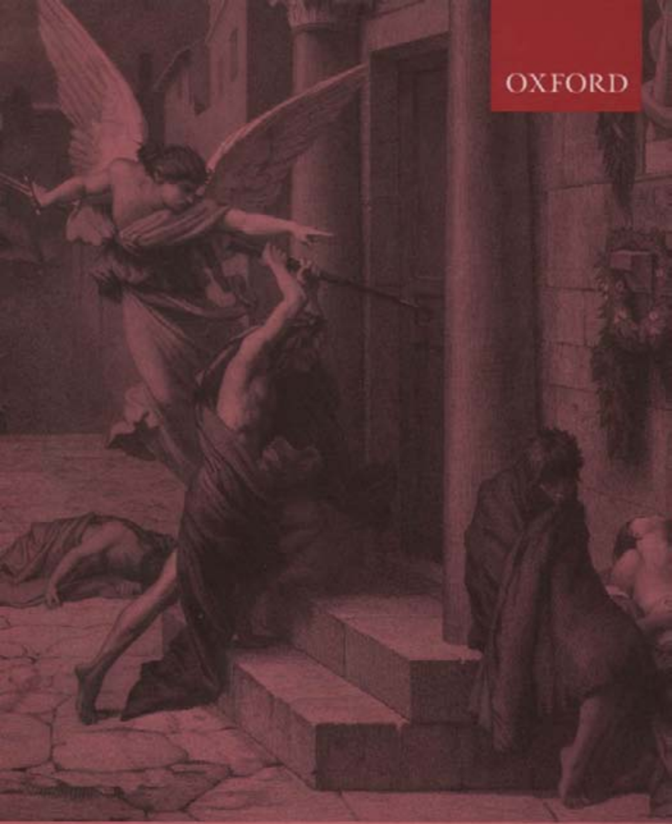

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MALARIA AND ROME

A History of Malaria in Ancient Italy

ROBERT SALLARES

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A history of malaria in ancient Italy

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To my parents

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PREFACE

A detailed knowledge of medical history is essential for understanding mortality patterns in past populations. Medical history in this context does not mean the history of ideas about causes of death, but the history of diseases themselves. It is a very demanding and difficult subject because it requires a multiplicity of different skills. It is necessary to possess the traditional skills in source criticism and analysis of conventional historians, as well as the ability to read texts in foreign or dead languages. However, there is another equally important dimension to it. It also requires a very solid foundation of knowledge about medicine and various branches of the natural sciences. Our knowledge and understanding of the malaria parasite *Plasmodium falciparum* is poised to increase exponentially as a result of the project to sequence its genome. Chromosomes 2 and 3 have already been completely sequenced, and it is likely that the complete DNA sequences of the other dozen chromosomes will have been obtained by the time that this book reaches the bookshops. At the beginning of the new millennium the history of diseases stands on the threshold of a revolution; a revolution created by the application of these new techniques of molecular biology to human skeletal remains excavated on archaeological sites. This revolution will eventually transform our understanding of the evolution, history, and distribution of diseases in prehistory and antiquity. I am engaged in such research, although very little is said about it in this book. Nevertheless the ultimate challenge must be to integrate the data yielded by different approaches, and there is still much to be learned from a comprehensive examination of the ancient documentary and literary sources for malaria, upon which this book concentrates. Very few people have the time and leisure and, dare one say it, the ability to master all the skills that are required by medical historians. The outstanding example of how it should be done is of course the late Mirko Drazen Grmek (obituary in Duffin (2000)). However, he was quite exceptional. There are many historians who are experts in the history of ideas about medicine, but know little or no science. Conversely, there are numerous doctors and scientists who know little or no history. This problem applies to the medical history of all ages, including the medieval and early modern periods, but it is particularly serious as far as classical antiquity is concerned, because of the way in which ancient historians are trained.

Disease and demography have generally been studied quite separately by classicists. There are few exceptions to this trend. Grmek (1983: 135–77) did include a chapter on palaeodemography in his marvellous book on diseases in the ancient Greek world. He concentrated on the evidence for life expectancy provided by ancient bones, a very thorny subject, but said little about the mortality and morbidity levels and epidemiology of even the most important infectious diseases, such as malaria and tuberculosis. The leading figures in research into Roman demography have paid virtually no attention at all to diseases, the major determinants of mortality patterns. Conclusions about the mortality patterns of ancient populations reached by historians who ignore the determinants of mortality patterns can only be pure description, at best. Nothing is being explained. In reality population history is embedded in a much larger ecological context. It cannot be understood without considering this wider context. Demonstrating this in relation to ancient history is the principal objective of this book. Mary Dobson's (1997) *magnum opus* on malaria in early modern England provides an admirable model of how it should be done.

She showed that the homogeneity of human populations, which is generally taken for granted by ancient historians, is basically a phenomenon of the twentieth century and the later stages of the nineteenth century AD. It cannot be taken for granted when studying earlier periods of history. The homogeneity of modern populations is a recent historical development, which was brought about by various specific means, for example the vaccination of entire populations against specific diseases (such as smallpox), and the provision of pure water supplies to whole populations (eliminating water-borne diseases). The development of universal health care services, for instance when the Italian government made the anti-malarial drug quinine available to the entire Italian population free of charge at the beginning of the twentieth century, also played a major role, as well as general improvements in nutrition and the standard of living. Even so, there are still significant differences in mortality patterns between different regions and different social classes in modern European populations. In Britain at the time of writing life expectancy for males varies between 68 and 78 years, and for females between 75 and 83, in different parts of the country. No modern population is entirely homogeneous. It is clear that the populations of early modern Europe were much less homogeneous. In fact, regional diversity prevailed. Yet the homogeneity of populations in antiquity is an assumption built into virtually all published modern literature on ancient Roman demography. There is no evidence at all for this supposed population homogeneity in antiquity. The assumption is the result of a particular method of analysis, namely the brandishing of life tables *not* derived from evidence for ancient populations as schematic models supposedly applicable to the entire Roman Empire. In contrast, this book is a regional case study demonstrating that the regional diversity of demographic patterns now known to have been the norm in early modern Europe was also the norm in antiquity. It argues that actual demographic conditions were strictly dependent on often very highly localized ecological circumstances, particularly the precise configuration of the local ecological community of diseases or *pathocoenosis* (to use Grmek's concept), which was in turn inextricably linked to other variables (e.g. climate, physical geography, hydrology, population density, the history of the distribution of disease vectors, etc.). In central and southern Italy in antiquity malaria was the single most important component of the pathocoenosis. The aim of this book is to focus attention on the effects of malaria on population structure, rather than population size.

In the course of this book frequent references are made to comparative material from later periods of Italian history. However, this book is most certainly not intended to be a comprehensive account of the history of malaria in medieval and early modern Italy. Obviously that would require another book or series of books, given the large volume of source material that is available. The intention here is rather to use later material selectively to explicate the generally fragmentary ancient sources. For example, when Cicero describes the course of an infection of quartan fever in Atticus, how typical was the case of Atticus? It is unique in ancient Latin literature for its chronological detail, but statistical analysis is impossible with a sample of one. It is only by considering more abundant evidence from later periods that we can see that his case history was an absolutely typical example of the chronology of cases of quartan fever in Italy in the past; undoubtedly there were countless other cases like it in antiquity (see Ch. 5. 2 below). It is exceedingly easy for ancient historians who are not specialists in medical matters to grossly underestimate how much material is in fact available. The Italian National Archive Office is currently undertaking a major project to publish all the documentation in its possession relating to malaria in Italy. Fantini and Muzzioli (1987) compiled a long catalogue of the numerous archives in the city of Rome containing documents relevant to the study of malaria in Italy, while in 1998 the journal *Medicina nei Secoli : Arte e Scienza* (10/3) published a long series of articles on the archival sources for malaria in Italy.

Traditionally ancient history ended with the downfall of the last Roman emperor in AD 476, with the implication of a sharp break between the ancient and medieval eras, although it is arguable that this date had no real significance. As far as the city of Rome is concerned, the Gothic wars described by Procopius in the sixth century AD did the worst damage to Rome itself. The old civic institutions such as the Roman Senate seem to have disappeared by the time of the reign of Pope Gregory the Great (AD 590–604). Some specialists in late antiquity speak of the transformation of the Roman world and extend the chronological span of antiquity forwards into the sixth or seventh centuries AD, reverting towards Henri Pirenne's (1937) opinion that the break between the ancient and the mediaeval worlds occurred in the time of Charlemagne in the eighth century, rather than in the fifth century. However, this position still leaves a dividing line between, on the one hand, ancient Roman history, and, on the other hand, later Italian history. The argument of this book is that the divide between ancient history and later periods is a barrier to understanding, at least as far as the topic of this book is concerned. It has prevented ancient historians from using the much more abundant and detailed later evidence to make sense of the fragmentary ancient sources.

ACKNOWLEDGEMENTS

This book was largely written during a very fruitful period of collaborative research with Walter Scheidel. Indeed it would probably never have been written at all without him. Our original intention was to integrate my research with Walter's research into a much larger volume comparing the effects of diseases on demographic patterns in different parts of the Roman world, but it became clear that our combined manuscript was too long for a single book. Consequently the original manuscript was broken up into pieces for separate publication. However, Walter's forthcoming book *Death on the Nile: disease and the demography of Roman Egypt* should be read as a complement to this book. It demonstrates convincingly that regional variation in mortality patterns was as normal in Egypt during the time of the Roman Empire as it was in Italy, as is argued here. His book considerably extends the critical discussion in Chapters 5 and 11 here of the irrelevance to ancient populations of model life-tables based on data from modern populations. It also contains interesting pages on malaria in Roman Egypt, where the disease flourished in environments very different from those described here, illustrating its adaptability.

Mario Coluzzi, Gilberto Corbellini, Tim Cornell, Peter Garnsey, Mirko Grmek, and John Scarborough all read previous versions of the text. Carmine Ampolo made helpful comments at a conference in Parma. Mary Dobson provided a photocopy of an important article that was difficult to obtain. Peter Attema and Franco Ravelli supplied copies of some of their own work. Mario Coluzzi, Clem Ramsdale, and Graham White provided information about mosquitoes. James Oeppen and Richard Smith gave advice on one technical detail about life-tables. The comments of the anonymous referees were very helpful. Susan Gomzi, Abigail Bouwman, and Cia Anderung worked alongside me on the bones from Lugnano in Teverina, which were provided by David Soren. I wish to thank Mario Coluzzi and Claudio Finistauri for their hospitality when I visited the Istituto di Parassitologia in La Sapienza University, Rome, and Lugnano in Teverina. I also wish to thank

Hilary O'Shea and the staff of Oxford University Press and Jane Wheare. Last but not least, financial support from the Leverhulme Trust was invaluable.

Obviously I am solely responsible for the views expressed and for any faults that remain. All the translations of Latin, Greek, and Italian texts are my own translations. I benefited enormously from the resources of the John Rylands Library in Manchester and the Wellcome Library for the History and Understanding of Medicine in London, as it is now called. One important work exploited in this book was accidentally discovered, while looking for something else, gathering dust on a shelf in the Rylands Library. It did not look as if anyone had read it for a hundred years. I hope this book will enjoy a better fate.

R. S.

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ILLUSTRATIONS

All photographs were taken by the author except where stated otherwise in the captions to the illustrations.

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1

Introduction

Keith Hopkins moved the study of the demography of the ancient Roman world into a new era with his demonstration that 'ages at death derived from Roman tombstones cannot be used to estimate expectation of life at birth or at subsequent ages'.[1] He suggested that the life expectancy at birth of the Roman population lay between 20 and 30 and advocated that life-tables derived from data from modern populations should be used as models for the age-structure of the Roman population in antiquity. Since then, the use of these model life-tables has enjoyed a considerable degree of popularity among ancient historians. Indeed it has become the current orthodoxy, almost an article of faith in certain quarters. Hopkins himself was careful to add an important qualification, in terms of a requirement for further research, at the end of his article: 'Our attention . . . should . . . be directed . . . to a more general assessment of the applicability of these model life tables and to an analysis of the determinants of mortality, both in Rome in particular, and in general.'[2] Unfortunately he never followed up his own recommendation. The bulk of subsequent research has also failed signally in this respect. Yet an analysis of the causes of death is absolutely essential if we are ever to move beyond attempting to *describe* mortality in antiquity towards *explaining* and *understanding* it. The message of this book is simply that in order to understand the demography of the ancient Roman world, it is necessary to pay much more attention to medical history than has been done in the bulk of research carried out so far into Roman demography.

Karl Julius Beloch, the pioneer of Roman demography, did not confine himself to antiquity. He intensively investigated Italian population history in more recent periods to provide a comparative foundation for his analysis of the scanty evidence from antiquity. A large proportion of the output of Roman historians over the last

[1] Hopkins (1966: 246). [2] Hopkins (1966: 264).

thirty years or so has failed to follow his example. Yet there is a wealth of evidence there, waiting to be exploited, which provides food for thought. The starting-point of the argument here is an extremely interesting recent discussion, by two leading Italian historical demographers, del Panta and Rettaroli, of an earlier study by one of them (del Panta) of the demography of Grosseto in the last century.[3] They observed that the age-structure of the population of Grosseto in the 1840s does not match closely any of the Coale and Demeny life-tables, the set of model life-tables for the age-structures of human populations most widely employed by demographers, which are so popular with some ancient historians. Nor did the age-structure of the population of Grosseto match any of the other available sets of model life-tables based on data for modern European populations. However, the demography of Grosseto in the last century does resemble something else that is completely different. What it resembles more than anything else, as they pointed out, is the demography of certain parts of Africa today where malaria is endemic.[4] Of course the demographic patterns are not, and never could have been, precisely identical, because of numerous profound differences in the environment between central Italy and tropical Africa.

Nevertheless the degree of similarity in the demographic patterns between Grosseto and tropical Africa is striking. Malaria has an awesome power as a determinant of demographic patterns. It is estimated to have caused about a million deaths in Africa in 1995, and it also has far-reaching indirect effects, as will be seen later.[5] In addition, it had the ability in the past to overcome the ecological barriers between tropical Africa and the Mediterranean world and so bring its power as a determinant of human demographic patterns to the ancient Mediterranean world, but this has been ignored by most Roman historians interested in ancient demography.[6]

[3] Del Panta and Rettaroli (1994: 201–3); del Panta (1989).

[4] Root (1999) discussed the relationship between differences in the intensity of malaria transmission and differences in spatial mortality patterns in various parts of Africa.

[5] Snow *et al.* (1999).

[6] A few historians have noted malaria as a possible contributing factor to mortality in antiquity. For example, J. C. Russell (1985: 88–9, 228, 234) rightly associated malaria with extremely high adult mortality, but regarded tuberculosis as more important. His suggestion that the 'Antonine plague' in the second century AD was *P. falciparum* malaria is exceedingly improbable (it was almost certainly smallpox). Similarly the suggestion (Karlen (1996: 69–70); Cartwright and Biddiss (2000: 9–10)), that the epidemic which struck Rome (Cassius Dio 66.23.5; Suetonius, *Divus Titus* 8.3–4) after the eruption of Vesuvius in AD 79 was *the first*

The crux of the matter, as a problem in demography, is the relationship between infant mortality and adult mortality. This balance is affected by the differing effects of malaria on different age groups. These effects of malaria on different age groups depend, in turn, on its transmission rate. In general, European populations in the past where malaria was endemic had higher levels of adult mortality relative to infant and child mortality than otherwise similar populations unaffected by malaria, as well as much higher total mortality. The overall effect of malaria in terms of increasing mortality has indeed long been known, at least in principle (and, as will be seen later, the essence of the matter was also known in antiquity). Angelo Celli, one of the pioneers of the important Italian school of malariology, wrote at the end of the nineteenth century as follows: 'the average life of the worker in malarious places is shorter, and the infant mortality higher, than in healthy places'.[7] However, at that time modern historical demography based on such techniques as family reconstitution had not yet developed. It is only more recently that it has become possible to appreciate in quantitative terms the sheer scale of the phenomenon. Del Panta and Rettaroli compared the demography of Grosseto in the last century with the demography of Treppio, an Appennine community located north-east of Pistoia which was not affected by malaria. The population of Treppio had a life expectancy at birth of 37, but the population of Grosseto had a life expectancy at birth of only 20, with corresponding substantial differences in the age distribution of mortality in the two populations. The effect of the presence of malaria was to nearly halve life expectancy at birth (see Ch. 5. 4 below for further discussion).

Given such enormous effects, it is not surprising that Italian historians, scientists, and politicians devoted a great deal of attention to malaria so long as it continued to be a major public health problem in Italy. As Bonelli put it, 'malaria was for centuries . . .

appearance of *P. falciparum* malaria in Rome, has nothing to recommend it, even if the emperor Vespasian himself did die from malaria in that year at Aquae Cutiliae in the Sabine region (Cassius Dio 66.17.1: νοσήσας . . . πυρετοῖς (he became ill with fevers); Suetonius, *Divus Vespasianus* 24.1). Scobie (1986: 422) mentioned malaria alongside gastro-intestinal diseases; Morley (1996: 43) also mentioned malaria; Salmon (1992) is rather more detailed. Nevertheless its importance has in the main not been appreciated by historians interested in ancient demography. A. Wear (1995: 226), writing about the early modern period, asserted that 'the falciparum form of malaria did not exist in Europe', an extraordinary error.

[7] Celli (1900: 18).

one of the determining factors of the demographic and socio-economic evolution of a large part of the Italian peninsula'.[8] Celli compiled a bibliography containing no less than 354 items on malaria in the Roman Campagna, up to the end of the last century.[9] Interest continued to be strong in the first half of the twentieth century. However, the level of interest has waned since the final eradication of malaria from Italy after the Second World War. The last cases of native malaria in Italy were recorded in 1962. A re-organization of research in Rome led to the demise of the principal journal in the field, the *Rivista di Malariologia*, in 1967. This decrease in interest is reflected in the length of the bibliography, compiled by the eminent medical historian Mirko Grmek, of studies written in the twentieth century devoted to malaria in antiquity, only 113 items.[10] This, in turn, is an example of the truism that historiography reflects contemporary interests. However, it is very important for modern historians to remember that so long as it was present, malaria was felt to be an enormous problem in Italy. The Pontine Marshes, one of the principal havens of malaria in central Italy, during the last two millennia attracted the attention of such major historical figures as Julius Caesar, Napoleon, and Mussolini, besides countless others of less note. Julius Caesar, who suffered from a quartan fever in his youth, conceived a scheme to drain the Pontine Marshes and make the area fit for agriculture, but it had not commenced at the time of his death.[11] Napoleon is reported to have been displeased when he learned that the French Empire contained a very large marsh. His efforts did not make any progress either, although the investigations of his prefect of Rome, M. le Comte De Tournon, constitute a fundamental source for the state of Lazio before modernization.[12] Mussolini finally succeeded where all his predecessors had failed for over two thousand years, and completely drained the Pontine Marshes, as part of his policy

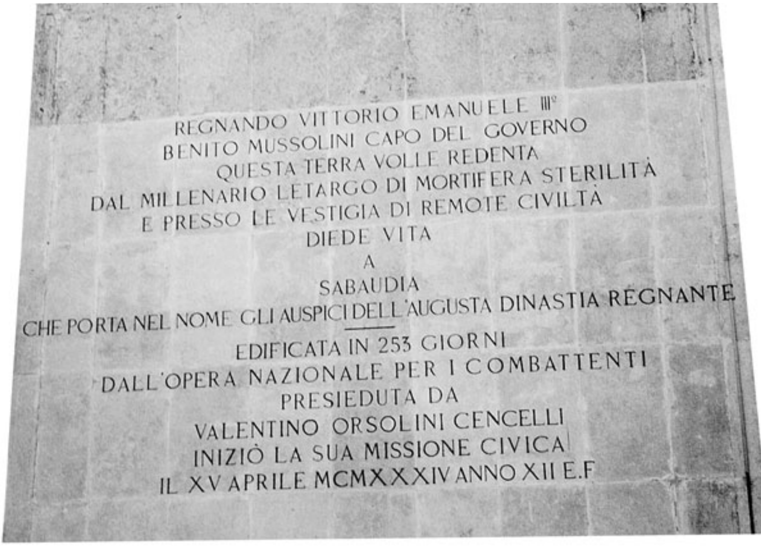
[8] Bonelli (1966: 659): '*la malaria fu per secoli . . . uno dei fattori determinanti della evoluzione demografica ed economico-sociale di una vasta parte della penisola italiana*'.

[9] Celli (1900: 256–75).

[10] Grmek (1994).

[11] Suetonius *DJ* 1.2: *morbo quartanae adgravante* (seriously ill with a quartan fever) and 44.3: *siccare Pomptinas paludes* (to drain the Pontine marches); Cicero, *Philippics* 5.7: *ille paludes siccare voluit* (he wanted to drain the marshes); Plutarch, *Caesar* 58.9, ed. Ziegler: τὰ μὲν ἕλη τὰ περὶ Πωμεντῖνον καὶ Σητίαν ἐκτρέψας πεδίον ἀποδεῖξαι πολλαῖς ἐνεργὸν ἀνθρώπων μυριάσι (he wished to turn the marshes around Pomentinum and Setia into a plain which could be cultivated by many thousands of men).

[12] Celli (1900: 102); De Tournon (1831).



1 Mussolini's inscription at Sabaudia, commemorating the eradication of malaria from the Pontine Marshes and the foundation of the new town of Sabaudia in 1934.

of internal colonization in Italy.[13] In doing so, he altered the environment in a way that makes it difficult to imagine now what it was like in the past. The justification for another lengthy discussion of malaria, in spite of the volume of literature on the subject, is that there is nothing recent which combines a comprehensive assessment of the ancient sources for malaria in Italy with the latest results in historical demography and the latest advances in medical research and the scientific understanding of malaria. This book is devoted to reassessing the history and ecology of malaria in western central Italy in antiquity, and in particular its demographic consequences.

[13] Collari (1949); Desowitz (1992: 210–11).


N
FRANCE
BOSNIA AND HERZEGOVINA
ALBANIA
TUNISIA
Milan
Venice
Ferrara
Genoa
Ravenna
Pistoia
Pisa
Florence
Livorno
TUSCANY
Ancona
Perugia
UMBRIA
Grosseto
Terni
MAREMMA
Pescara
Adriatic Sea
CORSICA
Rome
LAZIO
Pontine Marshes
APULIA
Capua
Bari
Brundisium
CAMPANIA
Naples
Tarentum
Paestum
SARDINIA
Metapontum
Tyrrhenian Sea
Sybaris
Paola
SILA
Croton
Cagliari
CALABRIA
Palermo
Mediterranean Sea
SICILY
Akragas (Agrigento)
Syracuse
Carthage
Camarina

Map 1. Italy

2

Types of malaria

There are about 200 species of malaria, eukaryotic parasitic protozoa that belong to the suborder *Haemosporina*, order *Eucoccidiida*, subclass *Coccidia*, class *Sporozoea* of the phylum *Apicomplexa*.[1] New species are indeed still being discovered; yet another instance which illustrates the incompleteness of our current knowledge of biodiversity.[2] Most of these species of malaria infect other primates, rodents, bats, reptiles, and birds. Avian species of malaria have a much wider geographical distribution than malaria parasites of terrestrial animals (except the human species transported by man around the world) because of the mobility of birds. The avian species of malaria are abundant at the heart of the geographical area under study here, in the Roman Campagna. Since research in molecular evolution indicates that the malaria parasites are a very ancient group of organisms that originated at least two hundred million years ago, and birds are now widely believed to be descendants of dinosaurs, it is quite likely that dinosaurs also suffered from malaria. Malaria is not solely a problem for humans. Indeed it can sometimes cause severe problems for other animals as well. For example, the role of the introduction of avian species of malaria to Hawaii in the extinction of species of birds indigenous to that country has been a subject of debate in conservation biology.[3] However, the focus of this book will be on human malaria.

The word 'malaria' originally signified 'bad air' (*mal'aria*) in Italian. This name was derived from the theory of the miasmatic nature of the disease which prevailed until Laveran's discovery of malarial parasites in human blood in 1880 (see Ch. 4. 1 below). Gilberto Corbellini and Lorenza Merzagora found that the first attested use of the term *mal aere* was by Marco Cornaro in a book entitled *Scritture della laguna*, which was published in Venice in 1440. The earliest Italian publication to use the word *malaria* without the

[1] For the Greek and Latin origins of these names see Scarborough (1992: 37, 111).

[2] Kreier and Baker (1987). Perkins (2000) is a recent report of the discovery of a new species of Plasmodium.

[3] Cann and Douglas (1999).

Table 1. Some of the species in the genus *Plasmodium*

Species	Host	Periodicity
P. vivax	Humans	Tertian
P. schwetzi	Chimpanzees	Tertian
P. pitheci	Orang-utans	Quartan?
P. hylobati	Gibbons	Quartan?
P. eylesi	Gibbons	Tertian
P. jefferyi	Gibbons	Tertian
P. cynomolgi	Monkeys	Tertian
P. ovale	Humans	Tertian
P. simium	Monkeys	Tertian
P. fieldi	Monkeys	Tertian
P. simiovale	Monkeys	Tertian
P. gonderi	Monkeys	Tertian
P. malariae	Humans	Quartan
P. inui	Monkeys	Quartan
P. brasilianum	Monkeys	Quartan
P. knowlesi	Monkeys	Quotidian
P. coatneyi	Monkeys	Tertian
P. fragile	Monkeys	Tertian
P. falciparum	Humans	Tertian
P. reichenowi	Chimpanzees	Tertian
P. berghei	Rodents	Quotidian ?
P. chabaudi	Rodents	Quotidian ?
P. girardi	Lemurs	Quartan
P. sandoshami	Colugo	Quartan
P. traguli	Mouse deer	?
P. bubalis	Water buffalo	Quartan
P. atheruri	Porcupines	Quotidian
P. voltaicum	Bats	?
P. relictum	Birds	36 hourly
P. subpraecox	Owls	Quotidian
P. cathemerium	Birds	Quotidian
P. matutinum	Birds	Quotidian
P. giovannolai	Birds	Quotidian
P. gallinaceum	Birds	36 hourly
P. circumflexum	Birds	Tertian
P. lophurae	Birds	Quotidian
P. pinottii	Birds	Quotidian
P. rouxi	Birds	Quotidian
P. elongatum	Birds	Quotidian
P. floridense	Lizards	?
P. mexicanum	Lizards	?
P. wenyoni	Snakes	?

