficult. The results of this inaugural study suggest, however, that strontium isotope analysis can be used in ancient Rome to isolate people who came to Rome from other areas of Italy and the Empire. By combining these results with oxygen isotope ratios presented in chapter 9, a more complete picture of mobility and migration in Imperial Rome begins to form.

Chapter 9

Oxygen Isotope Analysis

Oxygen isotopes and strontium isotopes represent two independent systems by which mobility and migration can be assessed in antiquity. As shown in chapter 8, strontium isotopes in the geology of Italy vary north-to-south, particularly because of the different volcanic systems. Oxygen isotopes, on the other hand, are related to climate and elevation and thus vary east-to-west on the Italian peninsula. The technique of pairing strontium and oxygen analyses to answer questions about mobility and migration, as presented in chapter 10, has produced good results in other parts of the world. In order to better understand the origins of the Imperial populations found at Casal Bertone and Castellaccio Europarco, therefore, oxygen isotope analysis was undertaken in addition to strontium.

An outline of the methodology and theoretical considerations for oxygen isotope analysis was presented in chapter 7. The current chapter presents the results of the oxygen isotope analysis of 55 individuals from the two Imperial Roman cemeteries in this study. The results are interpreted in light of a range that I establish for the local signature at Rome based on the data presented by Prowse and colleagues (2007). The data are also converted to drinking water values, and the geographical origins of nonlocal individuals are discussed. The chapter concludes with a discussion of the similarities and differences between the results of this oxygen isotope analysis and those of Prowse and colleagues (2007) at Portus.



(a) Casal Bertone

(b) Castellaccio Europarco

Figure 9.1: Demographics of Individuals Subjected to Oxygen Isotope Analysis

9.1 Sample Selection and Demography

The realities of funding did not allow every individual to be tested for all four elements under investigation. For oxygen isotope analysis, a stratified sample was drawn from the population subjected to strontium isotope analysis, including every individual for whom carbon and nitrogen isotope information was gathered as well as ten additional individuals, for a total of 60 samples. Four individuals were selected from the earlier phases of Castellaccio Europarco and are presented in appendix B. From the Imperial population at Castellaccio Europarco, 14 individuals were selected for analysis, and from Casal Bertone, 11 individuals from the mausoleum and 30 from the necropolis were studied. Only one individual from Casal Bertone (F9B) did not produce reliable results. In all, oxygen isotope analysis results are available from 55 individuals from the Imperial period of Castellaccio Europarco and Casal Bertone.

Figures 9.1a and 9.1b represent the demographic makeup of the sample populations. At Casal Bertone, 19 males and 11 females were tested, and at Castellaccio Europarco, eight males and three females were tested. As discussed in chapter 4, both sites had an under-representation of females. The samples for oxygen isotope analysis, however, were carefully selected to represent the age and sex distribution within the populations as accurately as possible. The similarities in demographic makeup can be seen in comparison with the sex and age distributions of the overall populations presented in figures 4.5 and 4.8.

9.2 Methods

It was not possible to undertake oxygen isotope analysis at the University of North Carolina, as the university does not own the equipment necessary to process and analyze stable light isotopes. I sent samples of dental enamel to Dr. Janet Montgomery in the Division of Archaeological, Geographical, and Environmental Sciences at the University of Bradford because of her extensive experience using both strontium and oxygen isotopes to answer questions of mobility and migration (e.g., Montgomery et al. 2005, 2007; Budd et al. 2003).

At the Stable Light Isotope Facility at the University of Bradford, the outer layer of each Roman tooth was cleaned using a diamond dental burr. A single sample of approximately 15 mg was extracted from the enamel of each tooth, and care was taken not to acquire any dentine. Between individuals, the dental burr was cleaned with 4M HNO_3, rinsed with deionized water, placed in an ultrasonic bath for five minutes, and swabbed with acetone. The facility's standard procedure for pre-treatment of enamel apatite is as follows, based on a method established by Sponheimer (1999). Each sample received 1.8 mL of NaOCl (sodium hypochlorite). Samples were rinsed with deionized water and centrifuged three times. 1.8 mL of 0.1M acetic acid was added, and the samples were again rinsed with deionized water and centrifuged three times. Samples were heat-dried overnight and finally freeze-dried before being weighed and loaded onto the IRMS. Values of $\delta^{18}O_{ap}$ and $\delta^{13}C_{ap}$ were obtained from the hydroxyapatite carbonate portion of tooth enamel using a Thermo Delta V Advantage CF-IRMS, and the samples were normalized relative to two laboratory standards: NBS19 and Merck $CaCO_3$. The international standard for reporting oxygen isotope abundances is Vienna Standard Mean Ocean Water (VSMOW), and the standard for carbon isotope abundances is Vienna Pee Dee Belemnite (VPDB). The average values of duplicate or triplicate samples of enamel from the Casal Bertone and Castellaccio Europarco teeth are reported below relative to these standards, with standard error (1σ) of 0.12 for $\delta^{18}O$ and 0.06 for $\delta^{13}C$.

Skeleton	Sex	Age	$\delta^{13}C_{ap}$ (‰ VPDB)	$\delta^{18}O_{ap}$ (‰ VSMOW)
ET31	I	0-5	-12.35	26.53
ET36	I	6-10	-12.78	24.91
ET67	I	11-15	-12.45	27.94
ET45	M	16-20	-12.63	25.65
ET44	M	16-20	-13.52	26.67
ET27	PM	16-20	-12.09	28.16
ET18	F	21-30	-12.52	26.34
ET69	M	21-30	-13.11	26.89
ET20	M	31-40	-4.00	25.33
ET72	M	31-40	-12.12	27.06
ET58	F	41-50	-11.74	25.41
ET68	F	41-50	-12.45	27.15
ET38	M	41-50	-7.64	25.69
ET42	PM	Adult	-13.80	26.69
		Mean	*-11.66*	*26.46*
		StDev	*2.63*	*0.97*

Table 9.1: Castellaccio Europarco δ^{18}O and δ^{13}C Ratios

9.3 Results

Results of the oxygen isotope analysis of the Imperial period samples are presented in tables 9.1 and 9.2. Only one sample, a first molar taken from 18-month-old individual F9B, produced unreliable results. Enamel samples were sent for oxygen analysis after the same teeth had been processed for strontium. Insufficient enamel was available from the incomplete first molar crown of F9B to process for oxygen analysis. In all, the Imperial populations of Castellaccio Europarco and Casal Bertone yielded 55 δ^{18}O results. Results from individuals from earlier periods of Castellaccio Europarco (n=4) are presented separately in appendix B.

Statistical investigation of the δ^{18}O values generated from the two sites based on demographics indicates that there are no significant differences in the oxygen isotope ratios between males and females at either Casal Bertone or Castellaccio Europarco. Additionally, no significant differences were found between the mausoleum and necropolis burials at Casal Bertone in terms of δ^{18}O measurements.

Skeleton	Sex	Age	$\delta^{13}C_{ap}$ (‰ VPDB)	$\delta^{18}O_{ap}$ (‰ VSMOW)
F10C	I	6-10	-10.42	27.35
F10D	I	11-15	-12.05	27.41
F1A	F	16-20	-11.96	25.73
F7B	M	16-20	-12.32	27.79
F5A	M	21-30	-11.72	25.01
F11A	F	31-40	-12.95	26.74
F12A	M	31-40	-14.22	26.48
F13C	F	41-50	-12.49	25.95
F3C	M	41-50	-12.47	26.12
F4B	F	51-60	-13.24	25.52
F6E	F	51-60	-12.37	26.64
T71	I	0-5	-13.05	25.73
T29	I	0-5	-12.35	25.78
T8	I	6-10	-10.91	25.44
T20	I	6-10	-13.45	26.02
T70	I	6-10	-12.62	28.92
T72	I	11-15	-11.91	25.60
T80	I	11-15	-14.78	27.14
T32	I	11-15	-12.37	27.37
T36	I	11-15	-6.76	28.46
T39	PF	16-20	-10.90	28.80
T83B	M	16-20	-13.43	26.08
T21	M	16-20	-13.45	26.62
T50	PF	21-30	-12.93	26.58
T81	M	21-30	-12.86	25.03
T14	M	21-30	-13.15	25.93
T23	M	21-30	-11.25	26.44
T42	F	31-40	-12.61	27.19
T34	M	31-40	-12.16	24.78
T15	PM	31-40	-12.32	25.60
T18	PM	31-40	-12.75	25.83
T10	M	31-40	-12.12	26.11
T76	PM	31-40	-12.44	26.43
T82A	F	41-50	-12.82	24.34
T30	PF	41-50	-12.29	26.60
T19	M	41-50	-10.91	24.86
T7	M	41-50	-12.48	26.25
T33	M	41-50	-12.74	27.59
T28	F	51-60	-11.78	25.26
T24	M	51-60	-10.87	24.40
T13	M	61-70	-12.04	26.40
		Mean	*-12.26*	*26.30*
		StDev	*1.25*	*1.09*

Table 9.2: Casal Bertone δ^{18}O and δ^{13}C Ratios

In order to visualize the distribution of oxygen ratios, a dot histogram of all 55 measurements was generated (figure 9.2). It is clear from the histogram that there is a large cluster of values from 25.3 to 26.7‰ VSMOW. Outside of this range, there are some smaller additional clusters both lower and higher, with obvious outliers on either end of the histogram. At least four individuals appear to have oxygen ratios that deviate from the mean upon visual inspection of the histogram.

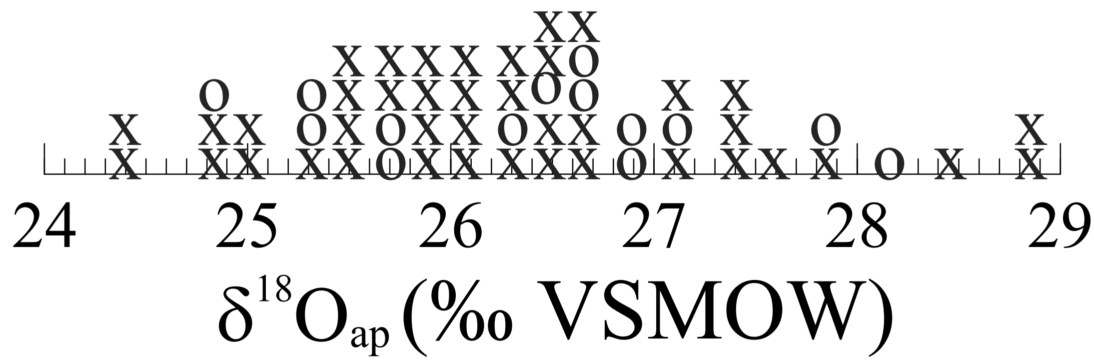


Figure 9.2: Dot Histogram of Imperial δ^{18}O Measurements
Castellaccio Europarco represented by symbol 'o', Casal Bertone by symbol 'x'.

Comparing the results from Casal Bertone with those from Castellaccio Europarco shows that the sample from Casal Bertone has a greater range of δ^{18}O values. This range could be the result of more diverse drinking water sources. In comparing the means of the two samples, no statistical significance was found in a two-tailed t test ($p = 0.6853$). The means of the strontium isotope ratios between the two sites, however, were found to be significantly different (see chapter 8), likely owing to the greater access to aqueduct water by the Casal Bertone population. If this hypothesis is correct, the insignificant difference in the δ^{18}O isotope means could be the result of undersampling of the Castellaccio Europarco population. Because of the geographical differences between the two sites and because of the statistically significant strontium isotope differences among their populations, I will conservatively assume that the two oxygen isotope sample sets were drawn from different populations.

9.4 Biological Measurements of δ^{18}O in Italy

As with strontium ratios, in order to determine which individuals were nonlocal to Rome based on δ^{18}O ratios, it is necessary to determine what the local range was at Rome. Unlike with strontium ratios, however, because of the effects of fractionation in the human body and because oxygen is sensitive to dietary differences among mammals, it is impossible to directly use environmental or faunal measurements of δ^{18}O to create a human baseline for Rome. Fortunately, the study of Prowse and colleagues (2007) provides a significant amount of data with which to identify trends in the δ^{18}O of humans born in Rome. In this section, I will discuss my creation of a local δ^{18}O range for Rome.

9.4.1 Published Human δ^{18}O Data

In their attempt to identify immigrants at Portus, Prowse and colleagues analyzed δ^{18}O ratios from 61 pairs of first and third molars from individuals buried in the Isola Sacra cemetery. Isola Sacra was used as a necropolis between about the 1st and 3rd centuries AD (Prowse et al., 2007), and the samples are therefore assumed to be from individuals contemporaneous with the populations buried at Casal Bertone and Castellaccio Europarco. Because no previous δ^{18}O study had been done in this area, Prowse and colleagues additionally analyzed 24 deciduous teeth collected from 19 children born in Rome between 1985 and 1989 as a control sample in order to help identify a local range. These data are presented in table 9.3, which lists the δ^{18}O as originally measured with respect to VPDB and converted to the VSMOW standard for ease of comparison with data in this study.

The data obtained by Prowse and colleagues from modern Romans range from -7.9 to -3.2‰ VPDB, or 22.78 to 27.67‰ VSMOW. In most cases, a local range measured from a human population unaffected by immigration and trade in food and drink is around 2‰ (White et al., 2004b). There is often a trailing ‘tail’ on the positive side of a histogram of the δ^{18}O values in a population as a result of importation of foodstuffs and/or boiling, evaporating, or

Tooth type	ID number	$\delta^{18}O_{ap}$ (‰ VPDB)	$\delta^{18}O_{ap}$ (‰ VSMOW)
i1	25	-4.3	26.49
i1	26	-5.1	25.66
i1	26	-5.3	25.46
i1	50	-4.5	26.28
i1	50	-4.8	25.97
i1	27	-3.2	27.62
i1	41	-4.7	26.07
i1	41	-4.7	26.07
i1	52	-5.3	25.46
i1	52	-5.1	25.66
i1	51	-5.2	25.56
i1	44	-3.8	27.00
i1	28	-4.6	26.18
i2	90	-5.1	25.66
i2	37	-4.4	26.38
i2	43	-4.7	26.07
i2	38	-4.9	25.87
m1	27	-7.2	23.50
m1	81	-7.0	23.70
m1	71	-7.9	22.78
m1	102	-6.7	24.01
m2	45	-5.4	25.35
m2	115	-4.9	25.87
m2	115	-4.7	26.07
	Mean	*-5.1*	*25.62*
	StDev	*1.1*	*1.1*

Table 9.3: $\delta^{18}O$ from Roman Children
Data reproduced from Prowse et al. (2007, Table 2).

brewing of water in the human diet (Daux et al. 2008; Janet Montgomery pers. comm.). Even given the patterns of food and drink importation in the modern diet, the modern Roman sample range of nearly 5‰ means that there are likely outliers in the population. Deciduous teeth begin forming in utero and thus, like early-forming permanent teeth, can be affected by the isotope ratio of the food and water ingested by the individual's mother. These teeth were collected from infants born in Rome, but no information was gathered on the origins of the infants' mothers (Prowse et al., 2007, p. 513). Anomalous data in the deciduous Roman sample, therefore, are possibly the result of mothers who had recently immigrated and who then gave birth in Rome.

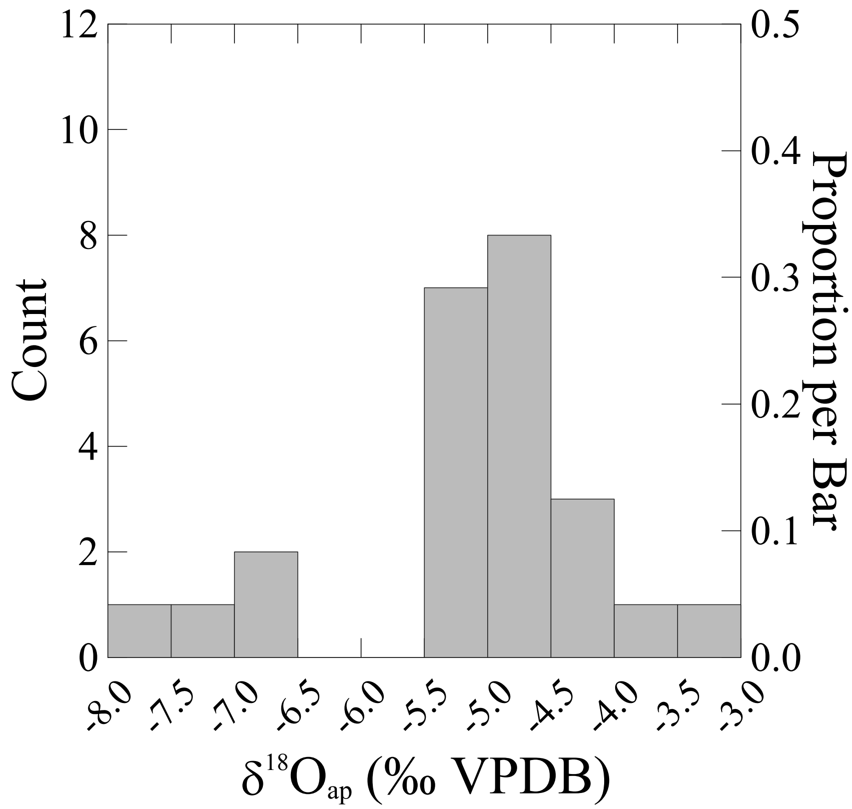


Figure 9.3: Histogram of Modern Roman Infants' δ^{18}O Measurements
Plotted from data in Prowse et al. (2007, Table 2).

Prowse and colleagues construct a histogram and visually assess that the majority of the data points fall within a range of -6 to -4‰ VPDB (or 24.73 to 26.80‰ VSMOW), which they then use as the local range for Rome. I have plotted a histogram from their data in figure 9.3. It is clear that this sample is not normally distributed and that there are several outliers among the more negative values. The four significantly more negative values are outside of Prowse and colleagues' defined local range and are all curiously from deciduous first molars. The authors suggest that these individuals with lighter δ^{18}O values (those from -6.7 to -7.9‰) might have been consuming a nonlocal source of water such as bottled spring water, but they offer no explanation for the fact that all of the lighter values are from deciduous molars. It is possible that the difference seen is related to the chronology of the formation of this tooth.

The deciduous first molar begins formation around the fifth month in utero, and its crown is complete around six months of age. In contrast, the other teeth studied, incisors and second molars, finish forming at about three months and 11 months of age, respectively. Unfortunately, no data were available to Prowse and colleagues on the duration of breastfeeding and time of weaning from the modern samples, but it is possible that the significantly different first molar values are related to the introduction of solid foods, specifically cooked cereals, into the infant's diet, which often occurs between four and six months in modern societies. As noted in section 7.4 of chapter 7, exclusively breastfed babies would see a trophic change once weaned onto solid foods or formula, and exclusively formula-fed babies would see a trophic change if their mothers prepared their formula with boiled, distilled, or bottled water as is often recommended for well water and other water sources with potential contaminants. Nursing and using distilled or boiled water for formula would make an individual's δ^{18}O more positive. A diet composed of cooked foods (meat, fish, legumes, and cereals) creates a more enriched δ^{18}O than a diet with significant amounts of raw fruits and vegetables. However, a diet composed predominately of cooked cereals actually produces a *lower* δ^{18}O value than a balanced or cereal-free diet (Daux et al., 2008). It is possible, therefore, that introducing cooked cereals produced the low δ^{18}O values seen in the deciduous first molars.

Regardless of the reason for the difference in δ^{18}O ratios for the first molars, however, which could also be simple measurement or sampling error, these data clearly form a second cluster within the histogram that is different from the cluster composed of deciduous first and second incisors and deciduous second molars. It is therefore inappropriate to include the deciduous first molar data in calculating a local range. By excluding these values, as Prowse and colleagues also did, it is possible to calculate a mean and standard deviation for the larger cluster of samples and produce a local range. With the lowest values excluded, the mean of the modern Roman sample is -4.74‰ VPDB or 26.0‰ VSMOW, with standard deviations of 0.53 and 0.55, respectively. Calculation of a 2σ range (95% CI) for the data yields -5.8 to -3.7‰ VPDB, which is close to the range visually assessed by Prowse and colleagues as the local Roman range. This range converted to the VSMOW standard is 24.9 to 27.1‰.

I take issue with the range that Prowse and colleagues constructed from their modern Roman sample as, based on the above, it should be approximately -5.8 to -3.7‰ VPDB rather than the oddly round numbers of -6 to -4‰. The more precise range fits both the ancient and modern histograms they present (figures 3 and 4 in Prowse et al. 2007) much better and does not materially change the spread of the range. Prowse and colleagues constructed a histogram of the δ^{18}O values from first molars from the Imperial Isola Sacra population and determined that most of them fell within their range of -6 to -4‰. A total of 20 individuals, or nearly one-third of the population, were outside of this range. They also found by analyzing the δ^{18}O of third molars from the same individuals that 45 had a local signature and 16 had a value outside of their local range, indicating that many people immigrated to Portus during childhood (Prowse et al., 2007, p. 517). Shifting the δ^{18}O range to -5.8 to -3.7‰ based on the modern Roman data and assumed outliers still yields 20 of the 61 first molars falling outside of it as nonlocals (Prowse et al., 2007, table 3). The choice of -6 to -4‰ as the local range of Rome is never fully explained by Prowse and colleagues except to say that "it is clear that the majority of the data points ($\sim$75%) fall within the range of -4 to -6‰ (sic)" (Prowse et al., 2007, p. 515). Elimination of statistical outliers and construction of a 2σ range of -5.8 to -3.7‰ is a more statistically sound method of estimating the $\delta^{18}O_{ap}$ value of the local range.

The data presented in Prowse et al. (2007) represent the only currently known δ^{18}O ratios from human dental enamel in both ancient and modern Italy. The number of individuals tested

(19 modern and 61 Imperial people) is relatively small, but the researchers tackle the question of diagenesis and mention the possible effects of breastfeeding, diet, and water supply in this short article. Although their inclusion of Longinelli and Selmo's (2003) isopleth precipitation map and discussion of the origin of immigrants to Portus are often confusing, the δ^{18}O measurements from both the modern Roman infants and the Imperial skeletons from Portus are consistent with expectations based on current knowledge of environmental oxygen isotope ratios in Italy. As such, the range calculated from the modern Roman deciduous teeth, -5.8 to -3.7‰ VPDB or 24.9 to 27.1‰ VSMOW, represents the best metric for identifying local versus nonlocal individuals from Casal Bertone and Castellaccio Europarco. In the future, creating a baseline from permanent premolars of modern people who were born and raised in Rome and its suburbs would greatly enhance our understanding of the δ^{18}O range of locals by obviating the effects of nursing and weaning.

9.4.2 Published Faunal δ^{18}O Data

Human δ^{18}O values cannot be directly compared with those of animals primarily because of the difference in diets but also because of the fact that humans can cook their food. Measurements of oxygen ratios from mammalian enamel, however, can provide a general idea of the δ^{18}O in an area.

The two faunal studies cited in chapter 8 with reference to strontium isotope measurements also analyzed oxygen isotope ratios and concluded that the sampled animals were local to the area of Rome. Pellegrini and colleagues (2008) studied deer and horse teeth from Grotta Polesini in an attempt to investigate transhumance in the past. They microsampled one deer tooth and one horse tooth, and the mean of the δ^{18}O values for enamel carbonate was 26.61‰ VSMOW for both species. Palombo and colleagues (2005) studied teeth from prehistoric elephants at the site of Casal de' Pazzi close to Rome. The average of all the elephants sampled (n=11) was 26.55‰ VSMOW from the carbonate portion of the enamel. The mean of Prowse and colleagues' Roman infants noted above, minus outliers, is 26.04‰ VSMOW, which is not statistically different from the δ^{18}O of the animals.

Deer, horses, and elephants, however, are all herbivores whereas humans are omnivores. Herbivores are known to consume a wider range of plants than humans, and their consumption of C_3 versus C_4 plants can also be different than humans'. Although this difference accounts for some interspecies variation in the δ^{18}O of herbivores (Daux et al., 2008), humans additionally have the ability to cook and otherwise process food, which can result in an enrichment of δ^{18}O through evaporation. For instance, humans who consume lots of cereals, legumes, and meat, which are rarely eaten raw, could have enriched δ^{18}O body water values. As noted above, though, consumption of primarily cooked cereals can have the opposite effect, lowering the δ^{18}O value. Humans also have access to more varied water sources, such as tap water, aqueduct water, wine, fruit juices, and bottled water, than animals do, and our δ^{18}O values can be offset because of our consumption of nonlocal waters. Seasonality of a water source is similarly more likely to affect the δ^{18}O of herbivores than humans, because both ancient and modern Romans had access to far-off water sources via aqueducts and could store water to circumvent drought conditions.

Because of the differing diets and sources of water between humans and animals and because of the fractionation of oxygen isotopes within the body, it is impossible to use faunal δ^{18}O values to help refine a local range for humans. The best comparative study for the present research remains Prowse and colleagues' (2007) investigation of the δ^{18}O of both modern Roman children and the Imperial population at Portus.

9.4.3 Establishing a Local Range

Because of the availability of comparative δ^{18}O data on both modern Romans and ancient inhabitants of Portus, I did no additional analyses to create an isotope baseline of locals. Confounding factors that could affect the applicability of this range to ancient Romans, however, in order of greatest to least effect on δ^{18}O ratios include: 1) climatic conditions and water sources; 2) average diet; and 3) duration of breastfeeding and choice of weaning foods.

First and most importantly, Prowse and colleagues (2007, p. 514) address the issue of climate by suggesting that temperature and precipitation, two of the main factors in the $^{18}O/^{16}O$ ratio, have not significantly changed since the Imperial period based on data from the *Global Network of Isotopes in Precipitation*. Further, a diachronic analysis of human skeletal remains from France dating from the Late Roman period to the present day discovered no statistically significant differences in $\delta^{18}O$ of enamel phosphate among different time periods (Daux et al., 2005). If this uniformitarian assumption is correct, using the modern range for the ancient population is uncompromised by the climate of Rome. Prowse and colleagues (2007, p. 514) also note that modern Romans do not drink precisely the same water as either ancient Romans or the residents of Portus. The similarity in the tap water of modern Rome and the tap water of ancient Rome, however, is greater than would be expected in a two millennia time span. Two of the ancient aqueducts, the Aqua Virgo and the Aqua Marcia, have been revamped in modern times into the Acqua Vergine Antica/Nuova and the Acqua Pia Antica Marcia. The source waters for these aqueducts are the same, namely, springs in the Monti Simbruini and in the Colli Albani, respectively (see chapter 8, section 8.5.1). There are differences between ancient and modern water sources, however, as in the present time water is also drawn from locales north of Rome, such as Lake Bracciano via the Acqua Paola. The $\delta^{18}O$ difference between the local water available to ancient Romans and that available to modern Romans is likely to be small, as a map of precipitation in Italy (Longinelli and Selmo, 2003) shows no significant differences in $\delta^{18}O$ at the resolution of the city and its suburbs, and a $\delta^{18}O$ calculator (Bowen and Revenaugh, 2003) based on latitude, longitude, and elevation also shows no significant differences in the $\delta^{18}O$ of the major ancient and modern source springs. Nevertheless, modern Romans have more access to imported water such as that in bottled water, wine, and fruit juices than did the ancient Romans, although the latter did import liquids such as wine from other areas of the Empire.

Second, as already mentioned, differences in diet among humans can affect their $\delta^{18}O$ ratios, particularly if they are consuming a large portion of foods that need to be cooked and/or hydrated to eat, such as legumes, cereals, meat, and fish. As noted in chapter 6, the ancient Roman diet is thought to have consisted primarily of cereals, legumes, fruits, and vegetables, with meat and fish making up a minor part of daily intake. In her dissertation, Prowse (2001) addressed the composition of the diet of the inhabitants of Portus. Prowse found that the adults of Portus were eating fish, as they were living on the Tyrrhenian coast, but that most subadults were eating a terrestrial diet (Prowse, 2001; Prowse et al., 2004, 2005). Although there is no single modern Mediterranean diet, in general, it is characterized by little consumption of red meat and quite a bit of cereal, fruit, vegetables, legumes, olive oil, and fish (Willett et al., 1995). Based on the isotope findings of Prowse and colleagues, the isotope findings of this study presented in chapter 6, and the general composition of the modern Italian diet, it stands to reason that any differences in diet between ancient and modern Romans are relatively minor and not of the magnitude to significantly affect $\delta^{18}O$ ratios (Daux et al., 2008).

Finally, as noted earlier and in chapter 7, section 7.4, the duration of breastfeeding or bottle-feeding and the choice of weaning foods can have an effect on an individual's $\delta^{18}O$ value. Historical texts indicate that Roman women nursed (or paid another woman to nurse) their children for as little as six weeks or as long as a few years. Texts for physicians, such as Soranus' *Gynaecology*, recommend a period of exclusive breastfeeding of four to six months and suggest that a child be given breastmilk for two to three years if possible. The contemporary recommendations (American Academy of Pediatrics, 2005) of six months of exclusive breastfeeding and giving a child breastmilk until at least one year of age are not far removed from the ancient texts. In both ancient and modern times, however, the choice of whether to breastfeed and for how long is at least partially a reflection of the social class of the mother. The best evidence for duration of breastfeeding in ancient times is carbon and nitrogen isotope analysis. As noted by Prowse (2001), weaning in the Portus population began as early as six months of age and could be a protracted process. It is likely that ancient Romans received breastmilk for a longer period of time than modern Romans, and I hypothesize that the evidence from the modern deciduous first molars that Prowse and colleagues studied reflects both this shorter duration and introduction of cooked cereals. There is no evidence, however, of a significant nursing effect or effect of weaning foods on the δ^{18}O of the modern Roman deciduous incisors or second molars. By excluding the deciduous first molars from the calculated local range, I assume for the sake of this study that duration of breastfeeding and choice of weaning foods have little to no effect on the δ^{18}O of Prowse and colleagues' modern Roman teeth.

In summary, because faunal studies cannot be used to help establish or refine a baseline of δ^{18}O values with which to compare ancient Romans, the establishment of a local range is based primarily on the work of Prowse and colleagues (2007). The best statistical approximation of the range of δ^{18}O in modern individuals born and raised in Rome is 24.9 to 27.1‰ VSMOW. With the caveats cited above, it is assumed that this range also reflects the δ^{18}O of individuals born and raised in Imperial Rome.

9.5 Locals and Nonlocals

In light of the calculated range of δ^{18}O among individuals born in Rome, the data from Casal Bertone and Castellaccio Europarco are presented in figures 9.4 and 9.5. The left-hand y axis represents the actual measurement of δ^{18}O of the carbonate portion of dental enamel with respect to the VSMOW standard, denoted $\delta^{18}O_{ap}$ and reported in permil (‰), and the bars are 1σ measurement errors. The right-hand y axis represents the δ^{18}O values from enamel carbonate converted to the approximate value of drinking water ingested while the tooth was forming, denoted $\delta^{18}O_{dw}$ and reported in permil (‰) with respect to the VSMOW standard. The x axis shows the $\delta^{13}C_{ap}$ value for each sample measured with respect to the standard VPDB, as this isotope is often measured along with δ^{18}O. The shaded box represents the range of δ^{18}O of Rome calculated in section 9.4.3.

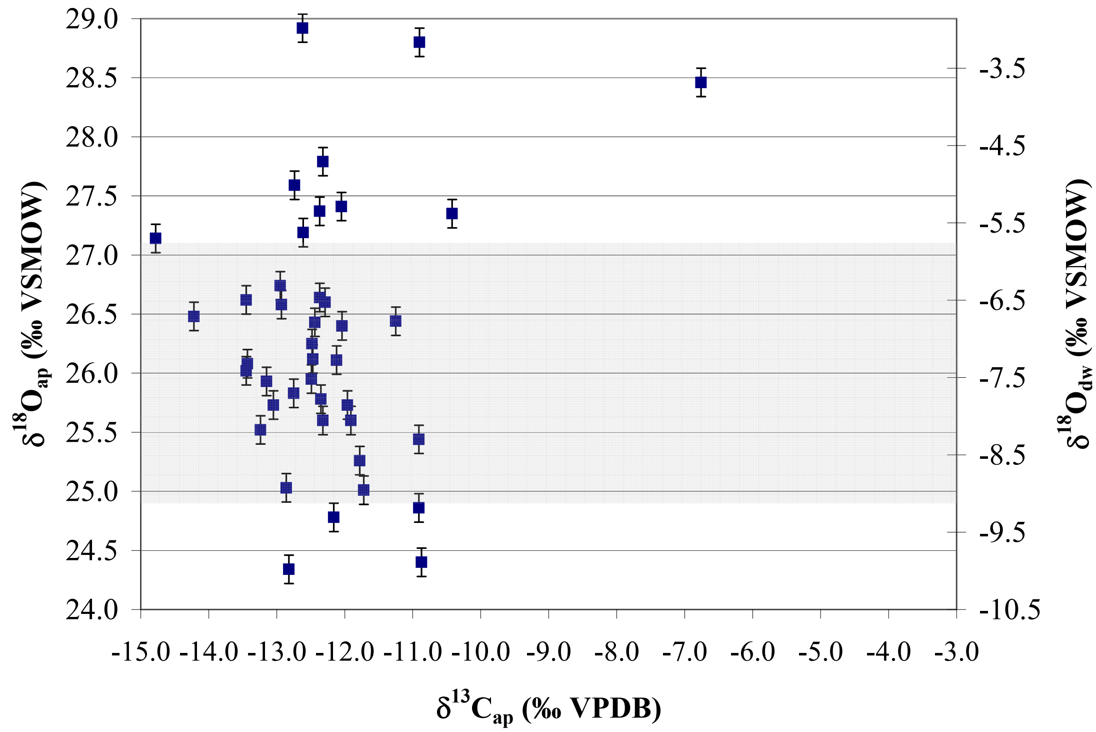


Figure 9.4: Casal Bertone - $\delta^{18}O_{ap}$ and $\delta^{13}C_{ap}$
Error bars are 1σ measurement errors. The right axis shows the calibration of $\delta^{18}O$ values to drinking water in Italy, and the shaded area represents the approximate range of drinking water in the vicinity of Rome.

9.5.1 Casal Bertone

Figure 9.4 shows all individuals from Casal Bertone whose enamel was tested for oxygen isotope analysis. There is a clear cluster of values centered around 26.0‰ as well as several individuals whose $\delta^{18}O$ values place them outside the local range of Rome. Two individuals have $\delta^{18}O$ values lower than the Roman range, both less than 24.4‰. Although there are two additional individuals whose $\delta^{18}O$ measurement falls lower than the Roman range, between 24.7 and 24.9, the 1σ isotope measurement error of $\pm$ 0.12 means that it is possible they actually fall within the local range. There are eight individuals whose $\delta^{18}O$ values are higher than the Roman range, three of which are over 28.5‰ and one of which has an anomalous $\delta^{13}C_{ap}$ value as well. Two individuals have $\delta^{18}O$ values whose measurement errors place them within the high end of the Roman range. In looking at figure 9.4, however, there is a clear gap between the highest number in the local group, 26.74‰, and the next highest value of

Skeleton	Sex	Age	$\delta^{18}O_{ap}$ (‰ VSMOW)
T82A	F	41-50	24.34
T24	M	51-60	24.40
T80	I	11-15	27.14
T42	F	31-40	27.19
F10C	I	6-10	27.35
T32	I	11-15	27.37
F10D	I	11-15	27.41
T33	M	41-50	27.59
F7B	M	16-20	27.79
T36	I	11-15	28.46
T39	PF	16-20	28.80
T70	I	6-10	28.92

Table 9.4: Nonlocal Individuals from Casal Bertone

27.14‰. Based on the clustering of the data and the calculated local range, I am cautiously interpreting these two individuals as nonlocal. The total number of Casal Bertone individuals whose δ^{18}O values are outside of the local Roman range is therefore 12. This means that roughly 29% (12/41) of the population of this site can be considered nonlocal based on oxygen isotope analysis.

Demographic information on nonlocal individuals is provided in table 9.4. Out of the 12 people whose δ^{18}O values indicate they did not consume local water when their first permanent molars were forming, three were adult females, three were adult males, and six were subadults at the time of their deaths. Females were therefore equally as likely to be nonlocal as males, and subadults were equally as likely to be nonlocal as adults.

9.5.2 Castellaccio Europarco

Figure 9.5 graphs the δ^{18}O values of individuals from Castellaccio Europarco whose dental enamel was tested for oxygen isotope analysis. Of these 14 people, only two individuals had δ^{18}O values that were outside of the local range of Rome. An additional two individuals, however, have statistically different $\delta^{13}C_{ap}$ values. These values, as mentioned in chapter 6,

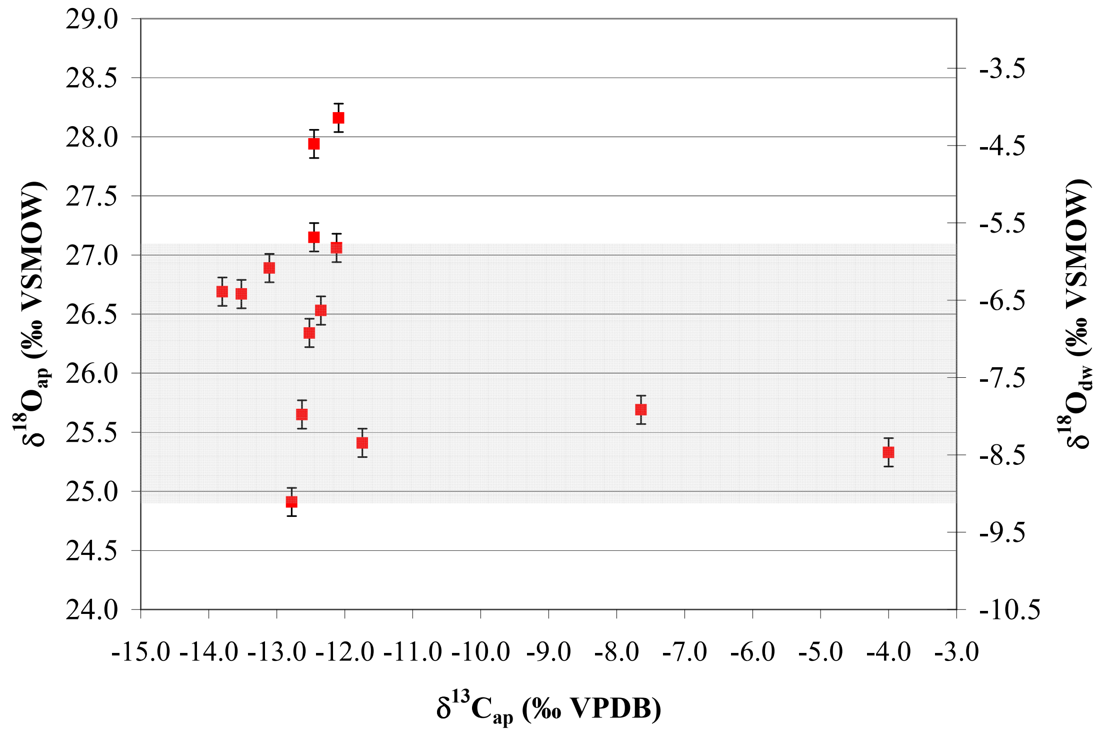


Figure 9.5: Castellaccio Europarco - $\delta^{18}O_{ap}$ and $\delta^{13}C_{ap}$
Error bars are 1σ measurement errors. The right axis shows the calibration of δ^{18}O values to drinking water in Italy, and the shaded area represents the approximate range of drinking water in the vicinity of Rome.

likely indicate anomalous consumption, either directly or indirectly, of C_4 plants such as millet during amelogenesis. It is possible that these individuals were from Rome and consumed porridges made from millet as children, but it is also possible that they originated from another area of the Empire such as Anatolia or North Africa where sorghum and millet enjoy a climatic and/or dietary niche but where δ^{18}O values from precipitation are within the range of coastal Italy (Bowen and Revenaugh, 2003). In oxygen isotope analysis, therefore, it is common practice to consider individuals with anomalous δ^{13}C values to have consumed a nonlocal diet. There are thus four individuals out of 14 from Castellaccio Europarco whose oxygen or carbon isotope values are outside of the local range. This means that nearly 29% of the individuals sampled were not originally from the area of Rome.