Source: Garnham (1966). There are numerous other species infecting mammals, birds and reptiles belonging to other genera which are closely related to *Plasmodium* but differ from it in that they are transmitted by vectors other than mosquitoes and in that schizogony does not occur in erythrocytes.

apostrophe that indicated its original meaning was Francesco Puccinotti's book *Storia delle febbri intermittenti di Roma*, published in Naples in 1838, although Guido Baccelli's book *La malaria di Roma*, published just two years before Laveran's discoveries, was the first work to apply it to the disease.[4] The word *malaria* was introduced into English literature by Horace Walpole in 1740. He made his exit from Rome just before the annual epidemic of *P. falciparum* malaria started. The English traveller did not expect to be able to get a Christian burial if he died from malaria in Catholic Rome!

> You will wonder, my dear Hal, to find me on the road from Rome: why, intend I did to stay for a new popedom, but the old eminences are cross and obstinate, and will not choose one, the Holy Ghost does not know when. There is a horrid thing called the malaria, that comes to Rome every summer, and kills one, and I did not care for being killed so far from Christian burial.[5]

Today there are known to be four species of human malaria belonging to the genus *Plasmodium*: *P. falciparum* (malignant tertian), *P. vivax* (benign tertian), *P. malariae* (quartan), and *P. ovale*. *P. ovale*, a fairly mild type of malaria, was not endemic in Mediterranean countries. Consequently only the first three species will be considered here.[6] Their common names, such as tertian and quartan fever, are no longer used in modern medical literature, but of course are found in historical sources. All three species generate a variety of clinical symptoms and syndromes, many of which can also be produced by other diseases.[7] Malaria can easily mimic typhoid fever, hepatitis A, or influenza, for example. It is above all

[4] Corbellini and Merzagora (1998: 53–4). Baccelli's work was reprinted in *Monografia* (1881).

[5] *Letters of Horace Walpole*, ed. C. D. Yonge (1889), i. 20, 'to the Hon. H.S. Conway', 5 July 1740.

[6] Garnham (1966: 217) recorded an isolated case of *P. ovale* malaria in Epirus in Greece. Qari *et al.* (1993) identified a new human malaria parasite morphologically similar to *P. vivax*, but with the same circumsporozoite protein as the monkey parasite *P. simiovale*, which they termed '*P. vivax*-like'. Since it occurs in Papua New Guinea (besides Indonesia, Madagascar, and Brazil), where there are no monkeys, it appears to be established now in human populations, although it doubtless arose as a zoonosis, cf. Escalante *et al.* (1995). Since there is no evidence for its occurrence in Mediterranean countries it is not relevant for current purposes. Other species of malaria which typically infect primates other than man may occasionally cause zoonoses in humans (Fiennes (1967: 70–5)).

[7] For the symptoms see Gilles and Warrell (1993: 35–49); Harinasuta and Bunnag in Wernsdorfer and McGregor (1988: i. 709–34); Marchiafava and Bignami (1894) and Marchiafava (1931) on symptoms of *P. falciparum* malaria in Italy; Armand-Delille *et al.* (1918: 13–77) described the symptoms of *P. falciparum* malaria in Macedonia.

the characteristic periodicity of intense fever recurring on the second day, in the case of *P. falciparum* and *P. vivax*, or on the third day, in the case of *P. malariae*, which distinguishes malaria from other diseases. This feature enables us to be certain that ancient texts do in fact refer to malaria.

There are indeed other diseases which have some periodic tendencies, for example relapsing fever (*Borrelia recurrentis*) transmitted by the human body louse, or brucellosis (undulant fever), which is most commonly acquired by ingesting contaminated milk or cheese. In relapsing fever attacks last for five to nine days, followed by a similar period of intermission, while in some cases of brucellosis there is a daily periodicity more reminiscent of that of malaria. These diseases certainly existed in Roman times.[8] However, they lack the characteristic association with certain types of environment, especially wetland environments, which are strongly associated with malaria, because they are not transmitted by mosquitoes. Similarly all the other major infectious diseases transmitted predominantly either directly by the respiratory route (e.g. tuberculosis, influenza, and smallpox) or by vectors other than mosquitoes (e.g. typhus and bubonic plague) do not have any epidemiological association with wetland environments. In the tropics important viral diseases transmitted by mosquitoes exist (for example, yellow fever and dengue fever). However, mosquito-transmitted diseases caused by viruses cannot become endemic in Europe because they induce complete immunity in survivors and require constant transmission to new hosts. Yellow fever, for example, cannot survive the winter in Europe because its vector mosquito (*Aedes aegypti*) cannot stand European winters.[9] In Europe malaria was the only major disease transmitted by mosquitoes in the past and so strongly associated with mosquito breeding sites in wetlands. Consequently in the search for ancient malaria in this book the focus will be on texts that give general descriptions of particular regions in which seasonal unhealthiness is associated with certain types of environments. Such descriptions on the whole constitute a better source

[8] Capasso (1999) has recently demonstrated the presence of brucellosis in a number of the skeletons from Herculaneum.

[9] Yellow fever caused brief summer epidemics in some Mediterranean cities in the eighteenth and nineteenth centuries. For example, Palloni (1804) described a yellow-fever epidemic at Livorno. It killed over 700 people out of a total population of about 70,000, but did not survive the winter or spread beyond the part of the town closest to the sea. The disease obviously arrived on board a ship.

of evidence for malaria than biographical accounts of the illnesses of individuals, such as Alexander the Great or various Roman or Byzantine emperors, which frequently provide too little detail for a reliable retrospective diagnosis.[10]

The periodicity of malarial fevers is caused by the synchronized process of schizogony (or merogony, a type of asexual reproduction unique to parasitic protozoa) at the end of which erythrocytes burst, releasing new merozoites into the bloodstream to invade other red blood cells. However, it is important to bear in mind that in practice the characteristic periodicity is not in fact observed in many cases, owing to infections with multiple generations of parasites whose developmental cycles are not synchronized. Experiments in which malaria was deliberately transmitted by infected mosquitoes to patients suffering from syphilis and afterwards cured with quinine (*Treponema pallidum*, the pathogen of syphilis, cannot tolerate the temperatures generated by malarial fevers inside the human body) were carried out for many years at Horton Hospital in Epsom in England. These experiments proved that in malaria caused by *P. falciparum*, the most dangerous species of malaria, most attacks take the form of subcontinuous or quotidian (peaking every twenty-four hours) fevers. It was also demonstrated that even in the milder type of malaria caused by *P. vivax* the periodicity of the fever is generally quotidian in primary infections throughout the course of the attack. The periodicity of vivax malaria is only tertian from the beginning of the attack in relapses. The tertian and quartan periodicities are the clearest symptoms of malaria found in historical sources. References to quotidian fevers have less diagnostic value because of the possibility of confusion with other diseases, for example typhoid fever (see Ch. 5. 2 below). However, it must be recognized that modern experimental research in medicine indicates that references to the tertian and quartan periodic fevers in ancient sources only reveal the tip of the iceberg of malaria in antiquity. This is a very important conclusion for the interpretation of the ancient evidence. A large proportion of all cases of both *P. falciparum* and *P. vivax* malaria, including virtually all primary infections, would have taken a quotidian form in antiquity just as they do today.[11]

[10] Illustrations of the biographical approach: Engels (1978) on Alexander; Lascaratos and Marketos (1997) on the Byzantine emperor Andronicus III Palaeologus.

[11] Covel and Nicol (1951) and Shute (1951) on the work at Horton Hospital, which

As a general rule, it may be said that the longer and the more regular the periodicity, the less dangerous the disease. It was well known in antiquity that quartan fevers were usually not dangerous (although *P. malariae* is now known to cause quartan malarial nephrosis, a severe kidney disease), but nevertheless lasted longer than other malarial fevers. *P. falciparum* infections do not last much longer than a year (but cf. Ch. 5. 4 below for recent modifications to this standard view found in the textbooks), and *P. vivax* infections do not last for longer than three to six years. However, there are cases in modern medical literature of individuals who had recrudescences with clinical symptoms of *P. malariae* over fifty years after the original infection. One woman from Karpathos in Greece was infected with quartan fever at the age of three in 1925, and then had no further attacks until she reached the age of seventy-two, when a recrudescence occurred following treatment for another medical condition with an immunosuppressive drug. Presumably in this particular case the human immune response was strong enough to keep the infection asymptomatic after the initial attack for seventy years, but not powerful enough to eliminate the parasites from the body completely. This suggests that *P. malariae* can effectively persist throughout the entire life span of the human host. The asymptomatic persistence of *P. malariae* infections has been frequently revealed in modern cases by the use of infected blood in transfusions. Celsus affirmed that quartan fevers did not kill anyone, although Antonio Benivieni of Florence (1443–1502), one of the earliest practitioners of pathological anatomy, described one fatal case of quartan fever in the fifteenth century AD.[12] The periodic episodes of fever during a malarial infection are probably a

followed the Nobel Prize-winning discovery of the malaria treatment for syphilis by Julius Wagner-Jauregg in Vienna in June 1917 (Whitrow 1990; see also Ch. 5. 2 below). Recent textbooks on malaria reiterate these conclusions, stating for example that 'tertian periodicity is rarely seen in falciparum malaria: persistent spiking fever or a daily (quotidian) febrile paroxysm is more usual' (Gilles and Warrell (1993: 37)).

[12] Garnham (1966: 275–6) and the monograph of Kibukamusoke (1973) on the kidney disease; L. H. Miller in Wernsdorfer and McGregor (1988: i. 729); Lentini and Tecce (1955), Guazzi and Grazi (1963), Garnham (1966: 271–2), Vinetz *et al.* (1998), and Chadee *et al.* (2000) on longevity of quartan fever; Garnham (1966: 45–9) on definitions of the terms *relapse*, *recrudescence*, and *recurrence* in malariology; Celsus, *de medicina* 3.15.6: *quartana neminem iugulat* (quartan fever kills no one); Oribasius, *synopsis ad Eustathium* 6.13, ed. Raeder: *τοὺς τεταρταῖον νοσοῦντας πρᾴως ἄγειν* (those who are sick with quartan fever have a mild disease); Galen 17A.226–7K and 17B.341–3K; Benivieni (1528/9), 59; Carmichael (1989: 34–5) discussed Benivieni.

non-specific immune response by the human body in an attempt to bring the infection under control, by making it too hot for the parasites to thrive.[13]

It is agreed by all those interested in this subject that *P. vivax* (and *P. malariae*, generally regarded as insignificant with regard to mortality) was present in the Mediterranean by the fifth century BC. This is shown by numerous texts in the Hippocratic corpus and later medical writers. Even if, for the sake of argument, only the presence of *P. vivax* (and *P. malariae*) in Greece in the fifth century BC is accepted, recent research in historical demography (see Ch. 5. 4 below) has demonstrated that *P. vivax*, in synergistic interactions with other diseases, is capable of enormous effects on the mortality regimes of human populations, even though it seldom kills otherwise healthy and well-nourished individuals by itself, according to the general consensus of medical literature.[14] The position with regard to the history of *P. falciparum*, the most dangerous species of human malaria, is more controversial. Some authors (e.g. G. Belios and J. P. Kardamatis for Greece) have regarded *P. falciparum* as present in Mediterranean countries from time immemorial. Similarly Brunt found no evidence in literary sources that malaria was regarded as a new disease in Italy in classical times. Nevertheless others have reached the conclusion that *P. falciparum* malaria was only introduced to the Mediterranean world in the course of the Graeco-Roman period. W. H. S. Jones originally suggested that it was introduced to Italy by Hannibal's soldiers during the Second Punic War, but later suggested that it had reached Sybaris by the end of the archaic period. He also maintained that the disease played a major role in the decline of classical Greek civilization. Grmek once argued that malaria flourished in Greece in the Neolithic period, continued to exist at a low level in dispersed locations, and spread again in the fifth century BC. More recently he declared that the evidence for *P. falciparum* malaria in Neolithic Greece, adduced by J. L. Angel, is no longer compelling, even though it is

[13] Gravenor and Kwiatkowski (1998), but cf. Hoshen *et al.* (2000).

[14] L. H. Miller in Wernsdorfer and McGregor (1988: i. 713): 'infections with *P. vivax* are rarely fatal', cf. Gilles and Warrell (1993: 44): 'severe vivax malaria has been described in the past (for example, in Europe) possibly related to malnutrition and other intercurrent diseases. However . . . the acute mortality of vivax malaria is very low'.

likely that it was present in small foci. Zulueta is even sceptical about the presence of *P. falciparum* in Greece as late as the fifth century BC. He dates its spread in the Mediterranean to the time of the Roman Empire. Celli, the author of what remains the only comprehensive survey of malaria in the Roman Campagna throughout history, sidestepped the debate about the time of introduction of *P. falciparum* by devising a theory of periodic attenuations of the virulence of the disease ('*grandi attenuazioni periodiche dell' infezione*'). Celli's book is still extremely valuable for its collection of historical sources. However, it is inevitably to some extent out of date owing to the steady march of progress in science and medicine during the twentieth century. Tomassetti reckoned that malaria was above all a phenomenon of the early modern period and was not so bad in antiquity, but he did not examine the ancient sources thoroughly. Many modern historians have expressed similar opinions without studying the relevant ancient sources (especially the medical authors—Celsus, Galen, and Asclepiades) in the necessary detail.[15] It is now time to examine some of these ancient sources.

Celsus, writing in the time of Tiberius in the early first century AD, provides important evidence. The interpretation of his text is easy if it is compared to the very detailed account and case studies of Ettore Marchiafava, who in collaboration with Celli first described *P. falciparum* under the microscope in 1889, in Italy. After describing quartan fevers caused by *P. malariae* (see Ch. 5. 2 below), Celsus continued as follows:

> There are two types of tertian fever. The first type commences and terminates in the same manner as quartan fever. Its distinguishing feature is that it disappears for one whole day and returns on the third day. The second type is much more pernicious. It too recurs on the third day. However, out of the forty eight hours, the paroxysm lasts for almost thirty-six hours (sometimes more or less), nor is there any total cessation during the remission, but it becomes less severe. Most doctors call this type of fever semi-tertian.[16]

[15] The Bibliography for this book concentrates on recent literature, although the most important older works are included. Fraccaro (1919) discussed the principal theories which had been proposed up to then; Jones (1907), (1908) and (1909*a*) and (1909*b*); Brunt (1987: 611–24); Corvisier (1994); Grmek (1983: 397–407) and (1994); Zulueta (1973), (1987: 200–3), and (1994); Celli (1933); Tomassetti (1910: i. 68–72, 164–71).

[16] Celsus, *de medicina* 3.3.2: *Tertianarum vero duo genera sunt. Alterum eodem modo, quo quartana, et incipiens et desinens, illo tantum interposito discrimine, quod unum diem praestat integrum, tertio redit. Alterum longe perniciosius, quod tertio quidem die revertitur, ex quadraginta autem et octo horis fere triginta et*

In a later passage, Celsus confirms that the pernicious semitertian fevers were frequently fatal. He ascribed that outcome to mistakes made by doctors, unintentionally suggesting that treatment may often have been worse than no treatment at all.[17] This point of view was explicitly enunciated, in relation to all diseases occurring in Italy, by Latanzio Magiotti, physician to the court of the Grand Duke of Florence in the seventeenth century AD. Celsus himself recommended blood letting at the beginning of treatment. This is unlikely to have been beneficial to patients with the anaemias typically associated with malaria.[18] Moreover tools used for bleeding could conceivably themselves have been a source of transmission of malaria via contaminated blood, if they were not cleaned thoroughly after each use. The elder Cato's denunciation of Greek medicine as worthless was probably well founded in practice, especially in relation to malaria, however interesting the Hippocratic approach to medicine may be to modern historians of medicine, although many treatments could have worked as placebos.[19]

Marchiafava wrote as follows: 'I may say, at once, on the basis of forty-three years' experience, that pernicious symptoms arise only in connection with . . . *P. falciparum* [and not *P. vivax*].' He later went on to differentiate *P. falciparum* from *P. vivax* malaria by 'the long duration of the febrile access, viz. from 24 to 36 hours or more, with brief and poorly defined intervals.[20] The tertian character of the fever is recognised from the period elapsing between the onset of one access and that of the next, and in pure forms, it can clearly

sex per accessionem occupat (interdum etiam vel minus vel plus), neque ex toto in remissione desistit, sed tantum levius est. Id genus plerique medici ἡμιτριταῖον appellant. Compare the Hippocratic definition of a semitertian fever as a fever which becomes milder on one day, without completely ceasing, and then severe again on the following day: Hippocrates, *Epidemics* 1.2, ed. Littré (1839–61), ii. 606–9: *τὸ μὲν ὅλον οὐ διαλείποντες· ὁ δὲ τρόπος ἡμιτριταῖος· μίαν κουφότεροι, τῇ ἑτέρῃ ἐπιπαροξυνόμενοι.*

17 Celsus, *de medicina* 3.8.2: *plurimique sub alterutro curantis errore subito moriuntur. Ac nisi magnopere res aliqua prohibet, inter initia sanguis mitti debet, tum dari cibus* (Many patients die suddenly as a result of various errors by doctors. And unless there is a strong reason for not doing so, bleeding should take place at the beginning of the illness, and then food should be given to enable the patient to sustain a long period of fever without aggravating it).

18 Cipolla (1992: 57) for Magiotti. Thomas Sydenham regarded blood-letting as very dangerous during acute attacks of malaria in the autumn (Dewhurst (1966: 134–5); Meynell (1991: 127)). Similarly Palmero and Vega (1988: 346) quoted the Spanish doctor Andrés Piquer as arguing in the eighteenth century that bleeding as a therapeutic method eventually led to the death of patients suffering from malaria.

19 Cato in Pliny, *NH* 29.7.14.

20 Marchiafava (1931: 4, 11), cf. Sambon (1901*c*: 348).

be seen that the attacks come on alternate days'. He stressed that all the symptoms of pure infections with *P. falciparum* are more intense and more severe than the symptoms of pure infections with *P. vivax*. The obvious similarity to Celsus' description was noted by Marchiafava himself, and it does not end there. In a passage too long to be reproduced here Celsus then went on to describe quotidian fevers, emphasizing the great range of variation they displayed.[21] The sheer length of his description of quotidian fevers relative to his description of tertian fevers indicates the great frequency and severity of quotidian fevers in ancient Rome and correlates precisely with the results of the modern research in medicine mentioned above. Celsus' account was indeed based on an accurate assessment of the relative importance of the various classes of malarial fever. Similarly Marchiafava, on the basis of the experiences of doctors treating cases of malaria from the Roman Campagna in the Santo Spirito (for men) and San Giovanni (for women) hospitals in Rome in the late nineteenth and early twentieth centuries, went on to describe quotidian fevers, irregular intermittent fevers, and subcontinuous fevers. These were all frequently caused by *P. falciparum*, as was confirmed by microscopic examination of blood smears. He emphasized that the subcontinuous fevers were generally serious, more dangerous than cases exhibiting the classic tertian periodicity. Marchiafava also emphasized that only primary attacks or early recrudescences can become pernicious.[22] After that, survivors are developing acquired immunity. Consequently people suffering from pernicious malaria often do not yet have enlarged spleens, another classic symptom of malarial infection, noted for example in the Hippocratic treatise *Airs, Waters, Places*. What are being described in such texts are survivors with a long history of repeated infections, not those killed directly by the disease at an early stage of infection. Splenomegaly is more pronounced in cases of *P. malariae* than in cases of *P. falciparum*. It is least frequent in *P. vivax* malaria. A spleen may weigh as much as twenty times its normal weight as a result of malaria. The splenomegaly associated with malaria was already well known to the Romans by

[21] Celsus 3.3.3–6.

[22] Marchiafava (1931: 14–20), cf. Marchiafava and Bignami (1894: 231–2) for their views on Celsus. The San Giovanni hospital, near the church of San Giovanni in Laterano, is now Rome's main accident and emergency hospital.

2. Ospedale di San Giovanni, in Piazza di Porta San Giovanni, is one of Rome's major hospitals. It formerly received patients with indigenous malaria.

the second century BC, and Cato prescribed cabbage as a remedy for splenomegaly.[23]

There is no doubt that *P. falciparum* malaria was present and well known in all its varied manifestations in Rome at the beginning of the imperial period. It is sometimes suggested that it was a completely new disease in Roman times.[24] However, it must be stressed that there is no positive evidence whatsoever for this hypothesis. There is not a ghost of a sign in the writings of Celsus, or Galen, or any other ancient Greek or Roman author, that any type of malarial fever was regarded by anyone as a new disease at any time in the period *c.*500 BC–*c.*AD 500. Both Celsus and Galen had no doubt that they could recognize all the types of intermittent fever

[23] Hippocrates, *Airs, Waters, Places* 24: *εἰ μέντοι ποταμοὶ μὲν μὴ εἴησαν, τὰ δὲ ὕδατα λιμναῖά τε καὶ στάσιμα πίνοιεν καὶ ἑλώδεα, ἀνάγκη τὰ τοιαῦτα εἴδεα προγαστρότερα καὶ σπληνώδεα εἶναι* (However if there are no rivers and it is necessary to drink stagnant water from marshes, people's bodies inevitably have swollen bellies and enlarged spleens); Cato, *RR* 157.7: *et si bilis atra est et si lienes turgent*; Gilles and Warrell (1993: 54) on the weight of the spleen; H. M. Gilles in Wernsdorfer and McGregor (1988: i. 774) lists other possible causes of splenomegaly.

[24] Bruce-Chwatt and Zulueta (1980); Zulueta (1973), (1987), and (1994); Karlen (1996).

existing in their own time in works in the Hippocratic corpus dating to the fifth and fourth centuries BC. The Hippocratic texts are basically very similar to, but less detailed than, the later Roman texts. For example:

> The most acute, most serious, most difficult and deadliest diseases were continuous fevers. The safest and easiest of all, but the longest in duration, was quartan fever . . . acute disease occurs in the fever called semitertian, which is more fatal than the others . . . exact tertian fever reaches its crisis rapidly and is not fatal.[25]

Although it would be nice to have more detail, basically this text looks very similar to Celsus, and Galen had no difficulty interpreting it in his commentary on this Hippocratic text.[26] It lists continuous fevers as the most dangerous of all (in agreement with Marchiafava), semitertian fevers as the most dangerous of the others (similar to Celsus), tertian fevers as not dangerous, and quartan fevers as the safest of all. Grmek has also adduced other evidence for *P. falciparum* malaria in the fifth century BC with his exquisite retrospective diagnosis of the case of Philiscus in the Hippocratic *Epidemics* as blackwater fever. In blackwater fever a breakdown of erythrocytes on a massive scale causes excretion of haemoglobin in the urine. This complication of *P. falciparum* malaria occurred not infrequently in adults in Mediterranean countries in the past.[27] The balance of the evidence, *pace* Zulueta, is that *P. falciparum* was already present in the fifth century BC in Greece. Marchiafava himself had no doubt whatsoever about this and quoted the very same text of Hippocrates quoted above. The origin of the name *semitertian* was uncertain in antiquity. Galen wrote that he could fill three volumes with what had been written about it previously. This indicates both its importance and its antiquity, since the origin of the term was hopelessly lost. Galen himself interpreted semitertian fever as a combination of tertian and quotidian fevers, although other ancient medical authors may have interpreted it in terms of other combinations of fevers.

[25] Hippocrates, *Epidemics* 1.11, ed. Littré, ii. 672–5: *εἰσὶ δὲ ὀξύταται μὲν καὶ μέγισται καὶ χαλεπώταται νοῦσαι, καὶ θανατωδέσταται ἐν τῷ ξυνεχεῖ πυρετῷ. ἀσφαλέστατος δὲ πάντων, καὶ ῥήϊστος, καὶ μακρότατος ὁ τεταρταῖος . . . ἐν δὲ τῷ ἡμιτριταίῳ καλεομένῳ ξυμπίπτει μὲν καὶ ὀξέα νουσήματα γίγνεσθαι, καί ἐστι τῶν λοιπῶν οὗτος θανατωδέστατος . . . τριταῖος ἀκριβὴς, ταχυκρίσιμος, καὶ οὐ θανατώδης.*

[26] Galen 17A.227–36K.

[27] Grmek (1983: 409–36); James (1920: 159–62); Stephens (1937: 530–3); Marchiafava (1931: 32–3) on blackwater fever.

It is important to distinguish the problem of the etymology of the word *semitertian*—a linguistic and philological problem—from the problem of identifying the clinical symptoms described under that heading, a problem in retrospective medical diagnosis.[28] Galen rightly formulated the problem in this way:

> the question is not about the reality of the disease, but about the meaning of the name, in relation to those fevers which are called tertian, semitertian, and fevers with a tertian form[29]

He then observed correctly that in relation to periodic fevers recurring on the fifth, seventh, or ninth days, which some other ancient medical authors claimed to have observed, the right question to pose concerned not the meaning of the names, but the very existence of these diseases. The uncertainty about the origin of the word *semitertian* is not a good reason for doubting the equivalence of the symptoms described under that heading with those of a recognizable modern disease, *pace* Jarcho.[30] It simply reflects the complexity of the manifestations of the disease, which has already been noted. The testimony of Marchiafava, which has already been examined, shows that Jarcho was quite wrong to suggest that modern doctors cannot recognize the disease that Celsus and Hippocrates called semitertian fever. Celli and the other early modern Italian malariologists and numerous other modern specialists such as Grmek have all made the same identification. Furthermore, the evidence adduced by Jarcho of the failure of early modern authors to recognize semitertian fever is not pertinent, since most of the authors he considered lived in cold climates in northern Europe where *P. falciparum* malaria could not possibly have been endemic. Consequently it would hardly be surprising, for example, if the famous English doctor Thomas Sydenham in the seventeenth century had not recognized a disease which could not have been

[28] Galen 17A.120K: *τρία μοι νομίζω βιβλία πληρωθήσεσθαι*, cf. 17A.228K for Agathinus' discussion of this problem; 7.363K: *ἡ γάρ τοι σύνθετος ἐκ τριταίου καὶ ἀμφημερινοῦ συνεχοῦς, ὃν ἡμιτριταῖον ὀνομάζομεν*; 7.369K; Oribasius, *Synopsis* 6.23: *ὁ ἀκριβὴς ἡμιτριταῖος ἐξ ἰσοσθενοῦς κράσεως δυοῖν πυρετοῖν γινόμενος, τριταίου διαλείποντος καὶ ἀμφημερινοῦ συνεχοῦς* (A genuine semitertian fever is made up of an equal mixture of two fevers, a tertian intermittent fever and a continuous quotidian fever); Aetios of Amida 5.82, ed. Olivieri (1950); Marchiafava and Bignami (1894: 88 n. 1). W. D. Smith (1981: 7) commented that the author of Hippocrates' *Epidemics* 7.43, 94–6 simply assumed that his audience would know what a semitertian fever was.

[29] Galen 17A.222K: *οὐ περὶ πράγματος, ἀλλὰ περὶ σημαινομένου καὶ ὀνόματός ἐστιν ἡ ζήτησις, οὓς τῶν προειρημένων πυρετῶν ὀνομάζειν προσήκει τριταίους, ἡμιτριταίους καὶ τριταιοφυεῖς.*

[30] Jarcho (1987), contrast Sambon (1901*b*, 305–10).

endemic in London in his own time during the climatic conditions of the 'Little Ice Age' (see Ch. 4. 5 below), although he undoubtedly did recognize 'ague' or 'marsh fever', the indigenous English malaria caused by *P. vivax* (see Ch. 5. 4 below). Even as late as the nineteenth century, Littré in his great edition of the Hippocratic corpus had to insist that the diseases described in it had to be searched for among those present in Greece, not among the diseases of northern Europe.[31]

Any attempt to trace the history of *P. falciparum* malaria in Greece before the fifth century BC encounters the perennial problem of the shortage of evidence, which bedevils the historiography of archaic Greece. There is no reason whatsoever for supposing that authors such as Hesiod or the lyric poets ever envisaged producing ancient equivalents of Pauly's *Realencyclopädie*. Consequently arguments from silence based on such sources are just as worthless in respect of malaria as they are in respect of other problems in Greek history. There is one passage in Homer which has attracted attention. The reference to 'fever' (*πυρετός*, a *hapax legomenon* in Homer) in such an early source is by itself inadequate to prove that this text is a reference to malaria. Although there is no doubt that specialist medical literature such as the writings of Celsus and Galen does refer specifically to malaria, there will always be room for doubt whether the vocabulary of authors who were not specialists in medicine was used in the same way as doctors used it.[32] The meaning of the Homeric text was already debated in antiquity, as shown by the scholiast.[33]

[31] Celli (1933: 47); *Œuvres complètes d'Hippocrate*, ed. Littré, ii. 538–84; Bruce-Chwatt (1976) on the history of the term *ague*. *Pace* Jarcho, there did continue to be some recognition of semitertian fevers in literature in northern Europe in the early modern period (e.g. Black (1789: 46, 49).

[32] The brief reference to an epidemic attributed to 'bad air' during the summer in Virgil, *Aeneid* 3.137–42 raises similar problems of interpretation. There is no detailed description of the symptoms. Livadas (1959: 301) quoted a passage from the 'Orphic' *Lithika* as 'pre-Hippocratic' evidence for malaria in Greece in the sixth century BC, but this poem is now regarded as a late work of the fourth century AD (so West (1983: 36) following R. Keydell in Pauly-Wissowa, *RE* xviii.2 (1942), cols. 1338–41): *εἰ δὲ πυριφλεγέθων ἑτερήμερος ἄνδρα θαμίζων | ἢ κρυερὸς μάρπτων πυρετὸς παραδηθύνῃσιν, | ἠὲ τεταρταίης πῆμα βραδύ, μή ποτε λήγειν | Βουλομένης, ἀλλ' αἰέν, ὅπῃ πελάσῃσι, μενούσης, | τόνδε σύ γ' ἰᾶσθαι δι' ἀμύμονος ἀντιαχάτου· | οὗτος γὰρ πυρετῶν πολὺ φέρτερος* (If a fever blazing like fire on alternate days regularly attacks a man, | or a fever creeps in while the man is in the grip of an icy chill, | or a quartan fever, never wishing to cease, but always remaining, | brings slow misery to a man as it approaches, | you cure this fever with an excellent agate[?]. | This stone is much better than fevers.) (*Lithika* 633–8, ed. Abel (1885)).

[33] *ὅτι ἅπαξ ἐνταῦθα ὁ πυρετός,* **AA**ext *καὶ ὅτι πυρετὸς κυρίως λέγει, οὐχ ὥς τινες δέχον-*

The old man Priam was the first to see him [sc. Achilles] with his eyes, as he hurried across the plain, shining like the star which rises at harvest time [sc. Sirius]. Its rays are conspicuous among the numerous stars in the dead of night, and it is called the dog of Orion by men. It is the brightest star, but its appearance is a sign of evil, for it brings much fever to wretched humans.[34]

Nevertheless, if the circumstantial details provided in this passage are approached with an open mind, without any preconceptions as to when *P. falciparum* reached Greece, the whole context is much more suggestive of *P. falciparum* malaria than anything else. The parallel with Achilles, avenging the death of Patroclus, suggests a disease capable of causing very high mortality rates.[35] The rising of Sirius (in late July) was definitely associated with malarial environments in Etruria by Tibullus:

Remain by the water which flows from Etruscan springs, a stream not to be approached during the heat at the time of the dog star, but now second only to the holy waters of Baiae, when the ground thaws during the variegated spring.[36]

The association with the harvest recalls the name 'aestivo-autumnal fever' that was frequently given to *P. falciparum* malaria by Italian doctors, such as Marchiafava and Bignami in the late nineteenth century. In contrast *P. vivax* only requires temperatures of 15–16°C to complete its cycle of development inside the mosquito and has a tendency to cause spring relapses following primary infections in the previous autumn. Consequently vivax malaria was

ται τὴν διάκαυσιν τοῦ ἀέρος· πρὸς γὰρ τὸ φθοροποιὸν ἡ παραβολή. καὶ ὅτι δειλοῖσιν ἀντὶ τοῦ δειλαίοις (The word 'fever' only occurs once [sc. in Homer]. Moreover it really means 'fever', not 'burning of the air' as some maintain, for the comparison is with something which causes destruction): *Scholia Graeca in Homeri Iliadem* [*Scholia Vetera*], ed. H. Erbse (1972), v. 268–9. The same pair of alternative explanations is found in Eustathius, *Commentarii ad Homeri Iliadem pertinentes*, ed. van der Valk (1987), iv. 566, writing in the twelfth century AD.

[34] Homer, *Iliad* 22.25–31: *τὸν δ' ὁ γέρων Πρίαμος πρῶτος ἴδεν ὀφθαλμοῖσι, | παμφαίνονθ' ὥς τ' ἀστέρ' ἐμπεσσύμενον πεδίοιο, | ὅς ῥά τ' ὀπώρης εἶσιν, ἀρίζηλοι δέ οἱ αὐγαὶ | φαίνονται πολλοῖσι μετ' ἀστράσι νυκτὸς ἀμολγῷ· | ὅν τε κύν' Ὠρίωνος ἐπίκλησιν καλέουσι. | Λαμπρότατος μὲν ὅ γ' ἐστί, κακὸν δέ τε σῆμα τέτυκται | καί τε φέρει πολλὸν πυρετὸν δειλοῖσι βροτοῖσιν.*

[35] The rising of the dog-star was regarded as an important time in the development of seasonal disease epidemiology by Hippocrates, *Airs, Waters, Places* 11.

[36] Tibullus, 3.5.1–4: *Vos tenet, Etruscis manat quae fontibus unda, | unda sub aestivum non adeunda Canem, | nunc autem sacris Baiarum proxima lymphis, | cum se purpureo vere remittit humus.*

observed from March onwards under Mediterranean environmental conditions and was not especially associated with the harvest as such, although it certainly was frequently transmitted during the harvest in the past (see Ch. 5. 4 below). Grmek rightly noted that acute enteric diseases are also prevalent in summer and autumn, as seen, for example, in the population of Florence at the time of the *Catasto* (census) of AD 1427 (see Ch. 5. 2 below).[37] However, the association with the harvest is very significant. Peasants often slept out in the fields during the harvest, where they were very vulnerable to mosquito bites but far from stagnant sources of water in urban areas, the commonest source of enteric diseases. A very important practical reason for farmers in Lazio to stay in their fields at night was to prevent their crops being stolen. The vulnerability of farm workers to malaria infection during the harvest has frequently been noted in Italy and other Mediterranean countries, and indeed all over the world, wherever malaria occurs. In the village of Lodé in north-eastern Sardinia, where in the 1930s the morbidity rate from malaria was 90%, 50% of the population slept outside the village during the summer.[38]

Besides this Homeric text, there is another, completely different, but much stronger line of argument for the presence of *P. falciparum* malaria in Greece by the eighth century BC. The B+ IVS nt 110 mutation for β-thalassaemia, which confers some resistance to *P. falciparum* malaria, reaches its highest frequencies in Greece and was spread by Greek colonization. It is also common in the modern populations of those parts of southern Italy which were colonized by the Greeks in the seventh and eighth centuries BC. This indicates that the mutation was already present in human populations in Greece by then. The implication is that *P. falciparum* was already active in Greece by the eighth century BC (see Ch. 5. 3 below for further discussion).

[37] Marchiafava and Bignami (1894); Grmek (1983: 65–6).

[38] For infection of harvesters see M. E. Danubio in Greene and Danubio (1997: 328) on Lodé; Bercé (1989: 242); Celli (1900: 176); North (1896: 243–4) on Lazio; Desowitz (1992: 111–12) on south-east Asia; M. T. Gillies in Wernsdorfer and McGregor (1988: i. 473) for Turkey; McNalty (1943) for infection of harvesters by *P. vivax* in Scotland in the eighteenth century. Plutarch, *Moralia* 137c, discussed by Jones (1908: 545), does not describe any symptoms of the ailments of harvesters. The Chronicle of Joshua the Stylite, ed. Wright (1882), ch. 85, p. 67, shows that in Syria at the end of the fifth century AD it was normal for farm-workers to sleep outside on the threshing floor at the time of threshing.

3

Evolution and prehistory of malaria

Several quite different arguments have been proposed in favour of the theory of a late introduction (or reintroduction) of *P. falciparum* malaria to Greece and Italy. W. H. S. Jones was looking for an explanation for the decadence, as he saw it, of ancient Hellenic civilization. This approach can be safely dismissed now without further discussion. Zulueta and Grmek and other authors exploited a series of much more scientific arguments which certainly merit extensive discussion, one by one. These ideas are briefly summarized here, before discussion:

(1) the hypothesis that *P. falciparum* must be a human pathogen of recent origin because its extreme virulence suggests that it has not had time to adapt to humans as a host;
(2) the hypothesis that large human population sizes would have been needed before malaria could become endemic in Greece and Italy;
(3) the hypothesis that the species of mosquito which were the most effective vectors of malaria in Europe would have taken several thousand years to spread into southern Europe after the end of the last Ice Age;
(4) the hypothesis that because these species of mosquito are refractory to tropical strains of *P. falciparum* a long period of evolution would have been required before they could become efficient vectors of the parasites.

It was once widely believed, as a general principle of parasite ecology and epidemiology, that parasites tend to evolve towards symbiosis or commensalism with their hosts, because in the long run it would not be in the interests of a parasite to kill its host. This is frequently given as a reason why *P. falciparum* malaria, an extremely virulent disease, must be a human disease of recent origin, which might only have evolved during the last few thousand years. This theory bolstered the conclusions of A. P. Waters and co-workers, who argued on the basis of phylogenetic analyses of

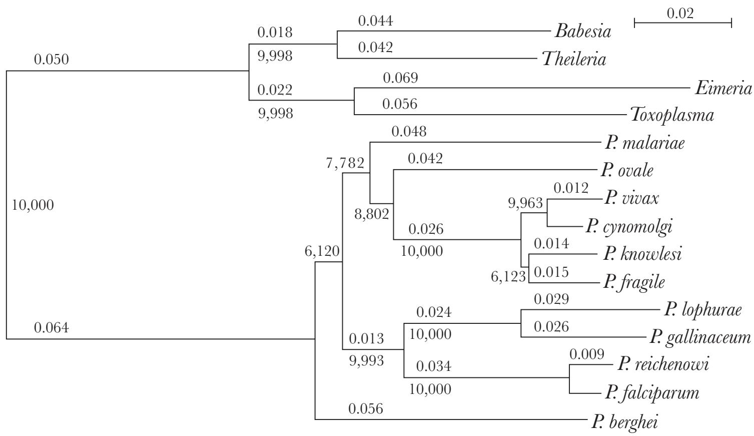


Figure 1. Evolutionary relationships of selected *Plasmodium* species indicated by neighbour-joining analysis of 18S ribosomal gene A sequences in a ClustalX alignment (Thompson *et al.* (1997)), modified manually in the BioEdit sequence editing program (Hall (1999)). The apicomplexan species *Toxoplasma gondii*, *Eimeria mitis*, *Babesia bigemina*, and *Theileria annulata* were used as outgroups, with 10,000 bootstrap replications. Bootstrap values are shown below the branches and branch lengths above the branches.

DNA sequences that *P. falciparum* is closely related to avian malarias, but not to other primate malarias, with the implication that *P. falciparum* malaria is the result of a lateral transfer of a malaria parasite from birds.[1] It remains controversial whether or not *P. falciparum* is more closely related to avian malaria species than it is to other primate malaria species. Settling this phylogenetic question is not essential for the purposes of this book, since the evolutionary relationships in question date back to over a hundred million years ago. However, the ecological problem is important for current purposes. Research in ecology in recent years has reached the conclusion that it is not inevitable that a parasite or other pathogen will evolve towards avirulence. It all depends on the precise circumstances, in particular it depends on the factors favouring transmission of the parasite to new hosts, which is what will determine its evolutionary fitness.

[1] Waters *et al.* (1991), discussed by Brooks and McLennan (1992) and McCutchan *et al.* (1996).

Since all the species of human malaria depend on *Anopheles* mosquitoes to convey them from human to human, it is not in the interests of the parasite to harm its vector. That might adversely affect transmission of the parasite to new hosts. Consequently none of the species of human malaria causes any great harm to mosquitoes, or at least mosquito immune defence systems appear to be adequate to limit damage. However, the situation with regard to the human host is much more complicated. In an environment where transmission from host to host is possible all the year round, as in the tropics, the type of parasite which will achieve the greatest evolutionary fitness is the one which achieves the highest rate of reproduction in the host, irrespective of what that does to the host. *P. falciparum* achieves a very high rate of reproduction in a number of ways, for example by having the ability to invade erythrocytes of all ages, whereas *P. vivax* only invades reticulocytes (immature erythrocytes) with the Duffy antigen. *P. falciparum* may infect up to 80% of all erythrocytes, whereas *P. vivax* does not infect more than about 2%, and *P. malariae* more than about 1% of all red blood cells. In cold environments, on the other hand, where transmission by mosquito is not possible all the year round, the parasite requires the host to survive during the winter in order to have an opportunity for transmission to new hosts the following year. These ecological considerations explain why extreme virulence is adaptive for *P. falciparum* in its home in tropical Africa, while avirulence is adaptive for *P. vivax* and *P. malariae* in colder environments. Consequently the extreme virulence of *P. falciparum* does not constitute evidence for a recent evolutionary origin.[2]

The exponential expansion of DNA sequencing in recent years has yielded the important result that the human parasite *P. falciparum* forms a monophyletic clade with *P. reichenowi*, a malaria species which infects chimpanzees in Africa. This clade is not closely related to any of the other three species of human malaria. Analysis of DNA sequences from ribosomal RNA genes (see Fig. 1) and from the circumsporozoite protein gene suggests that the

[2] e.g. Fiennes (1978: 105–12) regarded *P. falciparum* as a recent pathogen of man because of its virulence, but Garnham (1966: 279) was sceptical of such theories. Ewald (1994: 42–6), Anderson and May (1991: 648–52, cf. 392–419), and Coluzzi (1999) give various views on the significance of its virulence; Mackinnon and Read (1999*a*) and (1999*b*). Marchiafava and Bignami (1894: 103) observed that 'malignancy coincides *with an exceptionally abundant quantity of parasitic forms*, a quantity much more abundant—where the cases terminate fatally—in the blood of the viscera than in the blood of the finger'.

common ancestor of the *P. falciparum/P. reichenowi* clade diverged from the common ancestor of the *P. vivax/P. malariae* clade about 165 million years ago. *Anopheles* mosquitoes, which transmit human malaria, do not appear in the fossil record until the Oligocene period (26–38 million years ago), but studies of molecular evolution suggest that the *Anopheles* family is very ancient. The protein and DNA sequences of the 35kb circular DNA molecule and the enolase gene of *P. falciparum* manifest very ancient kinship, or at least very extensive horizontal transfers of DNA, embracing not only organellar but also nuclear DNA, with a plant-related lineage.[3] It remains controversial whether the various species of malaria were originally parasites of vertebrates or parasites of mosquitoes. It is possible that they were originally parasites of vertebrates because of the similarity of their developmental cycles to those of coccidian intestinal parasites of the suborder *Eimeriina*.[4]

However, the most interesting result of this research in molecular biology for current purposes is that statistical analysis of the degree of divergence between the DNA sequences of the human parasite *P. falciparum* and the chimpanzee parasite *P. reichenowi* puts their date of divergence in the time range of 5–11 million years ago. Given the inevitable margin of error in these statistical calculations, this date approximates the date of divergence between humans and chimpanzees given by palaeoanthropologists. Consequently it is likely that *P. falciparum* has been attacking humans and their hominid ancestors since the dawn of human evolution, the split from the chimpanzee lineage.[5] Similarly recent research suggests

[3] Escalante *et al.* (1995) and Qari *et al.* (1996) on the molecular evolution of Plasmodium from rRNA gene sequences, cf. Escalante *et al.* (1998*a*) for data from the *cytochrome b* gene and Rathore *et al.* (2001) for data from plastid sequences; Capasso (1991), Besansky *et al.* (1992), and Coluzzi (1999) on mosquito evolution; Hyde *et al.* (1994), Read *et al.* (1994) (nuclear DNA), and Köhler *et al.* (1997) (plastid DNA) on the links of *P. falciparum* to plant-related lineages; Felger *et al.* (1997) illustrate the sort of genetic variation which is now being discovered.

[4] Missiroli (1934: 10–11) was one prominent Italian malariologist who advocated the theory of the close evolutionary relationship of malaria parasites to coccidian intestinal parasites. Capasso (1985: 301) supported the alternative theory that malaria parasites were originally parasites of the salivary glands of mosquitoes. This theory leaves unresolved the transmission question, namely how did the parasites get from mosquito to mosquito, since mosquitoes don't bite each other. Going back even further in time, Halevy (1998) suggested that plasmodial parasites owe their similarities to plant genomes to descent from toxic algae which infected fish.

[5] Rich *et al.* (1998*a*) and Ayala and Rich (2000) found a very low rate of synonymous substitutions in housekeeping genes of *P. falciparum.* They drew the inference from the apparent lack of genetic variation in housekeeping genes of modern strains that all currently existing *P. falciparum* populations are derived from a single ancestor that lived a few thousand years

that other major parasitic diseases such as visceral leishmaniasis and trypanosomiasis also co-evolved with humans in Africa. *P. falciparum* is one of mankind's oldest, deadliest, and most persistent foes. This conclusion has considerable implications for the question of the size of host population required by *P. falciparum*. Evidently it was able to survive for very long periods during which all humans and their hominid ancestors were hunter-gatherers, long before the invention of agriculture, periods when human population sizes were very small. One thinks for example of the figure of 10,000 frequently given by molecular biologists as the effective population size (i.e. the size of the adult breeding population) of the populations (not necessarily the same population) to which belonged 'mitochondrial Eve', the last common female ancestor of all currently existing human mitochondrial DNA genotypes (assuming a rarity of recombination), and her male counterpart, the 'Adam' currently being revealed by studies of DNA sequences from the Y chromosome. *P. falciparum* is an extremely ancient human pathogen which was able to survive in small human populations in Africa, the cradle of human evolution.

In contrast, *P. vivax* and *P. malariae* are closely related to malaria parasites of monkeys in south-east Asia, outside the cradle of human evolution.[6] *P. vivax*, for example, closely resembles *P. cynomolgi*, a parasite of *Macaca* monkeys in south-east Asia, in respect of both morphology and DNA sequences. *P. vivax* and *P. malariae* were not originally human diseases. They probably first encountered the evolving hominids when *Homo erectus* spread out from Africa across Asia, probably between one and two million years ago. The

ago, even though they accept that the divergence between *P. falciparum* and *P. reichenowi* occurred several million years ago. Their controversial theory about *P. falciparum* cannot be discussed in detail here, but it is probably incorrect or, at best, an exaggeration (their views on the evolution of *P. vivax* and *P. malariae* are completely untenable). It does appear that different results are obtained from different parts of the genome, a problem frequently observed in research on molecular evolution (Gillespie (1991: 41)). Other regions of the *P. falciparum* genome currently being studied by other scientists are yielding results incompatible with those obtained by Ayala and Rich (e.g. Verra and Hughes (2000)). I hope that it will be possible within the next few years to obtain direct evidence from ancient DNA permitting an evaluation of the theory of Ayala and Rich concerning a recent cenancestor of *P. falciparum*.

[6] Of course the distribution both of species of nonhuman malaria and of other primates might have been different in earlier geological epochs. Skinner *et al.* (1995) suggested that periodic episodes of linear enamel hypoplasia in fossil teeth of *Dryopithecus* apes from Can Llobateres in north-eastern Spain, dating to the Miocene period about 9.5 million years ago, might have been caused by malaria.

question of the origin of *P. vivax* malaria in humans is tied to the question of the *FY*O* allele in the Duffy blood group locus, which prevents *P. vivax* parasites from adhering to and entering erythrocytes in nearly all members of sub-Saharan African populations. It is not known whether this allele spread in response to an existing parasite burden and drove *P. vivax* out of sub-Saharan Africa (its niche being taken by *P. ovale*), or whether an already high prevalence of this allele (perhaps in response to another pathogen) prevented *P. vivax* from ever establishing itself in Africa in the first place. In the last few years the Duffy negative allele has also appeared in Papua New Guinea, where *P. vivax* is endemic. This is an example of evolution in action in human populations today in response to malaria.[7]

Since *P. falciparum* was present in the heartland of human evolution in East Africa, presumably it would have been carried out of Africa by every successive wave of hominids and humans, from *Homo erectus* onwards. Whether it would have prospered outside Africa would have depended on the climate and on whether in new environments it encountered species of mosquito able to transmit it. These two factors are the last two pillars of the theory of the late spread of malaria into Mediterranean countries. Zulueta has quite correctly argued that the climate of Ice Age Europe was too cold both for the completion of the developmental cycle of *P. falciparum* itself within the mosquito and for the principal mosquito vector species in Italy, *Anopheles labranchiae* and *A. sacharovi* (= *elutus*). He then reckoned that it would have taken thousands of years for conditions to become favourable enough for *P. falciparum* and its vectors to spread into southern Europe. However, this argument was based on old and out-of-date literature about the Holocene climate. It ignores the mass of evidence which is now available for what climatologists call the mid-Holocene climatic optimum, a period after the end of the last Ice Age and encompassing the Neolithic period until *c.*3000 BC, when, owing to periodic shifts in the earth's position relative to the sun, the northern hemisphere received considerably more insolation than it does today. This resulted in the climate of many parts of the northern hemisphere being up to 2°C hotter than in subsequent millennia. Such temperatures are only now being approached again with the recent

7 Livingstone (1984); Zimmerman *et al.* (1999); Hamblin and Di Rienzo (2000).

trend towards anthropogenic global warming.[8] The effects of these climate changes in Italy have recently attracted attention because of their relevance to the preservation of the famous 'Iceman' discovered in the Alps (as it turned out, just on the Italian side of the border with Austria). Fortunately for modern archaeologists, the Iceman died towards the end of the mid-Holocene climatic optimum, in the late fourth millennium BC, at a time when neoglaciation was commencing (i.e. the Alpine glaciers were starting to advance again as mean annual temperatures dropped). This covered his body with ice, preserving it until anthropogenic global warming in the last few years caused the glacier to begin to retreat again, exposing the frozen corpse.[9]

The development of *P. falciparum* is heavily dependent on the temperature. Since it requires a minimum temperature of about 20°C for the completion of sporogony inside the mosquito, climatic conditions during the Neolithic period were in fact substantially *more favourable* for the spread of *P. falciparum* and its vector mosquitoes into southern Europe than they were in the first millennium BC or any other period after the Neolithic. What are now the Saharan and the Arabian deserts also received substantially more rainfall during the mid-Holocene climatic optimum than they do today, creating more breeding sites for mosquitoes.[10] This would have assisted the spread of malaria from tropical Africa towards the southern shores of the Mediterranean. It is even conceivable that the geographic range of members of the *Anopheles gambiae* complex, the most important vector of malaria in tropical Africa today, may have extended further north in Africa than it has done in recent times. Mosquitoes can evolve very rapidly. For example, populations of *Culex pipiens* confined to London Underground tunnels and separated from above-ground populations have evolved new host preferences (mice, rats, and humans instead of birds), reproductive isolation from above-ground populations, new mating patterns (stenogamy instead of eurygamy), loss of winter diapause, and the possibility of oviposition without prior ingestion of a blood meal, all in no more than about one hundred years. Similarly the most

[8] Zulueta (1973) and (1987); Sallares (1995) on the mid-Holocene optimum in western Eurasia. Recent research in China, reported in *Nature*, 390 (1997: 209), confirms that it was a world-wide phenomenon. It is estimated that the mean annual temperature was 2–4°C warmer, with 20–40% more rainfall, in China in the period 6000–2000 BC.

[9] Baroni and Orombelli (1996).