Demographic information on nonlocal individuals from this site is presented in table 9.5. All adults identified as nonlocal were male, and only one subadult was found to be nonlocal.

Skeleton	Sex	Age	$\delta^{18}O_{ap}$ (‰ VSMOW)	$\delta^{13}C_{ap}$ (‰ VPDB)
ET20	M	31-40	25.33	-4.00
ET38	M	41-50	25.69	-7.64
ET67	I	11-15	27.94	-12.45
ET27	PM	16-20	28.16	-12.09

Table 9.5: Nonlocal Individuals from Castellaccio Europarco

9.5.3 Nonlocal Individuals' Homelands

Identifying the homelands of individuals not local to an area is, unfortunately, not a straightforward endeavor in spite of the amount of research that has gone into creating linear equations to correlate δ^{18}O derived from phosphate or carbonate to the δ^{18}O of drinking water. As noted in chapter 7, section 7.3, it is necessary to convert δ^{18}O values from carbonate to phosphate in order to regress the values to an approximation of the water an individual ingested during amelogenesis. This multi-step process, however, can introduce error that skews the resulting drinking water estimates, making it difficult to match up individuals with geographic locales. Nevertheless, it is possible to investigate general trends in the δ^{18}O of meteoric precipitation in the Roman Empire in order to hypothesize the geographical origins of individuals nonlocal to Rome.

In order to compare individuals' measured δ^{18}O values to a map of the ancient world, conversions were made from carbonate to phosphate and from phosphate to drinking water as per the formulae in chapter 7, section 7.3. The results of the regression equation are plotted on the right-hand y axis in figures 9.4 and 9.5; the scale represents estimated δ^{18}O drinking water values.

Longinelli and Selmo (2003) created a map of average annual δ^{18}O values of meteoric water in Italy (figure 9.6). Their contour map shows that the Tyrrhenian coast of Italy has an average δ^{18}O precipitation range of -6 to -5‰ VSMOW. Values of δ^{18}O decrease with increasing altitude, such that the regions of the Apennines and Alps have values in the range of about -9 to -7‰. Although the heel of Italy can give δ^{18}O values slightly more positive than

Rome and the Tyrrhenian coast, for the most part, the coastal areas of the Italian peninsula, Sicily, and Sardinia are all around the same range, -6 to -5‰. Values that are significantly more positive than this range therefore indicate an origin from a different geographical locale than Italy. Values that are significantly more negative than Rome, which itself has a value of -5.65‰, indicate an origin either at a higher altitude in Italy or from a different geographical locale.

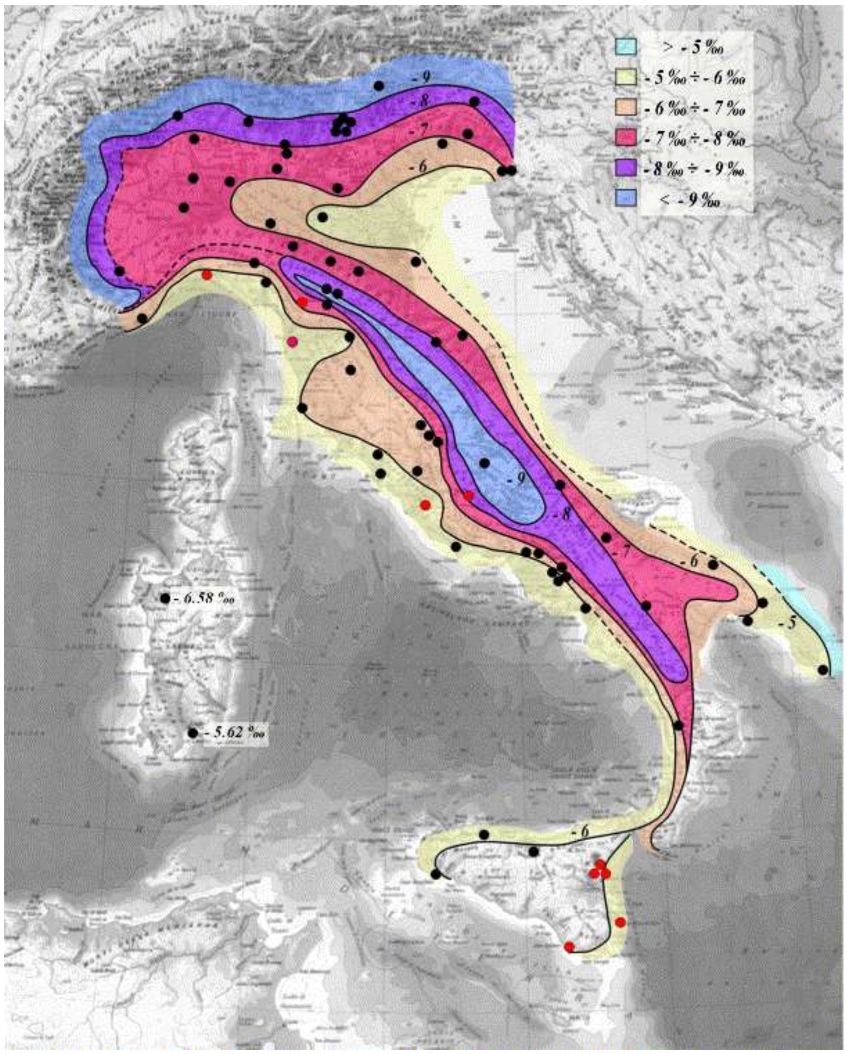


Figure 9.6: Isopleth Contour Map of Weighted Annual Mean δ^{18}O of Meteoric Precipitation in Italy

Reproduced from Longinelli and Selmo 2003, Figure 2.

$\delta^{18}O_{ap}$ (‰ VPDB)	$\delta^{18}O_{ap}$ (‰ VSMOW)	$\delta^{18}O_{p}$ (‰ VSMOW)	$\delta^{18}O_{dw}$ (‰ VSMOW)
-4.3	26.49	17.53	-6.72
-5.1	25.66	16.72	-7.98
-5.3	25.46	16.51	-8.29
-4.5	26.28	17.33	-7.03
-4.8	25.97	17.02	-7.51
-3.2	27.62	18.66	-4.99
-4.7	26.07	17.12	-7.35
-4.7	26.07	17.12	-7.35
-5.3	25.46	16.51	-8.29
-5.1	25.66	16.72	-7.98
-5.2	25.56	16.61	-8.14
-3.8	27.00	18.04	-5.93
-4.6	26.18	17.23	-7.19
-5.1	25.66	16.72	-7.98
-4.4	26.38	17.43	-6.88
-4.7	26.07	17.12	-7.35
-4.9	25.87	16.92	-7.66
-5.4	25.35	16.41	-8.45
-4.9	25.87	16.92	-7.66
-4.7	26.07	17.12	-7.35
-4.74	*26.04*	*17.09*	*-7.40*

Table 9.6: Modern Roman δ^{18}O Values Converted to Drinking Water
Original data, with first molars excluded, from Prowse et al. (2007, Table 2).
Figures in italics represent column means.

As noted, however, researchers tend to see a spread of about 2‰ in δ^{18}O in a local population owing to differences in food and water consumed. Although Longinelli and Selmo (2003) measured average annual precipitation at Rome at -5.65‰ VSMOW, human δ^{18}O values will actually fall within a range. Returning to the data of Prowse et al. (2007), the δ^{18}O values of modern Roman deciduous teeth, minus the first molars, have been converted to approximate drinking water values in table 9.6. Admittedly, there are three conversion steps in this process, any of which could introduce statistical error to the outcome. The resulting average of drinking water values for modern Roman children calculated from the δ^{18}O of their deciduous dental enamel is -7.4‰ VSMOW. This number is strikingly different than the average value of meteoric precipitation in Rome of -5.65‰ VSMOW.

In regard to the faunal analyses mentioned previously, the authors of those studies similarly converted their measured δ^{18}O values into approximate drinking water values. Human and animal δ^{18}O measurements are not directly comparable, but by using species-specific equations to approximate the δ^{18}O of drinking water, the results should be similar for local people and local animals. Pellegrini and colleagues (2008, p. 1719) apply formulae for deer and horses to the δ^{18}O measured from the faunal enamel at Grotta Polesini and get an average drinking water estimate of -7.0‰ VSMOW for both. Palombo and colleagues (2005, p. 167) convert their measured δ^{18}O values from elephant enamel to drinking water and obtain an average of -7.8‰ VSMOW. Prowse and colleagues' (2007) modern Roman enamel samples fall in the middle at -7.4‰ VSMOW. Although the measured δ^{18}O of meteoric precipitation in Rome is an annual average of -5.65‰ VSMOW, it is clear that the conversion equations for mammalian phosphate generate drinking water estimates that are too negative. This fact means that pinpointing an individual's homeland cannot currently be done with precision until better conversion equations are created and/or more human enamel is sampled from around the Empire. Trends in δ^{18}O within Italy and the Roman Empire, however, can provide an idea of the approximate geographical origin of nonlocal individuals.

The map of δ^{18}O precipitation values in Europe (figure 9.7) indicates that more positive δ^{18}O values are measured in geographical areas closer to the equator. The north coast of Africa, therefore, has average δ^{18}O values more positive than the Italian peninsula, while northern Europe has average δ^{18}O values more negative than the Italian peninsula. The map in figure 9.7 is an estimation of the δ^{18}O of precipitation based on factors such as latitude, longitude, elevation, and humidity. Further estimations can be made at closer resolution using the *Online Isotopes in Precipitation Calculator*,[1] which uses the methodology of Bowen and Revenaugh (2003) to estimate a δ^{18}O value for any point on the globe given latitude, longitude, and elevation. In this way, it is possible to estimate the δ^{18}O of drinking water from specific locations across the Roman Empire.

[1]This calculator can be found at http://www.waterisotopes.org.

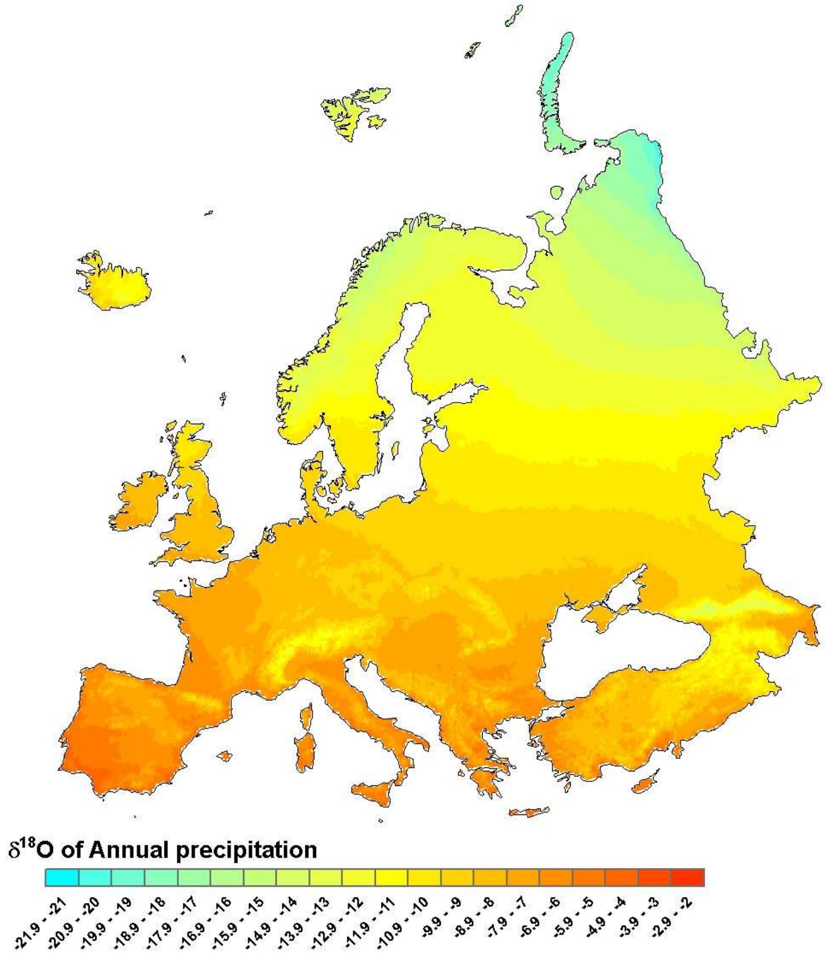


Figure 9.7: Estimation of δ^{18}O from Precipitation in Europe
Downloaded from WaterIsotopes.org, based on data from Bowen and Revenaugh (2003).

The measured δ^{18}O values for nonlocal individuals are presented in table 9.7, along with the conversions to approximate their drinking water values. Those individuals whose δ^{18}O values were within the local range but whose δ^{13}C values were anomalous - ET20 and ET38 from Castellaccio Europarco - could therefore have originated in a geographical area with average annual δ^{18}O around the same as Rome. Areas of the Roman Empire that fit this criterion according to Bowen's isotope calculator include Greece, Portugal, and the west coast of Turkey. Based on epigraphical evidence, which admittedly produces a far from balanced picture of mobility in the Empire, a fair number of civilian immigrants to Rome arrived from the ancient provinces of Asia Minor (modern west-coast Turkey), Hispania and Lusitania (modern Spain

Skeleton	Sex	Age	$\delta^{18}O_{ap}$ (‰ VSMOW)	$\delta^{18}O_{p}$ (‰ VSMOW)	$\delta^{18}O_{dw}$ (‰ VSMOW)
ET20	M	31-40	25.33	16.39	-8.49
ET38	M	41-50	25.69	16.74	-7.94
ET67	I	11-15	27.94	18.97	*-4.50*
ET27	PM	16-20	28.16	19.19	*-4.17*
T82A	F	41-50	24.34	15.40	**-10.00**
T24	M	51-60	24.40	15.46	**-9.91**
T80	I	11-15	27.14	18.18	*-5.72*
T42	F	31-40	27.19	18.23	*-5.65*
F10C	I	6-10	27.35	18.39	*-5.40*
T32	I	11-15	27.37	18.41	*-5.37*
F10D	I	11-15	27.41	18.45	*-5.31*
T33	M	41-50	27.59	18.63	*-5.04*
F7B	M	16-20	27.79	18.82	*-4.73*
T36	I	11-15	28.46	19.49	*-3.71*
T39	PF	16-20	28.80	19.83	*-3.19*
T70	I	6-10	28.92	19.94	*-3.01*

Table 9.7: Nonlocal Individuals' δ^{18}O Carbonate, Phosphate, and Drinking Water Values
Drinking water estimates in bold are lower than the range at Rome,
while estimates in italics are higher than the range at Rome.

and Portugal), and Greece (Noy, 2000, p. 58-60), so any of these geographical locales is a possible homeland. A recent study of δ^{18}O at 13th century Corinth (Greece) (Garvie-Lok, 2009) indicates that most individuals' carbonate δ^{18}O values fell within the range of 25.4‰ to 28.0‰ VSMOW. If the climate of Greece in the Middle Ages was similar to the climate in classical times, people from Casal Bertone and Castellaccio Europarco whose δ^{18}O values fall within the local range could very well have been from a geographical location with δ^{18}O similar to Corinth.

Those individuals whose δ^{18}O values are more negative than the local range include T82A and T24 from Casal Bertone. The areas of the Roman Empire that have significantly more negative average δ^{18}O values than Rome are areas with higher elevation. In Italy, this would potentially include the Apennines, but the Alps region presents even lower δ^{18}O values. The province of Germania produced a substantial fraction of foreigners who came to Rome through the military (Noy, 2000, p. 59), but little is known about mobility within Italy. Either of these locations therefore could represent a geographical origin for these two nonlocals from Casal Bertone.

The majority of the nonlocal individuals - ten from Casal Bertone and two from Castellaccio Europarco - have δ^{18}O values more positive than the range of Rome. More positive δ^{18}O values represent geographical locations that are drier and closer to the equator than Rome. In the Empire, this translates into the north coast of Africa, which was composed of several provinces: Mauretania, Numidia/Africa, Cyrene, and Egypt. According to Noy's (2000, p. 59-60) epigraphical study of the homelands of foreigners buried at Rome, just over 10% came to Rome from North Africa, and most of these people were civilians rather than associated with the military. According to the δ^{18}O study, however, 75% of the nonlocal individuals buried at Rome were likely from hotter, drier climates than central Italy. Prowse and colleagues (2007) found evidence of one individual (SCR 617) with a δ^{18}O value significantly more positive than Rome. By comparing the δ^{18}O obtained from the dental enamel of that individual with the δ^{18}O measured from a sample of ancient Egyptian teeth, Prowse and colleagues concluded that SCR 617 most likely originated in Egypt or in another part of North Africa.

Although attempting to pinpoint the exact geographical origins of nonlocals buried at Rome based on δ^{18}O values is fraught with difficulties, general trends can be seen in the data. Many nonlocals arrived at Rome from areas whose average annual δ^{18}O from meteoric precipitation was similar to the north coast of Africa, and some came from areas at significantly higher elevations than Rome, such as the Alps. A local δ^{18}O signature can be pinpointed based on climatic conditions in an area, but because of bodily fractionation of oxygen isotopes and differences in the diet adopted by humans, δ^{18}O values are distributed in a local range. As the Italian coast is not differentiated with respect to δ^{18}O values, it is possible that there are additional nonlocals within the local data set, individuals who arrived at Rome from another coastal area of Italy where the δ^{18}O value was similar or even from the foothills of the Apennines. This issue will be investigated further in chapter 10 by adding the strontium isotope results (chapter 8), which vary roughly north-to-south on the Italian peninsula, to the δ^{18}O results in this chapter. More specific information about the geographical origins of nonlocals buried at Casal Bertone and Castellaccio Europarco can thus be gleaned from a combination of the two independent isotope systems.

9.6 Discussion

Although the number of nonlocal individuals uncovered by oxygen isotope analysis (n=16) is small, this represents nearly one-third of the population tested. As such, it is useful to investigate similarities and differences in the number of nonlocal individuals found at the two study sites, the relative percentages of nonlocal males and females, and age-related mobility. The data generated in this study can also be directly compared with the results from Prowse and colleagues' (2007) oxygen isotope analysis of individuals buried at the Isola Sacra necropolis at Portus.

9.6.1 Site, Sex, and Age Related Differences in δ^{18}O

As noted, there was no statistically significant difference in the δ^{18}O measurements from Casal Bertone and those from Castellaccio Europarco. The number of nonlocal individuals found at each site is also similar. At Casal Bertone, 12 out of 41 individuals tested had δ^{18}O values outside the local range of Rome (29.3%), whereas at Castellaccio Europarco, four out of 14 individuals tested presented δ^{18}O values different from the local range (28.6%). Casal Bertone's necropolis burial context produced 75% of the nonlocals at the site, while the mausoleum held 25% of the identified nonlocals. More telling, however, is the comparison of nonlocals to total number of individuals tested. From the mausoleum, three out of 11 individuals were found to be nonlocal (27.2%), whereas nine out of the 30 tested from the necropolis were nonlocal (30%). In terms of approximated geographical origins of the nonlocals, at Casal Bertone there were two individuals whose δ^{18}O values were significantly lower than the Roman range, placing them perhaps in an Alpine region at the time of their births. At Castellaccio

Europarco, on the other hand, no one tested had a δ^{18}O lower than Rome, but two individuals had anomalous carbon values, suggesting they might have come from a nearby locale such as Greece. Aside from this difference in origins of nonlocals at the two sites, there would appear to be few intra-cemetery and inter-cemetery differences in nonlocals present in the populations of Casal Bertone and Castellaccio Europarco.

In terms of sex, the sample population subjected to oxygen isotope analysis had more males than females at both sites. There was not, however, a statistically significant underrepresentation of females in either oxygen sample. The Casal Bertone sample population consisted of 19 males and 11 females. Of these, three males and three females were found to be nonlocal, or 15.8% of males and 27.3% of females. The higher percentage of female nonlocals is quite surprising given historical and epigraphical information that migrants were more often male (Noy, 2000). At Castellaccio Europarco, eight males and three females were tested, resulting in three nonlocal males (37.5% of the male sample) and zero nonlocal females. Regardless of the sex ratio of the oxygen sample, there is a statistical underrepresentation of females at Castellaccio Europarco (see chapter 4). It is possible that there were nonlocal females in this population but that vagaries of sample selection and taphonomy prevented their study. The estimated geographical origins of male and female nonlocals from both sites are also similar. At Casal Bertone, one female and one male presented δ^{18}O values lower than Rome, and two females and two males were higher than Rome. At Castellaccio Europarco, two nonlocal males had δ^{18}O values similar to Rome, while one had a higher measurement. Although the absolute numbers of male and female nonlocals at Casal Bertone are the same, fewer females were tested, meaning the percentage of nonlocal females at this site was higher than expected. This finding will be further examined in chapter 10 in light of the addition of strontium isotope data.

Although all tested teeth were first molars, the crowns of which are complete by about the age of 3, it is possible to remark on age-related mobility in terms of the nonlocal individuals who died as subadults. At Casal Bertone, 11 individuals under the age of 16 were tested, and six of these (54.5%) were found to be nonlocal based on δ^{18}O measurements. At Castellaccio Europarco, three individuals under 16 were tested, but only one (33.3%) was found to be nonlocal. Although it is not possible from the first molar alone to know when in a person's life he or she moved to Rome, only that it was after the age of 3, testing teeth from younger individuals can provide an age window during which migration likely took place. Of the seven nonlocal subadults from the two study sites, two were in the 6-10-year-old age range at death, and five were in the 11-15-year-old age range. Dental development and epiphyseal closure can narrow an age range, indicating two individuals traveled to Rome before the ages of 7-9, and five individuals came before the ages of 10-16. Based on what is known about apprenticeships, marriage, slavery, and the age of legal majority in Roman society, it is possible that the nonlocal adolescents in the sample came to Rome voluntarily as young adults in order to find work or a suitable spouse or involuntarily as slaves. Of course, it is also possible that the nonlocal subadults journeyed to Rome as part of a family, contrary to the historical evidence that suggests married couples and nuclear families rarely immigrated (Noy, 2000, p. 66-7). The evidence of children buried in Rome who were not born locally fills a huge gap in the historical demographic literature, where there is a decided lack of evidence of foreign-born children. Further research into the nonlocals at Casal Bertone and Castellaccio Europarco is needed in order to understand the age at which individuals immigrated to Rome. By testing third molars, which were also gathered during data collection, it will be possible to narrow down the range at which nonlocal adults came to Rome and to better understand the phenomenon of subadult mobility.

9.6.2 Comparative δ^{18}O from Portus

The oxygen isotope study of individuals buried at the Isola Sacra necropolis at Portus represents the closest comparanda to the data generated in the present study. Portus acted as the port city to Rome, a way station where foodstuffs and goods entered the Italian peninsula and were brought to Rome via the Tiber River. The Isola Sacra cemetery at Portus was in use between the 1st and 3rd centuries AD. As such, the individuals buried therein represent a good comparative population for the individuals from the Roman cemeteries of Casal Bertone and Castellaccio Europarco.

Prowse and colleagues (2007) reasoned that the role of Portus as Rome's entrepôt meant that some people buried in the Isola Sacra necropolis probably came from other parts of the Empire along with the food or goods they were importing. Epigraphical evidence at the cemetery confirms this, placing the origins of individuals in diverse parts of the Empire: Asia Minor, Palestine, and Egypt (Prowse et al., 2007, p. 512). Prowse and colleagues performed oxygen isotope analysis on paired first and third molars from 61 individuals, a small sample of the more than one thousand burials found to date in the cemetery. They chose individuals for whom both first and third molars were present, so they did not test anyone younger than 12 years old.

As at Rome, Prowse and colleagues did not find any statistically significant differences in the δ^{18}O of males versus females. Although they did not test first molars from any individual under the age of 12, they did test third molars from each individual in order to find out if people moved to Portus between the ages of 3 and 12, or the gap between the development of the first and third molar crowns. Several individuals were found to have immigrated during childhood, many from areas with δ^{18}O values lower than Rome and some from areas with δ^{18}O values higher than Rome (Prowse et al., 2007, p. Fig.5). Although I have not tested any of the third molars gathered during data collection from Casal Bertone and Castellaccio Europarco, several nonlocal subadults were found in the first molar oxygen isotope analysis, indicating that, as at Portus, there was definite mobility of individuals under the age of majority. It would be interesting to analyze third molars particularly from adult individuals identified as nonlocal in this study in order to determine when in their lives they came to Rome.

The mean δ^{18}O value for first molars from the sample population of Portus was -5.3‰ VPDB (25.4‰ VSMOW), which is extremely interesting because the mean δ^{18}O values at Casal Bertone and Castellaccio Europarco for first molars are 26.3‰ VSMOW and 26.5‰ VSMOW respectively. A histogram of the data from Isola Sacra and the two sites in this work is presented in figure 9.8. It is clear from this graph that the Roman sites have a δ^{18}O range higher than that of Isola Sacra. Differences in mean first molar δ^{18}O values between populations could result from many factors, most notably water sources and diet.

The water sources at Portus were different than those at Rome itself, not least of all because the latter were affected by an influx of water from springs to the east. Portus had only one aqueduct, but Rome was fed by several that had their origins in the foothills of the Apennines. With an increase in elevation and distance from the sea, the δ^{18}O of the drinking water from these springs should be lower than that at Rome. What we see in the δ^{18}O from dental enamel, however, is that the individuals buried at Rome had a higher mean δ^{18}O value than the individuals buried at Portus. Water is thus not likely the direct cause of the δ^{18}O differences, although more research is needed into the isotopic composition of Roman aqueducts in order to better understand both oxygen and strontium isotope analysis of human skeletal remains.

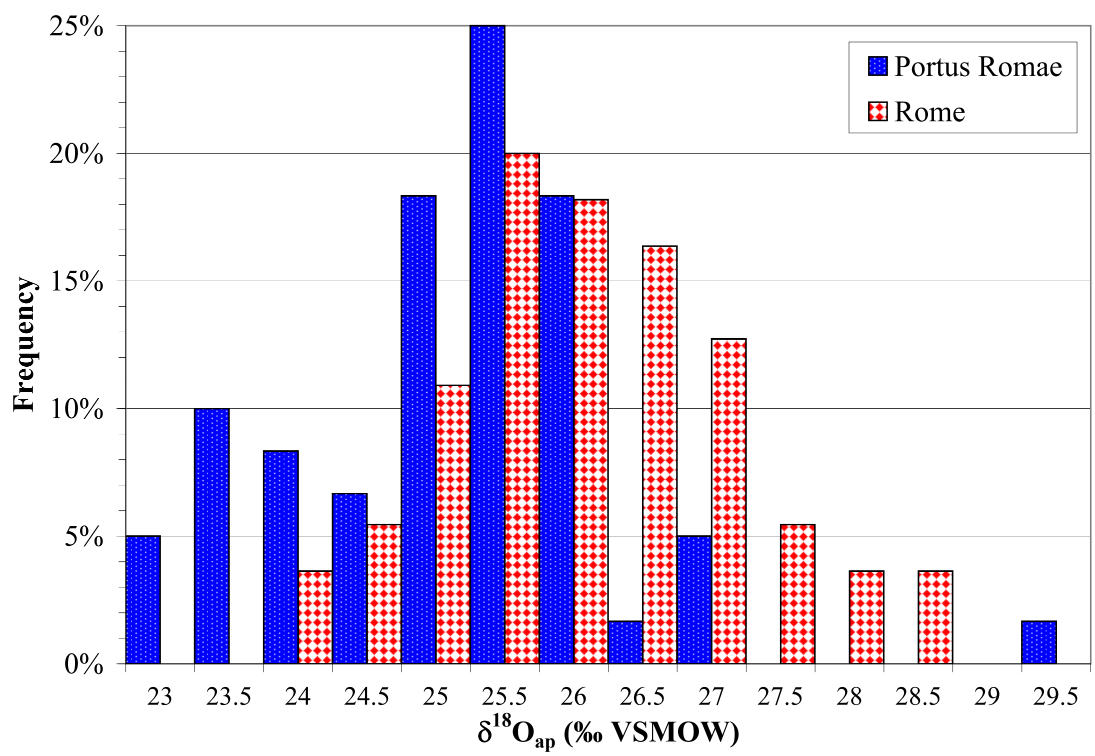


Figure 9.8: δ^{18}O Values from Imperial Rome and Portus

Another factor that could account for a higher average δ^{18}O among the people at Casal Bertone and Castellaccio Europarco would be a diet consisting of more cooked food, particularly meat, fish, grains, and legumes, than that of the people of Portus. As noted in chapter 6, although the carbon and nitrogen isotope analysis of Casal Bertone and Castellaccio Europarco shows that the diets of these people were similar to other populations in the region, the $\delta^{13}C_{co}$ measurements are a bit higher than those from Isola Sacra, and the $\delta^{13}C_{ap}$ values indicate the Romans were likely eating more C_4 grains (or animals foddered on them) and less seafood than the people of Portus. If the Roman lower classes were eating more of the low-cost and low-prestige grain millet or if they foddered their meat animals on this grain, it is possible that the δ^{18}O differences between people from Portus and Rome reflect this. A diet composed of more cooked food could also have an effect on the health of a people, as thorough cooking destroys bacteria and other pathogens. In addition to the fact that Romans had good access to clean water, it is possible that a diet of cooked food also contributed to the low incidence of, for example, cribra orbitalia and porotic hyperostosis compared to other populations from the region (see chapter 5). Again, more research is needed into the diet of people from around the Roman Empire in order to better interpret measured δ^{18}O values.

The final factor that could account for a difference in δ^{18}O range between Portus and Rome would be the homelands of nonlocal individuals. The percentage of nonlocal individuals found at Casal Bertone and Castellaccio Europarco is roughly the same as the number found at Portus. Although I take issue with Prowse and colleagues' rounded local range as detailed above, reassessing their data in light of a more precise δ^{18}O range does not materially change their conclusions. They found that roughly one-third of the population buried at the Isola Sacra cemetery presented nonlocal first molar values. In my sample of 55 individuals from two cemeteries at Rome, 16 individuals were nonlocal, for a total of 29% of the population. There is thus additional evidence that the population of Rome, like the population of Portus, was composed of people who were not born in the area. Prowse and colleagues further note that the nonlocal individuals comprise a continuous range of δ^{18}O values, leading them to conclude that people arrived at Portus from increasingly further distances. As shown in figure 9.8 above, the majority of the nonlocal individuals at Portus present δ^{18}O values lower than Rome, which would indicate they likely came from the east and north, areas of higher elevation than Rome. Most of the nonlocals from Casal Bertone and Castellaccio Europarco, on the other hand, present δ^{18}O values higher than Rome, which indicate that they came from areas to the south of Italy, possibly the north coast of Africa. The Imperial period represented the height of Rome's grain importation, which largely came from north Africa. It would stand to reason that many grain merchants and traders from Africa passed through Portus and that some nonlocal merchants might have been buried in the Isola Sacra cemetery. However, the δ^{18}O values seem to indicate that there were more short-distance immigrants to Portus from locales to the east and that there were more long-distance immigrants to Rome from locales to the south. With more research into the δ^{18}O of humans and better equations relating the δ^{18}O of dental enamel carbonate with that of drinking water, it would be possible to more precisely discuss the differing homelands of individuals buried at Isola Sacra and at Casal Bertone and Castellaccio Europarco. Nevertheless, if more nonlocal individuals living at Portus came from areas with lower δ^{18}O than did people living at Rome, the mean of the δ^{18}O values at each site would be affected.

The δ^{18}O values from Portus presented by Prowse and colleagues (2007) comprise an interesting data set with which to directly compare the results from the Roman cemeteries of Casal Bertone and Castellaccio Europarco. Although they claim that their findings represent evidence of immigration to Rome, there is little information on the extent of mobility between Portus and the city of Rome, which were separated by about 25 km. Portus was a different city, located directly on the Tyrrhenian coast, and thus was subject to a slightly different climate than Rome. Vagaries in the climate and in the average diet could easily contribute to a difference in δ^{18}O values between the inhabitants of Portus and of Rome. Prowse and colleagues did find, however, that there was no significant difference between males and females in terms of δ^{18}O values, that there was quite a bit of subadult mobility, and that nearly one-third of the population likely originated somewhere other than Rome. My analysis of δ^{18}O values from two Roman cemeteries similarly found significant subadult mobility and a population in which nearly one in three people hailed from elsewhere in the Empire. The differences between Portus and Rome, however, indicate that more research needs to be done in order to understand the variation in δ^{18}O values that can occur at two geographically proximate sites. With better characterization of the isotopic composition of geology, water sources, and the ancient diet, it will become possible to more precisely understand the δ^{18}O values measured from ancient human skeletal material.

9.7 Conclusions

In a sample of 55 individuals from two Imperial sites, 16 individuals were found to be nonlocal based on δ^{18}O values measured from dental enamel. Around 29% of the lower-class population from Casal Bertone and Castellaccio Europarco, therefore, is assumed to have been born somewhere other than the city of Rome. These nonlocals are both male and female. They were found in both the mausoleum and necropolis at periurban Casal Bertone and at suburban Castellaccio Europarco. Some individuals came to Rome before adolescence. More people relocated to Rome from Imperial provinces south of Italy, but a few likely came from areas to the north. Many of these findings are in line with the study from Portus, in which researchers found no significant sex differences and a surprising number of individuals who immigrated as children and adolescents. The cause of the difference in the sample means and center of the histograms between Portus and the Roman sites of Casal Bertone and Castellaccio Europarco is unknown, but factors such as different diets, water sources, and homelands of immigrants could be responsible. The differences between the Roman skeletons analyzed in this study and those from Portus indicate that even neighboring populations in the Roman Empire could vary greatly. More research is thus needed in the area of oxygen isotope analysis in order to better understand mobility and migration throughout the Empire.

Chapter 10

Synthesis of Migration to Rome

In this chapter, results of the strontium and oxygen isotope analyses are combined. An overlap in the separately calculated Roman ranges for each element provides a more precise way of identifying which individuals were local and which were not than does either strontium or oxygen isotope analysis in isolation. Following identification of the nonlocal individuals, their provisional homelands are narrowed down to geographical locales as specifically as possible. The composition of the immigrant group is discussed in terms of age, sex, and homeland, and comparisons are made between the populations from Casal Bertone and Castellaccio Europarco and the few populations around the Mediterranean that have been tested for either strontium or oxygen. Finally, additional research that will further our understanding of the immigrant population at Rome is proposed.

10.1 Combining Mobility Methods

Answering questions about human mobility and migration using isotope analysis is a relatively new practice. Most researchers elect to use either strontium or oxygen isotopes to investigate mobility, and they often choose the system based on criteria such as the presence of previously published baseline data, the geographical region in question, and the cost of analysis. The practice of using both strontium and oxygen isotopes started with British researchers, who for half a decade were the only ones publishing articles combining these two methods (Budd et al., 2001, 2003b, 2004; Bentley et al., 2005; Evans et al., 2006a,b). By the end of the decade, combining isotope systems in order to better understand ancient migrants surged in popularity, with studies published from sites around the world: Tiwanaku in Bolivia (Knudson and Price, 2007), Germany (Bentley et al., 2008; Müldner et al., 2009), North Africa (Buzon and Bowen, 2010), West Africa and Barbados (Schroeder et al., 2009), the Middle East (Mitchell and Millard, 2009), Machu Picchu and Nasca in Peru (Turner et al., 2009; Knudson et al., 2009), and additional Roman-period sites in England (Leach et al., 2009; Chenery et al., 2010).

The combination of strontium and oxygen isotope analyses is particularly useful in western Europe. Oxygen isotopes on the continent vary east-to-west and provide a broad geographical scale on which to locate an individual immigrant (see chapter 9, figure 9.7). Pinpointing a homeland is often difficult because of both fractionation in the human body and the undifferentiated swaths of meteoric water isotope gradients. On the other hand, strontium isotopes can uncover a more precise relationship between an individual and his or her homeland because the element passes unfractionated into human tissue and because the geology of any given geographical area is usually more differentiated than the climate. Nevertheless, given extremely complex geology, it can be more difficult to identify a local range for strontium than for oxygen.

In Italy, oxygen isotopes measured from meteoric precipitation vary in longitudinal bands from the coast to the Apennines (see chapter 9, figure 9.6), meaning people who came to Rome from the east coast or from areas north and south of the west coast are likely to be considered locals based on δ^{18}O measurements alone. The geology of Italy is quite complex in places, as the country is home to the Alps and Apennine mountain ranges, hundreds of kilometers of coastline, and several volcanic areas, in addition to large pockets of rock such as limestone, basalt, and travertine, all of which have distinctly different strontium values. At a macro scale, however, the strontium isotope ratios measured from geology and water sources vary roughly north-to-south, particularly in regard to the volcanic complexes on the Tyrrhenian coast. Because of the directional nature of variation in both oxygen and strontium isotope systems in western Europe, the combination of the two elemental analyses can yield a more precise picture of immigrants and their homelands.

10.2 Immigrants to Rome

The cemeteries in this study, Casal Bertone and Castellaccio Europarco, are thought to have been among the final resting places of Rome's lower classes. A lack of material culture in the simple graves means there are no tangible items that might indicate whether an individual was local to Rome or immigrated to the Imperial capital from elsewhere. A few tantalizing bits of evidence from historical documents and an oxygen isotope study of people from nearby Portus hint that there was significant mobility in the non-elite classes. In order to maximize the possibility of finding immigrants in the lower-class skeletal populations from Imperial Rome, chemical analysis of human remains was necessary. The combination of strontium and oxygen isotope analyses can help characterize the diversity of the ancient population of Rome.