[10] Claussen and Gayler (1997).

recent research in molecular evolution suggests that speciation in the *A. gambiae* complex in Africa is an active, ongoing process. Mario Coluzzi has cogently argued that the modern strains of *A. gambiae*, which are exceedingly efficient at transmitting malaria, are of recent (Neolithic period onwards) origin.[11] The evolution of these extremely efficient vector strains would have permitted an increase in the transmission rate of *P. falciparum* malaria in tropical Africa. Coluzzi has suggested that an increase in the pathogenicity of *P. falciparum* might have accompanied the increased transmission rate. Recent research in molecular diversity indicates that the populations of the *A. gambiae* complex have been increasing recently but have also long had a large effective population size (the size of the breeding population). This suggests that its potential as a vector of malaria in Africa does go back to prehistory and is not a product of human population growth in modern times in Africa, even if it was not quite as efficient a vector then as it is today.[12] One population of Pygmies (hunter-gatherers until very recently) in central Africa has a very high frequency of haemoglobin S, a mutation which confers resistance to *P. falciparum* malaria on heterozygotes for the sickle-cell trait. Cavalli-Sforza argued that this implies that *P. falciparum* malaria was already widespread in central Africa *before* the invention or spread of agriculture in Africa.[13] Because of the heat, the Neolithic period was the most likely period for the spread of *P. falciparum* malaria into southern Europe. Its previous evolutionary history, as has just been argued, suggests that the small human population sizes of that period would not have prevented it from becoming endemic in southern Europe then. Malaria is a disease that tends to exist in small foci because mosquitoes generally do not fly far from their breeding grounds, not more than five or six kilometres under Mediterranean environmental conditions, although occasional much longer migrations have been recorded. In 1959 a migration of about 280 kilometres by the Egyptian mosquito species *Anopheles pharoensis* reintroduced malaria to Gaza and the coast of Israel, from which it had previously been eradicated.

[11] Byrne and Nichols (1999) on the London mosquitoes; Coluzzi *et al.* (1979); Coluzzi (1999).

[12] Lehmann *et al.* (1998); Powell *et al.* (1999).

[13] Cavalli-Sforza (1986: 153–5, 416–19). Pygmy populations in forest environments, which *A. gambiae* is reluctant to enter, do not have high frequencies of haemoglobin S. Phylogenies based on mitochondrial DNA sequences suggest that some of the Pygmies are among the most ancient human populations.

A propensity towards such migrations by this important malaria vector-species in the lower Nile valley might have helped *P. falciparum* to break out of Africa in the distant past.[14]

J. L. Angel used to invoke the high frequency of porotic hyperostosis in crania belonging to skeletons recovered from Mesolithic–Neolithic archaeological sites in Greece as evidence for a high frequency of *P. falciparum* malaria in Greece at that time. There is now a general consensus among those interested in this problem that porotic hyperostosis, whose proximate cause is an iron-deficiency anaemia, has several other possible ultimate causes besides malaria. Consequently porotic hyperostosis cannot be used as evidence for the existence or frequency of *P. falciparum* malaria in Europe in the Neolithic period.[15] However, absence of evidence is not equivalent to evidence of absence. It still remains quite possible that it was spreading in that period. Recently the application of the techniques of molecular biology to ancient biomolecules has opened up new avenues of research. Immunological tests have been used by two different research groups to identify the histidine-rich protein-2 antigen of *P. falciparum* in the mummies of several predynastic individuals from Egypt, dating to *c.*3200 BC.[16] This constitutes some direct evidence for the existence and activity of *P. falciparum* on the periphery of the Mediterranean world already in the fourth millennium BC. Further research into ancient biomolecules (especially DNA) from human skeletal remains excavated on archaeological sites in southern Europe offers the best prospect of obtaining direct evidence for *P. falciparum* malaria in Europe in prehistory.[17] There was clearly some contact between Egypt and

[14] M. T. Gillies in Wernsdorfer and McGregor (1988: i. 455) expressed the view that mosquito flight range is a property of the environment, not the species, depending on the availability of breeding sites and food, but it is clear that they generally do not fly far; Garrett-Jones (1962); Halawani and Shawarby (1957) on malaria in Egypt in recent times.

[15] Angel (1966); Borza (1979), Zulueta (1987: 200), Sallares (1991: 275–7), Stuart-Macadam (1992), Grmek (1994), Corvisier (1994: 299–303), and Larsen (1997: 30–40) all agree that porotic hyperostosis does not necessarily indicate malaria.

[16] R. L. Miller *et al.* (1994); Cerutti *et al.* (1999). cf. Marin *et al.* (1999).

[17] The problem with trying to detect ancient proteins is that antibody reactions depend on the conformation of proteins. Since protein conformation would be expected to degenerate over time, it is not clear what degree of specificity could be expected in any particular antibody reaction with degraded proteins. G. M. Taylor *et al.* (1997) unsuccessfully tried to amplify ancient DNA from one of the same individuals studied by R. L. Miller *et al.* (1994), namely the Gurna mummy dating to *c.*700 BC. There are many possible explanations for this failure. Similarly C. Plowe, reported in *Parasitology Today*, 14 (1998: 9) expressed scepticism about the results obtained by R. L. Miller *et al.* (1994). Consequently further research is need-

Greece at least as early as the Early Bronze Age in the third millennium BC. The most striking illustration of this contact was the construction of the small-scale imitations of Egyptian pyramids at Hellenikon and Ligourio in the Argolid in Greece, which Pausanias passed on his travels much later. Consequently it is quite possible that *P. falciparum* could have been transmitted directly from Egypt to Greece at that time.[18]

However, there is another, even earlier, possibility. The Neolithic period commenced in Europe with the introduction of agriculture by human populations from the Near East, according to the generally convincing arguments presented in the monumental book by Cavalli-Sforza and his colleagues, a very important contribution to knowledge.[19] Agriculture—specifically the cultivation of cereals and legumes—first developed in the general vicinity of modern Israel, Jordan, and Syria. These regions in antiquity certainly included some significant areas of wetlands, along the Mediterranean coast and in the Jordan valley, which harboured amphibious animals as large as the hippopotamus and permitted the cultivation of aquatic plants like papyrus. In more recent times, until they were drained, these wetlands were intensely malarious. Similarly in antiquity Josephus described as pestilential in summer the air of the Great Plain around Lake Tiberias and the Dead Sea.[20] Consequently the earliest Neolithic farmers lived in a region that included some environments that were extremely favourable for malaria.[21] This consideration supports Angel's hypothesis that

ed to confirm their results. Sallares and Gomzi (2001) discussed the problems in applying immunological tests to ancient materials. However, the results of the studies in molecular evolution cited earlier based on comparisons of modern DNA sequences make it extremely likely in any case that *P. falciparum* was present in Egypt by the fourth millennium BC, since such research does not suffer from the same technical problems as research on ancient biomolecules. Schiff *et al.* (1993) described the *Para*Sight test.

[18] Theocharis *et al.* (1997) and Pausanias 2.25.6 on the Greek pyramids.

[19] Cavalli-Sforza *et al.* (1994).

[20] Josephus, *de bello Iudaico* 4.8.2, ed. Bekker (1855–6): *ἐκπυροῦται δὲ ὥρᾳ θέρους τὸ πεδίον, καὶ δι' ὑπερβολὴν αὐχμοῦ περιέχει νοσώδη τὸν ἀέρα* (The plain is burnt up during the summer season, and extreme drought makes the air unhealthy).

[21] Tacitus *Histories* 5.6–7 also described the Dead Sea region as pestilential with bad air: *lacus immenso ambitu . . . gravitate odoris accolis pestifer* (a lake with a huge circumference . . . whose oppressive smell brings pestilence to the local inhabitants). Hirsch (1883: 202) noted that malaria affected extensive regions near the Dead Sea in the nineteenth century, as well as the Bekaa valley in Lebanon at an altitude as high as 1200 metres (cf. Leeson *et al.* (1950)). Fisher (1952) made the interesting observation that mosquitoes are carried up to the Bekaa valley by rising air currents which regularly occur in that region; Amadouny (1997); Filon *et al.* (1995) extracted ancient DNA showing the presence of β-thalassaemia from human skeletal

all the three species of human malaria under consideration, including the most dangerous, *P. falciparum*, were carried to Europe inside the bodies of the very first Neolithic farmers. The diagnosis of thalassaemia, a human genetic disease that confers some resistance to malaria, in the skeleton Homo 25 (a male sixteen or seventeen years old) from the PPNB (Pre-Pottery Neolithic B) village of Atlit Yam (now submerged off the coast of Israel) supports the idea that malaria was already active in the Levant at the dawn of agriculture.[22] Given that the climate in the Neolithic period was actually exceedingly favourable to it, whether *P. falciparum* would have survived in new environments in southern Europe depended, as was noted earlier, on whether it encountered species of mosquito that were capable of acting as efficient vectors. Only a minority of the European species of *Anopheles* mosquito are good vectors for malaria.

This problem leads on to the fourth pillar of the late-introduction theories, namely the question of the possible refractoriness of mosquitoes to infection with *P. falciparum*. Experiments were performed using samples of *A. labranchiae*, originating from the coast of Tuscany near Tarquinia, and of *A. atroparvus*, from the Orcia river valley near Siena and from the upper Volturno valley north of Naples, to see if these Mediterranean populations of mosquitoes could ingest gametocytes from *tropical* strains of *P. falciparum* and successfully transmit sporozoites to new hosts.[23] The results were negative, in agreement with more extensive research of this kind subsequently performed in Russia which indicated that in general tropical strains of *P. falciparum* are not adapted to the mosquito species of Eurasia. Zulueta used these results to argue that a long period of adaptation would have been required to overcome refractoriness on the part of mosquito species in Greece and Italy.[24] However, even if this were the case, it would not prove that *P. falciparum* was a newcomer in classical times. Since the new data for its

remains from Akhziv in Israel. For hippopotamus and papyrus in the region see Sallares (1991: 26, 370, 400–2). Theophrastus, *HP* 9.7.1–2 also mentioned the marshes.

[22] Hershkovitz *et al.* (1991).

[23] Ramsdale and Coluzzi (1975); Zulueta, Ramsdale, and Coluzzi (1975). Earlier experiments at Horton Hospital in England had shown that the English malaria vector *A. atroparvus* is similarly unable to transmit tropical African strains of *P. falciparum*, although it can transmit Italian strains of *P. falciparum*. However, it could transmit all strains of *P. vivax* that were tested, although it is very inefficient at transmitting *P. malariae* (Shute (1940) and (1951)).

[24] Zulueta (1973), (1987), and (1994).

presence in Egypt in the fourth millennium BC suggest that *P. falciparum* was already present in the Mediterranean world thousands of years before classical times, a long period of time was indeed available for the refractoriness of European species of mosquitoes to be overcome. Moreover the experiments yielded no information about the critical factor of the length of time required for refractoriness to be overcome. It is not clear at the moment whether in this particular case overcoming refractoriness required evolution in the mosquito, evolution in the malaria parasite, or co-evolution.

Mosquitoes certainly have several defence mechanisms against intruding foreign bodies in general, and may have genes that specifically respond to invasion by malarial parasites. Melanotic encapsulation or melanization is the most well known of these processes. This process is employed by mosquitoes and other insects to surround and inactivate pathogens. A thick layer of melanin is deposited around the malaria parasite when it tries to cross the mid-gut epithelium of the mosquito, *en route* to the salivary glands for the formation of sporozoites for transmission to another human. Cross-breeding experiments suggest that it is under fairly simple genetic control (no more than about three major loci being involved), with the implication that the expression of the process of melanotic encapsulation can be increased or diminished rapidly in mosquitoes.[25]

However, there is the complication in the Mediterranean case that the mosquitoes, which transmitted Mediterranean strains of *P. falciparum* in the past, are refractory to modern tropical strains, as has just been seen. This suggests that differences between various strains of *P. falciparum* were also important in some as yet undefined way. Evolutionary processes tend to be very rapid among micro-organisms and, as will be seen shortly, *P. falciparum* has the capacity for very rapid genetic change. If it did not exist in the western hemisphere before Columbus, several species of mosquito indigenous to the western hemisphere quickly became effective vectors of *P. falciparum*, a pathogen which they had never encountered before 1492. The failure of Amerindian populations to develop high frequencies of any of the wide range of genetic mutations that confer degrees of resistance to *P. falciparum* malaria in

[25] Lombardi *et al.* (1986); Collins *et al.* (1986); Richman and Kafatos (1996); Yan *et al.* (1997); Zheng *et al.* (1997); Billker *et al.* (1998); Feldman *et al.* (1998); Paskewitz and Gorman (1999); Barillas-Mury *et al.* (2000); Oduol *et al.* (2000).

many Old World human populations suggests that they have only recently been exposed to it.[26] Grmek rightly observed that the different responses of European mosquitoes to strains of parasite from different geographical areas in fact suggest a long period of separation between the tropical and the subtropical/temperate strains of *P. falciparum*.[27] The experiments at Horton Hospital in England suggested that Italian strains of *P. falciparum* from Sardinia and Salerno were more severe and more virulent and exhibited a faster growth rate than strains originating in tropical countries (with the proviso that the sample sizes in these experiments were small).[28] A faster progression of the infection on the part of European strains of *P. falciparum* might well have been an evolutionary adaptation to the shortness of the season each year that was suitable for its reproduction because of the climatic constraints in Europe.

Another crucial argument is that since the western Mediterranean mosquito vector-species *A. labranchiae* is common in North Africa, which in fact is its main area of distribution, as well as in Italy, while *A. sacharovi*, the second major Mediterranean vector with a more easterly distribution, also occurs in the Near East as well as in Greece, *P. falciparum* had every opportunity to evolve adaptation to its European vectors in Africa and in the Near East before even arriving in Europe. The nature of *P. falciparum* malaria in North Africa in the past is an important unresolved question. The French colonists in North Africa in the nineteenth century had severe problems with malaria. Of course it was in North Africa that Alphonse Laveran discovered malarial parasites, at the hospital in Constantine in 1880. In 1832–3 two earlier French army doctors, Antonini and Maillot, working at the hospital of Bône in Algeria, found that giving high doses of quinine and a generous diet and ending the practice of bleeding reduced malaria mortality rates from 30% to 5%.[29] However, it is not clear whether the French colonists encountered the 'European' strains of *P. falciparum*, or the tropical strains, or both. Nevertheless, since *A. labranchiae* is abundant in North Africa as well as in Italy, and since the tropical strains

[26] Effertz (1909), Dunn (1965), and Cook ((1998: 48–9), wrongly identifying *P. vivax* with quartan fever) on the Americas. Li *et al.* (2001) published molecular evidence for two separate introductions of *P. vivax* to the western hemisphere, possibly both since Columbus.

[27] Grmek (1983: 402).

[28] Covel and Nicol (1951), reviewed more recently by Gravenor *et al.* (1995). Andrew Read pointed out the last reference to the author.

[29] Cohen (1983: 28), citing other literature.

spreading with humans across the savannah grasslands in what is now the Sahara during the mid-Holocene climatic optimum would first have encountered *A. labranchiae* in North Africa rather than Italy, the balance of probability is that North Africa is where the 'European' strains of *P. falciparum* malaria evolved. Malaria evolution in North Africa would not have been subject to the constraints of the European climate during the glacial periods. Consequently the argument from mosquito refractoriness is as unconvincing as the other arguments used to support late-introduction theories. Moreover when the mid-Holocene climatic optimum ended, populations of *P. falciparum* in North Africa would have become isolated from the populations in central Africa. The occurrence of evolution in isolated populations is a standard scenario frequently invoked in theories of evolutionary biology. Today the leading edge of the evolution of drug resistance by malaria is in south-east Asia, a geographical area very far removed from the heartland of *P. falciparum* in tropical Africa.

Grmek identified the disease which afflicted the Athenians camped outside Syracuse in Sicily in 413 BC, described by Thucydides, as most probably *P. falciparum* malaria.[30] He gave a cogent explanation of the role of malaria in the Syracusan military strategy against the Athenian forces. Unfortunately it is generally ignored by mainstream ancient historians. Grmek argued that the Syracusan generals deliberately confined the Athenian forces to an area which they knew was unhealthy and then waited to let malaria do their work for them. He also discussed the possibility that *P. falciparum* malaria was a new disease then because it took an epidemic form, attacking large numbers of adults (the Athenian soldiers and their allies), who evidently did not have acquired immunity to it and so presumably had not previously experienced it in childhood. This idea may seem plausible, but yet again the most recent scientific research casts doubt on it, even though it is true that in areas where malaria is hyperendemic, as it certainly has been in many places in Tuscany and Latium in recent times, virtually everyone is infected in early childhood. With constant reinfections in childhood acquired immunity develops, with the result that adults seldom have acute attacks of fever and may not appear to have any parasites in their blood upon microscopic examination. There is still

[30] Grmek (1979: 150–61), cf. the non-committal opinion of Villard (1994).

some experimental support for the older view that acquired immunity to malaria is short-lived and requires constant reinfection under holoendemic conditions to maintain it. However, the new techniques introduced into molecular biology in the last few years (the polymerase chain reaction (PCR); analysis of microsatellites; analysis of restriction fragment length polymorphisms (RFLP) of DNA) have produced new evidence which sheds further light on the situation.

P. falciparum displays a great deal of genetic variation. All the various stages of development in humans are haploid clones, but in the gut of mosquitoes diploid zygotes are formed, as mixtures of different clones of parasites mate. Recombination of genetic material during meiosis in heterozygotes then yields new genotypes of parasite. Experiments have shown that the extent of recombination in genes coding for cell-surface proteins exported by parasites to the surface of erythrocytes is very considerable. Moreover the genetic diversity generated in this way may date back millions of years, at least partially antedating the split between *P. falciparum* and the chimpanzee malaria parasite *P. reichenowi*.[31] With the mosquito as a secondary host, malaria parasites have access to the evolutionary benefits of sexual reproduction (i.e. the capacity to generate genetic variation to give them the ability to meet new challenges in their environment, e.g. variations in their host's immune response, new drugs used by modern doctors, etc.). PCR amplification of VNTR (variable number tandem repeat) sequences of DNA has shown that most individual cases of malaria in tropical countries today are infected with between two and six different haploid clones at the same time. The larger the number of haploid clones in a mosquito's blood meal, the greater the degree of recombination that is likely to occur. Much earlier, Marchiafava had already reached the conclusion, from examination of parasites visible under the microscope in blood smears, that it was usual for patients in Rome to be infected with at least two different generations of parasites simultaneously. This explains why quotidian fevers, not tertian fevers, were the norm in cases of *P. falciparum*

[31] Conway *et al.* (1999) found evidence for a high recombination rate in the merozoite surface protein 3 gene coding for a cell-surface protein involved in immunological interactions; Hughes (1993), Taylor *et al.* (2000), Ayala and Rich (2000), and Okenu *et al.* (2000) on the antiquity of such polymorphisms; it is the subject of current controversy. Some scientists maintain that genetic polymorphism in *P. falciparum* is primarily generated by mitotic recombination rather than meiotic recombination.

malaria in Rome both in the nineteenth century and in antiquity. There is now some evidence that acquired immunity to *P. falciparum* is clone-specific. Differential expression of surface antigens in erythrocytes is controlled by the recently discovered family of *var* genes. Successful reinfection only occurs when a new genotype is encountered. Consequently an individual who has acquired immunity to all the genotypes prevalent in the region of domicile is still vulnerable to different genotypes existing in other areas. The experiments at Horton Hospital in England showed that artificial infection with a strain of *P. falciparum* from India, for example, gave no protection at all against subsequent infection with a strain of *P. falciparum* from Sardinia.[32]

The relevance of all this to the plight of the Athenians outside Syracuse is that the fact that *P. falciparum* attacked many adults does not prove that it was a new disease then, either in Sicily or in Greece. It may simply have been the case instead that the Athenians and their allies encountered in Sicily a new strain of *P. falciparum* which was different from the strains to which they were accustomed in Greece. Nevertheless, Grmek's identification of *P. falciparum* malaria in the marshes outside Syracuse in 413 BC should be retained. There is also evidence for malaria in Sicily in the fifth century BC at Selinus, Camarina, and Akragas. Consequently it appears that malaria was widespread and severe in Sicily from at least the fifth century BC onwards.[33] Later on Sicily became an important source of grain for the city of Rome. Undoubtedly it also supplied malaria to that city. The inevitable result of prolonged

[32] Babiker and Walliker (1997); Gupta *et al.* (1994); Kemp *et al.* (1990); Walliker *et al.* (1987); Paul and Day (1998); Marchiafava and Bignami (1894: 93); Smith *et al.* (1995); Su *et al.* (1995); Covel and Nicol (1951); Freitas-Junior *et al.* (2000) explained the very high frequency of recombination in the *var* gene sequences of *P. falciparum* in terms of gene conversion between aligned *var* genes in the adjacent telomeric regions of heterologous chromosomes.

[33] Empedocles diverted two rivers to try to eliminate malaria from the vicinity of Selinus, according to Diodorus of Ephesus: *τοῖς Σελινουντίοις ἐμπεσόντος λοιμοῦ διὰ τὰς ἀπὸ τοῦ παρακειμένου ποταμοῦ δυσωδίας, ὥστε καὶ αὐτοὺς φθείρεσθαι καὶ τὰς γυναῖκας δυστοκεῖν, ἐπινοῆσαι τὸν Ἐμπεδοκλέα καὶ δύο τινὰς ποταμοὺς τῶν σύνεγγυς ἐπαγαγεῖν ἰδίαις δαπὰναις· καὶ καταμίξαντα γλυκῆναι τὰ ῥεύματα* (Since a plague afflicted the people of Selinus because of the evil smell of the adjacent river, causing death and making pregnant women miscarry, Empedocles had the idea of bringing two rivers there at his own expense. By mixing the waters he sweetened them.) (Diogenes Laertius 8.70). The reality of the drainage works is shown by fifth-century coins from Selinus (Pauly-Wissowa, *RE* II A.2, (1923), col. 1281). P. F. Russell (1955: pl. facing p. 161) illustrates one of these coins. Servius' commentary on Virgil, *Aeneid* 3.701, *Greek Anthology*, 9.685, and Suda s.v. *μὴ κίνει Καμάριναν* (don't move Camarina) mention malarial swamps at Camarina in Sicily. For Akragas see Ch. 4. 2 below.

exposure to intense endemic malaria in Sicily was the evolution of high frequencies of human genetic mutations giving some resistance to malaria. Besides β-thalassaemia and glucose-6-phosphate dehydrogenase (G6PD) deficiency, which are common in Sicily as in other Mediterranean populations with experience of endemic malaria (see Ch. 5. 3 below), the modern population of Sicily also exhibits a certain frequency (about 2%) of the sickle-cell trait (β^S). Haplotype analysis indicates that the sickle-cell trait reached Sicily from western central Africa. However, it is unclear whether this had already happened in antiquity, perhaps during the period of Carthaginian activity in Sicily, or during the time of the Roman Empire, as a result of the slave trade, or whether it happened later, as a result of the Arab conquests in the early medieval period.[34] Besides the G6PD mutations which are characteristic of Mediterranean populations, the principal African variant of G6PD deficiency (A) also occurs in Sicily. This is further evidence supporting the hypothesis of gene flow from central Africa to Sicily.

The tenor of the discussion so far has been to suggest that none of the arguments that have been proposed in favour of a very late introduction of *P. falciparum* to southern Europe is convincing. On the contrary, the trend of the most recent scientific research is to suggest that *P. falciparum* is an extremely ancient pathogen which has been pursuing humans and their hominid ancestors for as long as they have been present on earth. The conclusions reached here so far are compatible with the opinion of Brunt, who did not find anything in ancient literary sources to suggest that malaria was ever regarded as a new disease in the classical period. The possibility of the emergence of new diseases was certainly explicitly considered in classical antiquity, particularly in relation to leprosy, as is demonstrated by lengthy discussions in Pliny and Plutarch.[35] However, no ancient Greek or Latin author ever suggested that the intermittent fevers now called malaria were a new disease. Nevertheless Brunt's view yields a paradox that requires detailed investigation now. The paradox arises from the fact that the Etruscan cities in the Maremma and southern Etruria and numerous Greek colonies in the coastal regions of southern Italy were situated in locations so heavily infested with malaria in later times as to make it difficult to imagine how they could ever have prospered at all,

[34] Ragusa *et al.* (1988); Schilirò *et al.* (1990); Adekile (1992).
[35] Pliny, *NH* 26.1–6.1–9; Plutarch, *Moralia* 8.9.731b–734c.

if malaria had been present right from the start. According to Dionysius of Halicarnassus a major attraction of Veii, the important Etruscan city captured by the Romans in 396 BC supposedly after a siege lasting ten years, as a place to live was the healthiness of its site, since there were no marshes or rivers nearby which generated 'bad air':

> The city of Veii . . . had air around it that was extremely pure and very good for human health, since there was no marsh nearby to generate oppressive and evil-smelling vapours, nor any river from which cold breezes would arise at dawn.[36]

Dionysius' account implies that other localities were not so healthy.[37] Evidently it is not clear to what extent his account reflects the situation in his own time, rather than the fourth century BC. The doyen of Etruscologists, Massimo Pallottino, relying on the work of Toscanelli, suggested that 'life in the marshy areas of the Maremma and of the lower Po valley cannot be explained unless malarial infection was not yet common during the golden age of Etruscan civilization; but malaria must in fact have helped to hasten the decline of many Etruscan coastal towns in late Hellenistic times'.[38] Vetulonia (Etruscan *Vetlana* or *Vatulana*) is as good an example of the problem as any. It flourished in the eighth to sixth centuries BC, but then declined 'rapidly and completely after the beginning of the Roman period'.[39] Vetulonia is located close to modern Grosseto, which has already been noted as one of the most intense foci of malaria in Italy in recent times.[40] Paestum (Poseido-

[36] Dionysius Hal. 8.15: *ἡ Οὐιεντανῶν πόλις . . . ἔχουσα . . . τὸν ὑπερκείμενον ἀέρα καθαρώτατον καὶ πρὸς ὑγιείαν ἀνθρώποις ἄριστον, οὔτε ἕλους πλησίον ὄντος, ὅθεν ἕλκονται βαρεῖς ἀτμοὶ καὶ δυσώδεις, οὔτε ποταμοῦ τινος ψυχρὰς ἕωθεν ἀνιέντος αὔρας.*

[37] Since settlement at Veii declined from the second half of the third century BC onwards (Patterson *et al.* (2000)), the area may have become less salubrious later on. It was definitely unhealthy by the early modern period. Blewitt (1843: 520) described Veii as follows: 'the modern village of Isola is in a state of complete decay . . . the appearance of the population, which seldom exceeds 100 souls, bears sufficient evidence of the prevalence of malaria during the hot months'.

[38] Pallottino (1975: 182); Toscanelli (1927); contrast Heurgon (1964: 100–6) on Etruria. The survey of the archaeological evidence for Magna Graecia by Collin-Bouffier (1994) was rather inconclusive as far as malaria is concerned, cf. Livadie (1998).

[39] Pallottino (1975: 117).

[40] G. Radke in Pauly-Wissowa, *RE* VIII A.2 (1958), cols. 1874–80 s.v. *Vetulonia*. Michelucci (1981) noted some construction work at Vetulonia in the third century BC and inscriptions dating to the second century AD, proving some continued occupation of the site, and there were still some rural settlements after the decline of the urban centre (Celuzza (1993: 83–8)). The neighbouring city of Roselle was also considerably smaller in Roman times than it had

nia) is an excellent example of the problem in so far as it affected the Greek cities in Italy. Paestum flourished in the sixth and fifth centuries BC, when its famous Doric temples were built. Subsequently, it suffered the debilitating effects of malaria, which became endemic in adjacent marshes, as Strabo describes.[41] Nevertheless the site of the ancient city was not finally completely abandoned until about the ninth century AD, following Saracen attacks, when the settlement of Capaccio Vecchio, situated in a hilly location inland, began to flourish. This is a good example of a change in the settlement pattern in the medieval period whose ultimate cause had begun to operate at least a thousand years earlier in classical times.[42]

In a way, the problem was even observed and discussed in antiquity. Livy raised the question of how the Volsci, coming from areas with a low population density (at least of free men) in his own time, could have raised military forces of the size attributed to them in the Roman annalistic tradition for their wars with the Romans in the fourth and fifth centuries BC.[43] It is interesting that Livy found the numerical strength of Volscian armies hard to believe, while simultaneously accepting the Roman census figures recorded by the annalists for the same period. Carmine Ampolo argued convincingly, following Beloch, that the Roman census figures for the period of the kings and the first half of the fifth century BC indicate an unbelievably high population density for Latium Vetus, taking account of data for agricultural productivity, with its implications for carrying capacity, from as recently as the last century.[44] Evidently the disparity in Livy's own time between the population of Rome and the population of the parts of Latium occupied by the Volsci was so enormous that Livy found it inconceivable that the two populations could once have been anywhere near equally matched, as the accounts of the Volscian wars available to him

been during the Etruscan period (Celuzza (1993: 114)). Eventually Roselle was abandoned in favour of Grosseto, which nevertheless suffered from malaria very early in its history in the medieval period. The Benedictine monks abandoned Grosseto because of malaria in AD 1220 (Santi (1996: 132)).

[41] Strabo 5.4.13.251C: *ποιεῖ δ' αὐτὴν ἐπίνοσον ποταμὸς πλησίον εἰς ἕλη ἀναχεόμενος* (A neighbouring river flooding marshes makes the city unhealthy).

[42] Pedley (1990: 17, 132, 163); Nutton (1971) discussed the fate of the neighbouring Greek city of Velia in relation to malaria.

[43] Livy 6.12.2–6, esp. 5: *aut innumerabilem multitudinem liberorum capitum in eis fuisse locis quae nunc vix seminario exiguo militum relicto servitia Romana ab solitudine vindicant.*

[44] Ampolo (1980: 24–30); Cornell (1995: 204–8).

suggested. The two sides may once have been equal, but our conclusion must be that the sizes of the armies on both sides were exaggerated by later Roman historians. To understand the demise of the Volsci, it is essential to remember one other factor, besides Roman military prowess. The Volsci were new to the area, having invaded Latium from the Appennine mountain region in the early fifth century BC. Since *P. falciparum* malaria does not occur in the mountains (see Ch. 4. 2 below), the Volsci would not have had any sort of immunity to it. Consequently as malaria spread, its effects on the Volscian population in its new lowland territory are likely to have been particularly devastating.[45] Nevertheless the problem remains of reconciling the extreme antiquity (in terms of geological time) of *P. falciparum* malaria with its apparent late spread in Italy. To try to solve the problem, it is necessary now to examine in more detail the ecology of malaria in Italy, both in recent times and in antiquity.

[45] Lancisi (1717: 123) expressed the opinion that the unhealthy air of the Pontine region led to the decline of the Volsci. In contrast to the Volsci from the hills, the Latins were etymologically 'the people of the plain' (Quilici (1979: 30)).

4

The ecology of malaria in Italy

4.1 Malaria and mosquitoes

Before its eradication malaria was transmitted in Europe principally by mosquitoes belonging to a (complex of) species that was originally called *Anopheles claviger* by Battista Grassi and later renamed *Anopheles maculipennis*. Roubaud and Wesenberg-Lund then noticed that malaria did not occur in many places where these mosquitoes were found, the puzzling phenomenon of *anophelism without malaria*. Anophelism without malaria was observed in Italy for example in such places as Colle Salvetti, Livorno, Massarosa, Naples, Pisa, Val di Chiana, and Viaréggio. In all these localities malaria appeared to have disappeared spontaneously by the end of the nineteenth century, even though there were still plenty of *Anopheles* mosquitoes around.[1] The resolution of the paradox of anophelism without malaria in Italy began when Falleroni, studying the mosquitoes of the Pontine Marshes, discovered that in places where malaria occurred the *A. maculipennis* mosquitoes always laid eggs which had one of two distinctive patterns, while in places where there was no malaria the mosquitoes produced eggs with other, different, patterns. It was then realized that what had been named *A. maculipennis*, a single species, was in fact a complex of different species with different habits. At that time the patterns on the eggs constituted the only morphological trait that could be used for differentiating these species.[2] Nine separate biological species are now recognized in the *A. maculipennis* complex in Europe (see Table 2). All the nine species may be identified in the fourth instar larval and adult female forms by chromosomal banding patterns, isoenzyme profiles, and DNA sequence analysis. Seven of the nine can be distinguished by specific patterns on the upper surface of their eggs and the form of the egg floats. *A. martinius* and *A. sacharovi* can be distinguished from the other seven species, but

[1] Hackett and Missiroli (1931); Hackett (1937); Fantini (1994); Gilles and Warrell (1993: 115–16).

[2] Falleroni (1926); Missiroli (1938: 9–10).

Table 2. Palaearctic mosquito species in the *Anopheles maculipennis* complex

Species	Author
A. atroparvus	Van Thiel (1927)
A. beklemishevi	Stegnii and Kabanova (1976)
A. labranchiae	Falleroni (1926)
A. maculipennis s.s.	Meigen (1818)
A. martinius	Shingarev (1926)
A. melanoon	Hackett (1934)
A. messeae	Falleroni (1926)
A. sacharovi	Favre (1903)
A. subalpinus	Hackett and Lewis (1935)

Source: White (1978) and Ramsdale and Snow (2000). The *A. maculipennis* complex belongs to the subgenus *Anopheles* of the genus *Anopheles*, while tropical species that transmit malaria belong to the subgenus *Cellia*. Several other species in the *A. maculipennis* complex only occur in North America. Besides the mosquitoes of the *A. maculipennis* complex, the mosquitoes of the *Anopheles claviger* complex had a secondary role as malaria vectors in Europe (Zamburlini (1998); Schaffner *et al.* (2000)). Five other important mosquito species or complexes of species are mentioned in this book: *Anopheles gambiae* (the principal vector of malaria in tropical Africa), *Anopheles pharoensis* (vector of malaria in Egypt), *Anopheles plumbeus* (possible vector of malaria in England), *Aedes aegypti* (the vector of yellow fever), and *Aedes albopictus* (the original vector of dengue fever).

not from each other, by slight differences in adult morphology. Three of these species were very important vectors of malaria in the past. *A. labranchiae* occurred in North Africa, Corsica, Sardinia, Sicily, central and southern Italy, parts of the Murcia and Alicante provinces of Spain, and Croatia. *A. sacharovi* occurred in mainland Italy, Sardinia, Greece, and the eastern Mediterranean, while *A. atroparvus* was widespread in Spain and northern Europe, reaching its southern limit in Italy in Campania. *A. atroparvus* takes the place of *A. labranchiae* in northern Italy, while the two species coexist in central Italy. A fourth important vector-species, *A. superpictus*, occurs sporadically in southern Italy and Sicily. However, it does not belong to the *A. maculipennis* complex and its main geographical distribution lies in the Balkans and Near East. The study of chromosome translocations has shown that *A. labranchiae*, *A. sacharovi*, and *A. atroparvus* are closely related to each other, within the *A. maculipennis* complex. All three can breed in brackish water in marshes near the coast, but also in fresh water in inland streams and (in modern times) in rice-fields.[3]

[3] Ramsdale and Snow (2000) provide maps showing the current distribution of the Euro-

3. *Anopheles labranchiae*, the most important mosquito vector of malaria in western Mediterranean countries in the past. According to Falleroni (1926: 565), who first identified it as a separate species, 'it can be said that the winged insect does not live outdoors; it takes shelter and nourishes itself in houses, cowsheds, and pigsties' (*l'insetto alato si può dire non viva all'aperto; si ricovera e si nutrisce nelle abitazioni, nelle stalle, nei porcili*). © The Natural History Museum, London.

The existence of regions in which there were lots of mosquitoes but no malaria, such as the north-eastern coast of Italy around Ravenna (see Ch. 4. 2 below), is probably one reason why the ancient Greeks and Romans apparently failed to notice the connection between the periodic intermittent fevers of malaria and mosquito bites, as far as can be seen from extant literature. In Europe the theory that mosquito bites caused malaria was first proposed in print by Giovanni Maria Lancisi in his famous work *de*

pean species of *Anopheles* mosquitoes. In some cases these are different from their known historical distributions as a result of modern eradication campaigns. *A. sacharovi* is now thought to have been eradicated from Italy, and *A. labranchiae* from Spain. Coluzzi and Sabatini (1995) give information on current distributions in Italy. Proft *et al.* (1999) and Romi *et al.* (2000) described the latest, PCR-based techniques for mosquito identification; Russell (1943: 56–61).

4. Fontana di Trevi, Rome's most famous fountain, was completed in its modern form in 1762 by Niccolo Salvi. According to a late-eighteenth century author, the water from the Trevi fountain was excellent for breeding mosquitoes.

noxiis paludum effluviis eorumque remediis, published in 1717 and based on research in the Roman Campagna, as a possible alternative to the prevailing miasmatic theory that malaria was caused by bad air arising from marshes. Lancisi attempted to observe the life cycle of mosquitoes in an experimental fashion. He correctly noticed that they reproduce very quickly and attain very high population densities in wetland environments, and considered the comments of classical authors on mosquitoes.[4] Mosquitoes could equally well reproduce very fast inside a building in the city of Rome in a glass of water from the famous Trevi fountain, as the anonymous author of a late eighteenth century discourse on *mal'aria* observed.[5] However, the miasmatic theory of 'bad air' prevailed until Laveran's discoveries in 1880.[6]

[4] Lancisi (1717: 56–60); Pietro Paolo da Sangallo (1679) had already considered the life cycle of mosquitoes.

[5] Anon. (1793: 61): *due giorni bastano nei tempi di gran caldo, perchè in Roma la vantata acqua di Trevi medesima conservata dentro un bicchiere di vetro pulitissimo in una camera custodita produca i vermi, dai quali poco dopo escono le zanzare.*

[6] Puccinotti (1826) attempted to modify the miasmatic theory by arguing that intermittent fevers were caused by *miasma palustre* in association with *squilibrii periodici di temperatura*.

5. *Artemisia absinthium*, Roman wormwood, a plant lethal to mosquitoes.

In antiquity, mosquitoes were certainly regarded as troublesome pests. To try to keep them away a series of measures were employed. In many ways these presage some of the techniques (e.g. the spraying of DDT as a long-lasting residual insecticide on the interior walls of dwellings) employed in the eradication campaigns of the World Health Organization in the 1950s and 1960s. Several different plants were recommended as herbal fumigants, or for smearing on the skin as insect repellents.[7] Modern research has

[7] Beavis (1988: 229–38), on references to mosquitoes in ancient authors, cited Pliny *NH* 20.71.184 (Roman coriander as a fumigant kills *culices*), 22.74.157 (smoke of burnt wild lupins

shown that some of these plants do indeed have the desired properties. A good example is Roman wormwood (*Artemisia absinthium*) and related *Artemisia* species, whose properties are described extensively by Pliny the Elder and other ancient authors. Pliny states that both the smoke of burnt wormwood and rubbing the body with absinth extracts in oil deter mosquitoes (*culices*). Angelo Celli mentioned experiments which found that Roman wormwood incapacitated mosquitoes in a closed chamber within six hours and killed them within twenty-four hours.[8] Extracts from the related species *Artemisia annua* were used in China in traditional herbal remedies against malaria itself. Derivatives of the drug artemisinin (*qinghaosu*) obtained from this plant are now being investigated and may become a major weapon against strains of *P. falciparum* which have become resistant to other drugs, although developing resistance to artemisinin is already being reported in scientific literature. However, no such drugs were available in Europe until quinine was brought from South America in the bark of the cinchona tree after Columbus.[9] Besides Roman wormwood, the use of mosquito nets is also mentioned in classical sources.[10] Thus some of the anti-mosquito measures described in ancient sources might in fact have had some degree of efficacy, *if* they had been applied on a sufficiently regular basis.

kills *culices*), 23.61.114 (smoke of rind of wild pomegranates kills *culices*), and 27.28.52, Dioscorides, *MM* 3.23.4, and Galen 11.798–807K on wormwood. Note also the long chapter in the *Geoponica* 13.11, ed. Beckh (1895): περὶ κωνώπων. Beavis expressed the view that no one in antiquity was aware of the connection between mosquitoes and malaria.

[8] Lodi (1986: 341–2) described the cultivation of *Artemisia absinthium* in Italy. It also grows wild on wasteland and roadsides in Lazio. Theophrastus, *HP* 7.9.5 described the stalks and leaves of ἀψίνθιον as good to eat, albeit bitter. However, it is now known that prolonged ingestion causes hallucinations, tremors, and other symptoms of toxic effects on the central nervous system (Leporatti *et al.* (1996: 517)); Chiej (1984: no. 41) for the use of the related species *Artemisia abrotanum* as an insect repellent when rubbed on skin; Celli (1900: 143). Theophrastus, *HP* 9.15.1 described Latium and Tuscany as lands rich in medicinal plants. Galen, 14.30–31K also noted that there were many medicinal plants growing near Rome, but said that many of the inhabitants of Rome did not know anything about them.

[9] *Qinghaosu* (artemisinin) has been used in China in connection with fevers since at least AD 340 (Dobson (1998)); P. F. Russell (1955: 5, 78–9). Hirsch (1883: 209) noted that there was intense malaria in tropical and subtropical parts of China in the nineteenth century, including Hong Kong, Canton, and Macao. Malagón *et al.* (1997) suggested that other *Artemisia* species in other parts of the world might also contain antimalarial drugs, cf. Tan *et al* (1998); Reed *et al.* (2000) on drug resistance.

[10] Herodotus 2.95.2 (with the comments of Jöchle (1999: 504)), Varro, *RR* 2.10.8, Horace, *Epodes* 9.16, Propertius 3.11.45, and *Greek Anthology* 9.764–6, ed. Paton (1917–18), on mosquito nets (Latin *conopia*).

However, the fact remains that there is no evidence that the connection between mosquito bites and malaria infection was understood in classical antiquity. In this respect the ancient Greeks and Romans probably lagged far behind their contemporaries in other parts of the world, despite all the achievements of ancient Greek science. In ancient China a document written by Zuo Qiuming and dating to the Spring and Autumn period (770–476 BC) records that a minister contracted malaria following an insect bite. Two other Chinese documents, dating to the Warring States period (476–221 BC), state that malaria was caused by mosquito bites and often appeared in late summer or early autumn.[11] Similarly the connection between rats and bubonic plague was observed in China long before it was noticed in Europe. There are ancient Sanskrit texts from India which may also associate malaria with mosquito bites; however, these texts seem to be difficult to interpret and impossible to date.[12] Grmek convincingly argued that the concept of contagion or infection was rejected by ancient Greek and Roman medical writers because of its popular association with magic. Such associations were incompatible with the idea of a medicine based on rational thought, as the Hippocratic tradition required. Consequently there was no room in Hippocratic medicine for mosquito bites as a cause of 'fever' (πυρετός), which was instead attributed to an imbalance of the humours, especially by Galen. Pellegrin pointed out that nothing is known of *popular* thought in classical antiquity.[13] Peasants might have had different ideas from the élite. It is interesting to bear in mind that Celli recorded that a connection between malaria and mosquitoes was frequently noticed by peasants in the Roman Campagna in the last century, at about the time when the modern scientific understanding of malaria was just commencing. Mario Coluzzi pointed out to the author the importance in the history of malariology of the Italian doctor Guiseppe Mendini, who in the original Italian version of his hygienic guide to Rome, published in 1896, worked out purely through logical arguments that malaria must be transmitted by mosquitoes, before Ronald Ross and Battista Grassi had

[11] Dong *et al.* (1996: 95–6).

[12] P. F. Russell (1955: 37–9) quotes the original Sanskrit; Futcher (1936: 541–2); Zysk (1985: 34–44); Raina (1991: 1–4); Zurbrigg (1994).

[13] Grmek (1984), Nutton (1983), (1998), and (2000*a*), and Leven (1993) on contagion; Pellegrin (1988).

performed the laboratory experiments which proved it, in birds and in humans respectively.[14] However, as far as antiquity is concerned, it is striking that even the pseudo-Aristotelian *Problems*, a very interesting work of unknown authorship, described 'fever' (*πυρετός*) as not infectious, even though the author(s) of this work took an interest in contagion that was uncommon in ancient medicine, describing *φθίσις* (tuberculosis) and *ὀφθαλμία* (trachoma?) as infectious.[15] Cicero, following the view expressed centuries earlier in one of the works in the Hippocratic corpus, refused to accept that intermittent fevers were of divine origin just because of their periodicity.[16] Nevertheless it is clear that some people did consider intermittent fevers to be of divine or rather demonic origin, since there was a temple of *Dea Febris* on the Palatine hill, reputedly the site of the original settlement of Rome by Romulus. This might be significant with regard to the question of the antiquity of the cult.[17] There were also temples dedicated to this deity in at least two other sites in the city of Rome, according to Valerius Maximus:

When they worship other deities, they expect to receive a benefit. However Fever is worshipped, so that she will cause less harm, in temples one of which is situated on the Palatine hill, a second in the vicinity of the monuments of Marius, and a third in the highest part of the Vicus Longus, and remedies which have been applied to the bodies of ill people are brought there.[18]

[14] Celli (1900: 90), cf. Corti (1984: 660–1) on the various views about the aetiology of malaria held by early modern Italian peasants. Iliffe (1995: 58, 113) noted that some African peoples also associated malaria with mosquitoes.

[15] [Aristotle] *Problems* 7.8.887[a].

[16] Hippocrates, *On the sacred disease*, ed. Littré (1839–61) vi. 354–5: *οἱ πυρετοὶ οἱ ἀμφημερινοὶ καὶ οἱ τριταῖοι καὶ οἱ τεταρταῖοι οὐδὲν ἧσσόν μοι δοκέουσιν ἱεροὶ εἶναι καὶ ὑπὸ θεοῦ γίνεσθαι ταύτης τῆς νούσου* [sc. epilepsy], *ὧν οὐ θαυμασίως ἔχωσι* (Quotidian, tertian, and quartan fevers seem to me to be no less sacred and sent by god than this disease [sc. epilepsy], but no one wonders at them.); Cicero, *de natura deorum* 3.24: *si omnes motus omniaque quae certis temporibus ordinem suum conservant divina dicimus, ne tertianas quoque febres et quartanas divinas esse dicendum sit, quarum reversione et motu quid potest esse constantius*? (If we say that all movements and all phenomena that maintain their own order at set periodic intervals are divine, must we not declare that tertian and quartan fevers are also divine, for what is more regular than their recurrent cycle?) and 3.63: *Febris enim fanum in Palatio* (a shrine of Fever on the Palatine); Pliny, *NH* 2.5.16.

[17] Lactantius, *Inst. Div.* 1.20.17, ed. Monat, in *Sources Chrétiennes*, 326 (1986), M. Minucius Felix, *Octavius* 25.8, and Seneca, *Apocolocyntosis Divi Claudii* 6 also mention *Febris* as a divinity. Dumézil (1996: 230 and n. 40) regarded *Febris* as a demon, but noted that little is known about Roman demonology.

[18] Valerius Maximus, *factorum et dictorum memorabilium libri* 2.5.6, ed. Combès (1995): *Et ceteros quidem ad benefaciendum venerabantur. Febrem autem ad minus nocendum templis colebant, quorum*

[*cont. on p. 52*]

6. The Virgin of Fevers in the Sacristy of St. Peter's in the Vatican in Rome. Reproduction of engraving by Pietro Leone Bombelli (1737–1809) in 1792. The Wellcome Library, London.

Since most individual attacks of malaria in adulthood in endemic areas are not actually directly fatal (although overall life expectancy of the whole population is sharply reduced—see Ch. 5. 4 below), owing to acquired/inherited immunity, in practice many attempted 'treatments' in antiquity would have appeared to have been successful, even though they were in reality no better than placebos. St. Augustine was still well aware of the *Febris* cult in late antiquity.[19] The cult of Fever in fact long outlived antiquity.[20] Religious rites and festivals directed against fever have continued to exist in various parts of Italy until modern times. For example, Ferdinando Forlivesi described how in 1889 thousands of the inhabitants of the region around Ravenna went down to the sea to bathe on 10 August, the day when the festival of St. Lorenzo was celebrated, in the belief that bathing on that holy day gave protection against malarial fevers. At Mazzara in Sicily the feast day of Salvatore on 6 August was regarded as effective against intermittent fevers.[21]

The references to the *Febris* cult in antiquity remind us that probably only a small minority of the population in antiquity, belonging to the educated upper class which produced most of our literary texts, actually followed the precepts and mode of reasoning of Hippocratic medicine. This conflict of different types of explanation was not merely an intellectual debate. It also spilled over into the legal and judicial domain. In the reigns of the paranoid emperors Caracalla (AD 198–217), Constantius (AD 337–361) and Valentinian (AD 364–375) individuals were punished for wearing amulets to ward off quartan and tertian fevers, since it was

adhuc unum in Palatio, alterum in area Marianorum monumentorum, tertium in summa parte Vici Longi extat, in eaque remedia quae corporibus aegrorum adnexa fuerant deferebantur. The corrupt text of Theodorus Priscianus 3, ed. Rose (1894), does not add any further significant information, however it be emended.

[19] St. Augustine, *de civitate Dei* 3.25; Richardson (1992: 149–50); Jones (1909*a*); Burke (1996: 2266–71) gives an interesting discussion of the Fever cult, referring to Dunst (1968) for a Greek parallel from Samos (perhaps influenced by Roman practice); Cornell (1995: 96–7) on the Palatine hill; P. F. Russell (1955: 79–82).

[20] R. Lanciani, 'Sulle vicende edilizie di Roma', in *Monografia* (1881: 8) wrote about the Fever shrine in the Vatican as follows: *La chiesa di santa Maria delle Febri al vaticano, distrutta nella riedificazione della basilica, fu una delle più venerate tra i mille luoghi di culto che il Panvinio registra nel Magnus Catalogus eccles. urban. (Mai. Spicileg. IX, p. I. 79).* There were similar shrines elsewhere in Italy. Pitrè (1971: 218) mentioned a church dedicated to the Madonna of Fevers outside Partanna in Sicily, cf. Corti (1984: 666–7).

[21] Emiliani and Dalla Valle (1965: 379); Pitrè (1971: 222–3).

reckoned that any magic might be turned against the emperor.[22] Both Cicero and Pliny the Elder regarded the Roman custom of deifying evils such as fever as a mistake and a sign of the weakness of the human race, but it is likely that most people in ancient populations did indeed regard malaria as the work of a demon.[23] In his antiquarian book on the Roman calendar John Lydus (*c.*AD 490–560), working at Constantinople, described malaria under the heading of September. He attributed quotidian fevers to the demon of air, tertian fevers to the demon of water, quartan fevers to the demon of earth, and envisaged a constant struggle between these entities and the demon of cold in order to explain the periodicity of malarial fevers.[24] There are also documentary sources from Roman Egypt describing protective charms or exorcism spells for malarial fevers. It is striking that malaria is mentioned much more

[22] Lane (1999: 648–9) drew attention to these texts: Ammianus Marcellinus 19.12.14, *nam siqui remedia quartanae vel doloris alterius collo gestaret . . . pronuntiatus reus capitis interibat* (For if anyone wore around his neck amulets against quartan fever or any other illness . . . he was condemned to death and executed.), and 29.2.26, *anum quandam simplicem intervallatis febribus mederi leni carmine consuetam, occidit ut noxiam, postquam filiam suam ipso conscio curavit adscita* (He had a simple old woman, who used to cure intermittent fevers with a gentle charm, executed as a criminal, after she had been summoned with his knowledge and had treated his own daughter.), cf. 16.8.2; *scriptores historiae Augustae—Caracalla* 5.7: *damnatis et qui remedia quartanis tertianisque collo adnexas gestarent* (Some men were even condemned to death for wearing amulets against quartan and tertian fevers around their necks.). McCollough and Glazier-McDonald (1996) published a particularly fine example of a fever amulet with an Aramaic text from Sepphoris in Israel.