10.2.1 Combined Sr and O Results

Figures 10.1 and 10.2 represent scatterplots of the δ^{18}O versus ^{87}Sr/^{86}Sr measurements for the 55 individuals from Casal Bertone and Castellaccio Europarco who could be subjected to both isotope analyses. Given the local strontium range of 0.7079 to 0.7103 for the city and the *suburbium* (chapter 8) and the local oxygen range of 24.9 to 27.1‰ VSMOW calculated from modern Roman children (chapter 9), the box represents the best approximation of the combined strontium-oxygen isotope field in ancient Rome. Standard measurement errors (1σ = 0.12) for δ^{18}O are shown as whiskers on the symbol; standard measurement error of ^{87}Sr/^{86}Sr ratios is within the symbol ($1\sigma < 0.00001$). Individuals who are outside the local range of either strontium or oxygen are labeled for discussion below.

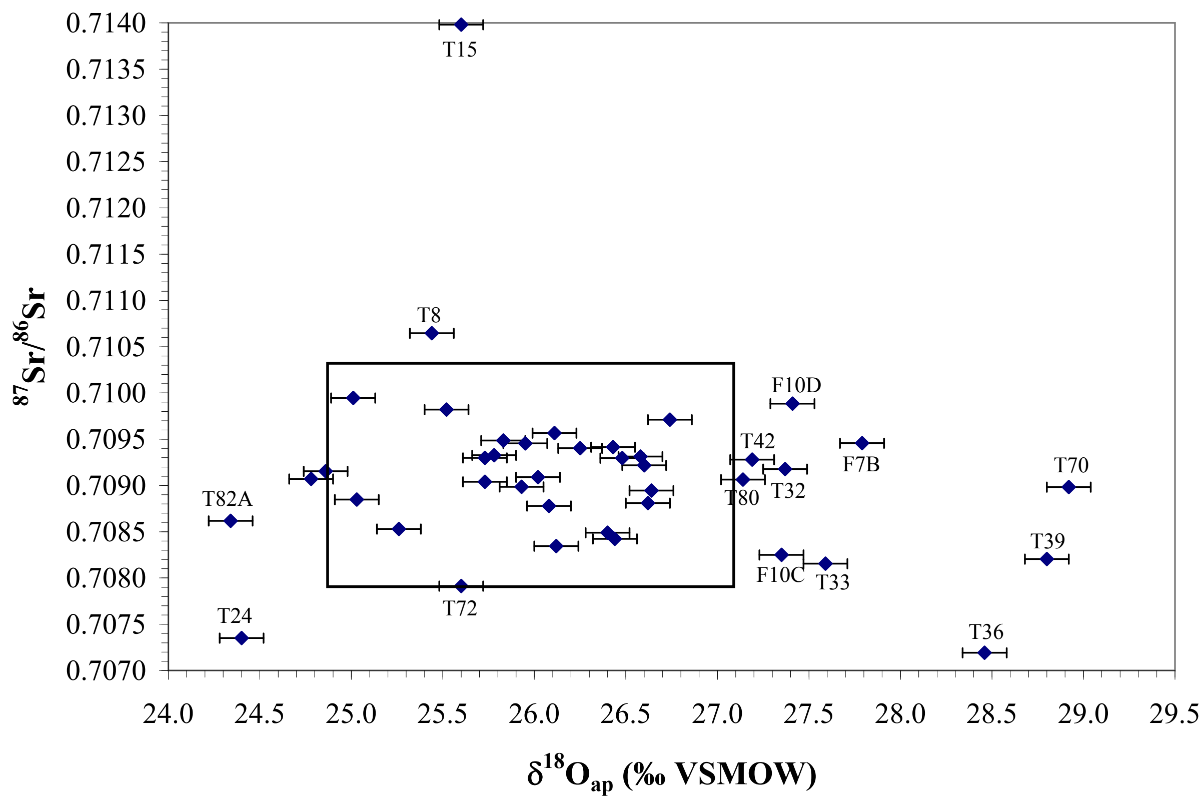


Figure 10.1: Casal Bertone ^{87}Sr/^{86}Sr and δ^{18}O Measurements
Box represents the local range.

The results presented in figure 10.1 show that there were 15 anomalous individuals from the Casal Bertone cemetery out of a sample population of 41, meaning about 37% of the population came to Rome from elsewhere. Table 10.1 lists the individuals identified as nonlocal to Casal Bertone. There are two individuals whose strontium and oxygen values both indicate a nonlocal origin: T24 and T36. Individuals whose strontium ratios were nonlocal but whose oxygen ratios were similar to Rome include T15, T8, and T72. Those with Roman strontium values and nonlocal oxygen results include the group composed of T42, T80, T32, T33, F10C, F10D, and F7B, as well as two additional individuals with dramatically higher oxygen values, T39 and T70, and one individual with a lower oxygen value: T82A.

The results presented in figure 10.2 show that there were three individuals from the Castellaccio Europarco cemetery whose strontium or oxygen values were outside of the local range. As presented in chapter 9, figure 9.5, however, there is one additional individual whose $\delta^{13}C_{ap}$

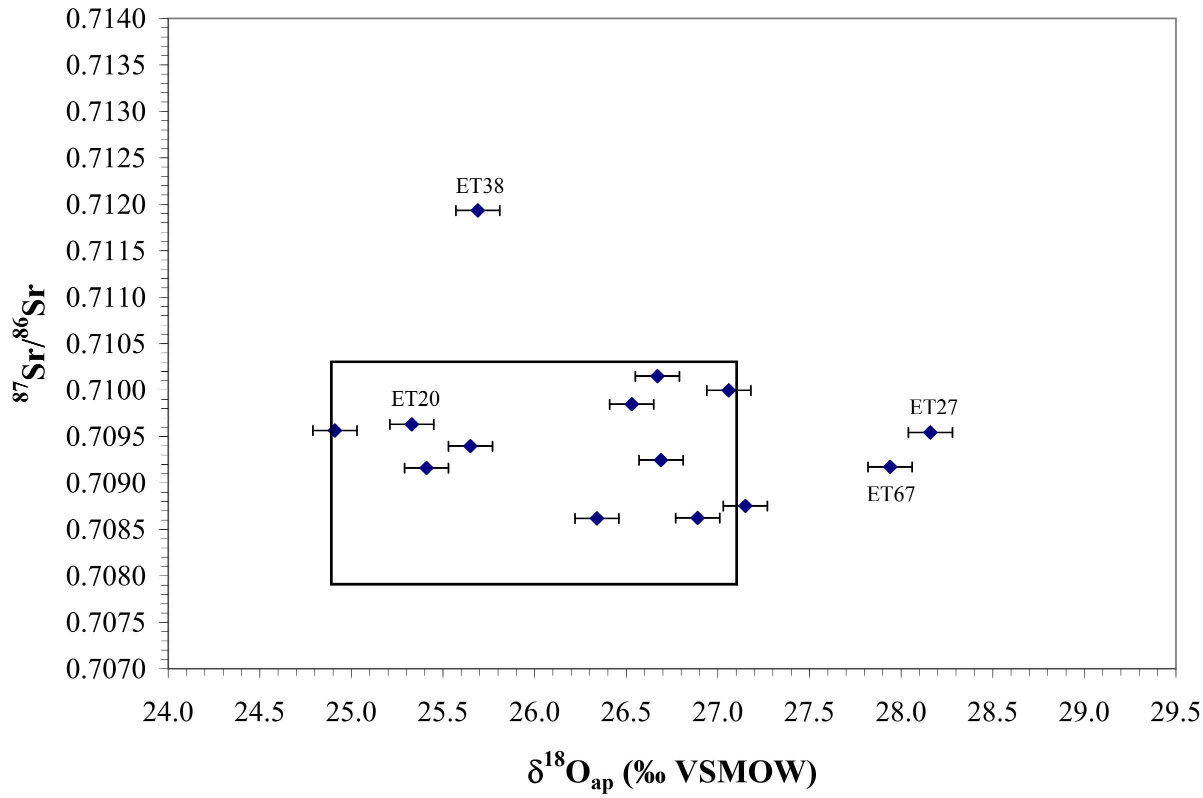


Figure 10.2: Castellaccio Europarco $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ Measurements
Box represents the local range.

value is significantly different than the mean. Strontium and oxygen isotope analyses are both predicated on the idea that a person's diet is the primary contributor of elements incorporated into the skeleton during ontogeny and development. As noted in chapter 9, anomalous carbon isotope values in dental enamel can be seen as evidence of consumption of a nonlocal diet. Additionally, one individual, ET76, presented a nonlocal strontium ratio but was not tested for oxygen. The total number of nonlocal individuals found at Castellaccio Europarco is thus 5. Out of the 14 individuals subjected to strontium, oxygen, and carbon isotope analysis, however, four can be considered nonlocal, meaning the sample population was composed of about 29% immigrants to Rome. Table 10.2 lists all five individuals from Castellaccio Europarco whose isotope values indicate they were born somewhere other than Rome. One individual, ET38, is local based on oxygen results but nonlocal based on an extremely divergent strontium signature. Two additional people, ET27 and ET67, have local strontium values but nonlocal oxygen

Skeleton	Sex	Age	^{87}Sr/^{86}Sr	$\delta^{18}O_{ap}$ (‰ VSMOW)	$\delta^{13}C_{ap}$ (‰ VPDB)	Possible Homeland(s)
T8	I	6-10	**0.710647**	25.44	-10.91	Tuscany-Lazio
T70	I	6-10	0.708984	**28.92**	-12.62	North Africa
F10C	I	6-10	0.708251	**27.35**	-10.42	Campania-Calabria
T72	I	11-15	**0.707914**	25.60	-11.91	Calabria-Sicily
T80	I	11-15	0.709064	**27.14**	-14.78	Greece, Cyprus, Asia Minor
T32	I	11-15	0.709178	**27.37**	-12.37	Greece, Cyprus, Asia Minor
T36	I	11-15	**0.707191**	**28.46**	**-6.76**	Egypt-Nubia
F10D	I	11-15	0.709885	**27.41**	-12.05	Greece, Cyprus, Asia Minor
T39	PF	16-20	0.708206	**28.80**	-10.90	North Africa
F7B	M	16-20	0.709457	**27.79**	-12.32	Greece, Cyprus, Asia Minor
T42	F	31-40	0.709280	**27.19**	-12.61	Greece, Cyprus, Asia Minor
T15	PM	31-40	**0.713980**	25.60	-12.32	Liguria
T82A	F	41-50	0.708617	**24.34**	-12.82	Apennines
T33	M	41-50	0.708155	**27.59**	-12.74	Campania-Calabria
T24	M	51-60	**0.707351**	**24.40**	-10.87	Apennines

Table 10.1: Casal Bertone Immigrants
Figures in bold are anomalous.

Skeleton	Sex	Age	^{87}Sr/^{86}Sr	$\delta^{18}O_{ap}$ (‰ VSMOW)	$\delta^{13}C_{ap}$ (‰ VPDB)	Possible Homeland(s)
ET76	PM	11-15	**0.710471**	—	—	Tuscany-Lazio
ET67	I	11-15	0.709173	**27.94**	-12.45	Greece, Cyprus, Asia Minor
ET27	PM	16-20	0.709543	**28.16**	-12.09	Greece, Cyprus, Asia Minor
ET20	M	31-40	0.709631	25.33	**-4.00**	North Italian Coast
ET38	M	41-50	**0.711934**	25.69	**-7.64**	Liguria-Tuscany

Table 10.2: Castellaccio Europarco Immigrants
Figures in bold are anomalous.

isotope results. Two individuals, ET38 and ET20, present anomalous $\delta^{13}C_{ap}$ values, and ET76 has a nonlocal strontium value but was not subjected to oxygen isotope analysis.[1]

In all, 19 of the 55 individuals whose first molars were tested for strontium, oxygen, and carbon isotope analyses likely hailed from a geographic locale outside of the city and suburbs

[1]As noted in chapter 8, individuals ET72 and F12A had anomalous strontium concentration values, which can be the result of living on nonlocal geology. Additionally, F12A had a surprisingly low $\delta^{13}C_{ap}$ value (chapter 6, figure 6.6) for the Casal Bertone mausoleum population. While it is possible that these individuals' seemingly local strontium and oxygen values are actually representative of a different coastal location, conservatively, in the absence of statistical significance of at least one isotope signature, they need to be considered local to Rome. As such, F12A and ET72 will not be further discussed as immigrants. Additional work is needed to establish a range of local strontium concentrations in Rome and to understand variations in the Roman diet.

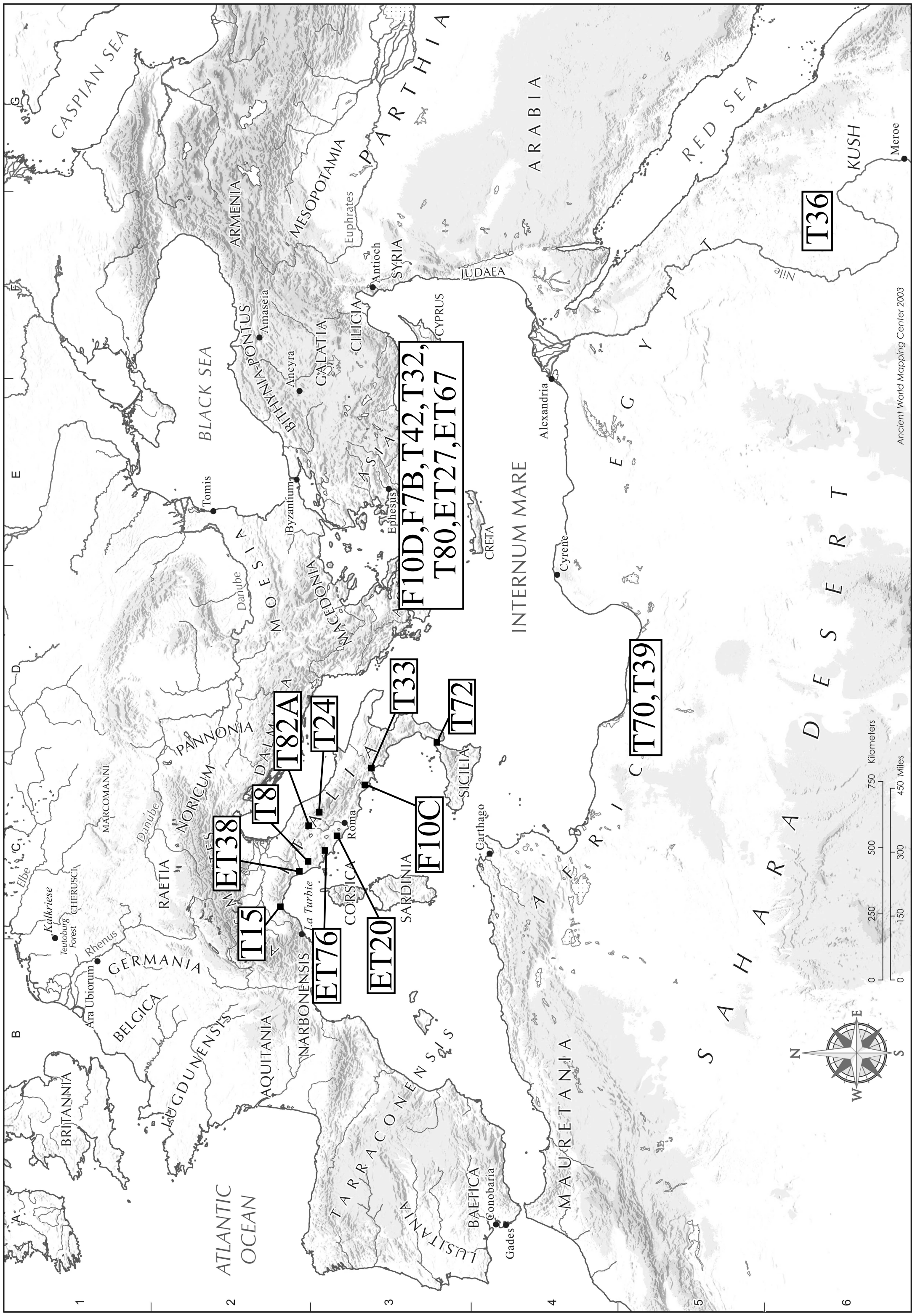
of Rome. Over one-third (34.5%) of all individuals chemically studied made a journey to the city of Rome sometime after the age of three. If the sample populations from periurban Casal Bertone and suburban Castellaccio Europarco are representative of other non-elite urban burials, it stands to reason that well over one-third of the lower-class population of Imperial Rome was not born there.

10.2.2 Identifying Migrants' Origins

Because strontium and oxygen vary directionally on the Italian peninsula, the combination of the two isotope systems provides the best method for approximating an immigrant's place of origin. Tables 10.1 and 10.2 present the possible regions of immigrants' origin, and figure 10.3 is a graphical representation of their origins on a map of the Roman Empire. The geographical areas of origin for immigrants in Europe and North Africa are hypothesized based on several factors: δ^{18}O measurements from human remains; extrapolated δ^{18}O based on climate and elevation (chapter 9, figures 9.6 and 9.7); ^{87}Sr/^{86}Sr isotope measurements from human and animal remains; and extrapolated ^{87}Sr/^{86}Sr ratios based on geological information (chapter 8, figures 8.6 and 8.7, and the IGME 5000 (Asch 2005)).

Origins in Northern Peninsular Italy

Those individuals with ^{87}Sr/^{86}Sr isotope ratios significantly higher than the Roman range include T15, ET38, T8, and ET76. In general, higher strontium values are from older rock (e.g., granite) and lower strontium values are from younger rock (e.g., magmic) (Faure and Powell, 1972). The geology of the Italian peninsula includes a variety of volcanic areas; higher strontium values can be found in the northern part of the peninsula (Tuscan magmic area), while lower values are found in Naples and in Sicily (see chapter 8 for a full discussion of the values and references thereto). Three individuals whose strontium values are higher than Rome have δ^{18}O values within the local range, and one (ET76) was not subjected to oxygen analysis. The homelands of these three individuals are thus geographical locales along the coast characterized



Map courtesy of the Ancient World Mapping Center at UNC (2003).

Figure 10.3: Map of Approximate Homelands of Immigrants to Rome

by older rock. Given the conservative assumption that many people were migrating to Rome from within Italy, individuals ET38 and T8 likely came from a volcanic area north of Rome, within the Tuscany-Lazio region for T8 and the Liguria-Tuscany region for ET38. T15 had the most divergent strontium value in the entire analysis, yet his δ^{18}O value falls within the local Roman range. This individual is likely to have come to Rome from a coastal area characterized by older rock. The area of the Italian peninsula that best fits these criteria is the province of Liguria, near present-day Genoa, whose pre-Alpine location is characterized by Triassic-Jurassic limestones and dolostones (Servizio Geologico d'Italia, 2004). ET76 has a strontium signature slightly higher than the Roman range and consistent with an origin on younger rocks, suggesting he came from a volcanic area just north of Rome, between Tuscany and Lazio. Future oxygen isotope analysis of this individual's dental enamel might be able to confirm a coastal origin. Finally, ET20 falls within the local range for both strontium and oxygen, but his $\delta^{13}C_{ap}$ value is significantly more positive than the average for the sample population, indicating greater than average consumption of either C_4 plants or seafood. It is possible this individual was simply fed large amounts of millet-based porridge when his first molar was forming, but the $\delta^{13}C_{co}$ results from the same individual's femur indicate a C_4-based diet during adolescence as well. Dietary behavior alone cannot indicate where a person came from, but two isotope studies of millet consumption in the classical world indicate that people who lived north of Rome ate more millet than people from the south (Murray and Schoeninger, 1988; Tafuri et al., 2009). The C_4 plants millet and sorghum are also found in Africa, and a dietary study of ancient Egypt found enrichment of carbon isotopes in human skeletal remains from that area (Dupras et al., 2001). ET20's δ^{18}O value, however, is consistent with a peninsular, coastal origin rather than a North African one, so his homeland is provisionally identified as an area north of Rome.

Origins in the Apennines

Those individuals with δ^{18}O measurements lower than the local range of Rome include T82A and T24. T24 is also divergent in his strontium value, whereas T82A is on the low end of the local Roman range. As noted in chapter 9 and shown in figure 9.6, δ^{18}O values of meteoric precipitation on the Italian peninsula get more negative with higher elevations. Conservatively, then, these two individuals with significantly lower δ^{18}O values than Rome likely came from either the Alps or the Apennines. Strontium isotope values, however, are generally higher in the north of Italy, as the Alps are composed of old metamorphic rock. The Apennines, on the other hand, are composed of Oligocene limestones and other young rock (Servizio Geologico d'Italia, 2004). The low strontium ratios of T82A and T24 thus rule out an Alpine origin, as they are more consistent with Apenninic limestone. A more specific homeland cannot be identified, but these two individuals possibly hailed from somewhere in central Italy.

Origins in Southern Italy

South of Rome along the coast are the present-day provinces of Campania (home to Naples), Calabria (Italy's toe), and Sicily. Three individuals have strontium values lower than or at the low end of the Roman range: F10C, T33, and T72. Both F10C and T33 present δ^{18}O values higher than the calculated local Roman range, whereas T72 has a δ^{18}O value around the same as Rome. As noted in chapter 8, the volcanic areas in Naples and on Sicily present lower strontium values than does the volcanic area around Rome. The province of Calabria is less well investigated in terms of strontium, but the geological map of Italy indicates a fair amount of Upper Cretaceous limestone in the modern Parco Nazionale del Cilento e Vallo di Diano. Although the geology of Puglia on the southeast coast of Italy also presents young rock, the δ^{18}O of average annual rainfall in cities such as Bari and Brindisi is actually a bit lower than in Rome. Calabria, however, has slightly more positive δ^{18}O values than Rome, as the δ^{18}O of average rainfall increases from Salerno south to Palmi. It is therefore possible that F10C and T33 came to Rome from the vicinity of Calabria. T72, on the other hand, presents a strontium ratio outside of the local Roman range with a seemingly Roman δ^{18}O value. The average δ^{18}O of the coast of Sicily is similar to Rome, and the strontium isotope values measured from the area around Mt. Etna are lower than at Rome. Additionally, the young (Plio-Pleistocene) rock on the southwestern part of the island, such as near Agrigento, is likely to have lower strontium values than Rome. The provisional homeland of T72 is therefore consistent with a location in Sicily or along the coast of Calabria.

Origins in the East

A number of individuals presented strontium ratios around 0.7092, the average value of seawater, but δ^{18}O values around 27.5‰, slightly higher than the average at Rome: T80, T32, F10D, F7B, T42, ET67, and ET27. It is not unusual for a distribution of δ^{18}O values within a population to have a tail on the positive end as a result of boiling, evaporating, or brewing dietary water (Daux et al., 2008), which enriches an individual's δ^{18}O value. The $\delta^{13}C_{ap}$ values measured from these individuals' teeth, however, are no different from the remainder of the people tested for oxygen and carbon isotope analyses. Dietary differences are still a possible explanation for this cluster of slightly higher δ^{18}O values, but another explanation is that these individuals came to Rome from a coastal area of the Empire with slightly higher oxygen isotope values.

Almost no strontium isotope analyses have been done on human remains in regions that historically were the origin of numerous immigrants, such as Pannonia, Thrace, Syria, and Asia Minor. There are, however, two published strontium studies in Greece, one of a Neandertal from Lakonis, in the southern Greek Peloponnese (Richards et al., 2008), and one comparing strontium ranges at Mycenae and Knossos (Nafplioti, 2008). In the latter, individuals from Knossos on Crete were found to have strontium ratios in the range of 0.7085-0.7092, while in the former, the Neandertal had an average strontium measurement of 0.7106. Greece has relatively complex geology and strontium values close to the range of Rome. Nevertheless, individuals living near the sea tend to inherit the strontium signature of seawater, which can be pulled up or down by the geology and food and water sources nearby, so the majority of the individuals mentioned above likely grew up in a coastal area. Turning to the δ^{18}O values, the north coast of Africa presents significantly higher δ^{18}O average annual precipitation values than continental Europe. The coasts of Spain and France present lower values than Rome, as do the ancient provinces of Pannonia and Dalmatia along the Adriatic coast of Italy. Parts of Greece, western Asia Minor, and Cyprus, however, present δ^{18}O values slightly higher on average than Rome (Bowen and Revenaugh, 2003).

In a study of human teeth from Frankish Corinth, Sandra Garvie-Lok (2009) found a range of 25.4 to 27.7‰ for the local group, which also had an average $\delta^{13}C_{ap}$ value of -12.1‰. Many of the individuals mentioned above fall within the range from Corinth, which is slightly higher than the local range at Rome. Most of the individuals from Casal Bertone and Castellaccio Europarco mentioned above also presented $\delta^{13}C_{ap}$ values around -12.2‰. A homeland of Corinth or another coastal area of Greece with similar geology is not unreasonable for these individuals. Other locations in the Empire with similar strontium and oxygen values, however, include western Asia Minor (near Ephesus) and southern Cyprus (near Akrotiri) (Asch, 2005; Bowen and Revenaugh, 2003). Additional elemental analyses, such as Pb, could help clarify the origins of these individuals, as could additional strontium and oxygen isotope work on human skeletal remains from the eastern part of the Roman Empire.

Origins in Africa

Finally, there are three individuals whose δ^{18}O measurements were significantly higher than the local Roman population: T70, T39, and T36. It is extremely unlikely that these individuals were from the Italian peninsula. Additionally, the strontium ratios of T70 and T39 are within the broad Roman range but are lower than the strontium values for the group with possible origins in the east. Much of the north coast of Africa, from ancient Carthage to Egypt, is composed of young rock dating to the late Cretaceous period to the Cenozoic era. Additionally, average annual δ^{18}O values from precipitation are higher in the north coast of Africa than in continental Europe and the Middle East.

Two bioarchaeological studies on human migration using δ^{18}O values have been done in the area of Roman Egypt. Dupras and Schwarcz (2001) studied individuals from the Roman-period site of Kellis in the Dakhleh Oasis in south-central Egypt and obtained a range of 24.3 to 31.6‰, with an average of 28.2‰. Prowse and colleagues (2007) analyzed a small sample of individuals from the Greco-Roman site of Mendes in the Nile Delta and got a range of 29.8 to 31.5‰ with an average of 31.1‰. Neither group of researchers utilized strontium isotopes, but Buzon (Buzon et al., 2007; Buzon and Bowen, 2010) measured both oxygen and strontium isotope ratios of individuals from Tombos, a second millennium BC site in ancient Nubia (modern Sudan). Buzon and colleagues obtained δ^{18}O values of, for example, 29.5‰, with a paired strontium value of 0.70712 (TOM-1) (Buzon and Bowen, 2010, Table 1).

Individuals T70 and T39 have strontium and oxygen values that could place them anywhere within the north coast of Africa, and their $\delta^{13}C_{ap}$ values are within the range of the Roman diet. T36, on the other hand, is the only individual in this study whose strontium, oxygen, and carbon values were all divergent from the local range at Rome. The high carbon isotope value indicates this individual was likely eating a lot of C_4 plants, and both millet and sorghum are grown in Africa. It is therefore extremely likely that T36 was a long-distance immigrant to Rome. All three elements are consistent with an origin in northern Africa, and the low strontium ratio indicates an inland rather than seaside origin. The isotope data for T36 are consistent with a homeland in central Egypt or Nubia.

10.3 Discussion

10.3.1 Demographics of Immigrants

There is some patterning of the demographics of immigrants to Rome. Out of the 20 individuals whose strontium, oxygen, and/or carbon measurements were identified as nonlocal, there were eight adult males, three adult females, and nine subadults. Of the sample population of 55 individuals who were subjected to both strontium and oxygen, 21.4% of females were found to be nonlocal, 25.9% of males were nonlocal, and 64.3% of subadults (individuals younger than 15) were nonlocal. Of the 19 nonlocals who were subjected to both strontium and oxygen isotope analysis, 15.8% were females, 36.8% were males, and 47.4% were subadults.

Although there are more males than females in the nonlocal group, the difference is not statistically significant based on a chi-square analysis ($\chi^2 = 2.27, p = 0.13$). In terms of homelands, however, males are much more likely to have come from the Italian peninsula than females. A chi-square analysis between the number of males and females from Italy, however, is not quite statistically significant ($\chi^2 = 3.57, p = 0.058$). No males were found to have hailed from northern Africa, but the sex ratio of individuals with eastern origins is more or less equal. Males are generally thought to have been more mobile in the Empire owing to occupations such as merchant and soldier. The results from Casal Bertone and Castellaccio Europarco, however, clearly indicate that females were also mobile, although it is likely that they were less often mobile than males.

For all individuals, a first molar was tested, the crown of which is complete by about age 3. It is therefore unclear when in life the male and female adults came to Rome. Dietary evidence presented in chapter 6 for ET20, however, seems to indicate that this man either retained his previous foodways or immigrated to Rome within the last few years before his death, as both his $\delta^{13}C_{ap}$ taken from dental enamel and $\delta^{13}C_{co}$ taken from bone are significantly more positive than the remainder of the population. Further discussion of this individual will be presented in chapter 11.

The ages at death of subadult individuals, however, constitute a *terminus ante quem* for their arrival at Rome. Out of the three subadults tested from the 0-5 age range, all were within the local isotope limits of Rome. In the 6-10 age category, five children were tested and three of those (60%) were found to be nonlocal. Two of these were likely from the Italian peninsula, while one possibly originated in northern Africa. The adolescent age category, 11-15, had six nonlocal individuals out of six sampled individuals, meaning 100% of the individuals tested in this category were nonlocal. The possible homelands of all of these adolescents are also further afield: one in Sicily, four in the east, and one in Africa. In total, nine out of the 14 subadults tested (64.3%) can be considered immigrants to Rome. This result is quite surprising given the lack of information about subadult mobility in the Roman Empire.

In their study at Portus, however, Prowse and colleagues (2007, p. 518) found that a "significant minority" of their immigrants came to Portus as children, by testing both first and third molars from individuals age 12 and older. Prowse and colleagues (ibid.) conclude that "migrants to Portus were families, most obviously as children accompanying their parents." In the Roman world, however, the age group that we consider biologically adolescent (11-15 years old) represents the age of majority, particularly for females. It is possible that younger individuals were traveling to Rome, perhaps to apprentice to an occupation or to find a spouse. It is also possible that younger individuals were being imported to Rome as slaves. Without additional information, however, about family relationships within a cemetery and about the isotope composition of teeth that form at different ages, it is impossible to conclude when individuals came to Rome, whether they came as individuals or as part of a family, and what brought them to the city. The relationship between immigrant status and disease load, which could explain the abundance of nonlocal children in the cemetery population, will be further detailed in chapter 11. The data from Casal Bertone and Castellaccio Europarco nevertheless track well with Prowse and colleagues' (2007) findings at Portus; in both cities, over 40% of the immigrants came to the area as children/young adults.

10.3.2 Immigrants' Homelands

Individuals identified as nonlocal by chemical analyses appear to have come from the Italian peninsula as well as other areas of the Roman Empire, although pinpointing a geographical location for a person's homeland can be difficult and imprecise. On the Italian peninsula, most of the immigrants presented δ^{18}O ratios characteristic of the coast, while two likely came from the higher elevation of the Apennines. Six of the seven adults from the peninsula were male, and three of the 10 nonlocals from the peninsula were subadults. Although the ratio is not quite statistically significant, it would appear that male mobility within the Italian peninsula was higher than female mobility. The approximate areas from which people came to Rome include locations within a few days' walking distance from Rome as well as locations that would have required sea travel. ET20 and ET76 possibly hailed from an area about 100 km north of Rome, ET38 and T8 from about 200 km north of Rome, while F10C and T33 possibly hailed from Naples, around 200 km south of Rome. The longer-distance immigrants from Italy include T15, perhaps from an area 600 km to the north of Rome, and T72, about 600 km to the south.

Those nonlocals whose isotope measurements place them outside of the Italian peninsula likely hailed from coastal areas to the east and to the south of Italy. Of these long-distance immigrants, there were two adult females, two adult males, and six subadults. All of the individuals who died at Rome in the 11-15-year-old age range came a long way to Rome, with most of them having come from geographical areas consistent with the eastern Mediterranean or northern Africa. The differences between the number of immigrants from Italy and the number from elsewhere in the Empire, however, are not statistically significant for any demographic group (for subadults, $\chi^2 = 1.0, p = 0.32$; for males, $\chi^2 = 2.0, p = 0.16$; and for females, $\chi^2 = 0.33, p = 0.56$).

With an immigrant population composed of 10 individuals from the Italian peninsula and 10 individuals from the larger Empire, it would appear that immigrants to Rome were equally as likely to have come from areas within Italy as they were to have come from other areas of the Empire. Within Italy, the nonlocal individuals came from areas progressively further from Rome, which is similar to the finding of Prowse and colleagues (2007) at Portus. More individuals buried at Rome than at Portus were found to have higher δ^{18}O values, indicating a larger percentage of immigrants coming to Rome from outside Italy. If the individuals sampled at Casal Bertone and Castellaccio Europarco are representative of the Imperial population of

Rome, a large percentage of the population is assumed to have undertaken a journey of 100 km or more to the city.

10.4 Conclusions

The combination of strontium, oxygen, and carbon isotopes presented above yielded 20 individuals identified as having grown up in an area outside of Rome. Because of the lack of previous strontium data, a local range at Rome was conservatively constructed in chapter 8 and thus identified few immigrants. It was possible to more accurately estimate the local δ^{18}O range at Rome based on data from modern Roman teeth presented in chapter 9, thereby adding individuals to the nonlocal group. The lower-class urban and suburban populations of Imperial Rome thus held significant percentages of immigrants. The provisional homelands of these nonlocal individuals are both within Italy and in the larger Empire, namely the eastern Mediterranean and northern Africa. People of both sexes traveled to Rome, and several children came to Rome before the age of majority. The finding that over one-third of the populations studied hailed from areas outside of Rome is quite exciting because of the lack of historical information on the mobility of various subaltern groups: the Roman lower classes, subadults, and females. The relative percentages of nonlocals at Portus and at Rome are similar, indicating that both cities were large draws for immigrants during the Empire, the former because of its seaport and the latter because of its status as capital of the Empire. Additionally, the immigrants at Portus are thought to have been merchants, while the individuals studied from Rome are thought to have been slaves and the free lower class. There was thus a significant amount of mobility among the non-elite in the area of Rome. It is not currently possible to identify push or pull factors that could have encouraged the influx of immigrants to Rome. Any number of reasons, from military service to slavery to job opportunities to marriage, could engender the need for mobility within the Empire.

Further work thus needs to be done on questions of migration and mobility in the Empire, particularly in terms of strontium and oxygen isotope analysis of populations from various locales, especially those from which there are abundant historical records of emigration. It was not possible to undertake a statistical analysis of craniometric data owing to the poor preservation of most of the samples in this study, but both metric and nonmetric analysis (see appendix C) of skeletal populations from Rome and the Empire could aid in a study of migration on a broad, population-level scale. Testing the remaining individuals who were not subjected to oxygen isotope analysis could produce a better picture of mobility within the Roman Empire, as more individuals were found to be nonlocal based on δ^{18}O values than were found based on the conservatively estimated strontium range. Finally, testing the third molars that were gathered during data collection could aid in narrowing down the age at which individuals immigrated to Rome.

In the concluding chapters, I contextualize the identified immigrants to Rome based on the bioarchaeological data presented in Part II of this work. Similarities and differences between immigrants and locals will be investigated in order to assess whether being an immigrant was correlated with health problems, dietary differences, or social status. The skeletal populations from Casal Bertone and Castellaccio Europarco, both immigrant and local, contribute to a characterization of life in both the periurban and suburban environments of Rome.

Part IV

Friends, Romans, Countrymen

Chapter 11

What Makes One Roman?

Based on historical records, scholars of ancient Rome have concluded that the population of the Imperial capital was quite heterogeneous in nature, owing in large part to the diversity of the slave population. In the previous chapters, I have similarly shown that there were foreigners at Rome and that they came from disparate areas of the Empire. It is highly unlikely, therefore, that every immigrant had the same experiences upon arriving at Rome. This chapter demonstrates that the lives of immigrants, insofar as the bioarchaeological data obtained in this study can indicate, were on the whole quite similar to those of locals. Further, the information gleaned about immigrants is discussed with reference to the importance of mobility in contemporary models of urban Rome.

11.1 Immigrants' Collective Experiences

Although immigrants came to Rome from all areas of the Empire and as slaves and free, soldiers and civilians, families and individuals, it has often been suggested, based on Roman authors' treatment of immigrants in the philological record, that their quality of life would have been less than that of locals (Noy, 2000; Burmeister, 2000). Other researchers, particularly historical demographers, feel this assumption is untenable because of the lack of evidence either way (Scheidel, 2005; Erdkamp, 2008). The study of immigrants to Portus by Prowse and colleagues (2007) found that, collectively, many immigrants came to Portus as children and adolescents. These researchers did not, however, pursue the implications of age-related immigration on the demographic make-up of the population, nor did they provide comparisons between the identified immigrants and the local population. In this section, I present all available information on demographics, disease, diet, and commemoration for the populations of immigrants and locals as defined in chapter 10, in order to better understand the lifestyles of these two groups of people at Rome.

11.1.1 Demographics

The demographic make-up of the immigrant population of Rome is not well known. Those individuals for whom there is epigraphical evidence of foreign birth are largely males who served in the military. The remainder of the immigrant population – the women, children, slaves, and civilian men – is virtually invisible to history. Although there is a general under-representation of females in the bioarchaeological record, a relatively even number of males, females, and subadults were studied isotopically for this project. Therefore, it is possible to compare the demographic profile of immigrants, which was presented in chapter 10, section 10.3.1, versus that of the locals.

From the sample of Casal Bertone skeletons subjected to both strontium and oxygen isotope analysis, there were 30 individuals whose sex could be estimated, 19 males and 11 females. Of these, 3 females and 4 males were found to be immigrants. Females buried at Casal Bertone were therefore more likely to be immigrants than males, but this result could relate to sampling bias or taphonomic processes. The difference is not statistically significant. Among the adults whose sex could be estimated, there were 23 locals and 7 nonlocals, meaning Romans outnumbered immigrants three to one. There were too few immigrants to break the sample population into age categories more precise than adult and subadult. Interestingly, 8 of the 12 subadults were found to be nonlocal, but only 7 of the 23 adults were immigrants. Subadults from Casal Bertone were therefore extremely likely to be identified as immigrants, although the difference is not statistically significant ($p = 0.07$ for a Fisher's exact test). Taking into account both age and sex, locals outnumber immigrants almost two to one.

At Castellaccio Europarco, there were no immigrant females found of the 3 tested, whereas 4 of the 9 males tested were not born at Rome. This is an admittedly small subsample of adults whose sex could be estimated, with 8 locals and 4 immigrants total, but at this site, locals outnumber immigrants only two to one. When age is considered, there is an equal number of locals and nonlocals among subadults, but there are more locals than immigrants among adults. No statistically significant differences could be obtained from this sample. Taking into account both age and sex, locals outnumber immigrants two to one.

Because of the small sample population, it is difficult to see patterns in subgroups of age and sex. When the immigrants and locals are pooled, however, it becomes clear that the former has a younger age-at-death than the latter, at 23 and 30, respectively. That is, on average, immigrants to Rome died younger than the local population. A two-tailed t test of the mean age-at-death for the two groups was statistically significant ($t = 2.79, p = 0.01$). This difference could be explained in two ways. First, differential mortality of immigrants could account for the lower age at death. If immigrants were of sicklier constitutions than locals, they would succumb to diseases at younger ages, and if immigrants fell ill upon arriving at Rome, their deaths could be blamed on lack of resistance to new pathogens. Second, the age at which migration occurred could account for a lower age at death. If the majority of immigrants came to Rome as children or young adults, as indicated in the large proportion of subadult immigrants from Casal Bertone, the overall age structure of the group would be skewed to the younger range. Thus, even normal levels of mortality in this population could make it seem like more young people were dying. Nevertheless, immigrants as a group can be expected to be older than locals, as the former enter a population some time after birth. At this time, it is unclear if the statistical difference in age at death between immigrants and locals was related to differential mortality or to the age structure of the populations.

In general, there are about twice as many locals at Casal Bertone and Castellaccio Europarco as there are immigrants. Even given the small sample, there are several male immigrants at Castellaccio Europarco. As this was probably an area of agricultural production, it is possible these males moved (or were forced to move) to the *suburbium* in order to engage in farm labor. Additionally, the large number of immigrant subadults at Casal Bertone is intriguing. This site was probably largely industrial, judging by the presence of a massive fullery/tannery. The historical record attests to slaves working as fullers (Bradley, 1994), and frescoes from the Fullery of Veranius Ipseus at Pompeii depict young and old working in Roman fulleries. It is possible these children came to Rome from elsewhere – through the slave trade, with their families, or by themselves – and went to work in the cloth cleaning business. Much more bioarchaeological data would be needed, however, to support these explanations based on contextual information.

11.1.2 Disease

With no access to modern medicine, ancient Romans would have succumbed to diseases easily treatable in contemporary times such as bacterial infections and viruses, and people would have died from conditions easily remedied with surgery, such as ruptured appendices, breech-presentation babies, and comminuted fractures. We do not know, however, what the differential mortality was for the upper versus lower classes, for slaves versus free, or for immigrants versus locals, as no large-scale studies have previously been done to assess the epidemiology of the Roman population. Chapter 5 presented frequencies of a variety of diseases, osteological responses, and degenerative conditions apparent on the bones and teeth of the individuals from Casal Bertone and Castellaccio Europarco. Compared to reports from other Imperial period Roman cemeteries and secondary literature on the sanitation conditions in the urban center, the individuals studied in this project were quite healthy, presenting lower frequencies of nearly all pathological conditions.

It is assumed that slaves and immigrants were less healthy than their elite counterparts, largely owing to differential access to foodstuffs and dental and medical care (Noy, 2000; Burmeister, 2000). By analyzing the indications of disease on the skeletons of both immigrants and locals, it is possible to test the series of hypotheses that immigrants and locals were different with respect to the frequency of diseases within their populations.

	#	OA	Periostitis	PH	Trauma	Congenital	Tumors
CE Immigrants	4	25	50	25	0	25	0
CE Locals	10	20	60	10	10	20	0
CB Immigrants	15	13	20	20	13	0	0
CB Locals	26	31	35	8	23	8	12
All Immigrants	19	16	26	21	11	5	0
All Locals	36	28	42	8	19	11	8

Table 11.1: Frequencies (%) of Skeletal Pathologies - Immigrants versus Locals

The skeletal diseases observed included: osteoarthritis (OA), periostitis, porotic hyperostosis (PH), trauma, the congenital abnormality spina bifida, and tumors. The number of individuals studied and the frequencies with which the skeletal pathologies appear in the subpopulations of immigrants and locals are presented in table 11.1. Categories in which locals had higher frequencies of skeletal pathologies than immigrants include trauma at Castellaccio Europarco and spina bifida and tumors at Casal Bertone. Trauma was found on only one of the 14 individuals in the subsample from Castellaccio Europarco, so this difference is not representative of a pattern of fracture. Two local individuals from Casal Bertone had spina bifida, and two individuals had evidence of auditory exostoses, whereas the immigrant population presented no evidence of either of these (non-deadly) conditions.

In order to figure out whether the differences in disease frequencies between immigrants and locals were statistically significant, a two-by-two contingency table reflecting the number of individuals who scored positively and negatively for a given disease category was tested for statistical significance using Fisher's exact test. Comparisons of these diseases in the immigrant and local subpopulations of Casal Bertone did not produce any statistically significant results, nor did comparisons of immigrants and locals from Castellaccio Europarco. Further, when the two sites were combined, the overall immigrant population was not statistically different in skeletal disease frequencies than the local Roman population. In spite of the greater absolute number of local individuals with spina bifida, auditory exostoses, and trauma, there is no evidence that immigrants suffered from skeletal diseases at higher frequencies than locals.

	#	Cavities	Calculus	Abscesses	AMTL	LEH
CE Immigrants	4	50	100	25	50	20
CE Locals	8	62.5	100	62.5	37.5	12.5
CB Immigrants	12	41.7	83.3	25	25	16.7
CB Locals	23	65.2	91.3	39.1	47.8	26.1
All Immigrants	16	43.8	82.4	25	31.3	18.8
All Locals	31	64.5	93.6	45.2	45.2	22.6

Table 11.2: Frequencies (%) of Dental Pathologies by Individual - Immigrants versus Locals

In terms of dental disease, the categories tested included carious lesions, abscesses, and linear enamel hypoplasias (LEH). Also analyzed were calculus and antemortem tooth loss. Frequencies of the dental pathologies in the immigrant and local populations are presented in tables 11.2 and 11.3.[1] Comparisons were run on the frequencies of these conditions both in the individuals in the populations (that is, number of skeletons with at least one incidence of each condition) and in the teeth or sockets (that is, number of teeth or sockets with at least one incidence of each condition).

Every individual studied from Castellaccio Europarco had some amount of calculus present, and the frequencies were high at Casal Bertone as well. In general, the local population has higher frequencies of all dental pathologies; that is, a local individual is more likely to have evidence of a dental disease than a nonlocal individual. Using Fisher's exact test on a two-by-two contingency table for each disease category, however, yielded no statistically significant differences between the immigrant and local populations at either site or when the subpopulations from the two sites were combined.

[1]All individuals in the age ranges of 0-5 and 6-10, however, were excluded from this analysis because of the lack of eruption of the permanent teeth.

	# Teeth	# Sockets	Cavities	Calculus	Abscesses	AMTL	LEH
CE Immigrants	117	126	9.4	42	1.6	3.2	5.1
CE Locals	189	230	5.8	49.7	3.5	6.1	1.6
CB Immigrants	325	341	4.6	26.5	0.9	2.1	4.0
CB Locals	582	710	5.2	**38.1**	1.8	**7.8**	3.3
All Immigrants	442	467	5.9	30.5	1.0	2.4	4.3
All Locals	771	940	5.3	**41.0**	2.2	**7.3**	2.9

Figures in bold are significant at the $p \leq 0.01$ level.

Table 11.3: Frequencies of Dental Pathologies by Tooth - Immigrants versus Locals

When dental pathologies are calculated per tooth rather than per individual, a slightly different picture emerges. In general, the teeth or sockets of locals are more likely to present evidence of calculus, abscesses, and antemortem tooth loss, whereas the teeth of immigrants are more likely to have linear enamel hypoplasias. Nevertheless, most of these differences are not statistically significant when tested using Fisher's exact test of a two-by-two contingency table. The teeth of the local population at Casal Bertone, however, presented a significantly higher frequency of calculus ($p \leq 0.01$) than the teeth of the immigrant population at that site. Similarly, when the immigrants and locals from the two sites were pooled, locals' teeth were more often affected by calculus than immigrants' ($p \leq 0.01$). In terms of antemortem tooth loss, locals from Casal Bertone again had a statistically higher frequency than immigrants ($p \leq 0.01$), and this significance carries over into the pooled local sample as well ($p \leq 0.01$).

Surprisingly, then, the significantly higher frequencies of dental disease were found in the local population. There are two likely explanations for this observation: differences in diet and differences in age. First, a difference in dietary practices or foods eaten could account for the accrual of calculus on the teeth. A bit of calculus on the teeth is expected in a population without modern dental care, as plaque build-up is easy to get and hard to remove, and the fact that 100% of the Castellaccio Europarco population had at least one tooth affected by calculus supports this expectation. Excessive calculus in the mouth, however, could indicate that the local population was eating something different. Although no statistically significant differences were found between the diets of locals and immigrants (see below), there is a vast range of foods that could contribute to calculus without showing up in the carbon and nitrogen isotope data. Dietary practices could also contribute to antemortem tooth loss, although a higher prevalence of carious lesions ought to be expected in this scenario.

Age is the second factor that could contribute to the differences seen. As noted above, the pooled local population is one age category older than the immigrant population, with age-at-death averages of 30 and 23, respectively. Calculus is an accretional process if one does not take pains to remove it; antemortem tooth loss can be considered a degenerative process, as carious lesions or periodontal disease can lead to abscesses that result in lost teeth. It is entirely possible, then, that the significant differences in dental disease between the local and immigrant populations are related to the older average age of the locals rather than to diet.

In general, locals appear to have a slightly higher frequency of all dental diseases, but statistically, the immigrant and local populations are similar. There are too few females and individuals of different age groups among the immigrants to attempt a study of differences in disease among subpopulations of immigrants versus locals. Thus, neither immigrants nor locals appear to have been differentially affected by skeletal or dental diseases.

11.1.3 Burial Style

Burial ritual can be considered a phenomenon of the internal cultural domain that is less easily influenced by social pressure to conform than aspects of the external, public domain (Burmeister, 2000). In particular, burial of marginal people, such as subadults, is more likely to betray continued ties to a nonlocal culture, religion, or ethnicity. The excavators of Casal Bertone and Castellaccio Europarco recorded the types of burial present and any grave goods found therein (Nanni and Maffei, 2004; Grandi and Pantano, 2007), which makes it possible to assess differences between the burials of immigrants and locals.

At Castellaccio Europarco, there were basically two burials styles: either *cappuccina* or simple pit (noted as *assente*, referring to the absence of a covering). Of the locals, 9 were simple pits and 1 was *cappuccina*, whereas there were 4 simple pits and 1 *cappuccina* burial among the nonlocals. Interestingly, two local individuals, ET18 and ET45, were buried prone, which is in contrast to the vast majority of Imperial burials found to date (Buccellato et al., 2008b). Both of these individuals were adults in their early 20s, one male and one female. Although the excavators diagnosed ET45, the male, with tuberculosis, there is no conclusive evidence of it on the skeletal remains I examined. It is unknown why these two individuals, in addition to a young child (ET31, figure 4.7b), were buried prone. In terms of grave goods, 5 of the local burials had at least one object whereas 4 had no goods whatsoever. Of the immigrants, 4 had at least one object whereas 2 had none. There is no statistical significance to either the burial styles or the number of grave goods, indicating burial ritual was not an area in which alternate ethnic or cultural identities of immigrants to Castellaccio Europarco were presented.

Casal Bertone consisted of two different burial contexts: an above-ground mausoleum and a necropolis. Of the individuals from the mausoleum who were chemically tested, only one-quarter (3 out of 12) were nonlocal, whereas nearly half of the necropolis population (12 out of 30 individuals) were probably immigrants, but this difference is not statistically significant. A variety of tomb styles existed in the necropolis, although the excavators' categories are a bit unclear: *cappuccina*, *piana* (open); *assente* (absent); unknown; and *in anfora* or *enchytrismos* (in an amphora). There are basically equal numbers of locals and nonlocals in the categories *piana*, *assente*, and unknown. However, the *cappuccina* burials are only found among the locals in this subsample, and the *in anfora* burials are only found among nonlocals. An explanation of this difference could be as simple as age: amphora burials tended to be reserved for children,[2] and *cappuccina* burials are more often found among adults. The high number of subadult immigrants at Casal Bertone and the comparatively low number of adult immigrants could be reflected in the burial style differences.

In terms of grave goods, the excavators of Casal Bertone listed the presence or absence of

[2]Practically, children's bodies are smaller and can fit more easily into pottery vessels than adults' bodies can. It is also possible, though, that children were buried in pottery as an extension of the home and as an indication of their role in the internal, private domain of the house rather than the adult, public domain. It has also been suggested that amphorae burial represent a return to the womb (Becker, 1995).

material culture in the burials of 27 locals and 13 nonlocals. Of the locals, 19 had no grave goods, and of the nonlocals, 9 had none. Individuals of both groups, then, were buried with minimal offerings, with nearly 70% of graves completely devoid of artifacts. The remaining graves, 9 local and 4 nonlocal, had goods such as bronze jewelry, bronze coins, glass, pottery, and iron objects.

The only possible evidence of retention of a different cultural tradition comes in the form of the burial of individual T36, a teenager of about 15, either in an amphora or covered by amphora pieces. Burying a nearly fully grown individual in an amphora is contrary to the typical pattern of amphora burial in Rome (Toynbee, 1971), and no *enchytrismos* burials of children over the age of 7 have been found at Casal Bertone or Castellaccio Europarco. Covering a grave with amphora pieces, however, is also an atypical practice from these two sites, although a few examples of inhumations covered by large halved amphorae can be found at the Isola Sacra cemetery of Portus (Toynbee, 1971). As detailed below, T36 was a long-distance migrant, perhaps from Africa, who came to Rome some time before death. Commemoration is indicative not of the dead person but of the person or people who buried the dead. It is possible that the individuals who buried T36 commemorated him or her in this way to pay homage to a different burial tradition. This form of burial was not anomalous for the Roman world but was usually reserved for a different age group. This act of burial is the only material evidence in the bioarchaeological record of these two sites that could be related to enaction of a foreign burial custom.

11.1.4 Diet

Rome was a culture interested in social dining, yet symposia and banquets were generally the purview of the elite. Most consumption of food was thus likely done in the private domain such as in the household and among family. Given similarities in food resources at sending and receiving areas, it is possible that immigrants would retain their learned foodways.

Chapter 6 showed both that the average diet was different between the two study sites

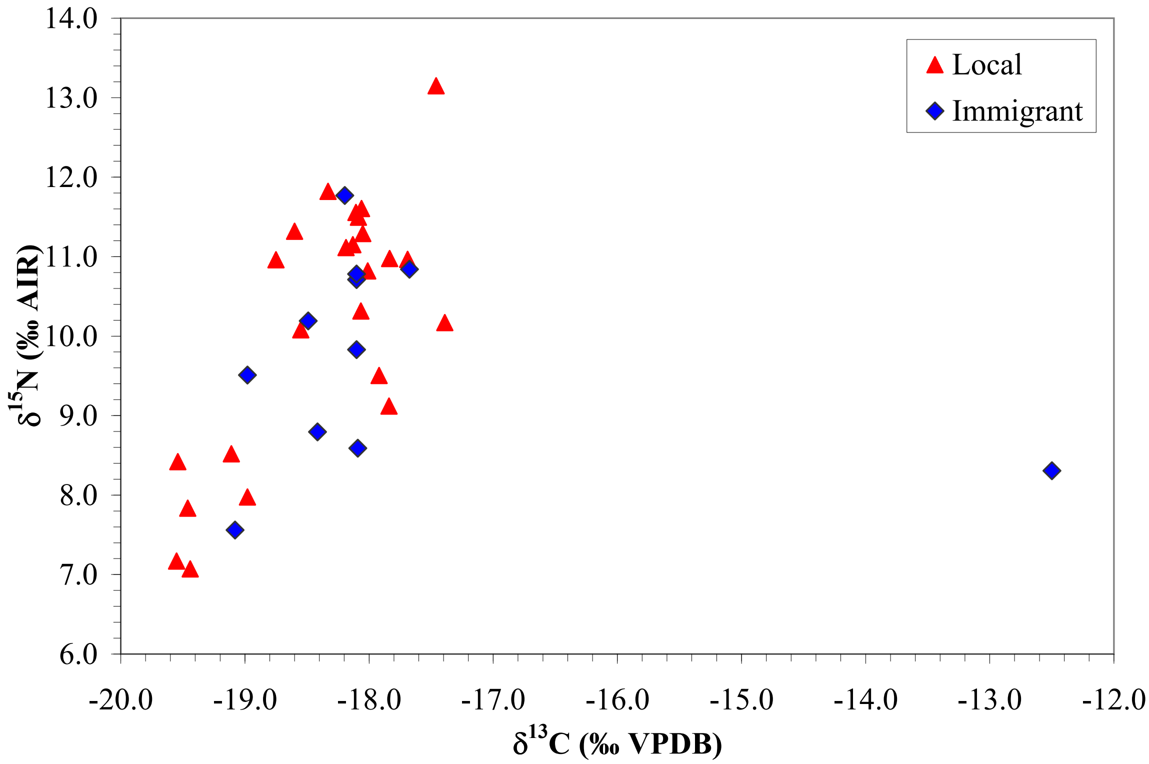


Figure 11.1: Dietary Data for Immigrants and Locals

(section 6.4.1) and that several individuals' diets changed during the period between childhood and death (section 6.4.4). Figure 11.1 shows that the diet that immigrants consumed before their death was very similar to the diet of people born in Rome, with the exception of ET20, a male in his 30s, whose δ^{13}C value is quite enriched. There are no statistically significant differences in the diets of the locals and nonlocals at either of the two sites. Two-tailed t tests of $\delta^{13}C_{co}$, δ^{15}N, $\delta^{13}C_{ap}$ (bone), and $\delta^{13}C_{ap}$ (enamel) of the immigrant and local subgroups at each of the sites produced no significant results.

The surprisingly high carbon measurement of ET20, however, deserves consideration. First, he might have continued to consume a largely C_4 based diet after he arrived at Rome. As noted in chapter 6, millet was known to have been grown in Italy and sold at Rome, so it is likely that ET20 could have gotten access to the grain or to animals that were foddered on it. In this scenario, ET20 either retained previous foodways or ate an individualized, anomalous diet, perhaps in response to a famine event (Garnsey, 1988). Second, ET20 could have arrived at Rome shortly before his death. In this case, even if he had begun consuming a diet with a carbon isotope value more typical of Rome, bone turnover might not have proceeded quickly enough to yield a carbon signature consistent with the local diet at Rome. Unfortunately, bone turnover rates are dependent on a huge variety of factors that cannot be precisely accounted for, such as age, nutritional status, physical activity, and diseases such as osteoporosis (Szulc et al., 2000; Parfitt, 2008). It might be possible in the future to test additional bones or teeth from this individual in order to understand his dietary variation better.

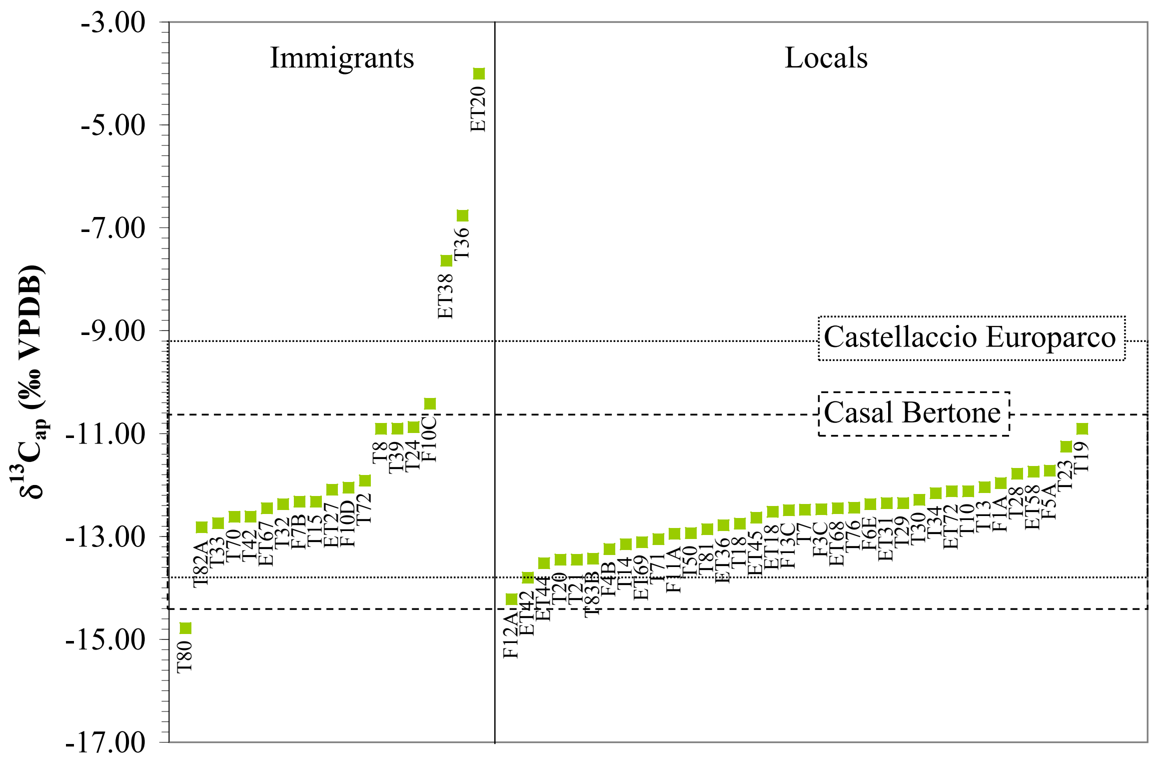
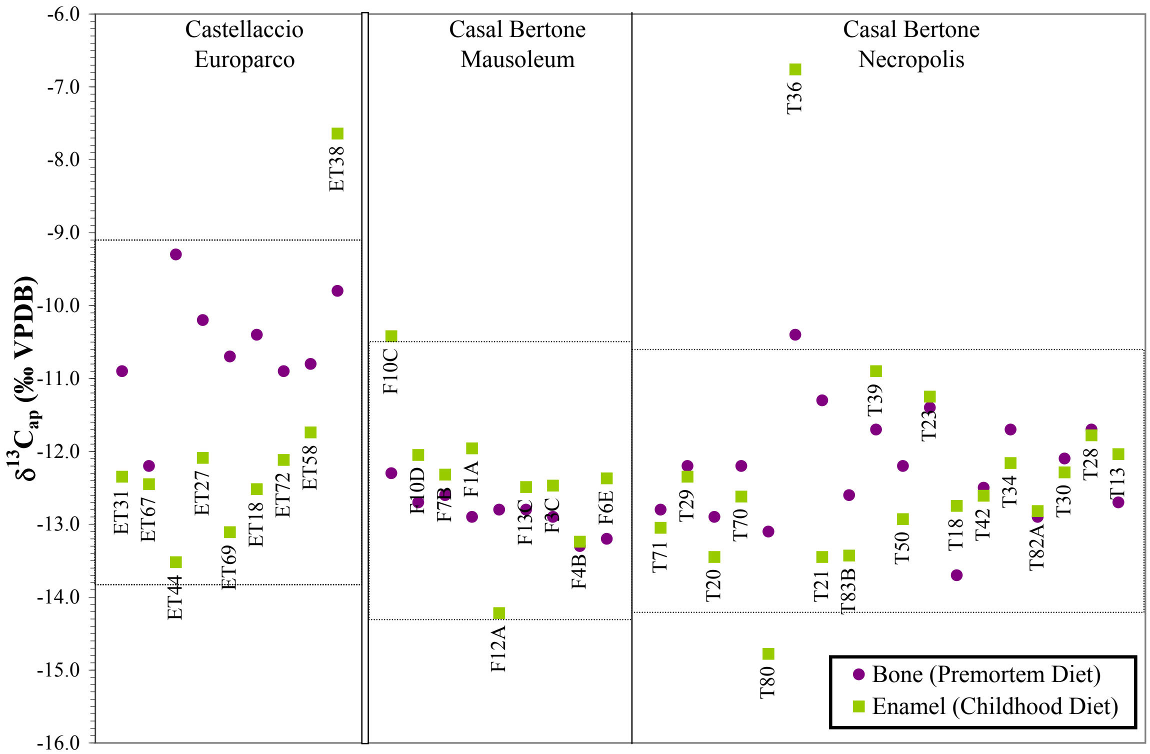


Figure 11.2: Enamel $\delta^{13}\mathrm{C}_{ap}$ Measurements for Immigrants and Locals
Dashed lines indicate the upper and lower limits of the 2σ range at each site.

In comparing the pooled diets of all immigrants and all locals from Casal Bertone and Castellaccio Europarco, there were no significant differences in $\delta^{13}\mathrm{C}_{co}$, δ^{15}N, or $\delta^{13}\mathrm{C}_{ap}$ from bone, which indicates that the adult diet, as noted above, was quite similar. However, a two-tailed t test of $\delta^{13}\mathrm{C}_{ap}$ measurements from the enamel of immigrants versus locals was statistically significant ($t = 2.52, p = 0.02$). This result indicates that the childhood diet of immigrants to Rome was significantly different than the childhood diet of those individuals who were born in Rome. Figure 11.2 clearly demonstrates that, whereas the enamel $\delta^{13}C_{ap}$ measurements of all of the locals are within the 2σ range for the site, the enamel $\delta^{13}C_{ap}$ measurements of 5 of the 19 immigrants analyzed are outside of this range. These data suggest that many immigrants to Rome came from geographical areas with different food resources and/or from cultures in which children consumed distinctly different food resources than adults. The majority of the individuals whose childhood diets differed from the average Roman diet were likely consuming a large quantity of C_4 resources, either directly as millet or sorghum or indirectly through consumption of the tissues (such as meat and milk) of animals fed millet or sorghum.

As indicated in section 6.4.4 and shown in figure 6.6, reproduced here as figure 11.3, three of the immigrants whose $\delta^{13}C_{ap}$ was measured for both enamel and bone (ET38, F10C, and T80) have bone values that are within the local Roman range. A fourth immigrant, T36, has a bone value that is close to the local range; it is possible this individual died before complete bone turnover could show a local diet.

The carbon and nitrogen isotope data generated in this study indicate that there were four individuals whose childhood diets were significantly different from the local Roman diet; all of these individuals were found to be immigrants through strontium and oxygen isotope analysis. To my knowledge, no previous study has used carbon apatite data from both bone and enamel to characterize changes in the immigrant diet, although Buzon and colleagues (2010) discuss $\delta^{13}C_{ap}$ and $\delta^{18}O$ data from immigrants in the Nasca region of Peru. One additional immigrant (ET20) provided a $\delta^{13}C_{ap}$ enamel value significantly higher than the local adult diet, but his adult diet is unknown because a $\delta^{13}C_{ap}$ value was not obtained from bone. On the whole, the dietary data provide evidence that immigrants to Rome were most likely to adopt a local diet, whether by choice or by necessity. There is no conclusive evidence that any individual retained past foodways that were significantly different than the local Roman tradition.



Dotted lines represent 2σ ranges for bone and enamel values.

Figure 11.3: $\delta^{13}C_{ap}$ of Bone Versus $\delta^{13}C_{ap}$ of Enamel

11.2 Discussion

The average quality of life of immigrants to Rome appears to have been about the same as that of locals, at least among the lower class individuals from Casal Bertone and Castellaccio Europarco. Demographically, immigrants of both sexes and different age groups came to Rome. At Casal Bertone in particular, female immigrants outnumbered males and subadult immigrants outnumbered adults. Migration and mobility were clearly not reserved for young males, a conclusion that was similarly reached by Prowse and colleagues' (2007) oxygen isotope analysis of migration to Portus. It is impossible to tell, however, whether people came to Rome as individuals, with a family, or as slaves. Immigrants do have a statistically younger average age-at-death than locals, but this difference could be related to the age at migration rather than differential mortality. For example, young adults in their 20s and 30s are often more likely to move than older adults (Burmeister, 2000), and slaves were often made of children and reproductive-age females following war (Bradley, 1994). These phenomena could easily lower the average age of immigrants to Rome, which in turn would yield a younger population of immigrants, many of whom would die at Rome. It is also possible that the younger age at death of immigrants relates to differential mortality, perhaps as a lack of acquired immunities or genetic protection against endemic diseases or perhaps as a result of occupational or interpersonal accidents. The influx of immigrants to Rome thus needs to be considered when assessing the age structure in demographic models of the city.

An analysis of the frequencies of skeletal and dental pathologies in the immigrant and local populations shows few significant differences reflecting epidemiological diversity of the two groups. Differences between immigrants and locals could only be found in frequencies of calculus and antemortem tooth loss. These differences could be related to diet or to the fact that the local population was, on average, older and therefore had more years to acquire dental decay. In terms of the bony skeleton, only easily observable pathologies were studied, and many diseases would have caused death before becoming pathognomic on bone. The lack of many significant differences between these two populations therefore suggests that, insofar as it is possible to tell from the skeleton, immigrants and locals suffered equally from the same diseases. However, differential mortality based on quick-killing diseases cannot be ruled out.

Burial style and grave goods can indicate status, gender, ethnicity, and other social aspects of a person's or a group's persona. Very few of the burials at Casal Bertone and Castellaccio Europarco had grave goods, and no differences were found in the amount or kind of goods present in immigrant versus local graves. In terms of burial style, at Casal Bertone, *cappuccina* burials were found only among locals, and amphora burials were found only among immigrants. It is possible that the locals were, on average, of higher status than the immigrants because *cappuccina* burials represent more cost and effort than simple pit burials. However, these differences could relate to age. As noted above, the local population was older on average than the immigrant population; *cappuccina* burials are more often found among older adults, whereas amphora burials are more often found among subadults. There is little evidence that the immigrant population was buried or commemorated differently than the local population.

The difference between the childhood diet of immigrants and the childhood diet of locals shows that the former is more enriched with respect to carbon, indicating greater consumption of C_4 foods such as millet as children. However, there are no significant differences in the adult diet to indicate that immigrants and locals were eating different foods at Rome. Isotope analysis is not a precise record of every food eaten, though, so it is possible that different foods with similar isotopic signatures were consumed by the two populations or that higher and lower qualities of staple foods such as bread and olive oil were eaten (Bradley, 1994).

Overall, there is no evidence that the quality of life of immigrants at Rome was worse than that of locals. In fact, the only statistically significant results indicate that locals had poorer dental health than immigrants. It is not known whether the immigrants came voluntarily or by force, nor is it known if any of the locals were *vernae* (children born of slave women), but it is likely that at least some of the identified immigrants were slaves at some point in their lives. Bioarchaeological and biochemical data do not capture the entirety of an individual's lifestyle, but it would appear that the collective immigrant experience at Rome was similar to that of the local *plebs urbana*.

11.3 Conclusions

This chapter has demonstrated that bioarchaeological analysis of human skeletal remains can yield information about immigrants' and locals' lifestyles in order to refute the longstanding assumption that slaves and immigrants suffered disproportionately in the urban jungle that was Imperial Rome. Further, the significantly lower average age at death of immigrants has striking implications for our current model of the demographic composition of the city of Rome. Comparisons of immigrants versus locals at Rome have not been done at this scale before, nor on a population of people traditionally ignored by history: the *plebs urbana*. Knowing that the collective experiences of immigrants to Rome, many of whom might have been slaves, did not differ significantly from the experiences of the locals indicates that geographical origin and sociolegal status likely contributed little to the quality of life of the Roman lower classes.

Chapter 12

Writing Immigrant Histories

People are fascinated by stories of humans who lived long ago, judging by the extensive media coverage of scientific discoveries relating to ancient bodies. From Ötzi the Iceman in Austria to King Tutankhamun in Egypt, these individual bodies have been subjected to all manner of scientific analysis in order to discover as many details as possible about each individual's life. The popularity of forensic science as entertainment in the U.S. provides an avenue for researchers to capture the public's attention with any skeleton. It is unsurprising, then, that recent publications on these famous men focus on the manner of their death; Ötzi suffered wounds inflicted by an assailant in the last few days of his life, and King Tut might have succumbed to malaria, his status no barrier to the bite of the lowly mosquito (Nerlich et al., 2009; Hawass et al., 2010).

Past individuals whose lives and deaths are so meticulously chronicled are generally either elite like Tut or amazingly well-preserved bodies like Ötzi. Yet bioarchaeological research is proceeding in all areas of the world, and few of us get to tell the stories of the individual people whose skeletons grace our lab tables day in and day out. Traditionally, bioarchaeology as a field is focused on a group of people, with the goal of understanding the community in which ancient people lived, whereas forensic anthropology focuses on the modern individual in order to identify that specific person's skeletal remains and understand cause of death. The beauty of bioarchaeology, though, is that, after the data have been compiled to understand as much group variation as possible, individual people can be reexamined and stories can be written about them. Roman history is unsurprisingly devoid of character sketches of the subaltern: women, children, immigrants, slaves, and the poor. This study has produced material evidence of individuals who fall into one or more of these categories. In this chapter, I indulge in biography of several immigrants to Rome, detailing their lives as thoroughly as the data allow. Whereas epigraphy depicts immigrants' deaths, bioarchaeology depicts their lives.

12.1 Kids from Afar

Immigrants to Rome were not just adult men and women. In this study, children were found to have immigrated at 7 years old or younger, and a large percentage of the identified immigrants were younger than 18 upon their deaths at Rome. Kids could have come to Rome as part of a family or as slaves; adolescents might have come as students or apprentices. The skeletons of individuals T36 and T80 bring us closer to understanding what life may have been like for immigrant adolescents and teenagers who came to Rome from other provinces of the Empire.

T36 - Teenager from Africa

Skeleton T36 was found in the Casal Bertone necropolis, buried in or covered by a ceramic amphora with no associated grave goods. Although the bones were poorly preserved, enough remained to estimate this person at about 14 to 16 years old at death, but sex could not be assessed. A palaeopathological analysis of the skeletal remains showed cribra orbitalia in the left orbit (figure 12.1a). The large, coalescing pores of the lesion indicate that the bone had not fully healed by the time of this individual's death. The right lateral clavicle presented evidence of myostitis ossificans, possibly evidence of overuse of or injury to the shoulder, and there was a small amount of periostitis on the right shin. The teeth of T36 were fairly good, which is to be expected for a young adult; only minor calculus and some chipping were evident.

(a) Cribra orbitalia, left eye orbit

(b) Inferior view of maxilla

Figure 12.1: Casal Bertone T36, (M?), 14-16 years old

With a strontium isotope ratio of 0.707191 and an oxygen measurement of 28.46‰, one strong possibility for the geographical homeland of this teenager is central Egypt to Nubia. Further, the childhood $\delta^{13}C_{ap}$ value of this person is -6.76‰, a measurement that indicates a diet enriched in C_4 foods. It is unfortunately impossible to tell from the data at hand exactly when T36 immigrated to Rome, although further analysis of teeth that form at different ages could help narrow down the range. The carbon and nitrogen isotope analysis of the recent diet of T36, however, indicates that this teenager stopped consuming large amounts of C_4 plants before death. The $\delta^{13}C_{ap}$ measurement from a section of midshaft femur is very close to the two standard deviation range calculated for the Casal Bertone necropolis but is still a bit high. This teenager appears to have consumed vastly different amounts of C_4 foods between childhood and several months or years before death. Whether this change in diet was voluntary or compulsory is, of course, unknown.

The life history of the teenager known in this study as T36 starts with a childhood spent in inland northeastern Africa. As a kid, T36 ate a lot of millet, sorghum, or animal products from livestock foddered on those grains. A nutritional deficiency or infection during childhood caused an anemic reaction sufficient to induce bony changes in the skull. During adolescence, T36 ate less millet, and his or her diet was very similar to the average at Rome, suggesting the change in diet was related to the change in geographical location. Shortly before death, T36 suffered minor trauma to the limbs. The person or people who buried T36 chose as a covering

(a) Skull, norma frontalis

(b) Superior view of mandible

Figure 12.2: Casal Bertone T80, about 12 years old

an amphora, which is usually reserved for Roman children under 10. They buried this teenager near a woman in her 40s, a man in his 30s, and a 5-year-old child, none of whom have similar isotope ratios that might suggest a familial relationship.

T80 - Adolescent from the East

The bones of T80 tell a different story. This adolescent, about 12 years old at death, was found in a simple pit grave in the Casal Bertone necropolis. Relatively complete and well-preserved (figure 12.2a), the skeleton gave few clues about this adolescent's health. Aside from a small amount of calculus on the anterior teeth and a chip in a molar, dental health is normal for an individual of this age (figure 12.2b). Similarly, the only skeletal anomaly was the presence of a rhomboid fossa on each clavicle.

This individual's strontium value of 0.709064 is evidence of a childhood spent near the coast; the oxygen value of 27.14‰, however, is slightly higher than is normally found in Italy and is more in line with values seen in further eastern areas of the Mediterranean such as

Greece, Cyprus, or Asia Minor. T80 was the only individual from Casal Bertone to present a significantly lower $\delta^{13}C_{ap}$ enamel value, indicating a childhood diet composed of more C_3 or terrestrial foodstuffs than typically seen in Rome. The bone $\delta^{13}C_{ap}$ value, however, is in line with that of other Romans, as are the carbon and nitrogen isotope measurements from collagen, indicating a change to a Roman-style diet before death.

The 12-year-old known as T80 might have arrived in Rome following a childhood in another coastal area of the Mediterranean in which the grain consumed was primarily wheat and/or barley. T80's dietary pattern changed in late childhood, possibly upon arriving at Rome, incorporating more C_4 foods such as millet. Good dental health and only minor indications of skeletal anomalies suggest that T80 was not subjected to harsh physical conditions for most of his or her life. This adolescent did die young; cause of death could have been any of a variety of factors such as starvation, accident, infection, or parturition. A simple burial in a pit with no grave goods marked the final resting place of this adolescent.

12.2 Apenninic Adults

Immigrants to Rome likely came from all over the Italian peninsula in addition to the provinces, yet little is known about migration and movement within Italy. The skeletons of T24 and T82A provide a window into the lives of both male and female emigrants from the Apennines.

T24 - Old man from the Apennines

A man in his 50s was buried a simple grave in the Casal Bertone necropolis and excavated as T24. As an older individual in a population with a short life expectancy, T24 presented normal degenerative changes of the skeleton: numerous sites of osteoarthritis. He stood at perhaps 175 cm (5'9"), a bit taller than the average male. He also had what appears to be a healed fracture of the right fifth metacarpal (figure 12.3b). Although some amount of dental

(a) Anterior view of maxilla, showing calculus, chipping, and unusual wear pattern

(b) Medial view of fifth metacarpals

Figure 12.3: Casal Bertone T24, M, 51-60 years old

issues are to be expected with advancing age in a society with pre-modern dental care, this man's jaw had a high frequency of antemortem tooth loss, abscesses, calculus, chipping, and tooth wear (figure 12.3a).

With strontium and oxygen measurements of 0.707351 and 24.40‰, respectively, this older man was likely born east of Rome, perhaps in the Apennines. A $\delta^{13}C_{ap}$ enamel value of -10.87‰ is a bit more enriched than the average at Rome, but the carbon and nitrogen isotope measurements of T24's adult diet indicate a consumption pattern similar to that of local Romans. There is thus no evidence that the diet of this older man changed significantly between childhood and the years before his death.