[23] Cicero, *de natura deorum* 3.63 and *de legibus* 2.28; Pliny, *NH* 2.5.15–16. Probably more representative of popular thought in antiquity is the obscure third century AD (?) Christian text called the *Testament of Solomon*. McCown (1922: 47) in his edition described this work as follows: 'the prime interest of the writer of the *Test* was medical. For him demons were what bacilli are to the modern physician, and his magical recipes and angel names are his pharmacopoeia'. Chapter 18.20 and 23 of the *Testament* mentions demons that bring fevers to men.

[24] John Lydus, *liber de mensibus* 4.130, ed. Wunsch (1957): *ὅτι πλεονάσαντος μὲν πυρὸς πυρετὸς γίνεται, ἀφημερινὸς δὲ ἀέρος, τριταῖος δὲ ὕδατος, τεταρταῖος δὲ γῆς. φιλεῖ δὲ τούτων προκατάρχειν τὸ ῥῖγος. ὁπόταν γὰρ ὑπὸ τοῦ ψυχροῦ—ἐπειδὴ τοῦτο ἴδιον ὕδατός τε καὶ γῆς—τὰ εἰρημένα ὑγρὰ παχυνθῇ, τηνικαῦτα φερόμενα διὰ τῶν ἀραιωμάτων ἐξωθεῖν μὲν οὐ δύναται τὰ πυκνότερα, ἐμπεσόντα δὲ ταῖς τούτων ἕδραις σύνωσιν καὶ θλίψιν ἐργάζεται, μέχρις ἂν ὑπὸ τοῦ πυρὸς ἐπειγόμενα τμηθέντα διαχυθῇ, ὅπερ ἀναγκαίως κλόνον τινὰ καὶ σεισμὸν ἐμποιεῖ, ὃ δὴ πάθος τρόμος καὶ ψῦχος ὀνομάζεται* (With excessive heat a fever is generated. Air produces quotidian fevers, water produces tertian fevers, and earth produces quartan fevers. However cold likes to begin before all of these. For whenever liquids are solidified by cold (since cold is unique to water and earth), being thicker they cannot be driven out through the interstices of the body, but falling into the bases of the interstices they created compression and pressure, until they are dissolved by fire, having being overpowered and thinned, wherefore it must cause a degree of agitation and commotion, and so the illness is called shivering and cold.).

frequently than any other disease in the magical papyri. The magical papyri use exactly the same terminology for malarial fevers as the mainstream medical authors such as Galen.[25] Such evidence suggests that religious or magical explanations of malaria and other diseases were widely adopted in antiquity and indeed afterwards. The word *abracadabra*, used in magic, originated as a spell against semitertian fever. 'Write down on papyrus the word abracadabra | and repeat it many times, moving down the paper, but each time remove the final letter | from the line so that more and more of the letters of the word are missing, and mark the others, | until there is only one letter in the last line of the diagram at the apex of a cone. | Remember to tie it around one's neck with a linen thread' (Quintus Serenus, *liber medicinalis*).)[26]

The shift from pagan religions to Christianity probably made no significant difference to popular perceptions of malaria, which was frequently the target of healing miracles in Christian literature. Just to give one set of examples here, Gregory of Tours in his book on the *Glory of the Confessors* made a series of references to healing miracles involving quartan fever, tertian fever, and fevers without any further specification. His evidence shows that malaria was common and well known in France in the sixth century AD.[27] In the thirteenth century even a pope, Honorius IV (1285–7), is said to

[25] Vakaloudi (2000: esp. 185, 196, 206) noted these texts, which are to be found in Daniel and Maltomini (1990) nos. 2, 3, 4, 9, 11, 14, 18, 19, 21, 22, 23, 25, 29, 31, 34, and 35. Part of no. 14, a papyrus dating to the fourth century AD, is reproduced here as an example: *τὸν Ἰωάννης τοῦ ἔχοντος ῥίγου καὶ πυρετοῦ . . . | καθημερινόν, ἀπὸ παντός ῥίγου . . .| κεφ]αλαργίας, καθημερινόν, νυκτερινόν . . . | τε]ταρτέον, ἡμιτριτέον, ἤδη ἤδη, ταχὺ, τ[αχὺ| ταν ἡμῶν ἀθάρατον ἄγγελον . . . | [τὸν Ἰωά]ννης ἀπὸ παντὸς ῥίγου καὶ π[υρετοῦ| ἀπὸ τῆς σήμερον ἡμέρα⟨ς⟩ καὶ ἀπὸ ἄρτι ὅρ[ας εἰς τὸν]| [ἅ]παντα χρόνον τῆς ὅλης αὐτοῦ δο[ῆς| [. . .]σιν, ἤδη ἤδη, ταχὺ, ταχύ* (. . . Ioannes of the shivering and fever that possess him | quotidian, from all shivering, | . . . headache, quotidian nocturnal fever, | . . . quartan, semitertian, now, now, fast, fast | . . . our immortal angel | . . . Ioannes from all shivering and fever from this day today and from this hour now for the entire time of the rest of his life | . . . now, now, fast, fast.).

[26] Quintus Serenus, *liber medicinalis* 51.935–40, ed. Pépin (1950) (*Hemitritaeo depellendo*): *inscribes chartae quod dicitur abracadabra | saepius et subter repetes, sed detrahe summam | et magis atque magis desint elementa figuris | singula, quae semper rapies, et cetera †figes†, | donec in angustum redigatur littera conum: | his lino nexis collum redimire memento.*

[27] Gregory of Tours, *Liber de gloria beatorum confessorum*, ed. Migne, *Patrologia Latina*, lxxi., cols. 838 (quartan), 845 (quartan), 890 (quartan), 893 (quartan), 895 (quartan), 904 (tertian). Of course, as we have already seen, references to periodic fevers are only the tip of the iceberg of malaria in antiquity. Consequently many of the other references made by Gregory to unspecified fevers will also have been cases of malaria. A likely example is col. 847, where the vocabulary is that of malaria (*febricitans*), even though no periodicity is mentioned. Cf. Horden (1992) on malaria in early medieval France.

have explained malaria in astrological terms. Ultimately Cicero's more 'rational' approach to periodic intermittent fevers was not an improvement on the explanation from religion. The ancient Chinese, whose conception of the nature of the subject of medicine was in some respects fundamentally different, came closer than the ancient Greeks and Romans to understanding the cause of malaria, as well as coming closer to finding an effective treatment for the disease, as has already been seen.[28]

4.2 Malarial environments

Given the failure of Greek rational thought, it was left to the practical instincts of the Romans to try to make an impact on the situation. Undoubtedly a limited measure of success was enjoyed, at least from time to time. As Scarborough put it, 'Roman practical acumen allowed a certain amount of experimental understanding of the problems involved', with regard to the siting of villas in relation to malarial swamps.[29] The association of malaria with swamps was common knowledge at least from the time of the Hippocratic *Airs, Waters, Places* onwards, if not long before. The Roman agronomists all warned of the dangers of marshes. Cato insisted that a farm had to be situated in a healthy place. Varro said that a farm facing a river was unhealthy in summer.[30] The recommendation to face away from the danger area was well founded. Celli noted that in the nineteenth century those inhabitants of the hill town of Sezze (ancient Setia) in Lazio whose houses faced a marsh contracted malaria, while those who lived on the opposite side did not. The population of Sezze experienced different rates of infection not only according to locality of residence, but also according to sex, since it was observed that women who stayed in their homes on the hill were infected less frequently than men who went down to work on the plain below the town.[31] Malaria penetrated far inland up

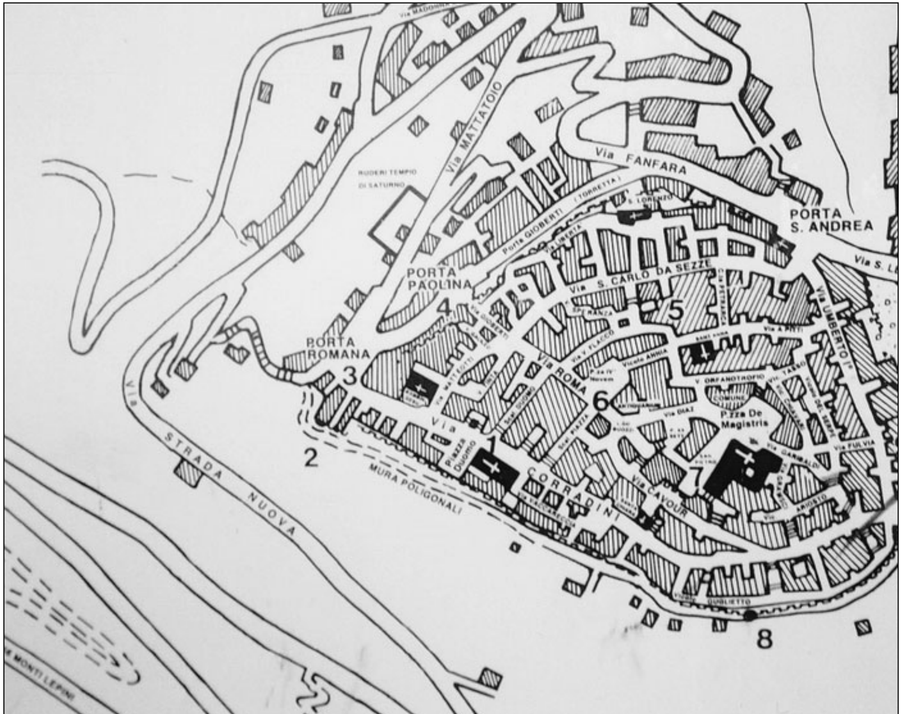
[28] According to Tomassetti (1910: i. 170) Honorius attributed malaria: *ad un movimento della ottava sfera del cielo*; Lloyd (1996) on China.

[29] Scarborough (1969: 82).

[30] Hippocrates, *Airs, Waters, Places* 7 and 24; Cato, *de agricultura* 1.3 (*loco salubri* (in a healthy place)); Varro, *RR* 1.12.1,*sin cogare secundum flumen aedificare, curandum ne adversum eam ponas; hieme enim fiet vehementer frigida et aestate non salubris* (If you have to build a villa next to a river, make sure that it does not face the river, since it will be very cold in winter and unhealthy in summer.).

[31] Celli (1900: 84, 132). Tommasi-Crudeli (1892: 131) and North (1896: 103) recorded that it was not uncommon for a woman of Sezze (their idleness was proverbial) to have had three

[*cont. on p. 57*]



7. Plan of modern Sezze (ancient Setia).

river valleys in the early modern period. For example, the Tiber was affected for a large part of its course, as were many other rivers in Lazio such as the Aniene, Arrone, Galera, Marta, Sacco and Timone. Tibullus' recommendation, quoted above, that the vicinity of rivers and streams in Etruria should be avoided in the summer, should be recalled. It suggests that river valleys were as unhealthy in the first century BC as in the early modern period.

Varro and Vitruvius also recommended building a villa on elevated ground, not in a hollow.[32] This was a frequent and again well-founded recommendation in antiquity, since mosquitoes, which are weak fliers, dislike flying upwards and dislike windy locations. Antyllus, writing in the second century AD, summarized the prevailing view in antiquity as follows:

> Localities situated at high altitude are the healthiest places, since the air is not static, but is scattered around and continuously driven away by the winds. Airy places are suitable for all afflictions of the chest and head and all the faculties.[33]

Procopius stated that the air on Mt. Vesuvius was very light and extremely healthy. Consequently patients with tuberculosis were sent there to recuperate.[34] At least such patients would have avoided the synergistic interactions of tuberculosis with malaria (see Ch. 5. 2 below). Celli noted that the town of Norma, situated on a hill 433 metres above sea level overlooking the Pontine Marshes, was free from malaria in the nineteenth century, while the vicinity of Ninfa (described by Gregorovius as 'the little medieval Pompeii'), located at the foot of the same hill, was intensely malarious, the cause of its abandonment between AD 1675 and 1680.[35] In

husbands, who had all died from malaria, by the time she reached the age of thirty. This was the inverse to the situation described in the English marshlands by Dobson (1997), where men who had been brought up in the marshes married women moving into the marshlands from other areas, who died rapidly. [Aristotle] *Problems* 1.21.862a described marshes as unhealthy.

[32] Varro, *RR* 1.12.3; Vitruvius 1.4.1.

[33] Antyllus *περὶ τόπων καὶ τῶν ἐν αὐτοῖς ἀέρων* in Stobaios, *florilegium* 101.18, ed. Wachsmuth and Hense: *οἱ ὑψηλοὶ τῶν τόπων ὑγιεινότατοι, τοῦ ἀέρος ἐν αὐτοῖς οὐ μένοντος ἀλλὰ καὶ περιχεομένου καὶ ὑπὸ τών ἀνέμων συνεχὲς ἀπωθουμένου· εὔπνοοί τε δὴ καὶ διαθέσεσι πάσαις ἐπιτήδειοι ταῖς περὶ θώρακα καὶ κεφαλῇ πεπονθυίᾳ καὶ τοῖς αἰσθητηρίοις πᾶσιν.* Nutton (2000*b*) discussed the ancient tradition of meteorological medicine.

[34] Procopius, *BG* 2.4.30, ed. Haury (1905).

[35] Celli (1900: 85); Pratesi and Tassi (1977: 140–1) described the area of Ninfa, as did Tomassetti (1910: ii. 393–406, esp. 399–400 for the date of Ninfa's abandonment). Tomassetti thought that Ninfa was healthy in antiquity, but there is no positive evidence for this.

8. View of Norma in the distance from Sermoneta. Situated on top of a hill overlooking the Pontine plain, modern Norma and the ancient Roman colony of Norba (450 metres above sea level), which lies beyond it, did not have endemic malaria, since mosquitoes are weak fliers.

9. View of Ninfa from Norma. Situated at the foot of the hill below Norma, in the Pontine plain, Ninfa suffered from intense malaria as a result of which the settlement was eventually completely abandoned in the seventeenth century. Today the ruins of the settlement are part of a botanical park and wildlife reserve administered by the Fondazione Caetani and the World Wildlife Fund.

general malaria was not found above 500 metres in Italy. Consequently it was not found in the higher parts of the Colli Laziali, Monti Lepini, Monti Simbruini, and Ciociaria in Lazio. In the eighteenth century population growth occurred in these more mountainous areas, while the lowland populations stagnated or declined, and the bulk of the population was concentrated in the more mountainous regions. However, in southern Etruria there are not many localities whose altitude exceeds 500 metres.[36] Malaria creates differential demography according to altitude. Nevertheless it is important to bear in mind that people who live at altitude but descend to work will still be vulnerable to infection in their working environment, as we have already seen in relation to Sezze. North observed that those inhabitants of Rocca Massima, situated at an altitude of over 700 metres, who went to work on the plain below frequently became infected with malaria. In general, upland areas were much healthier than lowland areas in the past in central and northern Europe, as various studies have shown. However, in the more mountainous parts of central Italy, where peasants often lived in housing which was inadequate for the winter, the winter cold could cause some adverse demographic effects. A comparison of Treppio, located 700 metres above sea level, with Casalguidi found that infant mortality in the first year of life was higher in Treppio for that segment of each cohort born during the winter months. To understand the ancient preference for elevated locations, it is essential to remember that it is only when the comparison is with lowland populations affected by endemic malaria that upland regions in central Italy in the past had an overwhelming advantage in terms of health. It is only in comparison with the intense malaria of Grosseto that Treppio appears extremely healthy.[37]

There is also a famous passage in Varro on the causes of disease in swamps:

Care must also be taken in marshy areas . . . because certain small animals

[36] Rendeli (1993: 121–2).

[37] Breschi and Livi-Bacci (1986) on Treppio and Casalguidi; on the effects of altitude on malaria in Italy see Bonelli (1966: 678–81); North (1896: 98–105); F. Giordano *Condizioni topografiche e fisiche* in *Monografia* (1881: ix–xvii); Celli (1900: 177); Douglas (1955: 305); Levi (1945: 74). Viazzo (1989: 198, 212, 215–18, 289) described the healthiness of Alpine environments. Balfour (1935: 329) stated that malaria was commoner below 250 metres above sea level in Greece, while Dobson (1997: 107) observed that the worst affected parishes in England were below 50 metres above sea level, while parishes above 400 metres were very healthy.

breed there. These animals cannot be seen with the naked eye and enter the body through the mouth and nostrils in the air and cause severe diseases.[38]

Varro's *animalia quaedam minuta* appear to be the invisible particles of disease postulated in the atomic theory of Lucretius, as suggested by Phillips, rather than mosquitoes, or even less likely, the protozoa of malaria. This passage is unparalleled in ancient Latin literature and Varro's idea had no practical consequences.[39] Nevertheless his recommendations are interesting, including the suggestion that unhealthy localities were better worked with hired labour rather than slaves.[40] This idea is significant for understanding the agricultural economy of the regions of Italy in which malaria was endemic in the past, as will be seen later.

Columella advised against siting farm buildings next to marshes, making a more direct reference to mosquitoes.[41] He also noted that the water of marshes was pestilential, but only in summer, and Vitruvius also observed that the most pestilential places were healthy in winter.[42] Antyllus and Athenaios both described marshes as pestilential in summer.[43] These texts introduce the very important question of the seasonality of malaria, which has recently been studied by Scheidel employing funerary inscriptions and modern

[38] Varro, *RR* 1.12.2: *Advertendum etiam, siqua erunt loca palustria . . . quod crescunt animalia quaedam minuta, quae non possunt oculi consequi, et per aera intus in corpus per os ac nares perveniunt atque efficiunt difficilis morbos.*

[39] Phillips (1982); Nutton (1983: 10–11) discussed Varro and Columella on marshes. He argued that Galen did take the 'seeds of disease' theory seriously as an explanation for some time, but eventually subordinated it to the humoral theory, in which a humoral imbalance was required for the 'seeds of disease' to have any effect.

[40] Varro, *RR* 1.17.3: *gravia loca utilius esse mercennariis colere quam servis.*

[41] Columella, *RR* 1.5.6: *nec paludem quidem vicinam esse oportet aedificiis . . . quod illa caloribus noxium virus eructat et infestis aculeis armata gignit animalia, quae in nos densissimis examinibus involant* (And there should not be a marsh close to the buildings . . . because it throws up an evil odour during the summer heat and produces insects armed with dangerous stings, which swoop upon us in dense swarms.).

[42] Columella, *RR* 1.5.3: *deterrima palustris, quae pigro lapsu repit; et pestilens, quae in palude sumper consistit. Hic idem tamen umor, quamvis nocentis naturae, temporibus hiemis edomitus imbribus mitescit* (Worst of all is marsh-water, which flows along with slow movements; and water which always remains in a swamp is pestilential. However this same water, although its nature is harmful, is tamed by the winter rains and becomes harmless.); Vitruvius, 1.4.4.

[43] Antyllus in Stobaios, *florilegium* 101.18: οἱ δὲ ἑλώδεις κακοὶ μὲν ἀεί, θέρους δὲ καὶ λοιμώδεις (Marshes are always bad, and pestilential in summer.); Athenaios in Oribasius 9.2.10, ed. Raeder (1926–33): ἐπινοσωτέρους οἰόμεθα τοὺς λιμνάζοντας καὶ ἑλώδεις τόπους, καὶ μάλιστα τοῦ θέρους, διὰ τὴν ἀνωμαλίαν τοῦ ἀέρος (We reckon that places with stagnant and marshy water are rather unhealthy, particularly in summer, because of the irregularity of the air.).

comparative evidence.[44] In the early eighteenth century Lancisi described the succession of different types of fever in the summer in Lazio, first benign tertian fevers, then continuous fevers, then pernicious fevers at the time of the autumn equinox (especially if there were showers, clouds, and south winds), and finally long-running quartan fevers.[45] In nineteenth-century Rome there were no new cases of *P. falciparum* malaria from March to June inclusive, because of its temperature requirements for sporogony in the mosquito. Any cases that developed during those months were recrudescences of previous infections. The annual epidemic broke out in Rome rather suddenly in July each year. The annual maximum number of cases was usually attained in Rome in August (but sometimes as late as October). This explains the significance of the *dog-days*, the period after the heliacal rising of Sirius (the hound of Orion and so the dog-star for the Greeks) in late July, as not only the hottest time of the year but also an extremely unhealthy season.[46] Theophrastus attempted to explain in climatic terms both the late summer peak of malarial fevers and the peak of gastro-intestinal infections that also occurred in the summer in Mediterranean countries. 'During the dog days, even though the air is very hot, nevertheless south winds blow and clouds form and trees themselves become visibly fluid and a certain degree of fluidity spreads under the bark, as a result of which there are flows of sap in trees even at this time of the year, either because of the concentration of the fluid owing to reciprocal displacement or because of some other cause. This also happens in humans, and that is why the bowels become very loose at this time and fevers are very frequent, since bodies become fluid.'[47]

Since malaria could take several months to be fatal, direct mortality from cases arising in August could be delayed until the winter. The timing of the seasonal peak varied from place to place. At

44 Scheidel (1996).

45 Lancisi (1717: 42).

46 Corti (1984: 665) commented on the attitudes of Italian peasants to the dog-star period in more recent times.

47 Theophrastus, *CP* 1.13.5–6, ed. Einarson and Link (1976): *ὑπὸ γὰρ τὸ ἄστρον* [sc. *ἐν τῇ τοῦ Κυνὸς ἐπιτολῇ*] *καίπερ ὄντος ἐμπύρου τοῦ ἀέρος, ὅμως καὶ νότια πνεῖ καὶ νέφη συνίσταται καὶ αὐτὰ τὰ δένδρα διυγραίνεται φανερῶς καὶ ὑπὸ τὸν φλοιὸν αὐτῶν διαδίδοταί τις ὑγρότης, ὅθεν καὶ ῥοαὶ καὶ κατὰ τοῦτον τὸν καιρόν, εἴτε οὖν συνελαυνομένου τοῦ ὑγροῦ καὶ ἀντιπεριστάσεως γινομένης, εἴτε δι᾽ ἄλλην αἰτίαν· πλὴν συμβαίνει γε τοῦτο καὶ τοῖς ἀνθρώποις· διὸ καὶ κοιλίαι μάλιστα λύονται, καὶ πυρετοὶ πολλοὶ γίνονται, καθυγραινομένων τῶν σωμάτων.*

Corneto (Tarquinia) near the coast the maximum number of cases did not occur until November in some years.[48] Marchiafava noted that even shepherds, who brought their flocks of sheep down from the mountains to graze in the Roman Campagna as part of the traditional pattern of transhumance at the end of the autumn, were still very vulnerable to infection with *P. falciparum* malaria at that time. Similarly there were a significant number of new cases in November at Grosseto during the epidemic of 1910. This is possible because *A. labranchiae* continues to be active in houses during the winter.[49] The seasonal mortality peak, which as will be shown later was indeed primarily caused by malaria, as Scheidel argued, was such a striking phenomenon that it was even noticed in antiquity. The author of the pseudo-Aristotelian *Problems* stated that the number of deaths was much higher in the hundred days after the summer and the winter solstices, and the autumn was less healthy than the spring.[50] The seasonality of disease patterns in Mediterranean countries in antiquity, which was shaped above all else by malaria, had a long history of discussion in ancient medical writers stretching back to the Hippocratic *Aphorisms*.[51]

Pliny the Elder followed the agronomists on the dangers of farming in unhealthy districts, recommending that villas should not be placed near marshes or next to rivers.[52] He added the following intriguing comment:

> The healthiness of a locality is not always revealed by the complexion of the inhabitants, since those who are accustomed to such conditions can continue working even in pestilential areas.[53]

[48] Celli (1900: 148–56). Aitken (1873) presented the following statistics for deaths directly from pernicious intermittent fevers in the city of Rome in 1872: 52 from January 1 to March 24, 39 from March 25 to June 16, 199 from July 15 to October 6, and 109 from October 7 to December 29. Rey and Sormani (1881) analysed mortality from malaria and other diseases in Rome on a weekly basis for the years 1874–6. Dobson (1997: 203–20) discussed seasonal patterns in the English marshlands.

[49] Marchiafava (1931: 52); Bellincioni (1934: 203), quoting G. Memmi's observations at Grosseto in 1910; Herlihy (1958: 48–53) and Cipolla (1992: 79, 90 n. 6) on Pisa. Corradi (1865: i. 455–6) described malaria at Pisa in October–November AD 1530.

[50] [Aristotle] *Problems* 1.26–7.862^{b}: *ἀποθνήσκουσι μάλιστα*.

[51] For references to the *Aphorisms* see Sallares (1991: 467 n. 381).

[52] Pliny, *NH* 18.7.33: *convenit neque iuxta paludes ponendam esse neque adverso amne, quamquam Homerus omnino e flumine semper antelucanas auras insalubres verissime tradidit.* It is interesting that he interpreted the Homeric line (*Odyssey* 5.469) as referring to the unhealthiness of rivers.