T24 was likely born in an area with slightly higher elevation and different geology than Rome, yet one that provided him with a childhood diet similar to his adult diet. At some point in his life, he moved to Rome, but nothing in his skeleton or burial indicates the timing of this immigration. His skeleton betrays the passing of time and possibly a life of physical activity, as his lower back and legs in particular were affected by arthritis. He broke the bone on the outside of his right palm, possibly during a hand-to-hand altercation, many years before his death. The pattern of disease and wear on the upper teeth of T24 and osteoarthritis of his temporomandibular joint suggest the repetitive use of his jaws in a function other than or in addition to regular chewing. Perhaps T24 used his teeth and jaws in service of an occupation

(a) Lateral view of right mandible

(b) Lateral view of right maxilla

Figure 12.4: Casal Bertone T82A, F, 40-45 years old

like leatherworking. This man lived a comparatively long life and was buried in a simple pit with no discernible grave goods.

T82A - Middle-aged female from the Apennines

T82A represents the skeleton of a female in her early 40s from the necropolis context of Casal Bertone. Excavators found five hair pins and a fragment of a bronze ring in her simple grave, making her burial more richly endowed than most from this site. Her skeleton was fairly well preserved and mostly complete, although quite fragmented, and long bone measurements put her living stature around 160 cm (5’3”), an average height for females from these populations. No significant pathologies were noted on her skeleton; her dental health, on the other hand, was quite poor. Her teeth were plagued by excessive carious lesions, at least one abscess, calculus, periodontal disease, and chipping (figure 12.4).

Although the strontium value of T82A is within the range of Rome, it is on the low end at 0.708617, and the oxygen measurement of 24.34‰ is similarly low. Both of these indicate an origin in a higher altitude to the east, probably the Apennines. The $\delta^{13}C_{ap}$ enamel value indicates a childhood diet of foods with mostly C_3 signatures, such as wheat and barley. Her adult diet was extremely similar in terms of carbon, as her $\delta^{13}C_{ap}$ bone value is, within measurement error, the same as her enamel value. The adult diet of T82A is similar to that of the average Roman diet in $\delta^{13}C$ but quite a bit lower (less enriched) in $\delta^{15}N$, likely indicating less consumption of fish and greater consumption of legumes.

T82A was probably born in the central region of the Italian peninsula. This woman does not seem to have performed significant amounts of physical labor in her lifetime nor to have been chronically ill. She likely consumed wheat and barley during childhood and as an adult, but in the later years of her life, she ate less fish and more legumes than most of the individuals buried at Rome. For such a seemingly healthy skeleton, T82A had surprisingly poor dental health. Numerous carious lesions in the molars and premolars might have resulted from eating sticky, sugary foods such as dried fruits, and rampant periodontal disease indicates a probable inflammation of the gum tissue (gingivitis) during life. This woman may even have had bad breath, as the oral bacteria that lead to gingivitis and cavities can also cause chronic halitosis. T82A appears to have lived a relatively comfortable life, and she was buried with several bronze jewelry items, both of which possibly indicate higher status than the other immigrants identified in this study. Her simple, unmarked grave, however, in no way differentiated her from the other occupants of the necropolis.

12.3 Northern Men

There seems to be no evidence of immigrants coming to Rome from areas in the western part of the Empire, but several people likely journeyed to Rome from points north and south. Of these, the most information is available on individuals T15 and ET38, adult males who likely arrived at Rome from the north.

(a) Skull, norma frontalis

(b) Left humerus and radius showing deformation of capitulum

Figure 12.5: Casal Bertone T15, PM, 31-40 years old

T15 - Middle-aged man from Northwestern Italy-Southeastern France

The well-preserved, largely complete skeleton of T15 was found in the necropolis of Casal Bertone. This male, who attained a height of perhaps 170 cm (5'7"), died in his 30s and was buried in a simple pit grave with no offerings. This man's dental health is a bit worse than would be expected for someone of his age, with evidence of a carious lesion and antemortem tooth loss of a pair of molars, in addition to calculus and chipping (figure 12.5a). Unsurprising was the evidence of osteoarthritis to the left acetabulum and femur and disc herniation in the lower thoracic spine. This man's left humerus had a curious deformity of the capitulum and corresponding radial head, possibly secondary to trauma (figure 12.5b).

At 0.713980, this man's strontium isotope value was by far the highest of any individual tested. T15's oxygen signature, however, is consistent with the coast of Italy at 25.60‰, making his likely homeland the far northwestern coast of Italy or southeastern coast of France, somewhere between Genoa and Nice. Unfortunately, bone from T15 was not analyzed for adult diet. A $\delta^{13}C_{ap}$ enamel value of -12.3‰ puts the carbon portion of the childhood diet of T15 within the range of the local Roman diet.

T15 was therefore born in an area far north of Rome, likely along the coast. This man developed arthritis during the course of his life, particularly in his left hip and lower back, and seems to have suffered trauma to the outer part of his left elbow as well. The left-sided pattern of injury is inconclusive, as it could be related to left-sided dominance (leading with the left) or to left-sided weakness (and therefore more injury-prone on that side). Without dietary data, it is unclear if this man's greater than average tooth wear and dental pathologies were related to the food he ate. There is no evidence of when in his life he migrated to Rome. T15 was buried in a simple grave with no apparent offerings.

ET38 - Middle-aged man from Tuscany-Liguria

The clearest immigrant buried in the Castellaccio Europarco necropolis is ET38, a male who died in his 40s. His skeleton was largely complete and decently preserved considering the condition of many of the remains from this site (see appendix B). He was a man of average height, standing perhaps 170 cm (5'7"), and was buried in a simple grave with a bronze coin found near his pelvis. In terms of skeletal pathology, ET38 presented normal age-related degeneration of the bones of the lower back, hip joints, and left knee joint, as well as bilateral rhomboid fossae. His dental health was decent, with some chipping and calculus apparent on the anterior mandible (figure 12.6).

The strontium signature of ET38, 0.711934, is quite high compared to that of the local Roman range, and the oxygen value of 25.69‰ indicates a coastal location in Italy, putting this individual's homeland north of Rome, perhaps in the province of Tuscany or Liguria. This man's childhood diet, as indicated by the enriched value of his enamel $\delta^{13}C_{ap}$, involved more C_4 foods than the typical Roman child's diet. His adult diet was within the range of the local Roman population, as was his $\delta^{13}C_{ap}$ bone value.

As a child, ET38 grew up in an area several hundred kilometers north of Rome, eating a

(a) Skull, norma frontalis (b) Superior view of mandible

Figure 12.6: Castellaccio Europarco ET38, M, 41-50 years old

diet composed of large amounts of millet or products from animals that ate millet. This man appears to have had a lifestyle of moderate activity, and he had better dental health than most people in this population. His adult diet changed following childhood and was in line with that of the average at Rome, as well as with the pattern of Castellaccio Europarco, which included a diet enriched in carbon. That is, the diet of ET38 indicates he spent the last several years of his life eating food similar to the people at Castellaccio Europarco but different than the people of Casal Bertone. ET38 was buried in the Roman *suburbium* in a simple grave, the bronze coin likely related to the custom of burying the dead with an obol in the mouth to pay Charon for ferry to the afterlife.

12.4 Conclusion

The vast majority of the population of the Roman Empire was never mentioned in historical records and left no archaeological traces. Notice is finally being paid to the poor, slaves, women, and children in one of the largest societies in the premodern world. Whereas chapter 11 outlined the ways in which the experiences of immigrants to Rome were both similar to and different from the experiences of locals, this chapter has presented detailed information about a select few immigrants, situating each of them within the context of the entire population.

With the increasing popularity of chemical analyses of human bone and enamel to learn more about individual humans who lived in the past, it becomes possible to both assess a population and refocus bioarchaeological analysis at the level of the individual to answer questions beyond demographics. Within the traditional bioarchaeological context of the group or community, we can start to make sense of the individual immigrant's life experiences, constructed identity, and patterns of mobility. The skeleton, in postprocessual approaches to the body in osteology, is a material record of "[social] relations between that person and others created through the constant alteration of skeletal structures and bone composition from the moment of conception until death" (Sofaer, 2006, p. 78). Biochemical and osteological analyses of bone therefore serve to elucidate relationships and histories, the dynamics of human interaction. Additional analyses could add to the stories above: testing teeth that form at different ages provides a way of seeing mobility within an individual's lifetime, and DNA analysis can find relatives within the cemeteries or affinities with populations from other areas of the Empire.

Immigrants to Rome moved between and among geographical areas, sociolegal statuses, and communities at their homeland and destination. The individual biographies above demonstrate that different people had different experiences. The life histories written on the bodies of a woman from the Apennines, a teenager from Africa, and a man from the foothills of the Alps tell distinct stories and help us understand the past from the perspective of an individual who was a lot like us. There was no singular immigrant experience, no one category of people was more likely to immigrate, no two skeletons' biochemical properties were exactly alike. Some of these people likely came to Rome via the slave trade, while others might have moved to Rome voluntarily. With a spectrum of skin colors and a range of accents, they came to Rome hoping for a new beginning or resigned to a life of servitude. Although we cannot recover every intention, every action, every minute detail, eulogizing these immigrants makes Roman history and the Imperial landscape inescapably corporeal.

Chapter 13

Cosmopolitan Rome

The city of Rome in the Imperial period was composed of a population of both sexes, different age ranges, and disparate geographical origins. Travel, tourism, immigration, and slavery were important to the creation and maintenance of Roman society; all of these phenomena brought people to Rome from nearby rural areas and from the farthest reaches of the Empire. The heterogeneous nature of this massive urban center has been demonstrated through historical texts, epigraphical inscriptions, and archaeological remains. Yet all of these data sources privilege elite males, allowing us only small glimpses into the worlds of women, children, slaves, and the *plebs*. Through an analysis of skeletal remains, this study has contributed to our understanding of Roman history and society by peopling the landscape with mobile individuals.

In this concluding chapter, I review the data and summarize my interpretations regarding migration to and mobility in Imperial Rome. The information gleaned from human skeletal remains is used to reassess the model of urban Rome, particularly in terms of the bidirectional relationship between the city and the immigrant. Finally, several new research streams are suggested for further study of immigrants in the Roman Empire in light of anthropological theories of migration. This project has opened up the *urbs* and *suburbium* of Rome to a multitude of questions about migration and mobility, but many more bioarchaeological analyses of Roman skeletons are necessary in order to better understand the nature of life in cosmopolitan Rome.

13.1 Migrants in Rome

In chapter 2, I defined movement in the Roman Empire with reference to both geographical space and length of residence. This study has generated the first concrete data of individuals who were not born at Rome, but it is easiest to see those individuals who were strikingly different from the locals. I refer to these individuals as immigrants because they likely came from distances hundreds if not thousands of kilometers from Rome and because their deaths at Rome imply recent residence there. Identification of immigrants' homelands, however, was necessarily conservative; with few data on the bioavailability of strontium and the large swaths of oxygen isopleths across the Italian peninsula, geographical origins of immigrants are little more than approximations. Nevertheless, statistically significant differences in strontium and oxygen isotope ratios were obtained, indicating immigrants came to Rome from areas of the Empire vastly different in geology and climate. No evidence was found to suggest people came to Italy from the west, but there are indications that migration from areas north, south, and east of Rome occurred.

Immigrants to Rome were demographically a diverse group. Males and females are both represented in the immigrant population, and children as young as seven came to Rome from elsewhere. Movement to Rome was therefore not the exclusive domain of men. Whether women and children immigrated individually or as part of a male-headed family is unclear, as there was no patterning of immigrants within either cemetery to suggest family groups. The immigrant population had an overall younger average age at death compared with the local population, suggesting either differential mortality of immigrants at younger ages or migration to Rome occurring at a young age in general. Future biochemical studies of human skeletal remains could contribute to our understanding of the demographics of immigrants, and DNA analysis could isolate family groups.

Investigation of the epidemiology of the immigrant population is limited by the osteological evidence: not all diseases produce characteristic lesions on bone, and many infectious diseases would have killed their host before bone involvement occurred. Most of the disease processes seen on bone are thus indicative of long-term or recurring issues rather than proximal cause of death. Although it has been suggested that Imperial Rome would have had a disease ecology similar to many 20th century third world countries, with frequent plagues of smallpox and endemic malaria, no concrete evidence of these diseases was found on either the immigrant or local populations to indicate mass epidemics or differential susceptibility to disease. It has also been suggested that immigrants, slaves, and the lower class might have been at increased risk of contracting a variety of diseases because of a lack of acquired or genetic resistance or because of their tendency to live in areas of Rome with poor sanitation and high population density. The only significant differences discovered between immigrants and locals in terms of disease relate to higher frequencies of calculus and antemortem tooth loss in the latter. Both of these dental issues could be related to dietary differences; had the locals eaten more sticky, sugary, or cariogenic foods, they could be at higher risk for developing pathologies related to the accumulation of food and bacteria on the teeth. Much more work is needed, therefore, in terms of characterizing the disease load of the population of Imperial Rome. Previously published studies of human skeletal remains in the Roman *suburbium* usually note frequencies of carious lesions, linear enamel hypoplasias, and porotic hyperostosis, and sometimes note pathologies such as trauma, osteoarthritis, osteomyelitis, and periostitis. In light of the available comparative evidence, on the whole, individuals from both Casal Bertone and Castellaccio Europarco are significantly healthier than individuals from every other published cemetery in the Imperial Roman *suburbium*. The lack of large-scale studies of the palaeopathology of Roman skeletal remains, however, needs to be remedied in order to situate both immigrants and locals within the context of the disease ecology of Rome and Lazio.

Historical evidence implies that the elite ate a vast range of high-quality foods, often in large quantities, that slaves were given substandard grain and olive oil, and that the rural poor supplemented their meager diets with local resources and with the occasional luxury item purchased at market. A dietary study of a subsample of the skeletons assessed in this project was accomplished in order to investigate whether immigrants ate substantially different foods than the locals and to determine if people at Rome ate the same diet as people from other areas of Lazio. Biochemical analyses of the carbon and nitrogen isotopes inherent in skeletal tissue showed no significant differences between the diets of the immigrant group and the local group. However, the carbon portion of the diet as measured from dental apatite was significantly different between the immigrants and the locals, suggesting several immigrants had a strikingly divergent diet as children, likely the result of growing up in another geographical area with alternate food resources. Comparisons of diet between the two sites showed differences in the carbon and nitrogen components, indicating people in the *suburbium* were probably consuming more legumes and millet, while people near the city were eating more fish. All of these values, however, were within the range of diets seen at other sites in the Roman *suburbium*. There was no single Roman diet, but it is currently unclear if there is patterning in the dietary variation based on age, gender, social status, legal status, geographical origin, religion, or other categories.

Those individuals identified as migrants to Imperial Rome thus had a similar quality of life as individuals who were born at Rome. The reason for this similarly, however, is currently unknown because we do not know precisely what constituted an immigrant in Rome. If the Empire was composed of people who spoke and understood Latin, who were familiar with the culture of the capital through circulation of the material trappings of Empire, who came into regular contact with travelers and foreigners, and who ate foods that were imported to Rome and redistributed, the concept of an immigrant as someone who exchanges one geographical and cultural context for another would need to be redefined, much in the same way that transnational migrants have been reconceived in a globalized world. It is imperative, therefore, to assess migration at all levels in the Roman Empire in order to better understand the epidemiology and demography of the capital but also to proceed with further questions about ethnicity and identity of the *plebs* as outlined below.

13.2 Migration in the Model of Urban Rome

Migration to Rome was necessary lest the city turn into an urban graveyard where emigration and mortality exceeded the birth rate. The incorporation of immigrants into the fabric of the city was therefore of utmost importance to its demographic character. This much has been recognized by historical demographers, who study epitaphs and foreign census data to model the population of Rome. Migrants dramatically changed the city of Rome, but the city also changed them. Contemporary anthropologists interested in migration focus on transnationalism, the idea that there is an articulation between home and abroad, that immigrants are in essence human links between the populations and geographies of the origin and of the destination. Transnational theories are concerned with both the individual and the structure, making them an ideal concept for framing questions about the city of Rome.

The immigrant – and the cultural and geographical context of the immigrant's home – contributed to the structure of the Imperial urban center primarily through demographics and disease. The age, sex, and origin of immigrants added to the heterogeneity of the Roman populace, forming a polyethnic society. Because all burials took place outside the city, no evidence has been found to indicate the presence of either polyethnic or monoethnic neighborhoods in Rome itself. Future research could help illuminate the composition of the Roman *vici* and demonstrate whether these social conditions had repercussions for their residents. Immigrants to Rome undoubtedly brought with them invisible pathogens. Many of these disease agents would have circulated harmlessly in the Roman population, but many produced plagues with high mortality. Some immigrants carried genetic advantages and resistance to endemic diseases from their own populations. The contribution of immigrants to the epidemiology of Rome, both good and bad, deserves more consideration, particularly from the bioarchaeological record.

The urban center also directly affected the lives of immigrants, subjecting them to environmental, economic, and social stress. With tremendous population density, the city of Rome and its *suburbium* constituted a reservoir of all manner of disease. People newly arrived at Rome were greeted not just by local people but also by local pathogens. Those not immune and with constitutions compromised from the journey would not have lasted very long. The bioarchaeological record, however, cannot show us squalid living conditions nor the ravages that deadly diseases such as typhoid wreaked on the *plebs urbana*. Many immigrants to Rome in the early Empire were not citizens, leaving them open to expulsion in times of economic crisis. The grain supply to Rome was also affected in troubled times, and the lower classes in particular likely supplemented their diets with any non-traditional food resources they could find in the local area. Famine probably affected immigrants and the lower classes far more severely than it did the upper class, meaning the economic hardships in the city of Rome created significant stress on the *plebs*. The osteological record does not provide information on conditions of unemployment or slavery, both of which affected economic conditions in the city. The heterogeneous lower class population of Imperial Rome living in cramped quarters almost certainly created conditions of social stress. Interpersonal violence occurred, again affecting the *plebs* more than the privileged elite. Most instances of social issues, however, are lost to archaeology. We are told, for example, that the emperor Septimius Severus spoke Latin with an accent, but we do not know how lower-class immigrants may have been treated. Were they shunned for being different? Harassed because of their appearance? Mocked for their manner of speaking?

The character of the city of Rome affected the lives of immigrants, yet the characteristics of immigrants affected the composition of the city of Rome. During the late Republic and early Empire in particular, Rome was dependent on its immigrants, most of whom came as slaves, and the urban environment cannot be understood without their genetic, cultural, and social contributions. Trying to make sense of the city-immigrant relationship requires a sort of hermeneutic process: the city is understood with reference to its individual immigrants, and the individual immigrants are understood with reference to the city. Attempts to discuss the city and its immigrants are therefore contextual, reliant on the culture, history, and archaeology of mobility and the structure of Empire.

The complicated relationship between immigrants and Rome has been investigated in this study by using bioarchaeological data to demonstrate the heterogeneity of the population, the differential use of food resources, and the disease load of the Roman populace. The lack of a singular immigrant experience at Rome demonstrates that the cosmopolitan nature of the city allowed for multiple lifestyles. Whether these differences were the result of personal choice or lack thereof is currently unknown, however. Future studies of migration in Rome, therefore, would benefit greatly from a more thorough construction of immigrants in terms of the sociocultural structure of the city of Rome.

13.3 Towards a Bioarchaeology of Roman Migration

A thorough understanding of migration to Rome requires much more research at a variety of scales, as I have argued previously (Killgrove, 2010). Series of analyses of multiple teeth from a single individual would greatly aid our assessment of mobility. Chemical analysis of small animals could help define the local range of bioavailable strontium in a volcanic area with quite complex geology. Further studies of strontium and oxygen isotopes of ancient Romans would similarly contribute to the identification of patterns of resource use, as of aqueduct water, whose influence on the chemical composition of dental enamel was only modeled in this study. The role of nursing in the Roman population similarly deserves additional study because of its potential effect on the chemical markers of teeth formed during infancy.

The combination of additional bioarchaeological analyses of immigrants as outlined above and theories of transnationalism can frame future research questions in terms of identity, ethnicity, and agency in ways that can be answered by the osteological, epigraphical, and historical records of Rome. Transnationalism involves migrants who transgress traditional boundaries and create and maintain relationships that span these borders. Two possible questions that can be asked of bioarchaeological data relating to the individual's transgression of boundaries and formation of identities include: Did the transmigrant move only once, multiple times during her life, or in a cyclical manner away from and then back to her homeland? Did the transmigrant maintain cultural ties to her homeland while living elsewhere? It is possible to investigate the first question using strontium or oxygen studies of an individual at several points during her life using teeth that form at different ages, an avenue that I plan to pursue with analysis of third molars gathered during data collection. Retention of cultural ties is generally approached archaeologically through material culture or burial style; however, that method would not pick up an individual who tried or was made to assimilate with the host culture. One method of investigating cultural ties is by an analysis of habitual actions (Sofaer, 2006), such as unique methods of manufacturing an object. The skeleton constantly remodels to accommodate the actions of muscles and joints, and specific patterns of movement could indicate retention of traditional methods of, for example, spinning or leatherworking. A study of enthesopathies and musculoskeletal markers could provide evidence of learned behavior specific to immigrants.

Transmigrants operate within a community, and the composition of that community is also anthropologically interesting. Transnational spaces in contemporary anthropology involve areas where transmigrants can construct multiple or situational identities. A Mexican transmigrant to the U.S., for example, likely has differing identities in her Spanish-speaking home and her English-language school. More concretely, transmigrants physically exist within a geographic space or ethnoscape, and the ethnic construction of that community is of interest to the anthropologist (Appadurai, 1996). We can ask questions such as, Did immigrants from the same homeland live in geographic proximity in the host country in homogeneous communities? Did immigrants live in polyethnic communities, heterogeneous in composition yet still separate from the local inhabitants? Were migrant communities dispersed throughout the city or were they located on the fringes of town? Although bioarchaeological data presented in this study have identified immigrants, burial was not permitted within the city walls of Rome. The spatial relationship between a person's *vicus* in Rome and eventual grave outside the city, therefore, is not usually known. Nevertheless, with new cemeteries and household sites frequently being uncovered in the *suburbium*, evidence of ethnic enclaves of either the dead or the living might soon be found.

Transmigrants and polyethnic communities operate within a larger sociopolitical structure. It is at this level that we can start engaging questions of migrant agency. What was the consensus about immigrants in the host culture? How did the migrant react to the sociopolitical context: by complete cultural assimilation, by maintenance of traditional ways, or somewhere in between? Did female immigrants react differently than males? Were upper class and lower class immigrants treated differently? It is no mistake that these questions return us to the experiences of individual transmigrants, as "migrants act and are 'acted upon' with reference to their social, cultural, and gendered locations" (Brettell, 2008, p. 136). That is, there is a dialectic of agency and structure, and both the individual and the structure are important for understanding the social process of transnational migration. Further bioarchaeological studies of skeletons from Rome could help clarify the individual and collective experiences of immigrants, particularly females, who were under-represented in this study.

Mobility and migration pervaded Roman society, not least of all in the form of slavery. Many of the immigrants identified in this study likely came to Rome as slaves, but their tenure as slaves could have been ended by manumission. The bioarchaeology of slavery is even more fraught with issues than the bioarchaeology of immigrants, yet it remains an important future avenue of research because slaves constituted perhaps one-third of the population of the city of Rome. The immigrants whose lives are chronicled in this work, regardless of legal status, were integral to the character of Imperial Rome. They contributed physical labor, novel pathogens, and diverse genes to the city, which in turn affected immigrants' lifestyles and experiences through social, environmental, and economic conditions.

Approaching migration in Imperial Rome from a transnational perspective that combines all available evidence has begun to yield interesting results and will allow us to see migrants to Rome in a way that has been impossible until now. The potential for a study of identity, ethnicity, memory, and agency of migrants in Imperial Rome is unparalleled on account of the vast amount of material and historical evidence at hand to help formulate questions and test hypotheses. Bioarchaeological approaches can provide evidence of the social phenomenon of migration both synchronically and diachronically at multiple levels of interaction: individuals, families, communities, the Empire, and even within one individual's lifespan. Transnationalism and diaspora are new ways of conceiving of migration in antiquity, and Roman archaeologists can harness these ideas to answer questions that have eluded us in the past. We can finally give voice to individual migrants who were agents within a social structure, who helped create, maintain, and negotiate their role in a polyethnic society.

Part V

Appendices

Appendix A

Demographics and Chemical Analysis Results

A.1 Castellaccio Europarco

Skeleton	Sex	Age	$^{87}Sr/^{86}Sr$ (enamel)	$\delta^{18}O_{ap}$ (enamel) ‰ VSMOW	$\delta^{13}C_{ap}$ (enamel) ‰ VPDB	$\delta^{13}C_{ap}$ (bone) ‰ VPDB	$\delta^{13}C_{co}$ (bone) ‰ VPDB	$\delta^{15}N$ (bone) ‰ AIR	Sr (enamel) ppm
ET15A	F	31-40							
ET15B	M	31-40							
ET16	I	0-5	0.709661						
ET17	I	6-10	0.708827						
ET18	F	21-30	0.708618	26.34	-12.52	-10.4	-18.8	11.0	
ET19	I	0-5							
ET20	M	31-40	0.709631	25.33	-4.00		-12.5	8.3	
ET21	I	0-5							
ET22A	F	31-40							
ET22B	M	21-30	0.708399						
ET27	PM	16-20	0.709543	28.16	-12.09	-10.2			250
ET30	I	Adult							
ET31	I	0-5	0.709848	26.53	-12.35	-10.9	-18.3	11.8	214
ET32	F	41-50							
ET33	PM	41-50	0.708783						
ET33B	PM	Adult							
ET36	I	6-10	0.709565	24.91	-12.78				
ET37	I	6-10	0.709570						
ET38	M	41-50	0.711934	25.69	-7.64	-9.8	-18.4	8.8	
ET39	M	21-30							
ET40	F	41-50	0.709175						

ET41	I	Adult							
ET42	PM	Adult	0.709245	26.69	-13.80				162
ET43	M	31-40	0.708126						
ET44	M	16-20	0.710150	26.67	-13.52	-9.3	-19.1	8.5	
ET45	M	16-20	0.709397	25.65	-12.63				
ET49	I	Adult							
ET51	PM	31-40	0.709335						
ET52	PM	21-30	0.708716						
ET53	PM	41-50							
ET58	F	41-50	0.709162	25.41	-11.74	-10.8	-17.9	9.5	260
ET63	I	6-10	0.709349						
ET67	I	11-15	0.709173	27.94	-12.45	-12.2			118
ET68	F	41-50	0.708754	27.15	-12.45		-18.1	11.5	
ET69	M	21-30	0.708624	26.89	-13.11	-10.7	-19.5	7.8	194
ET72	M	31-40	0.709996	27.06	-12.12	-10.9	-17.8	9.1	477
ET76	PM	11-15	0.710471						
ET77	M	31-40							
ET80	PM	Adult							
ET95	M	31-40							
ET96	M	21-30							
ET97	I	0-5							
ET100	I	0-5							
ET102	M	41-50							
ET103	PM	31-40	0.709105						

A.2 Casal Bertone

Skeleton	Sex	Age	^{87}Sr/^{86}Sr (enamel)	$\delta^{18}O_{ap}$ (enamel) ‰ VSMOW	$\delta^{13}C_{ap}$ (enamel) ‰ VPDB	$\delta^{13}C_{ap}$ (bone) ‰ VPDB	$\delta^{13}C_{co}$ (bone) ‰ VPDB	$\delta^{15}N$ (bone) ‰ AIR	Sr (enamel) ppm
F1A	F	16-20	0.709299	25.73	-11.96	-12.9	-18.1	11.3	156
F1B	M	31-40	0.709038						
F1C	F	51-60	0.709623						
F1D	PM	16-20	0.708787						
F2A	PM	Adult							
F2B	PM	Adult							
F2C	I	6-10							
F3A	PM	Adult							

F3B	I	Adult							
F3C	M	41-50	0.708346	26.12	-12.47	-12.9	-18.6	10.1	
F4A	I	11-15	0.709845						
F4B	F	51-60	0.709821	25.52	-13.24	-13.3	-19.4	7.1	
F4C	PM	16-20	0.709189						
F4D	I	11-15							
F5A	M	21-30	0.709945	25.01	-11.72		-17.5	9.3	
F6A	I	Adult							
F6B	I	6-10							
F6C	I	0-5							
F6D	I	Adult							
F6E	F	51-60	0.708944	26.64	-12.37	-13.2	-18.1	10.3	
F7A	PF	11-15							
F7B	M	16-20	0.709457	27.79	-12.32	-12.6	-17.7	10.8	
F9B	I	0-5	0.709769				-18.6	11.0	
F9C	PF	21-30	0.709212						
F9D	I	11-15							
F10A	PM	51-60							
F10B	I	6-10	0.709276						
F10C	I	6-10	0.708251	27.35	-10.42	-12.3	-18.1	8.6	
F10D	I	11-15	0.709885	27.41	-12.05	-12.7	-18.1	10.7	
F10E	PM	Adult							
F11A	F	31-40	0.709711	26.74	-12.95		-18.7	7.0	340
F11B	M	31-40	0.709008						
F11C	I	11-15	0.709576						
F11D	I	6-10							
F12A	M	31-40	0.709296	26.48	-14.22	-12.8	-18.1	11.2	57
F13A	I	6-10	0.709425						
F13B	I	0-5							
F13C	F	41-50	0.709455	25.95	-12.49	-12.8	-17.7	11.0	
T7	M	41-50	0.709404	26.25	-12.48		-18.2	11.0	
T8	I	6-10	0.710647	25.44	-10.91				
T9	I	0-5	0.709302						
T10	M	31-40	0.709566	26.11	-12.12				
T11	I	11-15	0.709325						
T12	M	16-20	0.709546						
T13	PM	61-70	0.708490	26.40	-12.04	-12.7	-18.2	11.1	
T14	M	21-30	0.708986	25.93	-13.15				
T15	PM	31-40	0.713980	25.60	-12.32				

T16	M	41-50							
T17	PF	31-40							
T18	PM	31-40	0.709485	25.83	-12.75	-13.7			254
T19	M	41-50	0.709153	24.86	-10.91				
T20	I	6-10	0.709089	26.02	-13.45	-12.9	-19.6	7.2	
T21	M	16-20	0.708811	26.62	-13.45	-11.3	-19.0	8.0	
T22	M	21-30	0.709070						
T23	M	21-30	0.708424	26.44	-11.25	-11.4	-18.1	11.6	208
T24	M	51-60	0.707351	24.40	-10.87		-18.1	9.6	
T25	I	Adult							
T26	PM	Adult	0.7091751						
T27	I	Adult							
T28	F	51-60	0.708529	25.26	-11.78	-11.7	-18.6	11.3	
T29	I	0-5	0.709327	25.78	-12.35	-12.2	-17.5	13.2	
T30	PF	41-50	0.709219	26.60	-12.29	-12.1	-17.8	11.0	107
T31	M	41-50	0.709181						
T32	I	11-15	0.709178	27.37	-12.37				225
T33	M	41-50	0.708155	27.59	-12.74		-17.2	9.7	131
T34	M	31-40	0.709071	24.78	-12.16	-11.7	-18.1	11.6	
T35	PM	16-20	0.709462						
T36	I	11-15	0.707191	28.46	-6.76	-10.4	-18.1	10.8	111
T37	PM	31-40	0.709183						
T38	PF	41-50	0.709323						
T39	PF	16-20	0.708206	28.80	-10.90	-11.7	-18.2	11.8	
T40	M	21-30							
T41	PF	16-20	0.7091722						
T42	F	31-40	0.709280	27.19	-12.61	-12.5	-18.1	9.8	
T45	I	11-15	0.709237						
T46	I	0-5							
T47	M	31-40	0.708652						
T48	PF	Adult	0.709508						
T49	I	31-40	0.709153						
T50	PF	21-30	0.709312	26.58	-12.93	-12.2	-18.0	10.8	
T51A	F	61-70							
T51B	I	0-5							
T52	PF	Adult							
T53	PM	21-30	0.708500						
T55	I	6-10	0.708933						
T56	I	11-15	0.709505						

T57	PM	31-40							
T59	M	Adult	0.708586						
T60A	I	0-5							
T60B	I	0-5	0.708586						
T61	PM	Adult							
T62	I	6-10	0.709155						
T63A	I	6-10							
T63B	I	Adult							
T64	I	Adult							
T65	M	41-50							
T66	PM	Adult	0.708730						
T67	PM	41-50	0.708354						
T68A	PF	21-30							
T68B	I	11-15							
T68C	I	6-10							
T69A	M	41-50	0.710089						
T69B	I	0-5							
T70	I	6-10	0.708984	28.92	-12.62	-12.2	-18.5	10.2	107
T71	I	0-5	0.709039	25.73	-13.05	-12.8	-17.4	10.2	
T72	I	11-15	0.707914	25.60	-11.91				
T73	M	31-40	0.709134						
T74	I	0-5							
T75	I	11-15	0.708737						
T76	PM	31-40	0.709415	26.43	-12.44				
T77	PM	31-40	0.709142						
T79	I	16-20							
T80	I	11-15	0.709064	27.14	-14.78	-13.1	-19.0	9.5	
T81	M	21-30	0.708849	25.03	-12.86				
T82A	F	41-50	0.708617	24.34	-12.82	-12.9	-19.1	7.6	
T82B	PM	Adult							
T83A	PM	Adult							
T83B	M	16-20	0.708780	26.08	-13.43	-12.6	-19.5	8.4	
T84	I	11-15	0.708898						
T85	I	11-15							
T86	PM	Adult							
US15A	I	0-5							
US15B	I	6-10							
US15C	PF	16-20							
US15D	PF	Adult							

US15E	PM	Adult	
US31A	PM	Adult	
US31B	I	Adult	
US36A	PM	Adult	
US36B	I	11-15	
US36C	I	Adult	
US36D	PF	Adult	
US36E	I	11-15	
US66A	I	0-5	
US66B	I	11-15	
US66C	PF	21-30	
US66D	PM	Adult	
US170	I	6-10	

Appendix B

Castellaccio Europarco Republican Burials

Castellaccio Europarco presented three different temporal contexts of burial. The majority of the burials dated to the Imperial period and were thus contemporaneous with those of Casal Bertone. As this dissertation relates to mobility and migration within the Roman Empire, only the Imperial-period populations from the two sites are discussed within the main body of the document. The earlier skeletons were studied because of the current lack of knowledge of Republican populations in Rome and the possibility of comparing individuals from the two historical time periods. However, the small number of burials from the two earlier phases and the poor preservation of the skeletons prevented thorough analysis of these individuals.

Additionally, there are no similar publications of Republican cemeteries that can furnish comparanda on demographics, pathology, diet, or immigration. There is a distinct need for bioarchaeological studies of Republican-period cemeteries, although a large hurdle is the fact that cremation was the popular burial rite in this time period. This appendix presents the basic demographic data collected in the field and the results of the stable isotope analyses, which were undertaken on a small sample of the Republican burials. It is my hope that future studies will help clarify the data on diet and migration that the individuals from Republican-period Castellaccio Europarco have furnished.

B.1 Preservation and Pathologies

The available skeletal material was found in various states of preservation, but the bones from the Republican time periods were more poorly preserved than those from the Imperial period. The cemetery at Castellaccio Europarco was found near a tributary of the Tiber River, and many burials were made near a retaining wall (chapter 4). As such, the combination of water, sediments, and ancient mortar created rock-hard concretions on numerous skeletons that made it impossible to separate and study the bones (see figure B.1).

Figure B.1: Norma Lateralis View of the Skull of ET62

Most individuals therefore could not be assessed for even gross pathological conditions such as porotic hyperostosis, periostitis, osteoarthritis, and fractures because the concretions obscured the periosteum and articulation sites. Although pathologies were recorded when noticed, it is impossible to interpret their incidence with respect to the population because so few individuals could be assessed for pathological conditions. Pathologies are therefore not reported here for individuals from the Republican phases.

B.2 Demographics

In Phase 1, an early Republican time period (4th-3rd century BC), there were 17 individuals for study. In Phase 2, a late Republican/early Imperial time period (2nd-1st century BC), there were 11 individuals for study. Table B.1 presents the Republican period individuals broken down by age, table B.2 presents the adults broken down by sex, and figure B.2 presents the data in an age-at-death histogram. There are clearly too few individuals in Phases 1 and 2 to assume that this is a representative sample or to draw conclusions about the demographic structure of the population.

	Ph 1 #	Ph 1 %	Ph 2 #	Ph 2 %	Total #	Total %
fetal	2	11.8	-	-	2	7.1
0-5	3	17.6	3	27.3	6	21.4
6-10	1	5.9	-	-	1	3.7
11-15	2	11.8	1	9.1	3	10.7
16-20	-	-	-	-	-	-
21-30	-	-	-	-	-	-
31-40	4	23.5	5	45.4	9	32.1
41-50	3	17.6	2	18.2	5	17.9
51-60	-	-	-	-	-	-
61-70	-	-	-	-	-	-
Adult	2	11.8	-	-	2	7.1
Total	17	100%	11	100%	28	100%

Table B.1: Age at Death of the Castellaccio Europarco Population, Early Periods

	Ph 1 M	Ph 1 F	Ph 2 M	Ph 2 F	Total M	Total F
16-20	-	-	-	-	-	-
21-30	-	-	-	-	-	-
31-40	3	1	2	2	5	3
41-50	2	1	1	1	3	2
51-60	-	-	-	-	-	-
61-70	-	-	-	-	-	-
Adult	-	-	-	-	-	-
Total	5	2	3	3	8	5
Sex Ratio	71.4%	28.6%	50%	50%	61.5%	38.5%

Table B.2: Sex of Castellaccio Adults and Age at Death

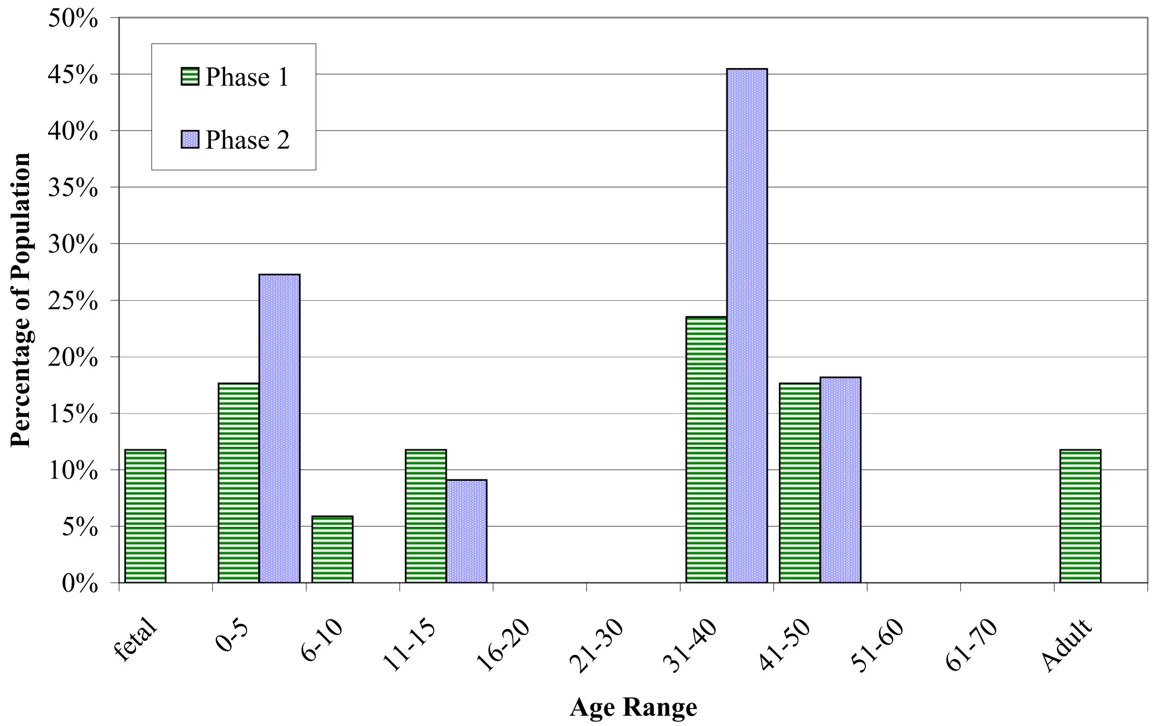


Figure B.2: Demography of Castellaccio Europarco Early Phases

	Male (n=7)	Female (n=4)
Phase 1	167.1	151.1
Phase 2	163.8	153.7

Table B.3: Average Height (in cm) of Castellaccio Population by Sex

Table B.3 presents the average height of the adults from the Republican phases of Castellaccio Europarco. In Phase 1, there were only five males and two females who presented long bones sufficient for stature estimation; thus, the average height of females in particular from this phase could be skewed from the lack of data. In Phase 2, there were two males and two females whose height could be estimated, and these average height estimates are similarly skewed. No conclusions about changes in height through time at Castellaccio Europarco can thus be drawn from this small data set.

Skeleton	Phase	Age	Sex	δ^{13}C ‰ VPDB	δ^{15}N ‰ AIR	C:N	% Yield	$\delta^{13}C_{ap}$ (bone)	$\Delta^{13}C_{ap-co}$ (bone)	$\delta^{13}C_{ap}$ (enamel)	$\Delta^{13}C_{ap}$ (bone-enamel)
ET93[1]	1	6-10	I	—	—	—	—	-9.8	—	-13.21	3.41
ET82	1	31-40	M	-17.9	9.9	3.2	1.3	-9.2	8.7	-7.36	-1.84
ET85	1	41-50	F	-19.8	8.6	3.2	0.6	-10.1	9.7	-12.26	2.16
ET70	2	41-50	F	-19.1	9.4	3.3	2.1	-10.4	8.7	-11.81	1.41

[1] = No collagen yield. All delta values are reported in permil.

Table B.4: Castellaccio Europarco Early Phases δ^{13}C and δ^{15}N Results

B.3 Dietary Analysis

Of the 28 individuals excavated from earlier phases at Castellaccio Europarco, only five from Phase 1 and one from Phase 2 possessed a first molar that could be tested for strontium. Four of these individuals were additionally subjected to oxygen isotope analysis to estimate place of origin, as well as carbon and nitrogen isotope analysis to reconstruct the ancient diet. In Phase 1, three individuals were chosen, two adults and one subadult. Unfortunately, the subadult yielded no bone collagen for analysis; $\delta^{13}C_{ap}$ was measured from bone and enamel for this individual, however. In Phase 2, only one individual was subjected to carbon and nitrogen isotope analysis. These four individuals likely do not constitute a representative sample of the populations from their respective time periods. As such, their individual diets can be interpreted in broad terms, but a lack of contemporaneous data means it is impossible to situate these early Romans within a social context.

Table B.4 presents the data obtained from carbon and nitrogen isotope analysis of bone and teeth, and figure B.3 is a scatterplot of the three individuals for whom both δ^{13}C and δ^{15}N values were obtained. All three individuals fall within the carbon and nitrogen isotope ranges presented by the Imperial individuals (see figure 6.2). The calculated $\Delta^{13}C_{ap-co}$ values are between a monoisotopic diet and one that included a significant amount of C_4 plants, and all of them cluster with the Imperial Castellaccio Europarco data (see figure 6.3). Individuals from earlier time periods in this area thus likely consumed a diet of C_3 plants and herbivore meat, with contributions from marine resources and C_4 foods. For the most part, the $\delta^{13}C_{ap}$ values from Republican individuals increase significantly from childhood to adult diet, similar to the increase seen in Imperial era individuals. Only ET82 has the reverse pattern; however, this individual was most likely an immigrant to Rome, as shown by the strontium and oxygen data below.

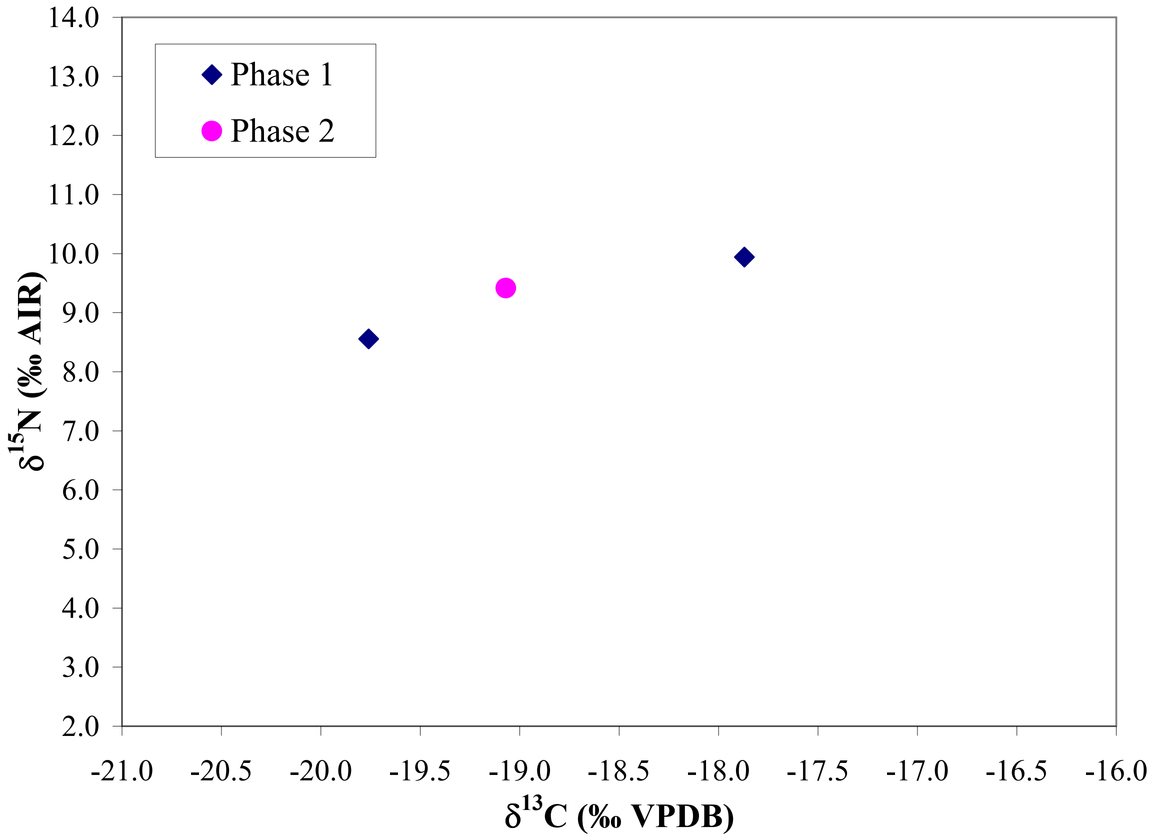


Figure B.3: δ^{13}C and δ^{15}N - Castellaccio Europarco Early Phases

Although there are few data points, a cautious interpretation of the dietary data from Republican period Castellaccio Europarco indicates a similar diet to the one enjoyed by Imperial period individuals, namely one composed primarily of C_3 grains and terrestrial meat with a very minor marine contribution but significant C_4 resource consumption in the adult diet.

B.4 Migration in Republican Times

Results of the strontium and oxygen isotope analyses of Phase 1 and 2 individuals are presented in table B.5. A graphical representation of the calculated local range of strontium and oxygen can be found in figure B.4. The Republican population at Castellaccio Europarco thus includes one individual (ET82) whose strontium ratio, 0.707175, is unlike the other individuals in those time periods. Further, individuals ET85 and ET70 have anomalous δ^{18}O measurements compared to the range established in chapter 9.

Skeleton	Phase	Age	Sex	^{87}Sr/^{86}Sr Ratio	Sr ppm	δ^{18}O ‰ VSMOW
ET93	1	6-10	I	0.709838	329	26.20
ET82	1	31-40	M	0.707175	—	25.78
ET79	1	31-40	M	0.710076	—	—
ET98	1	31-40	PM	0.709977	—	—
ET85	1	41-50	F	0.709523	—	27.51
ET70	2	41-50	F	0.710127	—	27.46

Table B.5: ^{87}Sr/^{86}Sr and δ^{18}O of Republican Burials from Castellaccio Europarco

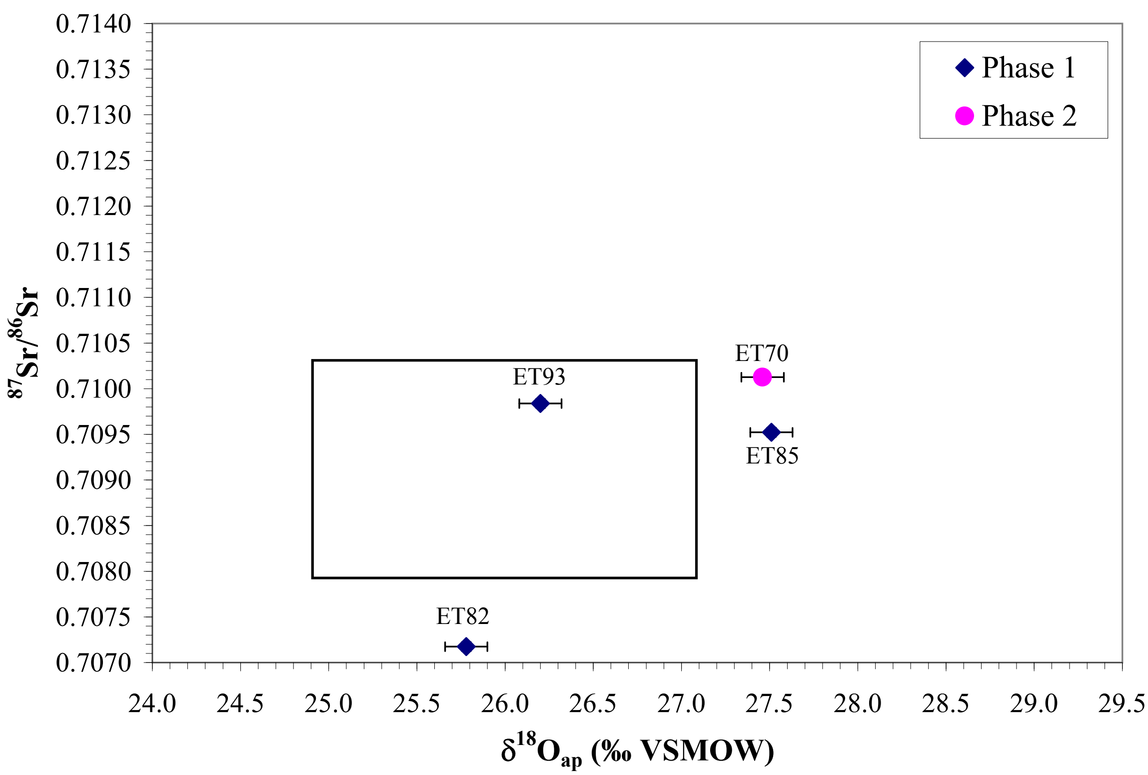


Figure B.4: Republican Strontium and Oxygen Ratios

The low strontium value of ET82's enamel indicates he was born and raised in an area with younger rock. A conservative approximation of his homeland would therefore be a volcanic area of Italy south of Rome: Naples or Sicily. As both of these areas are coastal, their expected δ^{18}O values mirror Rome's. ET82 could therefore be a long-distance immigrant to Rome from another coastal area with similar oxygen value to Rome. ET85 from Phase 1 and ET70 from Phase 2 present δ^{18}O values higher than the city of Rome but strontium ratios that could be local. Several people with similar strontium and oxygen values were interpreted in chapter 10 as possibly having come from the area of Greece, Cyprus, or Asia Minor. Only four individuals out of the total population of 28 dating to the Republican period of Castellaccio Europarco, however, could be tested for strontium and oxygen, so it is unclear whether or not they are representative of the rest of the population.

B.5 Discussion

The lack of published bioarchaeological data from Republican Italy makes assessing the early burials from Castellaccio Europarco impossible from a comparative perspective. Additionally, only a few individuals were tested for all isotopes, and the bioavailability of strontium in the suburbium during the Republican period is unclear. Nevertheless, the middle-aged male ET82 was an immigrant to Rome based on an extremely low strontium value and enriched δ^{13}C value. The decrease in $\delta^{13}C_{ap}$ from enamel to bone in ET82 is in contrast with the local $\Delta^{13}C_{ap}$ values from the three other Republican-era individuals who were tested for diet. Like Imperial individuals, the majority of the Republican $\delta^{13}C_{ap}$ values increase from childhood to adult diet. ET82, however, fits the dietary pattern of immigrants to Imperial Castellaccio Europarco: following a childhood diet with C_4 plants in it, his adult diet is less enriched and matches others from the site. ET82's oxygen value is not anomalous for Rome, but oxygen cannot distinguish among people from the Tyrrhenian coast. Conservatively, ET82 is from a volcanic, coastal area south of Rome, perhaps Naples or Sicily. Thus, as early as the 4th-3rd century BC, there is evidence to support the presence of nonlocal lower-class individuals in the Roman *suburbium*.

B.6 Conclusions

The few and poorly preserved human skeletal remains from the Republican phases of Castellaccio Europarco are difficult to interpret with a lack of comparative bioarchaeological data. Additionally, the popularity of cremation as a burial rite in this period means that large skeletal populations might never be found. The isotope analyses undertaken on a few individuals from pre-Imperial time periods are thus extremely important lines of evidence in reconstructing daily life in Republican Rome. Although the representativeness of the cemetery population is currently unclear, preliminary analysis of a couple dozen individuals indicates that immigration to Rome began much earlier than the Imperial period and that the average Roman diet did not change significantly over the centuries. Further analysis of other individuals from these early time periods, from periurban, suburban, and rural contexts, would constitute significant progress towards our understanding of the lower classes of Republican Rome. Finally, as Italy was inundated with foreign slaves at this point in history, particularly following wars abroad, the discovery of nonlocals at Rome and the characterization of their lives could help advance the archaeological study of slavery in the Republican period.

Appendix C

Morphometric Analyses

Because of the lack of precise information on both the structure of immigration and the demographics of the Roman people and because of the condition of the skeletal remains provided for analysis, it is necessary to start with a model-free statistical approach to characterize the population of Imperial Rome. Nonmetric cranial analysis was undertaken in this project not only as a way to understand population differences in the Imperial period but also as an exploratory statistical analysis for identifying possible immigrants. In this chapter, the nonmetric data analyzed by the mean measure of divergence statistic reveal differences between time periods and similarities between the sexes, anomalous individuals from Casal Bertone and Castellaccio Europarco are identified using Gower's general similarity coefficient, and the results of inter- and intra-population differences are discussed.

Although it is impossible to directly ask an archaeological population if they lived in Rome or elsewhere, analyzing various teeth and bones for strontium and oxygen isotopes and concentrations can provide us a general answer. These methods, however, can be costly, and many researchers test only a sample of the population at hand. Metric and nonmetric analyses of population dynamics are an ideal place to start data exploration when framing questions about migration and mobility in the past.

C.1 Model-Bound and Model-Free Approaches

Because of bioarchaeology's origin as a population-based approach, biological variation in archaeological samples has generally been investigated at the group level (Larsen, 1997).

Models of differences or comparisons were created to understand genetic variation among groups, arrive at an overall assessment of population structure, reconstruct population origins, quantify gene flow, and identify long-distance migration (Relethford and Lees, 1982; Buikstra et al., 1990; Larsen, 1997). Data gathered from skulls and teeth can be used to understand patterns within a group and between individuals, meaning biological distance can be assessed at multiple scales (Stojanowski and Schillaci, 2006).

With the legacy of native son Luigi Luca Cavalli-Sforza (Cavalli-Sforza, 1974; Cavalli-Sforza and Feldman, 1981; Cavalli-Sforza et al., 1988, 1993), Italian scholarship on population movement in Italy in the last two decades has dealt with understanding how the Romans interacted with the Etruscans, how disparate groups came together to form the Roman Republic, and how people interacted prior to urbanization in the Empire (Piazza et al., 1988; Moggi-Cecchi et al., 1997; Vernesi et al., 2004; Rubini et al., 2007; Coppa et al., 2007). These studies were largely done with model-bound methods in which parameters such as gene flow and genetic drift were investigated using quantitative traits. In model-bound approaches, cranial measurements are considered a proxy for genetic data, where the phenotypic appearance of the cranium is thought to be directly related to the frequency of inherited alleles. The difficulty with using a model-bound approach, however, is that a large number of relatively complete elements from both males and females are required in order to compare the expected and observed genetic makeup of the population of a region. Model-free methods of understanding biological distance, on the other hand, are often more suitable to archaeological data. Using multivariate statistics can uncover between-group and individual patterning in cranial and dental metric data as well as cranial and dental nonmetric data. In this view, populations are mosaics of individuals, and the nature of the difference between the populations is studied (Howells, 1973, p. 4).

C.2 Methods

C.2.1 Metric Analysis

Variation in size and morphology of the skeleton is related to genes but also to environmental factors, such as use of the jaws in masticatory functions (Larsen, 1997). Because many aspects of metric variation are both selectively neutral and heritable, analysis of metric traits provides an indirect means of understanding genetic variation within and between populations (Pietrusewsky, 2008). Metric measurements can only be taken when a bone is complete and should not be taken on reconstructed bones.

Generally, biodistance studies that use metric traits are performed with either cranial or dental data, with the goal of modeling gene flow between two populations. The statistics most commonly used for both categories of data are Mahalanobis' D^2 distance and Relethford and Blangero's **R** matrix, both of which can be easily visualized using cluster graphing.[1] Both D^2 and **R** are generally used to compare two or more populations, to answer questions posed at the inter-population or inter-community levels. For questions of intra-populational biodistance, principal components or factor analysis can be used. These methods identify underlying patterns within a sample, creating new axes of variation. Individuals can then be plotted on the new axes (Pietrusewsky, 2008).

Metric cranial and dental analyses are rarely used in asking questions about migration in the ancient world, although examples can be found in research in the Americas and the Pacific (Steadman, 2001; Sutter and Verano, 2007; Schillaci and Stojanowski, 2005; Pietrusewsky, 2006, 2008). Hemphill (1999) published a craniometric study of Bactrians from the Bronze Age that used the D^2 statistic, Zakrzewski (2007) used this statistic to look at craniometric variation across time periods in Egypt, and D'Amore and colleagues (2009) used a variety of multivariate techniques to study Late Pleistocene groups in Sicily. In terms of dental metrics

[1] Most standard statistical packages will calculate D^2, but for a more thorough explanation of the statistic and its application to biodistance studies, see Pietrusewsky 2008. For the **R** matrix technique, see Relethford and Blangero 1990.

in the ancient world, Nathan Harper (2008) is currently using **R** matrix analysis of dental metrics from Late Bronze Age Cypriot populations to investigate population movement. Finally, Michele Buzon (2006) carried out a principal components analysis of cranial measurements from a population from New Kingdom Nubia. Buzon was able to separate the population into distinct groups of Nubians and Egyptian immigrants.

Craniometric analysis of the skeletons from Casal Bertone and Castellaccio Europarco was not possible, however, because of the state of preservation and the underrepresentation of adult females at both sites. In addition, dental metrics were only recorded on two dimensions of M1s and M3s that were selected for chemical analysis, thus precluding their use in metric analysis. Investigating migration in Imperial Rome necessitates using a model-free approach, to which nonmetric data are better suited.

C.2.2 Nonmetric Analysis

Traits that cannot be measured linearly on the skull, teeth, or postcranium are known as nonmetric, discrete, discontinuous, or epigenetic traits. These are minor variants of the bone or tooth that are passed on genetically (Buikstra and Ubelaker, 1994; Larsen, 1997). The strength of nonmetric traits is that they can be recorded on incomplete skeletal remains.

The most common statistic for analyzing nonmetric traits for biological distance is C.A.B. Smith's mean measure of divergence (MMD) statistic, although Mahalanobis' D^2 is also frequently used. MMD and D^2 statistics are reported in a matrix when two or more groups are compared, and this matrix can be visually represented using cluster analysis or multidimensional scaling graphs. Other methods of assessing variation on an intra-cemetery level using nonmetric traits include: calculating frequencies of anomalous traits, with the idea that individuals who share similar traits are more likely to be related (Sjøvold, 1976); mapping trait frequencies onto a plan of a cemetery to find groups of individuals who share similar traits (Česnys and Tutkuvienė, 2007); and calculating a matrix of Gower similarity coefficients to identify anomalous individuals (Stojanowski and Schillaci, 2006).[2]

Two nonmetric trait analyses have recently been published from Italy, one using cranial traits and one using dental traits. Rubini and coworkers (2007) examined ten cranial series from central Italy dating from the 9th-5th centuries BC. Using the MMD, they found little evidence of population interaction. The groups clustered based on geography, with the coastal groups being distinct from the inland groups, indicating the possibility that the Apennine Mountains were a barrier to gene flow in the 1st millennium BC. Coppa and colleagues (2007) performed a nonmetric dental analysis of groups from different time periods and discovered that there was likely to have been significant gene flow during the Neolithic. Nonmetric analysis is thus being used in ancient Italy to investigate large-scale population movement largely in prehistoric periods.

Smith's Mean Measure of Divergence

C.A.B. Smith's mean measure of divergence (MMD) (Smith, 1972) is calculated by adding the squared differences between variables of two populations. When two populations are different, we would expect a large MMD value, and when they are similar, a smaller MMD value would result. This dissimilarity between populations is what is termed "biological distance," referring to Euclidean distance. Smith's MMD includes an angular transformation for trait frequencies for each population, which helps prevent sampling error from distorting the biodistance statistic. It is also necessary to correct for the small sample sizes that are often found in archaeological populations (Green and Suchey, 1976) by using the statistical transformation of Freeman and Tukey (1950).

---

[2]Whereas researchers who use metric analysis tend to be more conservative in their choice of statistical methods for analysis, researchers who work with nonmetric traits seem to be using a wider variety of statistics and asking a wider variety of questions. There are debates on either side about how heritable both metric and nonmetric cranial and dental traits are, and it is interesting that metric evidence is more often used in model-bound approaches whereas nonmetric data are used in model-free approaches (Stojanowski and Schillaci, 2006; Pietrusewsky, 2008; Relethford and Lees, 1982).

The MMD statistic used in this study is as follows:

$$MMD = \frac{\sum_{i=1}^{r}(\Theta_{1i} - \Theta_{2i})^2 - \left(\frac{1}{n_{1i}+\frac{1}{2}} + \frac{1}{n_{2i}+\frac{1}{2}}\right)}{r}$$

in which *r* is the number of traits used, Θ_{1i} and Θ_{2i} are the transformed frequencies in radians of the i^{th} trait in the comparison groups, and n_{1i} and n_{2i} are the numbers of individuals who are scored for the i^{th} trait in the group.

Freeman and Tukey's angular transformation is as follows:

$$\Theta = \frac{1}{2}\sin^{-1}\left(1 - \frac{2k}{n+1}\right) + \frac{1}{2}\sin^{-1}\left(1 - \frac{2(k+1)}{n+1}\right)$$

in which *k* is the number of individuals scored as "yes," and *n* is the total number of individuals scored in the population (i.e., scored as either "yes" or "no").

Finally, the variance and standard deviation of the MMD are calculated using the following formulae based on Sofaer (1986):

$$Var_{MMD} = \frac{2}{r^2}\sum_{i=1}^{r}\left[\frac{1}{n_{1i}+\frac{1}{2}} + \frac{1}{n_{2i}+\frac{1}{2}}\right]^2$$

$$sd_{MMD} = \sqrt{Var_{MMD}}$$

When the MMD is equal to or greater than twice the amount of the standard deviation, the value is significant at the $p \leq 0.05$ level (Sjøvold, 1977). Negative MMD values result from closely associated groups or too small a sample size (Turner and Bird, 1981). However, a significant MMD could be the result of random genetic drift over time in the same population rather than an indication of two different populations (Grüneberg, 1952, 1963).

The mean measure of divergence statistic can thus be used on nonmetric cranial data to produce a measure of how different one population is from another based on the pooled data of heritable traits. Although this statistic cannot identify individual immigrants, it helps to show the broad differences seen in the Casal Bertone and Castellaccio Europarco populations.

Gower's General Similarity Coefficient

Gower's general similarity coefficient, on the other hand, can be used to investigate intra-populational differences because it can compare two matrices of data. This statistic is defined as per Gower (1971):

$$s_{ij} = \frac{\sum_k w_{ijk} s_{ijk}}{\sum_k w_{ijk}}$$

in which s_{ij} compares the cases i and j, s_{ijk} indicates the contribution provided by the kth variable, and w_{ijk} is either zero or one depending on whether the comparison is valid for the kth variable. Many statistical software packages can quickly and easily compute this coefficient from user-provided data.

In the case of nonmetric traits, Gower's general similarity coefficient creates a matrix comparing the number of traits that two individuals both have, the number of traits they both lack, and the number of traits that one has but the other one does not. The coefficient derived from this two-by-two association table based on the formula given above is therefore an objective measure of how similar two individuals are with respect to their nonmetric cranial traits.

Similar to the MMD, Gower's general similarity coefficient can then be visualized in a cluster graph, where individuals who are more similar will cluster earlier than they will with individuals who are different. This statistic therefore has the potential to identify anomalous individuals within a population, provided those individuals have a strikingly different suite of nonmetric cranial traits than the remainder of the population. The morphometric methods used in this analysis, Smith's MMD and Gower's general similarity coefficient, can thus provide evidence of broad similarities and differences within and between the populations buried at Casal Bertone and Castellaccio Europarco based on heritable variation in adult crania.

C.3 Sample Demographics

For this analysis, nonmetric traits were recorded from any adult skeleton that presented a portion of the cranium. Out of the 217 individuals from all phases of the two sites, 69 adults from Casal Bertone and 35 adults from Castellaccio Europarco presented enough cranial remains to be assessed for at least one nonmetric trait. The list of traits selected can be found in table C.1 along with the recorded nonmetric cranial data. These traits can be characterized mostly as sutures, ossicles, and foramina and were selected based on descriptions of nonmetric traits from Berry and Berry (1967), Ossenberg (1976), Molto (1983), and Buikstra and Ubelaker (1994). Traits to be examined were also selected based on ease of recording and completeness of description in nonmetric trait literature. For a full explanation of the method and theory behind nonmetric trait analysis, particularly the use of the mean measure of divergence statistic, see Killgrove (2002, 2009).

Cranial nonmetrics can only be assessed on adults, as subadult crania have not finished growing. Most of the skeletons studied from Casal Bertone and Castellaccio Europarco were incomplete, and many bones were fragmented. Unlike metric analysis, nonmetric analysis can be undertaken on incomplete, fractured, and commingled remains. The demographics of the populations assessed for nonmetric traits can be seen in table C.2. Every adult individual for whom at least one nonmetric trait could be scored is included in the analyses presented below.

A range of nonmetric cranial traits was investigated, as noted in table C.1. Standard data reduction techniques were employed to eliminate rare traits with low incidences in pairwise population comparisons. Sjøvold (1977) suggests that removing traits with no significant differences eliminates background noise that can confound biodistance analysis. Of the 26 traits studied, 3 were removed from further analysis because of their zero frequency in both populations: coronal ossicle, bregmatic ossicle, and os inca. Included in the table are the number of individuals with the trait expressed, the number of individuals examined, and the percentage present.

Trait	CE Early	CE Imp	CB Nec	CB Maus
1 - Metopic suture present[1]	2/10 (20.0)	0/17 (0.0)	1/27 (3.7)	0/16 (0.0)
2 - Supraorbital foramen[1]	3/9 (33.3)	2/16 (12.5)	9/23 (39.1)	6/17 (35.3)
3 - Supraorbital notch[1]	6/9 (66.7)	13/16 (81.2)	20/26 (76.9)	11/17 (64.7)
4 - Infraorbital suture[3]	4/5 (80.0)	2/9 (22.2)	5/14 (35.7)	2/15 (13.3)
5 - Multiple infraorbital foramina[2]	1/5 (20.0)	0/9 (0.0)	0/16 (0.0)	0/16 (0.0)
6 - Zygomaticofacial foramina[2]	0/8 (0.0)	4/17 (23.5)	11/33 (33.3)	4/16 (25.0)
7 - Os japonicum present[2]	0/8 (0.0)	1/17 (5.9)	0/30 (0.0)	0/15 (0.0)
8 - Parietal foramen[1]	1/7 (14.3)	7/19 (36.8)	10/16 (62.5)	7/13 (53.8)
9 - Coronal ossicle[1]	—	—	—	—
10 - Bregmatic ossicle[1]	—	—	—	—
11 - Sagittal ossicle[2]	1/7 (14.3)	0/16 (0.0)	0/8 (0.0)	1/9 (11.1)
12 - Epipteric ossicle[1]	1/6 (16.7)	0/12 (0.0)	0/7 (0.0)	1/14 (7.1)
13 - Parietal notch ossicle[1]	1/10 (10.0)	1/19 (5.3)	2/13 (15.4)	1/13 (7.7)
14 - Occipitomastoid ossicle[3]	0/8 (0.0)	0/16 (0.0)	1/9 (11.1)	0/14 (0.0)
15 - Asterionic ossicle[1]	0/8 (0.0)	1/19 (5.3)	2/10 (20.0)	4/14 (28.6)
16 - Apical/Lambda ossicle[1]	1/8 (12.5)	1/18 (5.6)	0/16 (0.0)	2/14 (14.3)
17 - Lambdoidal suture ossicle[1]	1/7 (14.3)	6/18 (33.3)	6/14 (42.9)	8/13 (61.5)
18 - Os inca[2]	—	—	—	—
19 - Condylar facet double[1]	0/7 (0.0)	1/22 (4.5)	1/23 (4.3)	1/15 (6.7)
20 - Condylar canal present[4]	4/7 (57.1)	4/13 (30.8)	7/15 (46.7)	11/14 (78.6)
21 - Divided hypoglossal canal[1]	3/9 (33.3)	3/20 (15.0)	10/28 (35.7)	4/15 (26.7)
22 - Tympanic dihiscence[4]	1/10 (10.0)	0/20 (0.0)	0/23 (0.0)	0/14 (0.0)
23 - Mastoid foramen extrasutural[1]	0/9 (0.0)	5/16 (31.2)	7/13 (53.8)	4/14 (28.6)
24 - Mastoid foramen absent[1]	2/9 (22.2)	3/16 (18.8)	0/13 (0.0)	4/14 (28.6)
25 - Auditory exostosis present[4]	0/10 (0.0)	1/22 (4.5)	3/39 (7.7)	0/16 (0.0)
26 - Mental foramen multiple[2]	1/7 (14.3)	1/21 (4.8)	1/41 (2.4)	0/16 (0.0)

Table C.1: Nonmetric Trait List and Frequencies
Number with trait expressed / number of individuals present (%).
[1] = Berry and Berry 1967; [2] = Kennedy 1981;
[3] = Molto 1983; [4] = Buikstra and Ubelaker 1994

	CE 1	CE 2	CE 3	CB Nec	CB Maus	Totals
Male	4	2	18	36	10	70
Female	1	2	6	13	7	29
Unknown	-	1	1	2	1	5
Totals	5	5	25	51	18	104

Table C.2: Demographics of Individuals Assessed for Nonmetric Cranial Traits

C.4 Mean Measure of Divergence

Beginning at the inter-cemetery level, Smith's MMD statistic was used to quantify the biological distance among groups at Casal Bertone and Castellaccio Europarco. Few individuals from the earlier phases of Castellaccio Europarco were found, so for the purposes of this nonmetric analysis, the samples from the early (Republican) Phases 1 and 2 were combined. Table C.3 presents the results of an MMD among the two time periods of Castellaccio Europarco and the two burial contexts of Casal Bertone. The individuals from the earlier periods of Castellaccio Europarco are significantly different from the other three Imperial-period samples.[3]

	CE Early	CE Imp	CB Maus	CB Nec
CE Early	—	*0.163*	**0.256**	**0.399**
CE Imp	*1.824*	—	0.036	-0.031
CB Maus	**2.862**	0.613	—	0.077
CB Nec	**3.717**	-0.503	1.225	—

Table C.3: MMD of Biodistance Data
Standardized MMDs are below the diagonal, MMDs above.
Figures in bold are significant at the $p \leq 0.05$ level.
Figures in italics are significant at the $p \leq 0.10$ level.

At the intra-cemetery level, two more MMDs were calculated based on current thought

[3]For this and for other reasons (see chapter 4), data on the individuals from earlier phases at Castellaccio Europarco are presented separately, in appendix B.

about migration in the Empire. It is assumed that males migrated more frequently than females based on epigraphical evidence and the types of work that could be found at Rome (Noy, 2000, p. 60-1), so MMDs were calculated for males versus females at Casal Bertone and at Castellaccio Europarco. At Casal Bertone, the MMD between the sexes is 0.021, with a standard deviation of 0.08, meaning this result is not statistically significant. At Castellaccio Europarco, the MMD between males and females is -0.040, with a standard deviation of 0.06. This result is also statistically insignificant, and the negative value of the MMD indicates these two populations are very similar. Neither site therefore provided any evidence that might indicate an influx of nonlocals of one sex, such as in exogamous marriage patterns.

C.5 Gower's General Similarity Coefficient

The other statistic used on the nonmetric cranial data was Gower's general similarity coefficient, which compares the suite of nonmetric traits for each individual with that of another individual, providing a matrix of similarities that can be graphed using cluster analysis.

Three out of the 18 adults studied from the Casal Bertone mausoleum (figure C.1) are relatively dissimilar from the remainder of the individuals: F1C, F3A, and F3B. F3A and F3B were buried in the same place, loculus 3 of the mausoleum, and F1C was the third individual buried in loculus 1. In general, multiple burials in one loculus of a mausoleum are thought to represent a family grouping. It is therefore interesting that other individuals from loculi 1 and 3 do not cluster with these outliers, and that F3C and F1D are themselves quite similar. F3A and F3B, however, did not present teeth to be analyzed with strontium or oxygen isotope analysis, and they are very incomplete skeletons (0-25% complete). Whereas F1C could be identified as a female around 51-60 years old, both F3A and F3B could only be aged as middle-aged and older adults, with F3A being a probable male.

Figure C.2 is the cluster diagram of the Gower coefficient of the Casal Bertone necropolis. One group of six individuals clusters much later than the rest of the individuals and are thus

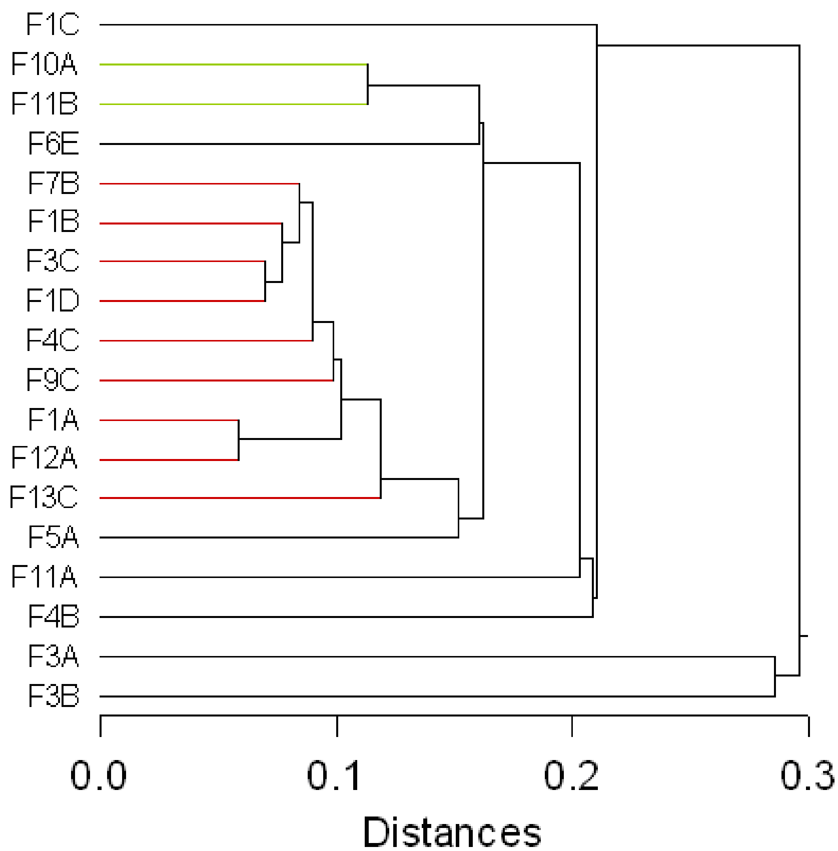


Figure C.1: Casal Bertone Mausoleum - Gower Similarity Coefficient

most dissimilar to the others: T48, T77, T30, T37, T10, and T83B. Unlike the mausoleum samples, the individuals identified as anomalous from the necropolis context of Casal Bertone represent a variety of adult age ranges and both sexes. All skeletons were at least 50% complete, but individuals T30 and T37 could only be scored for 6 and 5 nonmetric cranial traits, respectively. Issues of taphonomy likely affected the results of the Gower coefficient and subsequent cluster graph. Had all the crania in the necropolis been complete, it is likely that the Gower statistic would have produced very different results.