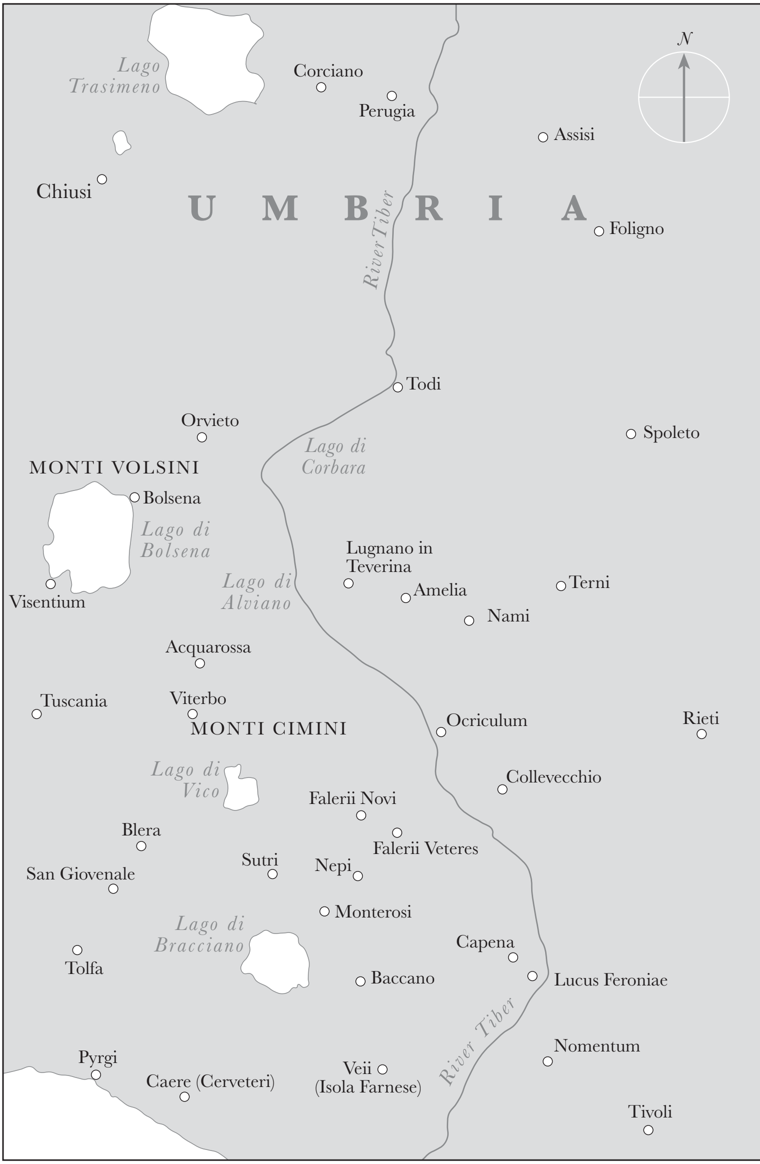
[53] Pliny, *NH* 18.6.27: *salubritas loci non semper incolarum colore detegitur, quoniam adsueti etiam in pestilentibus durant.*

Celli interpreted this statement and various kinds of proxy data (discussed in Ch. 9 below) as evidence that malaria was milder in Pliny's time than it was in certain other periods, in support of his cyclical theory of malaria in the Roman Campagna. There is in fact no reason for supposing that *P. falciparum* has ever displayed anything other than extreme virulence throughout its lengthy evolutionary history, as was suggested in Chapter 3 above following the latest scientific research. There was little detailed understanding of either inherited or acquired immunity to malaria in Celli's time. Either or both of these types of immunity (discussed in Chs. 4. 2 and 5. 3 below) provide a better explanation for Pliny's statement than Celli's inference that *P. falciparum* malaria was milder then.[54]

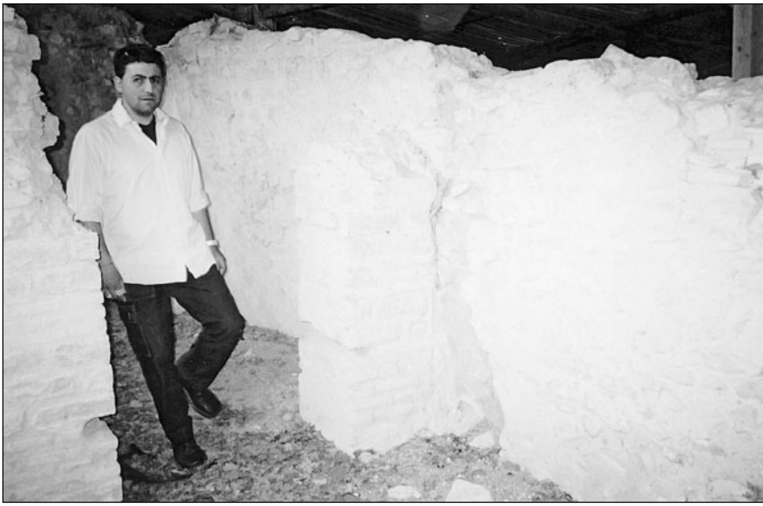
Malaria was as active in central Italy in late antiquity as it was in the late Republic and early Empire. According to his own account Sidonius Apollinaris was infected while travelling through Umbria, next to 'the pestilential region of Tuscany', along the Via Flaminia from Ravenna to Rome in AD 467. ('I entered and left immediately the other towns along the Flaminian road, moving forward with Picenum on the left and Umbria on the right; in Umbria either the Atabulus wind from Calabria or the pestilential region of Tuscany infected my body as I breathed in the air saturated with poison which caused alternate fevers and chills. Meanwhile fever and thirst devastated the inside of my body, my heart and marrow.')[55] This suggests that the disease had already matched by then its distribution in the early modern period, when Doni (an important figure in the historiography of malaria who will be formally introduced in Ch. 8 below) noted in the seventeenth century that the section of the Via Flaminia closest to Rome was unhealthy. Some parts of Umbria were certainly very healthy, for example Spoleto, which was singled out by Doni in this respect. Nevertheless other sources confirm the active presence of malaria in some regions of Umbria, for example around Narni where seasonal migrant farm

[54] Celli (1933: 42). G. Brasacchio, quoted by Arlacchi (1983: 179), described the physical appearance of the inhabitants of the Crotonese as follows: 'the pallor characteristic of malaria is hidden beneath the deep brown skin burnt by the summer suns, which give to the face a curious olive colour'. This also provides a reasonable explanation for the problem that concerned Celli. Mabeza *et al.* (1998) argued that intense pallor is associated with an increased risk of death in childhood malaria.

[55] Sidonius Apollinaris, *Letter to Heronius* 1.5.8: *hinc cetera Flaminiae oppida statim ut ingrediebar egressus laevo Picentes, dextro Umbros latere transmisi; ubi mihi seu Calaber Atabulus seu pestilens regio Tuscorum spiritu aeris venenatis flatibus inebriato et modo calores alternante, modo frigora vaporatum corpus infecit. Interea febris sitisque penitissimum cordis medullarumque secretum depopulabantur.*



Map 2. Umbria and northern Lazio

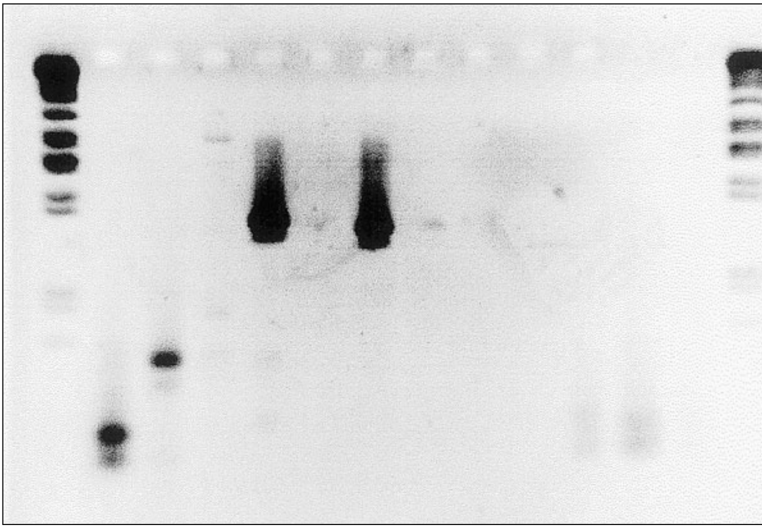


10. Part of the ruins of the Roman villa of Poggio Gramignano, near Lugnano in Teverina, Umbria, with Alessandro Dimiziani. The infant cemetery, which was established in the ruins of the villa in the fifth century AD, is the source for the first malaria epidemic in the ancient world to be documented archaeologically and through the use of ancient DNA.

labourers from the Marche sometimes became infected in the nineteenth century. In 1832 a local doctor, Angelo Sorgoni, made the very interesting observation that the migrant farm workers from the Marche, who could only have experienced *P. vivax* malaria in the Marche (unlike the natives of the region around Narni, where *P. falciparum* malaria also occurred) were more severely affected by attacks of pernicious malaria (*P. falciparum*) and required higher doses of quinine for treatment than the inhabitants of Narni. This situation suggests a degree of endemicity of *P. falciparum* malaria in south-western Umbria in the early nineteenth century sufficient to lead to the build-up of some acquired resistance in adults in the local population.[56]

David Soren and his colleagues have interpreted a child cemetery dating to the fifth century AD, excavated recently in the ruins of

[56] Doni (1667: 91, 115); Foschi (1983: 112) on Narni; Sorgoni (1832). Procopius, *BG* 1.17.6–11 described the site of the town of Narni itself, which was healthy as it is situated on a hill (244 metres above sea level). Pezzella (1997: 109, 159) recorded references to quartan fever in early modern texts of herbal medicine from Umbria.



11. PCR products amplified from the Lugnano bones with oligonucleotide primers for malaria 18S ribosomal DNA. Video print taken by Susan Gomzi. See Sallares and Gomzi (2001) for further discussion.

an abandoned villa at Poggio Gramignano near Lugnano in Teverina, not far from the Tiber in southern Umbria, as the result of an epidemic of *P. falciparum* malaria.[57] The site of the cemetery (185 metres above sea level) is located about 3.5 kilometres away from the river Tiber, which is visible in the distance down gently sloping land, a typical location for malaria in western central Italy. The location of the corresponding settlement is not known, but it was probably closer to the river. The dead, who were apparently buried over a short period of time, were almost all infants, neonates, or foetuses. The foetuses were the product of miscarriages of pregnant women, especially primigravidae, who are particularly vulnerable to malaria owing to suppression of the immune system during the last two trimesters, while infants and young children usually bear the brunt of direct mortality from *P. falciparum* malaria. Numerous studies have shown that *P. falciparum* malaria can cause an extremely high rate of miscarriages in pregnant women in areas of seasonal transmission with epidemic malaria. One survey of a series of cases

[57] Soren *et al.* (1995); Soren and Soren (1999).

in the United States in the first half of the twentieth century yielded a foetus mortality rate of 60%. Similarly many abortions occurred in pregnant women during the Monte Cassino epidemic in 1944, the last major malaria epidemic in the history of modern Italy.[58] The circumstantial evidence derived from the archaeological excavations for this interpretation of the Lugnano cemetery is currently being supplemented by studies of ancient DNA from the bones. One of the skeletons has yielded ribosomal DNA from *P. falciparum*, confirming its presence at Lugnano in the fifth century AD. Mario Coluzzi told the author that *A. labranchiae* occurred as far up the Tiber valley as Orte, only a few kilometres from Lugnano, as recently as the time of the Second World War. Further north it was replaced by *A. atroparvus*. Consequently the Lugnano epidemic in the fifth century AD occurred on the edge of the geographical distribution of both *A. labranchiae* and *P. falciparum*. It suggests that both had reached their maximum distributions in western central Italy by the mid-fifth century AD. In the past the town of Lugnano in Teverina itself was probably immune from malaria, since it is situated 450 metres above sea level. However, there are plenty of mosquitoes, which were observed by the author on a visit to the area, in the surrounding lowlands, but only *Culex* mosquitoes occur in the region today.[59]

Other literary sources from late antiquity show that marshy environments were still feared then. Palladius duly made the standard observations that marshy and pestilential land should be avoided.[60] He then added a more interesting comment:

> In any event a marsh must be avoided, especially if it faces south or west and tends to dry up during the summer, because of the pestilence or hostile little animals which it generates.[61]

Palladius' observation of the extreme peril posed by marshes which desiccate during the summer leads on to consideration of the exact requirements of *Anopheles* mosquitoes for breeding pur-

[58] McFalls (1984: 118); Zei *et al.* (1990); Dobson (1997: 340–2); Barbosa and Arjona (1935: 11–18); Torpin (1941); Diagne *et al.* (2000) showed that the period of increased susceptibility to malaria continues for about two months *after* birth.

[59] Sallares and Gomzi (2001); Sallares *et al.* (2002); North (1896: 24) observed that the vicinity of Orte is particularly vulnerable to Tiber floods.

[60] Palladius, *opus agriculturae* 1.5.5, ed. Rodgers (1975): *situs vero terrarum neque planus, ut stagnet*; 1.5.6: *qui ager pestiferi more fugiendus est.*

[61] Palladius 1.7.4: *palus tamen omni modo vitanda est, praecipue quae ab Austro est vel occidente et siccari consuevit aestate, propter pestilentiam vel animalia inimica quae generat.*

poses. Their larvae generally require water that is clear, in contrast to the larvae of *Culex* mosquitoes (non-transmitters of human malaria) which are happy in dirty water, although *Anopheles* larvae were also found in puddles of dirty water at Grosseto in the nineteenth century.[62] In addition, the water must be well oxygenated. This explains the success of spreading oil on the surface of pools as a modern control measure. *Anopheles* larvae prefer pool and canal margins where there is plenty of vegetation, which provides cover from predators. Sambon noted that at Ostia in the summer of 1900 all the pools and canals had enormous numbers of frogs, several species of fish (especially the young of the grey mullet), and swarms of dragonfly larvae and water beetles.[63] Consequently large permanent lakes are not necessarily any better for mosquitoes for breeding purposes than very small pools, which are only filled with water seasonally. Strabo noted that the large inland lakes of Tuscany, such as Vico, Bolsena, Chiusi, and Bracciano, produced substantial quantities of fish for the city of Rome.[64] A series of lakes along the coasts of Tuscany and Latium, such as the *Prilius lacus* near Grosseto and the lakes near Circeii, were also extensively exploited for fishing in Roman times.[65] In addition, the Romans created numerous artificial fish-ponds (*piscinae*) attached to coastal villas. Such fish-ponds have been found at many locations along the coast of Etruria, such as Cosa, Torre Valdaliga, Grottacce, Pyrgi, and also in Latium and Campania. Recent research into these artificial fish-ponds concludes that their water was usually brackish:

> The archaeological evidence is decisive in showing that the Romans preferred brackish conditions for their seaside *piscinae* . . . Arrangements for mixing salt water and fresh water to create a brackish environment were

[62] Celli (1900: 79) mentions Grassi's observations at Grosseto. Austen (1901) discussed the differences between *Anopheles* and *Culex* mosquitoes.

[63] Sambon (1901*a*: 199).

[64] Strabo, 5.2.9.226C. Quilici (1979: 104–6), noting the frequent presence of fish in offerings in archaic tombs in the Roman Forum, stressed that the River Tiber itself was an important source of fish in the early stages of Roman history, although it was wholly inadequate (and heavily polluted) by the time of the Roman Empire, cf. Nutton (2000*b*: 66) and LeGall (1953: 267–8, 318–19). Pratesi and Tassi (1977: 43) described the rich fauna of fish in the modern Lago di Bolsena. Dennis (1878: 30) interpreted the prodigy in Livy 27.23.3, *Volsiniis sanguine lacum manasse* (the lake at Volsinii flowed with blood), as a sign that the area around the Lago di Bolsena was becoming unhealthy in the late third century BC. Magri (1999: 173) noted that the settlement of Monte Bisenzo nearby was finally abandoned in 1816 because of *mal'aria* arising from the Lagaccione marsh.

[65] On the *Prilius lacus* see Cicero, *pro Milone* 74, with Celuzza (1993: 92–3) for the identification of the site of Clodius' villa; Pliny, *NH* 3.5.51.

common features in Roman fishponds and are well represented in the archaeological record from both the late Republic and early Empire.[66]

The chemical composition of water is very important for the breeding of *Anopheles* mosquitoes. Since they certainly can breed in brackish water, so long as it is not too salty, the water of some of these fish-ponds could have been favourable for malaria. The fish were an unfavourable factor for mosquito larvae, but a great deal would have depended on how much vegetation was present in these artificial fish-ponds. In any event, it is certain, as will be seen, that the coasts of Etruria and Latium were severely affected by malaria in the Late Republic and Early Empire. Strabo (quoted in Ch. 6 below) described the area around Circeii, which was a centre of fish farming, as pestilential. Consequently neither the hydraulic works of the fish-ponds nor their fish seriously impeded mosquito larvae.

The vicinity of the large inland lakes mentioned by Strabo was certainly heavily infested with malaria in the early modern period. Nevertheless, *Anopheles* larvae can flourish at least as well in the small depressions in the ground, only containing water for a few months each year, that frequently occur on the lower slopes of hills in Latium and Tuscany, and particularly in the undulating terrain of the Roman Campagna. All the literature on the early modern Roman Campagna lays stress on the importance of small seasonal pools and puddles for the generation of malaria. Tommasi-Crudeli, scaling up the results of a small field survey to provide an estimate for the whole Roman Campagna, suggested that there were quite literally *thousands* of breeding sites for mosquitoes in the Roman Campagna in the nineteenth century, before many of the modern drainage operations. This was also the origin (besides rivers and streams) of much of the malaria in the past in southern Italy, where it frequently occurred in the absence of marshes or large lakes.[67] Consequently the most dangerous wetlands were those which tended to dry up in the summer, as Palladius observed, since there were no predators to eat the mosquito larvae. The

[66] Higginbotham (1997: 16); Rustico (1999) has also discussed the Roman fish-ponds recently.

[67] e.g. North (1896: 113–15) emphasized that pools which dried up in summer were very dangerous; Tommasi-Crudeli (1892: 34). Tommasi-Crudeli and North also discussed this phenomenon in the region around Mantua, showing that it was not confined to Lazio, cf. Dobson (1997) on England.

anonymous author of a late-eighteenth-century discourse on *mal'aria* noted that many of the localities in the Roman Campagna which were marshy in winter became completely dry in summer. Similarly in the marshlands of early modern England mortality from *P. vivax* malaria increased after dry summers as the marshes dried out.[68] The pseudo-Aristotelian *Problems* noted that after a wet spring and dry summer the autumn is lethal to all age-groups, but especially to children, the main victims of *P. falciparum* malaria when it is endemic.[69]

That even large lakes were subject to major fluctuations in central Italy in antiquity is shown by the example of the former Lago di Fucino, in the territory of the Marsi beyond the Monti Simbruini, which experienced great fluctuations in its water level according to Strabo. Julius Obsequens recorded that the Lago di Fucino overflowed its banks for five Roman miles in all directions in 137 BC. Draining it was another of Julius Caesar's unfulfilled dreams. The emperor Claudius attempted at great expense to drain it. However, Tacitus' account, stating that the tunnel that was originally constructed did not even reach half-way down the lake, illuminates the difficulties faced by the Romans in effectively performing major drainage operations. Claudius' works were neglected by Nero. Later attempts in antiquity were made by Trajan and Hadrian, but the lake was not drained completely and permanently until the operations of Prince Torlonia commenced in AD 1862.[70] The plain

[68] Anon. (1793: 23); Dobson (1980: 378–80); see Ch. 5. 4 below.

[69] [Aristotle,] *Problems* 1.19.861^{b}: *Διὰ τί, ἐὰν τοῦ χειμῶνος βορείου καὶ τοῦ ἔαρος νοτίου καὶ ἐπόμβρου τὸ θέρος λίαν αὐχμηρὸν γένηται, θανατῶδες γίνεται τὸ μετόπωρον πᾶσιν, μάλιστα δὲ τοῖς παιδίοις, καὶ τοῖς ἄλλοις δὲ δυσεντερίαι καὶ τεταρταῖοι χρόνιοι γίνονται ἐν αὐτῷ* (Why is it that if the north wind prevails in winter, and the spring is damp and rainy, and the summer is very dry, then the autumn is deadly to all, particularly children, while others suffer from dysentery and prolonged quartan fevers?). This is a typical description of a year ending with an autumn epidemic of malaria. The pseudo-Aristotelian *Problems* also contains a lot of other material on the seasonality of disease patterns.

[70] Strabo 5.3.13.240C. Leveau (1993) discussed the ideology of Roman attempts to manage the Fucine Lake. Pratesi and Tassi (1977: 222–5) described the modern environment of the basin. Giraudi (1989) suggested that the lake's water level was low during the period *c.*300 BC–AD 200, followed by the Roman drainage, which he unjustifiably assumed to have been a complete success. The words of Julius Obsequens for 136 BC, *M Lacus Fucinus per milia passuum quinque quoquo versum inundavit*—(the Fucine lake overflowed its banks by five miles), show that Giraudi's generalizations must be taken cautiously. For the problems which beset the Roman drainage schemes see Tacitus, *Annals* 12.56–7; Pliny, *NH* 36.24.124; Suetonius, *Claudius* 20–21; Dio Cassius 61.33.5. Thornton and Thornton (1985) discussed the drainage works. The inscription *CIL* 9.3915 and *SHA Hadrian* 22.12 record the efforts of Trajan and Hadrian.

of the former Lago di Fucino might be too cold today for *P. falciparum*, situated as it is at an altitude of 669 metres (but not for *P. vivax*). However, the water of the lake exercised a moderating influence on temperature in the past. In antiquity the lake was once surrounded by a primeval forest, Angitia, mentioned by Virgil.[71] Deforestation of the mountain slopes encircling the basin, coupled with the effects of the modern drainage operation in 1862, significantly altered the microclimate of the region. It is now colder than it used to be, with more severe winter frosts. These climatic changes have eliminated the olive trees which formerly grew around the lake. They also gradually helped to convert the Fucine basin into an area of anophelism without malaria by the end of the nineteenth century. However, in the immediate aftermath of the drainage operations which commenced in 1862 it was observed that the frequency of malaria actually increased, presumably because the drainage left exposed areas of damp soil which had previously been permanently flooded, creating new breeding sites for mosquitoes. The example of the Fucine Lake illustrates the complexity of the environmental variables that have to be taken into account to understand the distribution and frequency of malaria. The modern experience suggests that the partial drainage achieved temporarily by Claudius would have actually increased the frequency of malaria around the remainder of the lake, especially considering that the climate as a whole was in any case warmer for much of the period of the Roman Empire (see Ch. 4. 5 below). The theme of unintended side-effects of human activity will recur in the course of this chapter.[72]

Mosquito larvae can grow very rapidly, in a few days. They may live in moist ground for three or four days. Once they have pupated, it does not matter if the water of the pool evaporates completely and the ground completely desiccates, since it suits the adult mosquitoes to emerge from completely dry soil or sand, for example sand from the banks of the river Tiber as shown by Celli's and Grassi's experiments.[73] Gradual desiccation of pools during

[71] Virgil, *Aeneid* 7.759–60.

[72] North (1896: 117–18) noted the temporary increase in malaria during the modern drainage operations, although by the end of the nineteenth century the Fucine basin had become one of the areas of anophelism without malaria discussed by Hackett and Missiroli (1931). Hare (1884: ii. 190) and Letta (1972: 13 n. 12) also commented on the presence of malaria around the lake in the early modern period.

[73] Celli (1900: 78); Sambon (1901*a*: 199).

12. The coastal forest of the Parco Naturale della Maremma, in the direction of the Ombrone river valley, and the Canale Scoglietto Collelungo. In the past the water in such drainage canals often flowed too slowly to prevent mosquitoes breeding in them. The pine forest (principally *Pinus pinea*) on the left was planted in the nineteenth century. The Monti dell' Uccellina (to the right and behind the line of sight) are covered by oak forests.

the summer was assisted by hot, dry south winds, which were associated with malaria by Theophrastus and other ancient authors.[74] In the fifth century BC Empedocles is said to have blocked up a mountain gorge in order to prevent a pestilential south wind from bringing problems in pregnancy to women (placental malaria) and disease on to the plain surrounding his own city of Akragas in Sicily.[75] Horace also mentioned the pestilential south wind in his odes.[76] Similar ideas recurred throughout later history. The doctor Perinto Collodi at Bibbona gave a detailed description of the

[74] Theophrastus, *de ventibus* 57, ed. Coutant and Eichenlaub (1975): *καὶ πάλιν ξηροὶ καὶ μὴ ὑδατώδεις ὄντες οἱ νότοι πυρετώδεις.*

[75] Plutarch, *Moralia* 515c: *ὁ δὲ φυσικὸς Ἐμπεδοκλῆς ὄρους τινὰ διασφάγα βαρὺν καὶ νοσώδη κατὰ τῶν πεδίων τὸν νότον ἐμπνέουσαν ἐμφράξας, λοιμὸν ἔδοξεν ἐκκλεῖσαι τῆς χώρας* (It was thought that the natural philospher Empedocles shut pestilence out of his country by blocking a gorge, which allowed an oppressive and unhealthy south wind to blow on to the plains.). See also Plutarch, *Moralia* 1126b and the other sources cited by Diels-Kranz 31 A1, A2, A14.

[76] Horace, *Carmina* 23.1–8.

association of the sirocco wind with disease among seasonal migrant workers returning from the Tuscan Maremma to Liguria in 1614. Domenico Panarolo (1587–1657) described the austral wind as a 'deadly enemy of health'. Elsewhere in his works on winds and airs he noted the idea prevalent in Rome at the time that the sirocco wind brought 'bad air' to Rome from the Pontine Marshes. Not everyone accepted such ideas. The anonymous author of a tract on *mal'aria* written in the late eighteenth century perceptively argued that 'bad air' was generated regardless of which wind was blowing and that in fact it was most abundant if there was no wind at all (mosquitoes don't like strong winds). Baccelli maintained that the sirocco wind was unhealthy in Rome in the nineteenth century, particularly if it was humid.[77] However, a very long period of continuous dry heat during the summer tended to reduce the frequency of cases of malaria, since the mosquitoes eventually began to run out of breeding sites. Consequently the frequency of malaria increased after occasional summer showers, and particularly after the first autumn rains.[78] This combination of circumstances again illustrates the complexity of the phenomena in question.

Anopheles larvae generally prefer stagnant water. Lancisi noted that running waters were healthy.[79] Nevertheless they can also thrive in water that is moving very slowly. *A. labranchiae* and *A. sacharovi* are happy to breed in ditches or canals so long as the water is not moving faster than about two kilometres per hour. Consequently the construction of canals to drain marshes frequently made the situation with regard to malaria worse rather than better in central Italy in the past. This happened, for example, during the project to reclaim the Tiber delta region around Ostia in 1885–9, since the new drainage channels proved to be even better breeding habitats for *Anopheles* mosquitoes than the marshes that they drained. Around Ostia *Anopheles* larvae were found in most of the drainage canals, which were stagnant and overgrown with aquatic vegetation, by the time of Sambon's field observations in the

[77] For south winds as 'bringers of fever' (πυρετώδεις) see also [Aristotle,] *Problems* 1.23.862[a], Pliny, *NH* 2.48.127, Celsus, *de medicina* 1.10.4 and 2.1.3–4; Sidonius Apollinaris 1.5.8 associated the Atabulus wind from Calabria with malaria; Doni (1667: 79–84); Lancisi (1717: 49); Cipolla (1992: 52) on Bibbona; Panarolo (1642*a*) and (1642*b*): *inimico mortale della salubrità*; Lapi (1749: 64–5); Anon. (1793: 24); Baccelli (1881: 161–3); North (1896: 138).