At Imperial Castellaccio Europarco, the Gower statistic identified four individuals that cluster late with the rest of the population (figure C.3): ET69, ET27, ET72, and ET43. All of these skeletons were at least 75% complete, and every nonmetric trait could be scored on the crania from ET27, ET43, and ET69. In the Imperial phase of this site, taphonomy was not likely an

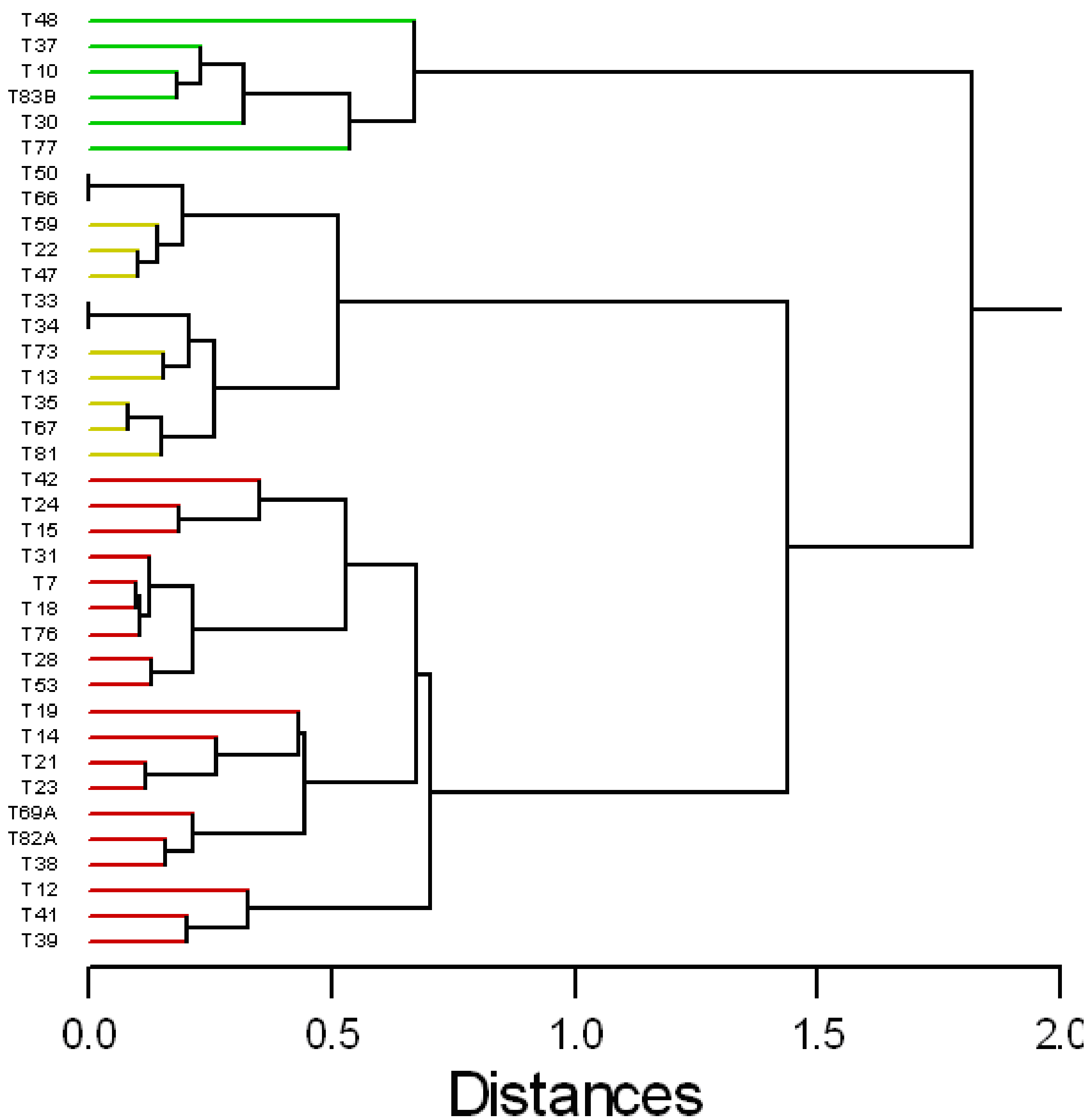


Figure C.2: Casal Bertone Necropolis - Gower Similarity Coefficient

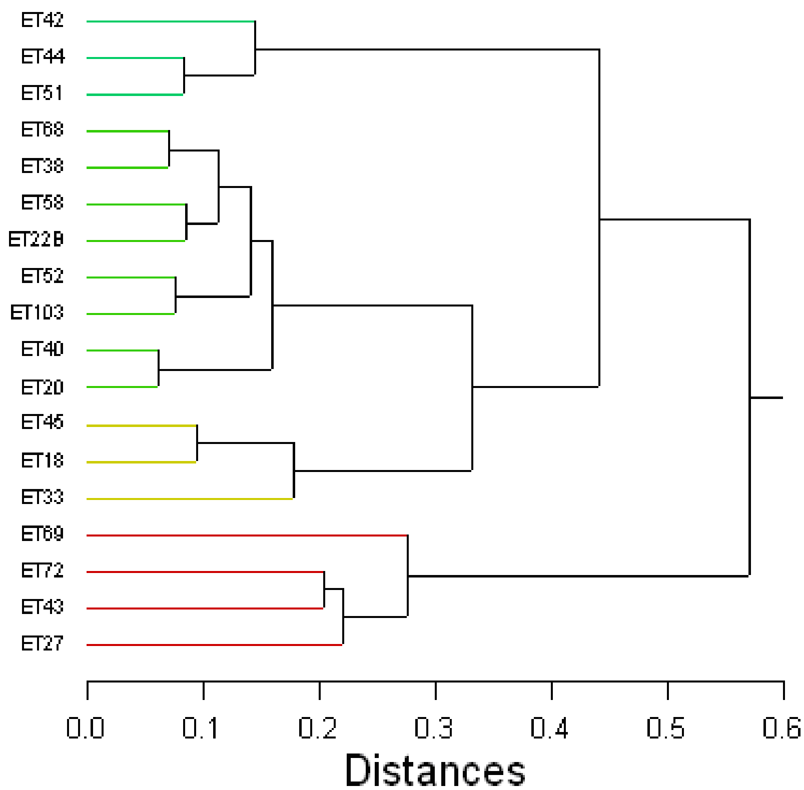


Figure C.3: Castellaccio Europarco - Gower Similarity Coefficient

issue that affected the Gower statistic. Only males are represented in the anomalous cluster, which might lend support to a hypothesis that more males than females migrated to Rome. There is a statistically significant underrepresentation of females at Castellaccio Europarco (see chapter 4, section 4.4.2), however, so conclusions about sex-related differences in migration practices cannot be based solely on this one nonmetric analysis.

At both Casal Bertone and Castellaccio Europarco, there appears to be no strong pattern (e.g., age, sex, preservation) to the individuals identified as different by the Gower coefficient. Males are represented far more often than females, but both sites have a skewed sex ratio. The Gower statistic has no explanatory power, however, so the differences seen in the nonmetric trait data could be related to taphonomy or to a number of variables affecting skeletal remains, from growth and development to diet and disease.

C.6 Discussion

The main goals of this project are to isolate individuals who likely immigrated to Rome, figure out where they emigrated from, and characterize their lives in the Imperial capital. Nonmetric trait analysis furthers these goals by indicating which skeletons are statistically dissimilar from the rest. Because the structure of the Roman population and, particularly, of immigration to Rome is unknown, model-bound approaches in which hypotheses are tested are inappropriate for this study. The model-free approach of using cranial nonmetric traits as the data set for the mean measure of divergence statistic and Gower's general similarity coefficient allows for broad generalizations about the two study populations and about individuals whose suite of nonmetric traits is anomalous.

Dozens of nonmetric traits were scored as a routine part of data collection in order to understand in broad terms the composition of the population at the two sites. Biodistance analysis using Smith's MMD showed that the people from the earlier phases of Castellaccio Europarco were significantly different than those from the Imperial phases of both sites. This finding could be spurious as a result of small sample size, as the combined Republican sample from Castellaccio Europarco totaled only 10 individuals. However, most of these individuals presented crania that could be scored for nearly all nonmetric traits. It is not unreasonable to interpret this difference as related to an influx of new people, and thus new genes, at some point in the early Imperial period, as Rome became the seat of a huge Empire and the city's population grew quickly. Because of the small number of individuals from the earlier phases of Castellaccio Europarco and because of the chronological difference between them and the Imperial contexts of both sites, the earlier Republican individuals are discussed separately in appendix B. Nonmetric trait analysis further indicates that these individuals are not comparable to the Imperial populations studied in this project.

The Gower coefficient is very easy to calculate but difficult to interpret. It is up to the researcher to decide which individuals in which cluster represent anomalous individuals, and in this case the impossibility of scoring every cranium for every nonmetric trait complicates the measurement of the statistic. This coefficient, however, can possibly find anomalous individuals in a large pool of data. If a researcher is hindered by lack of funding for chemical analysis, using non-destructive methods such as the Gower similarity coefficient on nonmetric trait data is a way to pare down a population. Selecting a sample population for chemical analysis with reference to the Gower coefficient of nonmetric crania trait data maximizes the possibility of finding individuals with minimal destructive analysis.

C.7 Conclusions

Nonmetric cranial analysis is not the best method for identifying immigrants in the lower-class Roman populations in this study, as nonmetric traits are mostly used to ask inter-population questions of a population of pooled data. The one statistical method applicable for identifying anomalous individuals lacks explanatory power and therefore serves as a way to understand general trends within the populations. Destructive chemical analysis, in spite of drawbacks of its own, much more clearly delineates anomalous individuals in the Roman population than statistical analysis does. Identification of anomalous individuals at Rome using non-destructive analysis is thus best done through cranial and dental metrics, data sets that are not available in this project owing to the condition of remains of the individuals from Castellaccio Europarco and Casal Bertone. Chemical methods, however, remain the best way to uncover immigrants from these two populations. As the Archivio Antropologico osteological database of the Soprintendenza Archeologica di Roma (Catalano, 2001) grows through the contributions of Italian, French, and American bioarchaeologists who study Roman remains, it will become possible in the future to use both model-free and model-bound approaches to investigate population interaction.

Bibliography

Acsádi G, Nemeskéri J. 1970. History of human lifespan and mortality. Budapest: Akadémiai Kiadó.

Aicher P. 1995. Guide to the aqueducts of ancient Rome. Wauconda, IL: Bolchazy Carducci.

Alcock J. 2006. Food in the ancient world. Westport, CT: Greenwood Publishing Group.

Alföldy G. 1985. The social history of Rome. Totowa, NJ: Barnes & Noble Books.

Ambrose S. 1990. Preparation and characterization of bone and tooth collagen for isotopic analysis. Journal of Archaeological Science 17(4):431–451.

Ambrose S, Norr L. 1993. Experimental evidence for the relationship of the carbon isotope ratios of whole diet and dietary protein to those of bone collagen and carbonate. In: Lambert J, Grupe G, editors. Prehistoric human bone: archaeology at the molecular level. New York: Springer-Verlag. p 1–37.

American Academy of Pediatrics. 2005. Breastfeeding and the use of human milk. Pediatrics 115(2):496–506.

Amundsen D, Diers C. 1969. The age of menarche in Classical Greece and Rome. Human Biology 41(1):125–132.

Anderson B. 1983. Imagined communities. New York: Verson.

Anderson D, Thompson G, Popovich F. 1976. Age of attainment of mineralization stages of the permanent dentition. Journal of Forensic Sciences 21(1):191–200.

Andreau J. 1999. Banking and business in the Roman world. Cambridge: Cambridge University Press.

Angel J. 1966. Porotic hyperostosis, anemias, malarias, and marshes in the prehistoric eastern Mediterranean. Science 153:760–3.

Anthony D. 1990. Migration in archeology: the baby and the bathwater. American Anthropologist 92:895–914.

Anthony D. 1997. Prehistoric migration as social process. In: Chapman J, Hamerow H, editors. Migrations and invasions in archaeological explanation. Oxford: BAR International Series 664, Archaeopress. p 21–32.

Appadurai A. 1996. Modernity at large: cultural dimensions of globalization. Minneapolis: University of Minnesota Press.

Asch K. 2005. IGME 5000: 1:5 million international geological map of Europe and adjacent areas.

Ashby T. 1935. The aqueducts of Rome. Oxford: Clarendon Press.

Avanzinelli R, Elliott T, Tommasini S, Conticelli S. 2008. Constraints on the genesis of potassium-rich Italian volcanic rocks from U/Th disequilibrium. Journal of Petrology 49(2):195–223.

Baker B, Dupras T, Tocheri M. 2005. The osteology of infants and children. College Station, TX: Texas A&M University Press.

Barberi F, Borsi S, Ferrara G, Innocenti F. 1969. Strontium isotopic composition of some recent basic volcanites of the Southern Tyrrhenian Sea and Sicily Channel. Contributions to Mineralogy and Petrology 23(2):157–172.

Barbieri M, Masi U, Tolomeo L. 1979. Origin and distribution of strontium in the travertines from Latium (Central Italy). Chemical Geology 24:181–8.

Barbieri M, Morotti M. 2003. Hydrogeochemistry and strontium isotopes of spring and mineral waters from Monte Vulture volcano, Italy. Applied Geochemistry 18(1):117–125.

Barbieri M, Sappa G. 1997. Application of geochemical and isotopic analysis methods ($^{87}Sr/^{86}Sr$) in hydrogeological characterization of some springs in Simbruini Mountains (Italy). Proceedings of the International Symposium on Geology and Environment:77–81.

Barrow R. 1928. Slavery in the Roman empire. London: Methuen & Co. Ltd.

Basch L, Glick Schiller N, Szanton Blanc C. 1993. Nations unbound: transnational projects, global predicaments, and deterritorialized nation-states. New York: Gordon and Breach.

Basore J. 1928. Seneca's moral essays. Loeb Classical Library.

Beard B, Johnson C. 2000. Strontium isotope composition of skeletal material can determine the birth place and geographic mobility of humans and animals. Journal of Forensic Sciences 45(5):1049–1061.

Becker M. 1995. Cremations and fragmentary human skeletons from Pontecagnano (Salerno), Italy: new directions in research. Old World Archaeology Newsletter 18(3):26–35.

Bentley R. 2006. Strontium isotopes from the earth to the archaeological skeleton: a review. Journal of Archaeological Method and Theory 13(3):135–187.

Bentley R, Knipper C. 2005. Geographical patterns in biologically available strontium, carbon, and oxygen isotope signatures in prehistoric SW Germany. Archaeometry 47(3):629–644.

Bentley R, Pietrusewsky M, Douglas M, Atkinson T. 2005. Matrilocality during the prehistoric transition to agriculture in Thailand? Antiquity 79(306):865–882.

Bentley R, Price T, Stephan E. 2004. Determining the 'local' Sr-87/Sr-86 range for archaeological skeletons: a case study from Neolithic Europe. Journal of Archaeological Science 31:365–375.

Bentley R, Wahl J, Price T, Atkinson T. 2008. Isotopic signatures and hereditary traits: snapshot of a Neolithic community in Germany. Antiquity 82(316):290–304.

Berger S, Young N, Edberg S. 1989. Relationship between infectious diseases and human blood type. European Journal of Clinical Microbiology & Infectious Diseases 8(8):681–689.

Berry A, Berry R. 1967. Epigenetic variation in the human cranium. Journal of Anatomy 101(2):361–379.

Black R. 2001. Fifty years of refugee studies: from theory to policy. International Migration Review 35:57–78.

Blakey M, Leslie T, Reidy J. 1994. Frequency and chronological distribution of dental enamel hypoplasia in enslaved African Americans: a test of the weaning hypothesis. American Journal of Physical Anthropology 95:371–371.

Bodel J. 2000. Dealing with the dead. Undertakers, executioners and potter's fields in ancient Rome. In: Hope V, Marshall E, editors. Death and disease in the ancient city. New York: Routledge. p 128–151.

Boushell L, Kaku M, Mochida Y, Bagnell R, Yamauchi M. 2007. Immunohistochemical localization of matrixmetalloproteinase-2 in human coronal dentin. Archives of Oral Biology 53:109–116.

Bowen G, Revenaugh J. 2003. Interpolating the isotopic composition of modern meteoric precipitation. Water Resources Research 39(10):1299–1311.

Bowman A. 1998. Life and letters on the Roman frontier: Vindolanda and its people. New York: Routledge.

Bradley K. 1994. Slavery and society at Rome. Cambridge: Cambridge University Press.

Bradley M. 2002. "It all comes out in the wash": looking harder at the Roman fullonica. Journal of Roman Archaeology 15(1):20–44.

Braudel F. 1995. The Mediterranean and the Mediterranean world in the age of Philip II. Berkeley: University of California Press.

Brettell C. 2008. Theorizing migration in anthropology. In: Brettell C, Hollifield J, editors. Migration theory: talking across disciplines. New York: Routledge. p 113–160.

Brettell C, Hollifield J. 2008. Preface. In: Brettell C, Hollifield J, editors. Migration theory: talking across disciplines. New York: Routledge. p vii–viii.

Brooks S, Suchey J. 1990. Skeletal age determination based on the os pubis: a comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods. Human Evolution 5:227–238.

Brothwell D. 1988. Foodstuffs, cooking, and drugs. In: Grant M, Kitzinger R, editors. Civilization of the ancient Mediterranean. New York: Charles Scribner's Sons. p 247–61.

Brothwell D, Brothwell P. 1998. Food in antiquity: a survey of the diet of early peoples. Baltimore: Johns Hopkins University Press.

Bruegmann R. 2005. Sprawl: a compact history. Chicago: University of Chicago Press.

Brunt P. 1971. Italian manpower, 225 BC-14 AD. Oxford: Clarendon.

Bryant D, Koch P, Froelich P, Showers W, Genna B. 1996. Oxygen isotope partitioning between phosphate and carbonate in mammalian apatite. Geochimica et Cosmochimica Acta 60(24):5145–5148.

Buccellato A. 2007. L'antica via Laurentina: l'arteria e le infrastrutture. FASTI Online 88.

Buccellato A, Caldarini C, Catalano P, Musco S, Pantano W, Torri C, Zabotti F. 2008a. La nécropole de Collatina. Les Dossiers d'Archéologie 330:22–31.

Buccellato A, Catalano P, Arrighetti B, Caldarini C, Colonnelli G, Di Bernardini M, Minozzi S, et al. 2003. Il comprensorio della necropoli di via Basiliano (Roma): un'indagine multidisciplinare. Mélanges de l'École Française de Rome: Antiquité 115:311–376.

Buccellato A, Catalano P, Pantano W. 2008b. La site et la nécropole de Castellaccio. Les Dossiers d'Archéologie 330:14–19.

Budd P, Chenery C, Montgomery J, Evans J. 2003a. You are where you ate: isotopic analysis in the reconstruction of prehistoric residency. In: Parker Pearson M, editor. Food, culture and identity in the Neolithic and Early Bronze Age. British Archaeological Reports International Series 1117. p 69–78.

Budd P, Chenery C, Montgomery J, Evans J, Powlesland D. 2003b. Anglo-Saxon residential mobility at West Heslerton, North Yorkshire, UK from combined O- and Sr-isotope analysis. In: Holland G, Tanner S, editors. Plasma source mass spectrometry: applications and emerging technologies. Cambridge: Royal Society of Chemistry. p 198–208.

Budd P, Millard A, Chenery C, Lucy S, Roberts C. 2004. Investigating population movement by stable isotope analysis: a report from Britain. Antiquity:127–141.

Budd P, Montgomery J, Barreiro B, Thomas R. 2000. Differential diagenesis of strontium in archaeological human dental tissues. Applied Geochemistry 15(5):687–694.

Budd P, Montgomery J, Evans J, Chenery C. 2001. Combined Pb-, Sr- and O-isotope analysis of human dental tissue for the reconstruction of archaeological residential mobility. In: Holland G, Taylor S, editors. Plasma source mass spectrometry: the new millennium. Cambridge: Royal Society of Chemistry. p 311–323.

Buikstra J. 2006. Introduction: On to the 21st century. In: Buikstra J, Beck L, editors. Bioarchaeology: the contextual analysis of human remains. New York: Elsevier. p 347–358.

Buikstra J, Frankenberg S, Konigsberg L. 1990. Skeletal biological distance studies in American physical anthropology: recent trends. American Journal of Physical Anthropology 82:1–7.

Buikstra J, Ubelaker D. 1994. Standards for data collection from human skeletal remains: Proceedings of a seminar at the Field Museum of Natural History. Fayetteville, AR: Arkansas Archeological Survey.

Bulloch B, Schubert C, Brophy P, Johnson N, Reed M, Shapiro R. 2000. Cause and clinical characteristics of rib fractures in infants. Pediatrics 105(4):e48.

Burmeister S. 2000. Archaeology and migration. Current Anthropology 41(4):539–567.

Buzon M. 2006. Biological and ethnic identity in New Kingdom Nubia. Current Anthropology 47(4):683–695.

Buzon M, Bowen G. 2010. Oxygen and carbon isotope analysis of human tooth enamel from the New Kingdom site of Tombos in Nubia. Archaeometry (Early View).

Buzon M, Conlee C, Bowen G. 2010. Refining oxygen isotope analysis in the Nasca region of Peru: an investigation of water sources and archaeological samples. International Journal of Osteoarchaeology (Early View).

Buzon M, Simonetti A, Creaser R. 2007. Migration in the Nile Valley during the New Kingdom period: a preliminary strontium isotope study. Journal of Archaeological Science 34:1391–1401.

Calci C, Messineo G. 1989. Casal Bertone (circ. V). Bullettino della Commissione Archeologica Comunale di Roma 93:133–4.

Canci A, Nencioni L, Minozzi S, Catalano P, Caramella D, Fornaciari G. 2005. A case of healing spinal infection from classical Rome. International Journal of Osteoarchaeology 15(2):77–83.

Capo R, Stewart B, Chadwick O. 1998. Strontium isotopes as tracers of ecosystem processes: theory and methods. Geoderma 82:197–225.

Carafa P, Carandini A, Capanna M. 2005. Origin and development of the Roman landscape: the *Suburbium* experiment. In: Santillo Frizell B, Klynne A, editors. Roman villas around the urbs. Projects and Seminars, 2: Swedish Institute in Rome.

Carandini A. 1988. Schiavi in Italia. Roma: La Nuova Italia Scientifica.

Catalano P. 2001. Bioarcheologia. Archivio antropologico. In: Filippi F, editor. Archeologia e Giubileo. Gli interventi a Roma e nel Lazio nel Piano del Grande Giubileo del 2000. Napoli: Ministero per i Beni e le Attività Culturali, Ufficio Centrale per i Beni Archeologici, Architettonici, Artistici e Storici. p 123.

Catalano P. 2008. Les ensembles funéraires de l'époque impériale à Rome. Les Dossiers d'Archéologie 330:10–13.

Catalano P, Arrighetti B, Benedettini L, Caldarini C, Colonnelli G, Di Bernardini M, Di Giannantonio S, et al. 2001a. Vivere e morire a Roma tra il primo ed il terzo secolo. Mitteilungen des Deutschen Archäologischen Instituts, Römische Abteilung 108:355–363.

Catalano P, Minozzi S, Pantano W. 2001b. Le necropoli romane di età Imperiale: un contributo all'interpretazione del popolamento e della qualità della vita nell'antica Roma. In: Quilici L, Quilici Gigli S, editors. Urbanizzazione delle campagne nell'Italia antica. Roma: L'Erma di Bretschneider. p 127–137.

Cavalli-Sforza L. 1974. The genetics of human populations. Scientific American 231(3):80–89.

Cavalli-Sforza L, Feldman M. 1981. Cultural transmission and evolution: A quantitative approach. Princeton, NJ: Princeton University Press.

Cavalli-Sforza L, Menozzi P, Piazza A. 1993. The history and geography of human genes. Princeton, NJ: Princeton University Press.

Cavalli-Sforza L, Piazza A, Menozzi P, Mountain J. 1988. Reconstruction of human evolution: bringing together genetic, archaeological, and linguistic data. Proceedings of the National Academy of Sciences 85(16):6002–6006.

Česnys G, Tutkuvienė J. 2007. Topographical approach to kinship assessment within population according to discrete cranial traits: the 5th-6th cc. Plinkaigalis cemetery. Acta Medica Lituanica 14(1):7–16.

Chamberlain A. 2006. Demography in archaeology. Cambridge: Cambridge University Press.

Champlin E. 1982. The suburbium of Rome. American Journal of Ancient History 7(2):97–117.

Chenery C, Müldner G, Evans J, Eckardt H, Lewis M. 2010. Strontium and stable isotope evidence for diet and mobility in Roman Gloucester, UK. Journal of Archaeological Science 37:150–163.

Cookson S, Waldman R, Gushulak B, MacPherson D, Burkle F, Paquet C, Kliewer E, et al. 1998. Immigrant and refugee health. Emerging Infectious Diseases 4(3):427.

Cool H. 2006. Eating and drinking in Roman Britain. Cambridge: Cambridge University Press.

Coppa A, Cucina A, Lucci M, Mancinelli D, Vargiu R. 2007. Origins and spread of agriculture in Italy: a nonmetric dental analysis. American Journal of Physical Anthropology 133:918–930.

Cowgill G. 2004. Origins and development of urbanism: archaeological perspectives. Annual Review of Anthropology 33:525–49.

Craig H. 1961. Isotopic variations in meteoric waters. Science 133(3465):1702–1703.

Craig O, Biazzo M, O'Connell T, Garnsey P, Martinez-Labarga C, Lelli R, Salvadei L, et al. 2009. Stable isotopic evidence for diet at the Imperial Roman coastal site of Velia (1st and 2nd centuries AD) in southern Italy. American Journal of Physical Anthropology 139(4):572–583.

Crowe F, Sperduti A, O'Connell T, Craig O, Kirsanow K, Germoni P, Macchiarelli R, et al. 2010. Water-related occupations and diet in two Roman coastal communities (Italy, first to third century AD): Correlation between stable carbon and nitrogen isotope values and auricular exostosis prevalence. American Journal of Physical Anthropology (Early View).

Cruse A. 2004. Roman medicine. Stroud: Tempus Publishing.

Cucina A, Vargiu R, Mancinelli D, Ricci R, Santandrea E, Catalano P, Coppa A. 2006. The necropolis of Vallerano (Rome, 2nd-3rd century AD): an anthropological perspective on the ancient Romans in the *suburbium*. International Journal of Osteoarchaeology 16(2):104–117.

D'Alessandro W. 2006. Human fluorosis related to volcanic activity: a review. In: Kungolos A, Brebbia C, Samaras C, Popov V, editors. Environmental toxicology. Southampton: WIT Press. p 21–30.

Daux V, Lécuyer C, Adam F, Martineau F, Vimeux F. 2005. Oxygen isotope composition of human teeth and the record of climate changes in France (Lorraine) during the last 1700 years. Climatic Change 70(3):445–464.

Daux V, Lécuyer C, Héran M, Amiot R, Simon L, Fourel F, Martineau F, et al. 2008. Oxygen isotope fractionation between human phosphate and water revisited. Journal of Human Evolution 55(6):1138–1147.

de Ligt L. 1993. Fairs and markets in the Roman empire. Amsterdam: Gieben.

Droysen G. 1886. Allgemeiner historischer Handatlas in sechsundneunzig Karten mit erläuterndem Text. Bielefeld: Velhagen & Klasing.

Dupras T, Schwarcz H. 2001. Strangers in a strange land: stable isotope evidence for human migration in the Dakhleh Oasis, Egypt. Journal of Archaeological Science 28(11):1199–1208.

Dupras T, Schwarcz H, Fairgrieve S. 2001. Infant feeding and weaning practices in Roman Egypt. American Journal of Physical Anthropology 115(3):204–212.

Dyson S. 1988. Rise of complex societies in Italy: historical versus archaeological perspectives. In: Gibson D, Geselowitz M, editors. Tribe and polity in Late Prehistoric Europe. New York: Plenum Press. p 193–203.

Eckardt H. 2010. A long way from home: diaspora communities in Roman Britain. In: Eckardt H, editor. Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire. Journal of Roman Archaeology, Supplement 78.

Eckardt H, Chenery C, Booth P, Evans J, Lamb A, Müldner G. 2009. Oxygen and strontium isotope evidence for mobility in Roman Winchester. Journal of Archaeological Science 36(12):2816–2825.

Edwards C. 2007. Death in ancient Rome. New Haven, CT: Yale University Press.

Egidi R, Catalano P, Spadoni D (Eds.). 2003. Aspetti di vita quotidiana dalle necropoli della via Latina, località Osteria del Curato. Rome: Ministero per i Beni e le Attivitá Culturali, Soprintendenza Archeologica di Roma.

Ellwood N, Albertano P, Galvez R, Funicello R, Mosello R. 2009. Water chemistry and trophic evaluation of Lake Albano (Central Italy): a four year water monitoring study. Journal of Limnology 68(2):288–303.

Erasmo M. 2008. Reading death in ancient Rome. Columbus, OH: Ohio State University Press.

Erdal Y, Duyar İ. 1999. A new correction procedure for calibrating dental caries frequency. American Journal of Physical Anthropology 108:237–240.

Erdkamp P. 2008. Mobility and migration in Italy in the second century BC. In: de Ligt L, Northwood S, editors. People, land, and politics: demographic developments and the transformation of Roman Italy 300 BC-AD 14. Boston: Brill Academic Publishers. p 417–450.

Ericson J. 1989. Some problems and potentials for strontium isotope analysis for human and animal ecology. In: Rundel P, Ehleringer J, Nagy K, editors. Stable isotopes in ecological research. New York: Springer Verlag. p 252–259.

Evans J. 1980. "Plebs Rustica." The peasantry of classical Italy. American Journal of Ancient History 5:134–173.

Evans J, Chenery C, Fitzpatrick A. 2006a. Bronze Age childhood migration of individuals near Stonehenge, revealed by strontium and oxygen isotope tooth enamel analysis. Archaeometry 48(2):309–321.

Evans J, Stoodley N, Chenery C. 2006b. A strontium and oxygen isotope assessment of a possible fourth century immigrant population in a Hampshire cemetery, southern England. Journal of Archaeological Science 33:265–272.

Ezzo J, Johnson C, Price T. 1997. Analytical perspectives on prehistoric migration: a case study from east-central Arizona. Journal of Archaeological Science 24(5):447–466.

Faas P. 1994. Around the Roman table: food and feasting in ancient Rome. Chicago: University of Chicago Press.

Faure G. 1986. Principles of isotope geology. New York: John Wiley & Sons.

Faure G, Powell J. 1972. Strontium isotope geology. New York: Springer-Verlag.

Federico M, Peccerillo A, Barbieri M, Wu T. 1994. Mineralogical and geochemical study of granular xenoliths from the Alban Hills volcano, Central Italy: bearing on evolutionary processes in potassic magma chambers. Contributions to Mineralogy and Petrology 115(4):384–401.

Fildes V. 1986. Breasts, bottles and babies: a history of infant feeding. Edinburgh: Edinburgh University Press.

Filippi F (Ed.). 2001. Archeologia e Giubileo. Gli interventi a Roma e nel Lazio nel Piano del Grande Giubileo del 2000. Napoli: Ministero per i Beni e le Attività Culturali, Ufficio Centrale per i Beni Archeologici, Architettonici, Artistici e Storici.

Finley M. 1981. The ancient city: from Fustel de Coulanges to Max Weber and beyond. In: Shaw B, Saller R, editors. Economy and society in ancient Greece. London: Chatto & Windus. p 3–23.

Fogel M, Tuross N, Owsley D. 1989. Nitrogen isotope tracers of human lactation in modern and archaeological populations. Carnegie Institution of Washington Yearbook:111–117.

Frayn J. 1993. Markets and fairs in Roman Italy. New York: Oxford University Press.

Freeman M, Tukey J. 1950. Transformations related to the angular and square root. Annals of Mathematical Statistics 21:607–611.

Frier B. 1999. Roman demography. In: Potter D, Mattingly D, editors. Life, death, and entertainment in the Roman Empire. Ann Arbor, MI: University of Michigan Press. p 85–109.

Frier B. 2001. More is worse: some observations on the population of the Roman empire. In: Scheidel W, editor. Debating Roman demography. Boston: Brill. p 139–160.

Fuller B, Molleson T, Harris D, Gilmour L, Hedges R. 2006. Isotopic evidence for breastfeeding and possible adult dietary differences from late/sub-Roman Britain. American Journal of Physical Anthropology 129(1):45–54.

Garnsey P. 1983. Grain for Rome. In: Garnsey P, editor. Trade in the ancient economy. Berkeley: University of California Press. p 188–230.

Garnsey P. 1988. Famine and food supply in the Graeco-Roman world. Cambridge: Cambridge University Press.

Garnsey P. 1989. Infant health and upbringing in antiquity. In: Garnsey P, editor. Food, health and culture in classical antiquity. Cambridge Faculty of Classics Working Papers No. 1. p 50–101.

Garnsey P. 1991. Mass diet and nutrition in the city of Rome. In: Giovannini A, editor. Nourrir la plèbe. Actes du colloque tenu a Genève les 28 et 29 IX 1989 en hommage a Denis van Berchem. Kassel: Friedrich Reinhardt Verlag Basel. p 67–101.

Garnsey P. 1999. Food and society in classical antiquity. Cambridge: Cambridge University Press.

Garnsey P, Rathbone D. 1985. The background to the grain law of Gaius Gracchus. Journal of Roman Studies 75:20–25.

Garvie-Lok S. 2009. Population mobility at Frankish Corinth: evidence from stable oxygen isotope ratios of tooth enamel. In: Schepartz L, Fox S, Bourbou C, editors. New directions in the skeletal biology of ancient Greece. American School of Classical Studies at Athens. p 245–256.

Gat J. 1996. Oxygen and hydrogen isotopes in the hydrologic cycle. Annual Review of Earth and Planetary Sciences 24(1):225–262.

Gilbert W, Jandial D, Field N, Bigelow P, Danielsen B. 2004. Birth outcomes in teenage pregnancies. Journal of Maternal-Fetal and Neonatal Medicine 16(5):265–270.

Glick Schiller N, Basch L, Szanton Blanc C. 1995. From immigrant to transmigrant: theorizing transnational migration. Anthropological Quarterly 68(1):48–63.

Goldsworthy A. 2003. The complete Roman army. New York: Thames & Hudson.

Gower J. 1971. A general coefficient of similarity and some of its properties. Biometrics:857–871.

Gowland R, Garnsey P. 2010. Skeletal evidence for health, nutritional status, and malaria in Rome and the Empire and implications for mobility. In: Eckardt H, editor. Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire. Journal of Roman Archaeology, Supplement 78.

Grandi M, Pantano W. 2007. Necropoli in località Castellaccio Europarco. Soprintendenza Archeologica di Roma, Servizio di Antropologia.

Green R, Suchey J. 1976. The use of inverse sine transformations in the analysis of non-metric cranial data. American Journal of Physical Anthropology 45:61–68.

Grmek M. 1989. Diseases in the ancient Greek world. Baltimore: Johns Hopkins University Press.

Grüneberg H. 1952. Genetical studies on the skeleton of the mouse. IV. Quasi-continuous variations. Journal of Genetics 51:95–114.

Grüneberg H. 1963. The pathology of development. A study of inherited skeletal disorders in animals. New York: Wiley.

Grupe G, Price T, Schröter P, Söllner F, Johnson C, Beard B. 1997. Mobility of Bell Beaker people revealed by strontium isotope ratios of tooth and bone: a study of southern Bavarian skeletal remains. Applied Geochemistry 12(4):517–525.

Grupe G, Price T, Sollner F. 1999. Mobility of Bell Beaker people revealed by Sr isotope ratios of tooth and bone: a study of southern Bavarian skeletal materials. A reply to the comment by Peter Horn and Dieter Müller-Sohnius. Applied Geochemistry 14:271–5.

Gustafson G, Koch G. 1974. Age estimation up to 16 years of age based on dental development. Odontologisk Revy 25(3):297–306.

Hales S. 2003. The Roman house and social identity. Cambridge: Cambridge University Press.

Hanihara T, Ishida H. 2009. Regional differences in craniofacial diversity and the population history of Jomon Japan. American Journal of Physical Anthropology 139(3):311–322.

Harper N, Fox S. 2008. Recent research in Cypriot bioarchaeology. Bioarchaeology of the Near East 2:1–38.

Hawass Z, Gad Y, Ismail S, Khairat R, Fathalla D, Hasan N, Ahmed A, et al. 2010. Ancestry and pathology in King Tutankhamun's family. Journal of the American Medical Association 303(7):638–647.

Hengen O. 1971. Cribra orbitalia: pathogenesis and probable etiology. Homo 22(2):57–75.

Herring D, Saunders S, Katzenberg M. 1998. Investigating the weaning process in past populations. American Journal of Physical Anthropology 105(4):425–439.

Hillson S. 1996. Dental anthropology. Cambridge: Cambridge University Press.

Homo L. 1971. Rome impériale et l'urbanisme dans l'antiquité. Paris: Albin Michel.

Hope V. 2007. Death in ancient Rome: a source book. New York: Routledge.

Hope V. 2009. Roman death: the dying and the dead in ancient Rome. New York: Continuum.

Hopkins K. 1965. The age of Roman girls at marriage. Population Studies 18(3):309–327.

Hopkins K. 1978. Conquerors and slaves. Cambridge: Cambridge University Press.

Horden P, Purcell N. 2000. The corrupting sea: a study of Mediterranean history. Oxford: Blackwell.

Horevitz E. 2009. Understanding the anthropology of immigration and migration. Journal of Human Behavior in the Social Environment 19(6):745–758.

Howells W. 1973. Cranial variation in man; a study by multivariate analysis of patterns of difference among recent human populations. Cambridge, Mass.: Harvard University Press.

Hülsen C. 1906. The Roman forum: its history and its monuments. Rome: Loescher & Co.

Huskinson J. 2000. Experiencing Rome: culture, identity and power in the Roman Empire. New York: Routledge.

Hutchinson D. 2002. Foraging, farming, and coastal biocultural adaptation in Late Prehistoric North Carolina. Gainesville: University Press of Florida.

Hutchinson D, Denise C, Daniel H, Kalmus G. 1997. A reevaluation of the cold water etiology of external auditory exostoses. American Journal of Physical Anthropology 103(3):417–422.

Iacumin P, Bocherens H, Mariotti A, Longinelli A. 1996. Oxygen isotope analyses of co-existing carbonate and phosphate in biogenic apatite: a way to monitor diagenetic alteration of bone phosphate? Earth and Planetary Science Letters 142:1–6.

Jasny N. 1942. Competition among grains in classical antiquity. American Historical Review 47(4):747–764.

Johnston F. 1962. Growth of the long bones of infants and young children at Indian Knoll. American Journal of Physical Anthropology 20(3):249–254.

Jongman W. 2003. Slavery and the growth of Rome: the transformation of Italy in the second and first centuries BCE. In: Edwards C, Woolf G, editors. Rome the cosmopolis. New York: Cambridge University Press. p 100–122.

Joshel S. 1992. Work, identity, and legal status at Rome. Norman: University of Oklahoma Press.

Katzenberg M. 2008. Stable isotope analysis: a tool for studying past diet, demography, and life history. In: Katzenberg M, Saunders S, editors. Biological anthropology of the human skeleton. New York: Wiley-Liss. p 413–442.

Katzenberg M, Herring D, Saunders S. 1996. Weaning and infant mortality: evaluating the skeletal evidence. American Journal of Physical Anthropology 101:177–199.

Kearney M. 1986. From the invisible hand to visible feet: anthropological studies of migration and development. Annual Review of Anthropology 15(1):331–361.

Keenleyside A, Schwarcz H, Panayotova K. 2006. Stable isotopic evidence of diet in a Greek colonial population from the Black Sea. Journal of Archaeological Science 33(9):1205–1215.

Keenleyside A, Schwarcz H, Stirling L, Ben Lazreg N. 2009. Stable isotopic evidence for diet in a Roman and Late Roman population from Leptiminus, Tunisia. Journal of Archaeological Science 36(1):51–63.

Kennedy B. 1981. Marriage patterns in an archaic population: a study of skeletal remains from Port au Choix, Newfoundland. Archaeological Survey of Canada, National Museum of Man, Mercury Series. Paper No. 104.

Keppie L. 1998. The making of the Roman army: from republic to empire. Norman, OK: University of Oklahoma Press.

Killgrove K. 2002. Defining relationships between Native American groups: a biodistance study of the North Carolina coastal plain. M.A. thesis, East Carolina University, Greenville, NC.

Killgrove K. 2005. Bioarchaeology in the Roman world. M.A. thesis, University of North Carolina, Chapel Hill.

Killgrove K. 2008. Slums or suburbs? Health status of a population from Imperial Rome. American Journal of Physical Anthropology 135, S46:129.

Killgrove K. 2009. Rethinking taxonomies: skeletal variation on the North Carolina coastal plain. Southeastern Archaeology 28(1):87–100.

Killgrove K. 2010. Identifying immigrants to Imperial Rome using strontium isotope analysis. In: Eckardt H, editor. Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire. Journal of Roman Archaeology, Supplement 78.

King H (Ed.). 2005. Health in antiquity. New York: Routledge.

Klein H, Palmer C, Knutson J. 1938. Studies on dental caries. I. Dental status and dental needs of elementary schoolchildren. Public Health Reports 53:751–765.

Knudson K, Price T. 2007. Utility of multiple chemical techniques in archaeological residential mobility studies: case studies from Tiwanaku-and Chiribaya-affiliated sites in the Andes. American Journal of Physical Anthropology 132(1):25–39.

Knudson K, Torres-Rouff C. 2009. Investigating cultural heterogeneity in San Pedro de Atacama, Northern Chile, through biogeochemistry and bioarchaeology. American Journal of Physical Anthropology 138(4):473–485.

Knudson K, Williams S, Osborn R, Forgey K, Williams P. 2009. The geographic origins of Nasca trophy heads using strontium, oxygen, and carbon isotope data. Journal of Anthropological Archaeology 28(2):244–257.

Koch P, Tuross N, Fogel M. 1997. The effects of sample treatment and diagenesis on the isotopic integrity of carbonate in biogenic hydroxylapatite. Journal of Archaeological Science 24(5):417–429.

Krueger H, Sullivan C. 1984. Models for carbon isotope fractionation between diet and bone. Stable Isotopes in Nutrition, ACS Symposium Series 258:205–220.

Kyle D. 1998. Spectacles of death in ancient Rome. New York: Routledge.

Larsen C. 1997. Bioarchaeology: interpreting behavior from the human skeleton. Cambridge: Cambridge University Press.

Larsen C, Schoeninger M, Van der Merwe N, Moore K, Lee-Thorp J. 1992. Carbon and nitrogen stable isotopic signatures of human dietary change in the Georgia Bight. American Journal of Physical Anthropology 89(2):197–214.

Larsen C, Shavit R, Griffin M. 1991. Dental caries evidence for dietary change: an archaeological context. In: Kelley M, Larsen C, editors. Advances in dental anthropology. New York: Wiley-Liss. p 179–202.

Laurence R. 1998. Territory, ethnonyms, and geography. In: Laurence R, Berry J, editors. Cultural identity in the Roman Empire. New York: Routledge. p 95–110.

Laurence R. 1999. The roads of Roman Italy: mobility and cultural change. New York: Routledge.

Laurence R, Berry J. 1998. Cultural identity in the Roman Empire. New York: Routledge.

Leach S, Lewis M, Chenery C, Müldner G, Eckardt H. 2009. Migration and diversity in Roman Britain: A multidisciplinary approach to the identification of immigrants in Roman York, England. American Journal of Physical Anthropology 140(3):546–561.

Lee E. 1966. A theory of migration. Demography 3(1):47–57.

Lee-Thorp J, Sponheimer M. 2003. Three case studies used to reassess the reliability of fossil bone and enamel isotope signals for paleodietary studies. Journal of Anthropological Archaeology 22(3):208–216.

Lefkowitz M, Fant M. 2005. Women's life in Greece and Rome: a source book in translation. Baltimore: Johns Hopkins University Press.

Levinson A, Luz B, Kolodny Y. 1987. Variations in oxygen isotopic compositions of human teeth and urinary stones. Applied Geochemistry 2(4):367–371.

Lilley I. 2004. Diaspora and identity in archaeology: moving beyond the Black Atlantic. In: Meskell L, Preucel R, editors. A companion to social archaeology. Oxford: Blackwell. p 287–312.

Lilley I. 2006. Archaeology, diaspora and decolonization. Journal of Social Archaeology 6:28–47.

Lindsay H. 2000. Death-pollution and funerals in the city of Rome. In: Hope V, Marshall W, editors. Death and Disease in the Ancient City. New York: Routledge. p 152–73.

Lo Cascio E. 2006. Did the population of Rome reproduce itself? In: Storey G, editor. Urbanism in the preindustrial world: cross-cultural approaches. Tuscaloosa: University of Alabama Press. p 52–68.

Lomas K. 1996. Roman Italy, 338 BC-AD 200: a sourcebook. New York: Routledge.

Lomas K. 1997. The idea of a city: élite ideology and the evolution of urban form in Italy, 200 BC - AD 100. In: Parkins H, editor. Roman urbanism: beyond the consumer city. London: Routledge. p 21–41.

Longinelli A. 1984. Oxygen isotopes in mammal bone phosphate: a new tool for paleohydrological and paleoclimatological research. Geochimica et Cosmochimica Acta 48(2):385–390.

Longinelli A, Selmo E. 2003. Isotopic composition of precipitation in Italy: a first overall map. Journal of Hydrology 270(1-2):75–88.

Lott J. 2004. The neighborhoods of Augustan Rome. Cambridge: Cambridge University Press.

Lovejoy C, Meindl R, Pryzbeck T, Mensforth R. 1985. Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of adult skeletal age at death. American Journal of Physical Anthropology 68(1):15–28.

LTURS. 2001-08. Lexicon topographicum urbis Romae: suburbium. Vol. 1–5. Rome: Edizioni Quasar.

Lukacs J. 1995. The 'caries correction factor': a new method of calibrating dental caries rates to compensate for antemortem loss of teeth. International Journal of Osteoarchaeology 5:151–156.

Luz B, Kolodny Y, Horowitz M. 1984. Fractionation of oxygen isotopes between mammalian bone-phosphate and environmental drinking water. Geochimica et Cosmochimica Acta 48:1689–1693.

Macchiarelli R, Salvadei L, Catalano P. 1988. Biocultural changes and continuity throughout the 1st millennium B.C. in central Italy: anthropological evidence and perspectives. Rivista di Antropologia 66:249–272.

MacDonnell W. 1913. On the expectation of life in ancient Rome, and in the provinces of Hispania and Lusitania, and Africa. Biometrika 9(3/4):366–380.

MacMullen R. 1974. Roman social relations. New Haven, CT: Yale University Press.

Manzi G, Salvadei L, Vienna A, Passarello P. 1999. Discontinuity of life conditions at the transition from the Roman Imperial Age to the Early Middle Ages: example from central Italy evaluated by pathological dento-alveolar lesions. American Journal of Human Biology 11:327–341.

Manzi G, Sperduti A, Passarello P. 1991. Behavior-induced auditory exostoses in imperial Roman society: evidence from coeval urban and rural communities near Rome. American Journal of Physical Anthropology 85:253–260.

Mariotti V, Dutour O, Belcastro M, Facchini F, Brasili P. 2005. Probable early presence of leprosy in Europe in a Celtic skeleton of the 4th-3rd century BC (Casalecchio di Reno, Bologna, Italy). International Journal of Osteoarchaeology 15:311–325.

Marmot M, Adelstein A, Bulusu L. 1984. Lessons from the study of immigrant mortality. Lancet 1(8392):1455–7.

Martin S, Guatelli-Steinberg D, Sciulli P, Walker P. 2008. Brief communication: comparison of methods for estimating chronological age at linear enamel formation on anterior dentition. American Journal of Physical Anthropology 135(3):362–365.

McNeill W. 1976. Plagues and people. Garden City, NY: Anchor Press.

Meindl R, Lovejoy C. 1985. Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the lateral-anterior sutures. American Journal of Physical Anthropology 68(1):57–66.

Meinecke B. 1927. Consumption in classical antiquity. Annals of Medical History 9:379–402.

Millard A, Schroeder H. 2010. 'True British sailors': a comment on the origin of the men of the Mary Rose. Journal of Archaeological Science 37:680–682.

Minissale A, Kerrick D, Magro G, Murrell M, Paladini M, Rihs S, Sturchio N, et al. 2002. Geochemistry of Quaternary travertines in the region north of Rome (Italy): structural, hydrologic and paleoclimatic implications. Earth and Planetary Science Letters 203:709–728.

Mitchell P, Millard A. 2009. Migration to the Medieval Middle East with the crusades. American Journal of Physical Anthropology 140(3):518–525.

Moatti C. 2006. Translation, migration, and communication in the Roman Empire: three aspects of movement in history. Classical Antiquity 25(1):109–140.

Moggi-Cecchi J, Chiarelli B, Pacciani E, D'Amore G, Brown K. 1997. The anthropological study of Etruscan populations. Etruscan Studies 4:73–86.

Molto J. 1983. Biological relationships of southern Ontario Woodland peoples: the evidence of discontinuous cranial morphology. Ottawa: National Museums of Canada, Archaeological Survey of Canada. Paper No. 117.

Montgomery J. 2002. Lead and strontium isotope compositions of human dental tissues as an indicator of ancient exposure and population dynamics. PhD dissertation, University of Bradford.

Montgomery J, Budd P, Cox A, Krause P, Thomas R. 1999. LA-ICP-MS evidence for the distribution of Pb and Sr in Romano-British medieval and modern human teeth: implications for life history and exposure reconstruction. In: Metals in antiquity: proceedings of the international symposium. Oxford: Archaeopress.

Montgomery J, Budd P, Evans J. 2000. Reconstructing the lifetime movements of ancient people: a Neolithic case study from southern England. European Journal of Archaeology 3(3):370.

Montgomery J, Evans J, Chenery S, Pashley V, Killgrove K. 2010. "Gleaming, white and deadly": lead exposure and geographic origins in the Roman period. In: Eckardt H, editor. Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire. Journal of Roman Archaeology, Supplement 78.

Montgomery J, Evans J, Cooper R. 2007. Resolving archaeological populations with Sr-isotope mixing models. Applied Geochemistry 22(7):1502–1514.

Montgomery J, Evans J, Neighbour T. 2003. Sr isotope evidence for population movement within the Hebridean Norse community of NW Scotland. Journal of the Geological Society 160(5):649.

Montgomery J, Evans J, Powlesland D, Roberts C. 2005. Continuity or colonization in Anglo-Saxon England? Isotope evidence for mobility, subsistence practice, and status at West Heslerton. American Journal of Physical Anthropology 126(2):123–138.

Moorees C, Fanning E, Hunt E. 1963a. Age formation by stages for ten permanent teeth. Journal of Dental Research 42:1490–1502.

Moorees C, Fanning E, Hunt E. 1963b. Formation and resorption of three deciduous teeth in children. American Journal of Physical Anthropology 21:205–213.

Morley N. 1996. Metropolis and hinterland: the city of Rome and the Italian economy 200 B.C.-A.D. 200. Cambridge: Cambridge University Press.

Morley N. 1997. Cities in context: urban systems in Roman Italy. In: Parkins H, editor. Roman urbanism. New York: Routledge. p 42–58.

Morley N. 2005. The salubriousness of the Roman city. In: King H, editor. Health in antiquity. New York: Routledge. p 192–204.

Morris I. 1992. Death-ritual and social structure in classical antiquity. Cambridge: Cambridge University Press.

Motta L. 2002. Planting the seed of Rome. Vegetation History and Archaeobotany 11:71–77.

Müldner G, Montgomery J, Cook G, Ellam R, Gledhill A, Lowe C. 2009. Isotopes and individuals: diet and mobility among the medieval Bishops of Whithorn. Antiquity 83(322):1119–1133.

Murray M, Schoeninger M. 1988. Diet, status, and complex social structure in Iron Age central Europe: some contributions of bone chemistry. In: Gibson D, Geselowitz M, editors. Tribe and polity in Late Prehistoric Europe. New York: Plenum Press. p 155–176.

Musco S, Catalano P, Caspio A, Pantano W, Killgrove K. 2008. Le complexe archéologique de Casal Bertone. Les Dossiers d'Archéologie 330:32–39.

Nafplioti A. 2008. "Mycenaean" political domination of Knossos following the Late Minoan IB destructions on Crete: negative evidence from strontium isotope ratio analysis ($^{87}Sr/^{86}Sr$). Journal of Archaeological Science 35:2307–2317.

Nanni A, Maffei L. 2004. Nodo di Roma. Penetrazione urbana A V - linea FM2. Italferr/TAV. Relazione antropologica. Area AI (E). Casal Bertone. Necropoli e Mausoleo. Soprintendenza Archeologica di Roma, Servizio di Antropologia.

Nenci G. 1999. Il miglio e il panico nell'alimentazione delle popolazioni mediterranee. In: Vera D, editor. Demografia, sistemi agrari, regimi alimentari. Bari: Edipuglia. p 25–36.

Nerlich A, Peschel O, Egarter-Vigl E. 2009. New evidence for Ötzi's final trauma. Intensive Care Medicine 35(6):1138–1139.

Nicolet C. 1991. Space, geography, and politics in the early Roman Empire. Ann Arbor: University of Michigan Press.

Noy D. 2000. Foreigners at Rome: citizens and strangers. London: Duckworth.

Noy D. 2010. Epigraphic evidence for immigrants in Rome and Roman Britain. In: Eckardt H, editor. Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire. Journal of Roman Archaeology, Supplement 78.

Nutton V. 2000. Medical thoughts on urban pollution. In: Hope V, Marshall E, editors. Death and disease in the ancient city. New York: Routledge. p 65–73.

Ortner D. 2003. Identification of pathological conditions in human skeletal remains. New York: Academic Press.

Osborne R. 1991. The potential mobility of human populations. Oxford Journal of Archaeology 10(2):231–252.

Ossenberg N. 1976. Within and between race distances in population studies based on discrete traits of the human skull. American Journal of Physical Anthropology 45(3):701–716.

Ottini L, Ricci R, Angeletti L, Costantini R, Catalano P. 2001. Le condizioni di vita nella popolazione di età imperiale. Mitteilungen des Deutschen Archäologischen Instituts, Römische Abteilung 108:364–366.

Ousley S. 1995. Should we estimate biological or forensic stature? Journal of Forensic Sciences 40:768–768.

Ousley S, Jantz R. 1996. FORDISC 2.0: Personal computer forensic discriminant functions. Forensic Anthropology Center, University of Tennessee, Knoxville.

Paine R, Storey G. 2006. Epidemics, age at death, and mortality in ancient Rome. In: Storey G, editor. Urbanism in the preindustrial world: cross-cultural approaches. Tuscaloosa: University of Alabama Press. p 69–85.

Palombo M, Filippi M, Iacumin P, Longinelli A, Barbieri M, Maras A. 2005. Coupling tooth microwear and stable isotope analyses for palaeodiet reconstruction: the case study of Late Middle Pleistocene *Elephas (Palaeoloxodon) antiquus* teeth from Central Italy (Rome area). Quaternary International 126:153–170.

Pals JP, Voorrips A. 1979. Seeds, fruits and charcoals from two prehistoric sites in northern Italy. Archaeo-Physica 8:217–235.

Parfitt A. 2008. Skeletal heterogeneity and the purposes of bone remodeling: implications for the understanding of osteoporosis. In: Marcus R, Feldman D, Nelson D, Rosen C, editors. Osteoporosis, 3rd Ed. New York: Elsevier Academic Press. p 71–90.

Parker Pearson M. 2001. The archaeology of death and burial. College Station, TX: Texas A&M University Press.

Parkin T. 1992. Demography and Roman society. Baltimore: The Johns Hopkins University Press.

Patrick A. 1967. Disease in antiquity: Greece and Rome. In: Brothwell D, Sandison A, editors. Diseases in antiquity. Springfield: Charles C. Thomas. p 238–248.

Patterson J. 1992. Patronage, collegia and burial in Imperial Rome. In: Bassett S, editor. Death in towns: urban responses to the dying and the dead, 100-1600. Leicester: Leicester University Press. p 15–27.

Patterson J. 2000. On the margins of the city of Rome. In: Hope V, Marshall E, editors. Death and disease in the ancient city. London: Routledge. p 85–103.

Pellegrini M, Donahue R, Chenery C, Evans J, Lee-Thorp J, Montgomery J, Mussi M. 2008. Faunal migration in late-glacial central Italy: implications for human resource exploitation. Rapid Communications in Mass Spectrometry 22(11):1714–1726.

Pennisi M, Leeman W, Tonarini S, Pennisi A, Nabelek P. 2000. Boron, Sr, O, and H isotope geochemistry of groundwaters from Mt. Etna (Sicily): hydrologic implications. Geochimica et Cosmochimica Acta 64(6):961–974.

Perry M, Coleman D, Dettman D, al-Shiyab A. 2009. An isotopic perspective on the transport of Byzantine mining camp laborers into southwestern Jordan. American Journal of Physical Anthropology 140(3):429–441.

Phenice T. 1969. A newly developed visual method of sexing in the os pubis. American Journal of Physical Anthropology 30:297–301.

Piazza A, Cappello N, Olivetti E, Renadine S. 1988. A genetic history of Italy. Annals of Human Genetics 52:203–213.

Pietrusewsky M. 2006. A multivariate craniometric study of the prehistoric and modern inhabitants of Southeast Asia, East Asia and surrounding regions: a human kaleidoscope? In: Oxenham M, Tayles N, editors. Bioarchaeology of southeast Asia. Cambridge: Cambridge University Press. p 59–90.

Pietrusewsky M. 2008. Metric analysis of skeletal remains: methods and applications. In: Katzenberg M, Saunders S, editors. Biological anthropology of the human skeleton. New York: Wiley-Liss. p 487–532.

Pollard A, Batt C, Stern B. 2007. Analytical chemistry in archaeology. Cambridge: Cambridge University Press.

Price T, Bentley R, Lüning J, Gronenborn D, Wahl J. 2001. Prehistoric human migration in the *Linearbandkeramic* of Central Europe. Antiquity 75:593–603.

Price T, Burton J, Bentley R. 2002. The characterization of biologically available strontium isotope ratios for the study of prehistoric migration. Archaeometry 44(1):117–135.

Price T, Grupe G, Schröter P. 1994a. Reconstruction of migration patterns in the Bell Beaker period by stable strontium isotope analysis. Applied Geochemistry 9(4):413–417.

Price T, Johnson C, Ezzo J, Burton J, Ericson J. 1994b. Residential mobility in the prehistoric southwest United States: a preliminary study using strontium isotope analysis. Journal of Archaeological Science 21:315–330.

Price T, Manzanilla L, Middleton W. 2000. Immigration and the ancient city of Teotihuacan in Mexico: a study using strontium isotope ratios in human bone and teeth. Journal of Archaeological Science 27(10):903–913.

Prowse T. 2001. Isotopic and dental evidence for diet from the necropolis of Isola Sacra (1st-3rd centuries AD), Italy. PhD dissertation, McMaster University.

Prowse T, Schwarcz H, Garnsey P, Knyf M, Macchiarelli R, Bondioli L. 2007. Isotopic evidence for age-related immigration to Imperial Rome. American Journal of Physical Anthropology 132:510–519.

Prowse T, Schwarcz H, Saunders S, Macchiarelli R, Bondioli L. 2004. Isotopic paleodiet studies of skeletons from the Imperial Roman-age cemetery of Isola Sacra, Rome, Italy. Journal of Archaeological Science 31:259–272.

Prowse T, Schwarcz H, Saunders S, Macchiarelli R, Bondioli L. 2005. Isotopic evidence for age-related variation in diet from Isola Sacra, Italy. American Journal of Physical Anthropology 128:2–13.

Purcell N. 1987. Tomb and suburb. In: von Hesberg H, Zanker P, editors. Römische Gräberstrassen: Selbstdarstellung, status, standard: Kolloquium in München vom 28 bis 30 Oktober 1985. Bayerische Akademie der Wissenschaften. p 25–41.

Purcell N. 1995. Eating fish: the paradoxes of seafood. In: Wilkins J, Harvey D, Dobson M, editors. Food in antiquity. Exeter: University of Exeter Press. p 132–149.

Purcell N. 2003. The way we used to eat. American Journal of Philology 124(3):329–358.

Quilici L. 1974. La campagna romana come suburbio di Roma antica. Parola del Passato 29:410–438.

Redfield R. 1941. The folk culture of Yucatan. Chicago: University of Chicago Press.

Relethford J, Blangero J. 1990. Detection of differential gene flow from patterns of quantitative variation. Human Biology 62(1):5–25.

Relethford J, Lees F. 1982. The use of quantitative traits in the study of human population structure. Yearbook of Physical Anthropology 25:113–132.

Renfrew C. 1996. Prehistory and the identity of Europe. In: Graves-Brown P, Jones S, Gamble C, editors. Cultural identity and archaeology: the construction of European communities. New York: Routledge. p 125–137.

Ricci C. 2005. Orbis in urbe: fenomeni migratori nella Roma imperiale. Roma: Quasar.

Ricci C. 2006. Stranieri illustri e comunità immigrate a Roma: vox diversa populorum. Roma: Quasar.

Ricci R, Mancinelli D, Vargiu R, Cucina A, Santandrea E, Capelli A, Catalano P. 1997. Pattern of porotic hyperostosis and quality of life in a II century A.D. farm near Rome. Rivista di Antropologia 75:117–128.

Richards M, Fuller B, Hedges R. 2001. Sulphur isotopic variation in ancient bone collagen from Europe: implications for human palaeodiet, residence mobility, and modern pollutant studies. Earth and Planetary Science Letters 191(3-4):185–190.

Richards M, Harvati K, Grimes V, Smith C, Smith T, Hublin J, Karkanas P, et al. 2008. Strontium isotope evidence of Neanderthal mobility at the site of Lakonis, Greece using laser-ablation PIMMS. Journal of Archaeological Science 35(5):1251–1256.

Rickman G. 1980. The corn supply of ancient Rome. Oxford: Oxford University Press.

Robb J. 1997. Violence and gender in Early Italy. In: Martin D, Frayer D, editors. Troubled times: violence and warfare in the past. Gordon and Breach Publishers. p 111–144.

Roberts C, Buikstra J. 2003. The bioarchaeology of tuberculosis: a global view on a reemerging disease. Gainesville: University Press of Florida.

Robinson M. 2002. Domestic burnt offerings and sacrifices at Roman and pre-Roman Pompeii, Italy. Vegetation History and Archaeobotany 11:93–99.

Rogers J, Waldron T. 1995. A field guide to joint disease in archaeology. New York: John Wiley & Sons.

Rogers L. 1992. Radiology of skeletal trauma. London: Churchill Livingstone.

Rubini M, Mogliazza S, Corruccini R. 2007. Biological divergence and equality during the first millennium BC in human populations of central Italy. American Journal of Human Biology 19:119–131.

Rutgers L, van Strydonck M, Boudin M, van der Linde C. 2009. Stable isotope data from the early Christian catacombs of ancient Rome: new insights into the dietary habits of Rome's early Christians. Journal of Archaeological Science 36(5):1127–1134.

Sallares R. 2002. Malaria and Rome: a history of malaria in ancient Italy. Oxford: Oxford University Press.

Salvadei L, Ricci F, Manzi G. 2001. Porotic hyperostosis as a marker of health and nutritional conditions during childhood: studies at the transition between Imperial Rome and the Early Middle Ages. American Journal of Human Biology 13:709–717.

Sanjek R. 2003. Rethinking migration, ancient to future. Global Networks 3:315–336.

Scheidel W. 1997. Quantifying the sources of slaves in the early Roman empire. The Journal of Roman Studies 87:156–169.

Scheidel W. 2001. Progress and problems in Roman demography. In: Scheidel W, editor. Debating Roman demography. Boston: Brill. p 1–82.

Scheidel W. 2003. Germs for Rome. In: Edwards C, Woolf G, editors. Rome the cosmopolis. New York: Cambridge University Press. p 158–176.

Scheidel W. 2004. Human mobility in Roman Italy, I: the free population. Journal of Roman Studies 94:1–26.

Scheidel W. 2005. Human mobility in Roman Italy, II: the slave population. The Journal of Roman Studies 95:64–79.

Schillaci M, Irish J, Wood C, Foundation B. 2009. Further analysis of the population history of ancient Egyptians. American Journal of Physical Anthropology 139(2):235–243.

Schillaci M, Stojanowski C. 2005. Craniometric variation and population history of the prehistoric Tewa. American Journal of Physical Anthropology 126:404–412.

Schoeninger M, DeNiro M. 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. Geochimica et Cosmochimica Acta 48:625–639.

Schoeninger M, DeNiro M, Tauber H. 1983. Stable nitrogen isotope ratios of bone collagen reflect marine and terrestrial components of prehistoric human diet. Science 220(4604):1381–1383.

Schroeder H, O'Connell T, Evans J, Shuler K, Hedges R. 2009. Trans-Atlantic slavery: isotopic evidence for forced migration to Barbados. American Journal of Physical Anthropology 139(4):547–557.

Schwarcz H, White C, Longstaffe F. 2010. Stable and radiogenic isotopes in biological archaeology: some applications. In: West J, Bowen G, Dawson T, editors. Isoscapes: understanding movement, pattern, and process on Earth through isotope mapping. New York: Springer. p 335–356.

Schweissing M, Grupe G. 2003. Stable strontium isotopes in human teeth and bone: a key to migration events of the Late Roman Period in Bavaria. Journal of Archaeological Science 30(11):1373–1383.

Schwirian K, Nelson A, Schwirian P. 1995. Modeling urbanism: economic, social and environmental stress in cities. Social Indicators Research 35(2):201–223.

Scobie A. 1986. Slums, sanitation, and mortality in the Roman world. Klio 68:399–433.

Scott E. 1979. Dental wear scoring technique. American Journal of Physiscal Anthropology 51:213–218.

Sealy J. 1989. Reconstruction of later Stone Age diets in the south-western Cape, South Africa: evaluation and application of five isotopic and trace element techniques. PhD dissertation, University of Cape Town.

Sealy J, Armstrong R, Schrire C. 1995. Beyond lifetime averages: tracing life histories through isotopic analysis of different calcified tissues from archaeological human skeletons. Antiquity 69:290–300.

Servizio Geologico d'Italia. 2004. Geological map of Italy, 1:1,250,000 scale. 32nd International Geological Congress.

Singh G, Siahpush M. 2002. Ethnic-immigrant differentials in health behaviors, morbidity, and cause-specific mortality in the United States: an analysis of two national databases. Human Biology 74(1):83–110.

Sjøvold T. 1976. A method for familial studies based on minor skeletal variants. Ossa 3/4:97–107.

Sjøvold T. 1977. Non-metrical divergence between skeletal populations: the theoretical foundation and biological importance of C.A.B. Smith's mean measure of divergence. Ossa 4 (supplement 1):1–133.

Smith B. 1984. Patterns of molar wear in hunter-gatherers and agriculturalists. American Journal of Physical Anthropology 63(1):39–56.

Smith C. 1972. Review of T.S. Constandse-Westermann: coefficients of biological distance. Annals of Human Genetics 36:241–245.

Smith M, Schreiber K. 2006. New World states and empires: politics, religion, and urbanism. Journal of Archaeological Research 14(1):1–52.

Sofaer J. 2006. The body as material culture. Cambridge: Cambridge University Press.

Sofaer J, Smith P, Kaye E. 1986. Affinities between contemporary and skeletal Jewish and non-Jewish groups based on tooth morphology. American Journal of Physical Anthropology 70(2):265–275.

Southern P. 2006. The Roman army: a social and institutional history. Santa Barbara, CA: ABC-Clio, Inc.

Sperduti A. 1997. Life conditions of a Roman Imperial age population: occupational stress markers and working activities in *Lucus Feroniae* (Rome, 1st-2nd cent. AD). Human Evolution 12(4):253–267.

Sponheimer M. 1999. Isotopic ecology of the Makapansgat Limeworks fauna. PhD dissertation, Rutgers University.

Spurr M. 1983. The cultivation of millet in Roman Italy. Papers of the British School at Rome LI:1–15.

Spurr M. 1986. Arable cultivation in Roman Italy: c. 200 BC - c. AD 100. Society for the Promotion of Roman Studies.

Stambaugh J. 1988. The ancient Roman city. Baltimore: Johns Hopkins University Press.

Steadman D. 2001. Mississippians in motion? A population genetic analysis of interregional gene flow in west-central Illinois. American Journal of Physical Anthropology 114:61–73.

Steckel R. 1995. Stature and the standard of living. Journal of Economic Literature 33(4):1903–1940.

Stein G. 1998. Heterogeneity, power, and political economy: some current research issues in the archaeology of Old World complex societies. Journal of Archaeological Research 6(1):1–44.

Stein G. 2002. From passive periphery to active agents: emerging perspectives in the archaeology of interregional interaction. American Anthropologist 104:903–916.

Stojanowski C, Schillaci M. 2006. Phenotypic approaches for understanding patterns of intracemetery biological variation. Yearbook of Physical Anthropology 49:49–88.

Storey G. 1997a. Estimating the population of ancient Roman cities. In: Paine R, editor. Integrating archaeological demography: multidisciplinary approaches to prehistoric population. Southern Illinois University at Carbondale: Center for Archaeological Investigations. p 101–130.

Storey G. 1997b. The population of ancient Rome. Antiquity 71(274):966–978.

Storey G (Ed.). 2006. Urbanism in the preindustrial world: cross-cultural approaches. Tuscaloosa: University of Alabama Press.

Storey R. 1992. Preindustrial urban lifestyle and health. In: Huss-Ashmore R, Schall J, Hediger M, editors. Health and lifestyle change. MASCA Research Papers in Science and Archaeology, vol. 9. p 33–42.

Sutter R, Verano J. 2007. Biodistance analysis of the Moche sacrificial victims from Huaca de la Luna Plaza 3C: matrix method test of their origins. American Journal of Physical Anthropology 132:193–206.

Swärdstedt T. 1966. Odontological aspects of a Medieval population in the province of Jämtland, mid-Sweden. Stockholm: Tiden-Barnängen Tryckerier.

Szanton Blanc C, Basch L, Glick Schiller N. 1995. Transnationalism, nation-states, and culture. Current Anthropology 36(4):683–686.

Szulc P, Seeman E, Delmas P. 2000. Biochemical measurements of bone turnover in children and adolescents. Osteoporosis International 11(4):281–294.

Tacoli C. 1998. Rural-urban interactions; a guide to the literature. Environment and Urbanization 10:147–166.

Tafuri M, Craig O, Canci A. 2009. Stable isotope evidence for the consumption of millet and other plants in Bronze Age Italy. American Journal of Physical Anthropology 139(2):146–153.

Taylor R. 2000. Public needs and private pleasures: Water distribution, the Tiber River, and the urban development of ancient Rome. Rome: L'Erma di Bretschneider.

Temkin O. 1991. Soranus' Gynecology. Baltimore: Johns Hopkins University Press.

Terrenato N. 2001. Introduction. In: Keay S, Terrenato N, editors. Italy and the West: comparative issues in Romanization. Oxford: Oxbow Books. p 1–6.

Thompson F. 2003. The archaeology of Greek and Roman slavery. London: Duckworth.

Todd T. 1921a. Age changes in the pubic bone I: the male white pubis. American Journal of Physical Anthropology 3:285–334.

Todd T. 1921b. Age changes in the pubic bone III: the pubis of the white female. American Journal of Physical Anthropology 4:1–70.

Torino M, Rognini M, Fornaciari G. 1995. Dental fluorosis in ancient Herculaneum. Lancet 345(8960):1306.

Toynbee J. 1971. Death and burial in the Roman world. Ithaca, NY: Cornell University Press.

Treggiari S. 1973. Domestic staff at Rome in the Julio-Claudian period, 27 BC to AD 68. Social History 6:241–55.

Trotter M. 1970. Estimation of stature from fragments of long limb bones. In: Steward T, editor. Personal identification in mass disasters. Washington, D.C.: Smithsonian Institution. p 71–83.

Trotter M, Broman G, Peterson R. 1960. Densities of bones of white and negro skeletons. The Journal of Bone and Joint Surgery 42(1):50.

Trotter M, Gleser G. 1952. Estimation of stature from long bones of American Whites and Negroes. American Journal of Physical Anthropology 10(4):463–514.

Turi B, Taylor H. 1976. Oxygen isotope studies of potassic volcanic rocks of the Roman Province, Central Italy. Contributions to Mineralogy and Petrology 55(1):1–31.

Turner B, Kamenov G, Kingston J, Armelagos G. 2009. Insights into immigration and social class at Machu Picchu, Peru based on oxygen, strontium, and lead isotopic analysis. Journal of Archaeological Science 36(2):317–332.

Turner C. 1979. Dental anthropological indications of agriculture among the Jomon people of central Japan: X. Peopling of the Pacific. American Journal of Physical Anthropology 51:619–36.

Turner C, Bird J. 1981. Dentition of Chilean paleo-Indians and peopling of the Americas. Science 212(4498):1053–1055.

Tykot R. 2004. Stable isotopes and diet: you are what you eat. In: Martini M, Milazzo M, Piacentini M, editors. Physics methods in archaeometry. Bologna: Società Italiana di Fisica. p 433–444.

Underwood E, Mertz W. 1977. Trace elements in human and animal nutrition. New York: Academic Press.

van Dommelen P. 2001. Cultural imaginings. Punic tradition and local identity in Roman Republican Sardinia. In: Keay S, Terrenato N, editors. Italy and the West: comparative issues in Romanization. Oxford: Oxbow Books. p 68–84.

Vernesi C, Caramelli D, Dupanloup I, Bertorelle G, Lari M, Cappellini E, Moggi-Cecchi J, et al. 2004. The Etruscans: a population-genetic study. American Journal of Human Genetics 74(4):694–704.

Vika E. 2009. Strangers in the grave? Investigating local provenance in a Greek Bronze Age mass burial using δ^{34}S analysis. Journal of Archaeological Science 36(9):2024–2028.

Vinciguerra S, Del Gaudio P, Mariucci M, Marra F, Meredith P, Montone P, Pierdominici S, et al. 2009. Physical properties of tuffs from a scientific borehole at Alban Hills volcanic district (central Italy). Tectonophysics 471(1-2):161–169.

Walker P. 1997. Wife beating, boxing, and broken noses: skeletal evidence for the cultural patterning of violence. In: Martin D, Frayer D, editors. Troubled times: violence and warfare in the past. New York: Gordon and Breach. p 145–179.

Walker P. 2000. Bioarchaeological ethics: a historical perspective on the value of human remains. In: Katzenberg M, Saunders S, editors. Biological anthropology of the human skeleton. New York: Wiley-Liss. p 3–39.

Webster J. 2001. Creolizing the Roman provinces. American Journal of Archaeology 105:209–225.

Webster J. 2005. Archaeologies of slavery and servitude: bringing ‘New World’ perspectives to Roman Britain. Journal of Roman Archaeology 18(1):161–179.

Webster J. 2008. Less beloved. Roman archaeology, slavery and the failure to compare. Archaeological Dialogues 15(2):103–149.

Webster J. 2010. Routes to slavery in the Roman world: a comparative perspective on the archaeology of forced migration. In: Eckardt H, editor. Roman diasporas: archaeological approaches to mobility and diversity in the Roman Empire. Journal of Roman Archaeology, Supplement 78.

White C, Longstaffe F, Law K. 2004a. Exploring the effects of environment, physiology and diet on oxygen isotope ratios in ancient Nubian bones and teeth. Journal of Archaeological Science 31(2):233–250.

White C, Spence M, Le Q, Stuart-Williams H, Schwarcz H. 1998. Oxygen isotopes and the identification of geographical origins: the Valley of Oaxaca versus the Valley of Mexico. Journal of Archaeological Science 25(7):643–655.

White C, Spence M, Longstaffe F, Law K. 2004b. Demography and ethnic continuity in the Tlailotlacan enclave of Teotihuacan: the evidence from stable oxygen isotopes. Journal of Anthropological Archaeology 23(4):385–403.

White K. 1976. Food requirement and food supplies in classical times. Progress in Food and Nutrition Science 2:143–191.

White K. 1988. Farming and animal husbandry. In: Grant M, Kitzinger R, editors. Civilization of the ancient Mediterranean. New York: Charles Scribner's Sons. p 211–246.

White K. 1995. Cereals, bread and milling in the Roman world. In: Wilkins J, Harvey D, Dobson M, editors. Food in antiquity. Exeter: University of Exeter Press. p 38–43.

White T, Folkens P. 2005. The human bone manual. New York: Academic Press.

Whittaker C. 1995. Do theories of the ancient city matter? In: Cornell T, Lomas K, editors. Urban society in Roman Italy. New York: St. Martin's Press. p 9–26.

Wiedemann T. 1981. Greek and Roman slavery. New York: Routledge.

Wiedemann T. 1989. Adults and children in the Roman Empire. New Haven: Yale University Press.

Wilkins J, Hill S. 2006. Food in the ancient world. New York: Wiley-Blackwell.

Willett W, Sacks F, Trichopoulou A, Drescher G, Ferro-Luzzi A, Helsing E, Trichopoulos D. 1995. Mediterranean diet pyramid: a cultural model for healthy eating. American Journal of Clinical Nutrition 61(6):1402–6.

Wiseman T. 1969. The census in the first century B.C. Journal of Roman Studies 59:59–75.

Witcher R. 2005. The extended metropolis: *urbs*, *suburbium*, and population. Journal of Roman Archaeology 18:120–138.

Wong W, Lee L, Klein P. 1987. Deuterium and oxygen-18 measurements on microliter samples of urine, plasma, saliva, and human milk. American Journal of Clinical Nutrition 45(5):905–913.

Wood J, Milner G, Harpending H, Weiss K. 1992. The osteological paradox: problems of inferring prehistoric health from skeletal samples. Current Anthropology 33(4):343–370.

Yavetz Z. 1958. The living conditions of the urban plebs in Republican Rome. Latomus 17:500–517.

Zakrzewski S. 2007. Population continuity or population change: formation of the ancient Egyptian state. American Journal of Physical Anthropology 132:501–509.

Zanker P. 1990. The power of images in the age of Augustus. Ann Arbor: University of Michigan Press.

Zazzo A, Lécuyer C, Sheppard S, Grandjean P, Mariotti A. 2004. Diagenesis and the reconstruction of paleoenvironments: a method to restore original $\delta^{18}O$ values of carbonate and phosphate from fossil tooth enamel. Geochimica et Cosmochimica Acta 68(10):2245–2258.