[78] Hirsch (1883: 258) noted that an epidemic started in Rome in October 1795 after the first autumn rains, following a long dry summer.

[79] Lancisi (1717: 30–2).

summer of 1900.[80] This is likely to be one reason why the reported drainage of the Pontine Marshes in 160 BC by Cornelius Cethegus failed to make any impact on malaria and probably even intensified it, since malaria was certainly endemic in this region in the Late Republic, as will be seen in Chapter 6 below. The gradient of the land in the Pontine Marshes was too low for canals to carry water away rapidly. Drainage is a complicated business. Many, perhaps even most, drainage schemes in antiquity were probably failures. There are numerous examples of early modern drainage schemes that were spectacular failures with regard to malaria, besides the Ostia project already mentioned. Doni noted that the bonifications (the reclamation by drainage of marshlands) of Pope Sixtus V (1585–90) did not make the Pontine region any healthier. Sixtus V was brave enough or foolish enough to visit his own bonifications while they were in progress, and his death was attributed by some contemporary authors to tertian fever contracted during his visit.[81] There is some detailed information available for the demography of the human population of the Pontine Marshes at the time of the last major attempt at drainage before Mussolini finally succeeded, namely the attempt by Pope Pius VI in the late eighteenth century. These records show that mortality significantly *increased* following the drainage operations.[82] Almost certainly the operations in 160 BC produced the same result. Even the reassessments by Traina and Leveau of ancient attitudes towards marshes, which attempt to put them in the most favourable light possible (and in doing so fail to comprehend that many Mediterranean wetlands were rendered almost uninhabitable by malaria in the past), are forced in the end to admit that drainage schemes in antiquity produced limited results.[83] Herlihy, discussing the problems of Pisa in the face of malaria during the Renaissance, observed acutely that 'of course the expenditure of much wealth and energy upon public works does not prove that conditions are salubrious but only that the

[80] Hackett (1937: 18); Sambon (1901*a*: 198).

[81] Doni (1667: 139–40); Nicolai (1800: 138).

[82] Corti (1989) for modern demographic research; Nicolai (1800: bks iii and iv) gave a contemporary view of Pius' bonifications.

[83] Hackett (1937: 17). Traina (1986: 712) concluded that: *tutte le opere di sistemazione idraulica anteriori al XVII secolo, in Occidente, sono delle migliorie più che delle bonifiche vere e proprie; in ogni caso, il mondo antico conosceva la bonifica idraulica, non quella integrale.* Leveau (1993: 16) affirmed that '*en fait l'Antiquité n'a pas connu le drainage total au sens où nous l'envisageons. Les véritables assèchements ont commencé au XVIIIe siècle et il serait faux de croire que les terres conquises aient été le plus souvent drainées à l'époque romaine puis reconquises par le marais au Moyen Age*'.

13. The entrance (near Ponte Palatino) to the Cloaca Maxima, ancient Rome's biggest sewer, complete with modern graffiti. Ancient Rome had drainage problems from the beginning of its history.

problem is great'.[84] Lake Velinus, first drained by M. Curius Dentatus in the early third century BC, was a typical example of the results of drainage in antiquity. Varro commented on how rapidly grass grew on the drained plain. As a result it was famous for animal husbandry, especially horse breeding, but Cicero stated that the drainage of the plain left the soil moist. That is not surprising if it could sustain rapid plant growth. This type of drainage would not have defeated the mosquito vectors of malaria, and might have even favoured them.[85]

In antiquity networks of cuniculi (underground tunnels connected by vertical shafts to the surface) were constructed in various parts of Etruria and Latium. The character of these waterworks resembles the famous Cloaca Maxima, which was originally constructed to turn a stream running through the Roman Forum into a canal. Pliny the Elder described the large investment of labour

[84] Herlihy (1958: 47).

[85] Cicero, *Letters to Atticus* 90.5, ed. Shackleton-Bailey (1965–70): *Lacus Velinus a M. Curio emissus interciso monte in Nar⟨em⟩ defluit; ex quo est illa siccata et umida tamen modice Rosea.* Pratesi and Tassi (1977: 98–103) described the modern environment of the Lake Velinus region; Varro, *RR* 1.7.10.

required for the construction of the sewers of Rome, which he attributed to Tarquinius Priscus.[86] Both the purpose(s) and date(s) of the cuniculi have been hotly debated. This type of hydraulic technology was widely distributed in central Italy. The view has been expressed that the Etruscans devised it and passed it on to the Latins, although other historians have suggested that it is a mistake to assume Etruscan influence lies behind everything that the Latins did. The largest of the cuniculi, namely the emissaries for the Lago di Nemi and the Lago di Albano, might have had some religious significance, in view, for example, of the tale told by ancient authors of the prophecy that the Romans would not capture Veii until they had drained the Alban Lake.[87] Some cuniculi are connected to Etruscan roads, although others are linked to Roman villas, while a few are definitely post-classical, but in most cases dating criteria are elusive. In fact, different scholars have placed them in every century from *c.*800 to *c.*400 BC. Ampolo expressed the view that the cuniculi of Veii, which have received the most intense scrutiny, were mainly built in the fifth and fourth centuries BC, either side of the Roman conquest of Veii, for drainage purposes. Veii itself was apparently healthy then (see Ch. 3 above), but that does not necessarily have anything to do with the cuniculi. Ampolo also observed that drainage was particularly important for olive cultivation in Latium in antiquity. Quilici Gigli concluded that the cuniculi of the Velletri region, immediately north of the Pontine Marshes, were more sophisticated than those around Veii and were constructed during the period of intense Roman activity in the Pontine region in the fourth century BC (see Ch. 6 below). This is the most plausible solution to the problem, but there are other hypotheses. Attema reckoned that the cuniculi of Velletri were created in the sixth century BC to facilitate arable farming. He also discussed Blanchère's ideas.[88]

In the nineteenth century de la Blanchère had raised the question of whether the cuniculi played a role in the history of malaria

[86] Pliny, *NH* 36.24.104–8 on the sewers of Rome; in *NH*, 3.16.120 he attributed a canal in the Po delta to the Etruscans.

[87] Livy 5.15.2–16.1, 16.8–11, and Dionysius Hal. *AR* 12.10–13 on the emissary from the Alban Lake.

[88] Blanchère (1882*a*) and (1882*b*); Tommasi-Crudeli (1881*a*) and (1882); Celli (1933: 12–16, 19–20); Ampolo (1980: 36–8); Potter (1979: 84–7) and (1981: 9–11); Quilici (1979: 322); Nicolet (1988: 57); Attema (1993: 65–76); Thomas and Wilson (1994: 143). Cornell (1995: 164–5) argued that the cuniculi cannot be dated; Quilici Gigli (1997: 194–8).

in central Italy in antiquity. However, their geographical distribution was not correlated with the distribution of malaria, which reached its greatest intensity along the coast, but with a particular geology. This can readily be seen by comparing Judson and Kahane's map of the distribution of the cuniculi with the map of the distribution of malaria in Latium in 1782 given by Bonelli. Judson and Kahane argued that most of the cuniculi are associated with a particular type of impermeable soil, namely the brown Mediterranean soil of the mesophytic forest. This pedological formation is most abundant in the southern and western slopes of the Alban Hills and around Veii, overlying volcanic *tufo*. Consequently Angelo Celli and more recently Franco Ravelli were probably right to argue that the cuniculi were mainly built before the spread of malaria in western central Italy and were not intended as a defence against malaria. The cuniculi were not designed to eliminate malaria, and certainly did not have that effect either in antiquity or more recently. In some cases they might conceivably have even facilitated the spread of malaria, if they were built before that happened, as the commonest view among historians maintains. If the connection with malaria is discarded, various possibilities for the function(s) of the cuniculi remain. Judson and Kahane suggested that most of the cuniculi were intended to improve certain types of badly drained land for agricultural purposes. This has been a popular opinion. However, Franco Ravelli, an expert on irrigation systems, has argued that the cuniculi were intended principally to capture and purify water for drinking purposes. He observed that they are mostly dry today and suggested that they were constructed in a period in the middle of the first millennium BC when there was more rainfall than there is today (see Ch. 4. 5 below).[89]

Another important environmental factor for the larvae of *Anopheles* mosquitoes is the degree of salinity or freshness of the water. In Italy in antiquity marshes that were frequently flooded with seawater, such as those around Ravenna, were healthy, while those which did not have any natural or man-made connection with the sea, such as the Pontine Marshes, were pestilential. Similarly in early modern England marshes that were closed off from the sea tended to become breeding grounds for the mosquito

[89] Bonelli (1966: 678–9); Judson and Kahane (1963); Ravelli and Howarth (1988) and (1989).

species *A. atroparvus*, a vector of malaria.[90] Vitruvius described the situation in Italy as follows:

When ditches have been excavated to provide outlets for (marsh) water to the seashore, and the sea rises during storms, overflows into the marshes and mixes the marsh water with seawater, the reproduction of the typical fauna of marshes becomes impossible . . . The Gallic marshes around Altinum, Ravenna, Aquileia, and other towns in such situations, next to marshes, illustrate this point, because they are extraordinarily healthy. However, stagnant marshes which do not have outlets either in the form of rivers or ditches, like the Pontine Marshes, putrefy as they stand and emit noxious and pestilential vapours in such places.[91]

Similarly Strabo noted that Ravenna, although situated within marshes and dissected by rivers, received plenty of seawater during the tides, which periodically cleansed the marshes and eliminated 'bad air', δυσαερία in Greek. Other ancient authors also described Ravenna. Sidonius Apollinaris noted that seawater came right up to the city's gates on one side, while on the other side the water in the channels was extremely dirty. The larvae of *Anopheles* mosquitoes prefer clear water.[92] There was a shortage of good drinking

[90] Dobson (1997). Compare the account in Pausanias 7.2.11, ed. Rocha-Pereira (1989), of how the silting up of the channel next to the city of Myus in Ionia by the river Maiander created an inland marsh cut off from the sea. The marsh became a breeding site for hordes of mosquitoes, forcing the abandonment of the city. This had happened by the time of Strabo 14.1.10.636C. Atarneus also suffered the same fate.

[91] Vitruvius 1.4.11–12: *Fossis enim ductis aquae exitus ad litus, et mare tempestatibus aucto in paludis redundantia motionibus concitata marisque mixtionibus non patitur bestiarum palustrium genera ibi nasci . . . exemplar autem huius rei Gallicae paludes possunt esse, quae circum Altinum, Ravennam, Aquileiam, aliaque quae in eiusmodi locis municipia sunt proxima paludibus, quod his rationibus habent incredibilem salubritatem. Quibus autem insidentes sunt paludes et non habent exitus profluentes neque flumina neque per fossas, uti Pomptinae, stando putescunt et umores graves et pestilentes in is locis emittunt.* The words of the jurist Iuventius Celsus in Digest 17.1.16 are also sometimes quoted as evidence that Ravenna was healthy in the second century AD: *cum Aurelius Quietus hospiti suo medico mandasse diceretur, ut in hortis eius quos Ravennae habebat, in quos omnibus annis secedere solebat, sphaeristerium et hypocausta et quaedam ipsius valetudini apta sua inpensa faceret* (since Aurelius Quietus is said to have instructed a doctor, a guest of his, to make (at Quietus's own expense) a ball-court, a sweating-room, and whatever else would be conducive to his own health, in the doctor's own gardens at Ravenna which he was accustomed to visit every year). See also Borca (1996) with abundant further bibliography on Ravenna.

[92] Sidonius Apollinaris, *Ep.* 1.5.5–6 to Heronius; Jordanes, *de origine actibusque Getarum* 29, 148–51, ed. Mommsen (1882), *Monumenta Germaniae Historica. Auctorum Antiquissimorum Tomi v. Pars Prior*; Martial 3.56; Procopius, *BG* 1.1.16–23 (discussed critically by Fabbri (1991: 9–10)); Michelini (1995); Manzelli (1997). Mazzarino's idea, discussed by Michelini, that Ravenna owed its healthiness to the construction of the port of Augustus there for the Adriatic fleet, is untenable because Vitruvius makes it clear that other towns in the region, such as Aquileia and Altinum, were equally healthy. Consequently a factor specific to Ravenna itself cannot explain the salubrity of the entire region.

Map 3. Ravenna and Emilia-Romagna

water at Ravenna because of these hydrological conditions. Strabo regarded as a marvel the fact that the air over the marshes of Ravenna was healthy.[93] This suggests that most marshes in other parts of Italy were not healthy.

The coastal regions of north-eastern Italy and the Po delta became heavily infested with both *P. falciparum* and *P. vivax* malaria in the late medieval period, as extensive alluviation gradually isolated towns like Ravenna and its marshes from the sea, thereby changing their chemical composition and altering mosquito breeding sites. Ravenna today is about ten kilometres from the sea, and the waterlogged Roman strata in the town are up to ten metres below the current ground level. Already in late antiquity and the early Byzantine period the immediate vicinity of the town had begun to dry up.[94] At that time Ravenna had a flourishing medical school which produced a series of commentaries on and Latin translations of the works of the Greek medical writers. It is quite possible that human interference with the natural environment, such as the bonifications attempted by Theoderic at the end of the fifth century AD, played a role in the deterioration of the situation. Doni described Ravenna as afflicted with severe malaria in the seventeenth century.[95] In the eighteenth century Francesco Ginanni wrote a comprehensive study of the natural history of the marshy woodlands in the vicinity of Ravenna. He noted the abundance in the woods in summer of the two species of mosquito that had been named *Culex cinereus* and *Culex fuscus* by Linnaeus, and observed that they bit humans frequently. However, it is striking that his account of the mosquitoes of Ravenna is located far away in his large book from his description of the 'bad air' of the region; Ginanni completely failed to connect mosquitoes with malaria. Nevertheless he

[93] Strabo 5.1.7.213C: *ἔστι μὲν οὖν καὶ τοῦτο θαυμαστὸν τῶν ἐνθάδε, τὸ ἐν ἕλει τοὺς ἀέρας ἀβλαβεῖς εἶναι.*

[94] Fabbri (1991: 19) described the developments in the early Byzantine period as follows: *in sostanza è una situazione di progressivo inaridimento idrico quello che la città vive nell'alto Medievo: una situazione di sempre più precarie condizioni igienico-ambientali, specialmente favorevoli allo stabilirsi della malaria in forma endemica. Già in queste condizioni si possono ricercare le premesse di fenomeni di depopolamento e di crisi economia e funzionale.* Squatriti (1992) is an interesting account of attitudes to marshes in early medieval Ravenna, but without any serious study of malaria or the relevant ancient sources. The most recent synthesis of Italian demographic history advocates a completely different view, so far as malaria in early medieval Italy is concerned: '*la malaria . . . si diffuse in vaste aree della penisola per effetto del degrado ambientale che trasformó in stagni e paludi gran parte delle pianure costiere e molte vallate interne*' (G. Pinto in del Panta *et al.* (1996: 18).

[95] Cavarra (1993) and Bio (1994) described the medical culture of Ravenna; *CIL* 11.10 for Theoderic's activities at Ravenna (*sterili palude siccata*); Doni (1667: 86, 89).

did accurately describe the environmental conditions that favoured endemic malaria, observing that the marshes of Ravenna tended to dry out in summer each year but retained some moisture, permitting plant growth.[96] Ginanni described the seasonality of malaria around Ravenna in the eighteenth century as follows:

> The period of considerable danger from bad air in these pine woods usually runs from the summer solstice until the autumn equinox. However, it sometimes varies from year to year, because if the season is very hot, bad air begins as early as May and continues until the middle of October; nevertheless it regularly terminates during the first heavy and repeated autumn rains, which fill the already nearly desiccated beds of adjacent marshes with fresh water.[97]

Ginanni argued that the 'air' of the town of Ravenna itself was healthier than its reputation suggested, although he acknowledged that 'bad air' was endemic in the surrounding area. Attempts to defend the reputation of settlements afflicted by malaria are frequently found in Italian local history. Ginanni observed that the unhealthiness of the air did not prevent numerous people living on the rich agricultural land in the vicinity of the Po delta. He even attempted to quantify mortality risks and concluded that the local inhabitants were much less likely to die from an infection of malaria than visitors to the area.[98] The reasons for that are now known; not only would those who survived childhood infections have developed acquired immunity, but the population of the area also has a high frequency of genetic mutations such as thalassaemia that confer some resistance to malaria (see Ch. 5. 3 below). This is evidence for intense pressure exercised by malaria as an agent of natural selection in the past in this region.[99] In fact, the distribution

[96] Ginanni (1774), ch.on *Acque* (pp. 105–21), chapter on *Aere* (pp. 122–34), section on mosquitoes (pp. 431–2). Jordanes, *de origine actibusque Getarum*, 57, shows that the famous pine forest along the coast south of Ravenna, described by Boccaccio, Dante, Byron, and other writers, already existed in late antiquity, since Theoderic encamped 'about three miles from the city in the place called Pineta' (*tertio fere miliario ab urbe loco qui appellatur Pineta*).

[97] Ginanni (1774: 132): *l'aere aliquanto pericoloso di queste Pinete è per l'ordinario dal solstizio di Estate infino all'equinozio di Autunno. Ma varia talora col variar delle annate, perché se calda molto è la stagione, vi principia l'aria pericolosa anche nel Maggio, e continua a mezza Ottobre; regolarmente però ella cessa d'esserlo nelle prime pioggie copiose, e replicate d'Autunno, che riempono d'acque dolci i letti, già quasi prosciugati de'vicini paduli.*

[98] Ginanni (1774: 133–4 n. 3).

[99] Interpretation of the situation is complicated by the fact that the Po delta region was an area of Greek colonization. It can be difficult to disentangle evolution *in situ* from gene flow caused by human migrations (the same problem occurs in Sardinia, discussed in Ch. 4. 3

of β-thalassaemia mutations in this region closely matches the distribution of mosquito breeding habitats.[100] Thus Ginanni was right to argue that the local people were less likely to die in the short term from individual malarial infections. However malaria had profound long-term effects on such populations, sharply reducing overall life expectancy and distorting the age-structure of the population. These long-term effects were already obvious to Doni in the seventeenth century and will be described in more detail later on (see Chs. 5 and 11 below). Ginanni's observations on the resistance of the local population to malaria are in fact paralleled by the situation in human populations in parts of tropical Africa today where malaria is endemic. In such African populations one is unlikely to die directly from malaria once one survives past a certain age in childhood—the precise age varies from region to region in Africa and depends on the transmission rate of malaria, in other words the frequency of infections—by which time acquired immunity has developed, but malaria nevertheless has a deep influence on age-specific life expectancy. Under such circumstances it is quite easy for both the inhabitants of regions with intense malaria themselves and outside observers to jump to the conclusion that malaria is not a major problem. The only legitimate inference to be drawn from such a conclusion, as in Ginanni's case, is that it demonstrates a lack of understanding of the immunology of malaria—not surprising in an eighteenth-century author. It does not constitute evidence for any mildness or avirulence of the disease. The studies that were done at the beginning of the twentieth century showed that *P. falciparum* was common in the coastal regions of north-eastern Italy alongside *P. vivax* and *P. malariae*, although *P. vivax* lasted longer than *P. falciparum* once eradication measures commenced. A survey in 1849

below). Greeks were present in the cities of Atria and Spina from the sixth century BC onwards (intermingled with Etruscans, other local Italic peoples, and later on Celts as well), who might well have carried with them genetic mutations related to malaria from their homeland in Greece, another area of endemic malaria. Consequently thalassaemia, for example, may already have occurred in north-eastern Italy in the fifth century BC even though the area did not yet suffer from malaria.

100 In the province of Ferrara allele frequencies for β-thalassaemia mutations decrease from the Adriatic coast westwards, while in the province of Rovigo there is no such decrease (Barrai *et al.* (1984)). In Ferrara, south of the river Po, marshy areas were largely confined to the east of the province, while in Rovigo, north of the Po, there were marshy areas throughout the entire province.

14. *Anopheles sacharovi*, a very important vector of malaria in Italy and eastern Mediterranean countries. © The Natural History Museum, London.

concluded that 16.7% of the entire population of the province of Venezia suffered from malaria in that particular year.[101]

In recent times *Anopheles sacharovi* was common in certain foci of intense malaria around Ravenna, breeding in brackish water, although *A. labranchiae* was virtually absent from this region. Presumably in antiquity the hydrological conditions of the marshes around Ravenna were unsuitable for *A. sacharovi*, preventing this species, the most efficient vector of malaria in Mediterranean countries, from breeding in the area. Gilberto Corbellini and Lorenza Merzagora observed that the early Venetian writers on *mal'aria* (see Ch. 2 above) emphasized the importance of the mixing of fresh water and seawater for the generation of malaria. This shows that the modern ecology of the coastal regions of north-eastern Italy, with brackish conditions favourable for *A. sacharovi*, already existed by the end of the medieval period. Among the more zoophilic species of *Anopheles* mosquito, *A. maculipennis s.s.* prevailed to the north of Venice, while *A. atroparvus* (a secondary

[101] Rausa and Romano (2000) and Hirsch (1883: 213–14) described the distribution of malaria in northern Italy in the nineteenth century.

malaria vector in northern Italy), was common in the Po delta, and *A. messeae* also occurred in places. There certainly were plenty of mosquitoes in north-eastern Italy in antiquity, since Martial mentioned the *culices* of Atria, another town in the same region, while Sidonius Apollinaris mentioned the mosquitoes of Ravenna. However, we may infer that these were predominantly not anthropophilic anopheline species, but zoophilic anopheline species or culicine mosquitoes. Culicine mosquitoes can breed in dirty water but do not transmit malaria to humans, although they are the vectors of the avian species of malaria.[102] The Po delta, like other major Mediterranean deltas such as the Ebro in Spain and the Nile in Egypt, has increased in size substantially within the last three or four centuries, as a result of very extensive alluviation following that which had already taken place in antiquity. This process of alluviation, a very important theme to return to later, led to the abandonment of a number of towns which functioned as ports in various parts of the Mediterranean. For example, Strabo observed that Spina in the Po delta region, which was on the coast when it was founded, was ninety stadia inland by the first century BC. Similarly Luni on the other side of Italy was stranded in the same way, and malaria moved in, just as it did at Ravenna. Further south in Campania, the Greek colony of Cumae had a lagoon on its northern side connected to the sea, which provided a sheltered harbour when the colony was founded in the eighth century BC. However, by the end of the first century BC the lagoon entrance had become silted up, destroying the harbour. Subsequently the lagoon started to fill in slowly from the north, until it was finally completely drained by Mussolini. These are all illustrations of a very widespread, long-running process of change. Virtually all the coastal regions of Italy were completely different in antiquity from the way they look today.[103] Thus the development of the coastal malarial environments of Italy as they appear today was a prolonged process which unfolded over a period of several thousand years.

In Lazio the delta of the River Tiber underwent a similar process

[102] Martial 3.93; Sidonius Apollinaris, *Letters*, 1.8.2. to Candidianus. Neri and Gratch (1938) and Zamburlini (2000) discussed the mosquitoes of Ravenna and the Veneto. See also Christie and Gibson (1988); Veggiani (1973) and (1986: esp. 26) on malaria.

[103] Strabo 5.1.7.214C and 5.2.5.222C; Potter (1981: 7) on Spina; Laquidara (1989) on malaria at Luni; Vecchi *et al.* (2000) on Cumae. Spivey and Stoddart (1990: 24–6) described the changes in the coastline around Pisa and Populonia. Hunt *et al.* (1992) described one example of continuing erosion in Tuscany within the last millennium.

of development. The history of the Roman port of Ostia, at the mouth of the river, in relation to malaria merits some discussion. Ostia was probably founded to exploit salt deposits at the mouth of the Tiber.[104] It was probably not unhealthy to begin with, like Ravenna, because the salinity level was too high for *Anopheles* mosquitoes. Nevertheless there was always a potential for the spread of malaria in the vicinity because of Tiber floods. The opinion of Meiggs, namely that Ostia must have been healthy during the time of the Roman Empire simply because it was a flourishing town, is an untenable argument from silence.[105] It is very hard to believe that Ostia was perfectly healthy in the second century AD, at the time when Galen regarded malaria as endemic in the city of Rome itself (see Ch. 8 below), and there certainly are explicit signs that Ostia was at the very least becoming unhealthy in late antiquity. St. Augustine's mother, Monica, died from malaria at Ostia, after an illness lasting nine days, on the way from Rome back to Africa, while Augustine himself also contracted malaria at Rome. Justinian's general Belisarius suffered from a life-threatening fever at Ostia in AD 536.[106] The cases of Belisarius, Augustine, and his mother are classic illustrations of the general principle that immigrants were more vulnerable than natives in areas where malaria was endemic. The spread of malaria at Ostia intensified in post-classical times, as sediment deposition created and enlarged an alluvial plain on both sides of the river near its mouth, steadily reducing the size of the large early Holocene lagoons behind the coastal barrier on either side of the river. Procopius noted the abandonment of Ostia in favour of Portus on the other side of the Tiber in late antiquity owing to silting of the harbour. Modern research in geomorphology has confirmed that the major extension of the ancient coastline seawards towards its current location has occurred principally since about AD 1500, when the modern marine-delta area began to move beyond the coastal barrier separating the ancient lagoons from the sea.[107] However, the letters of

[104] Grandazzi (1997: 74–83).

[105] Meiggs (1973: 101, 233).

[106] St. Augustine, *Confessions* 9.8, 11: *decubuit febribus . . . die nono aegritudinis suae . . . anima illa religiosa et pia corpore soluta est* (she developed fevers . . . on the ninth day of her illness . . . that religious and holy soul was released from her body); 5.9: *ingravescentibus febribus* (fevers becoming worse); Procopius, *BG* 3.19.

[107] LeGall (1953: 24–5, 320–2); Bellotti *et al.* (1995); Dionysius Hal. *AR* 3.44; Procopius *BG* 1.26.3–13.

St. Peter Damian prove that there was endemic malaria in Ostia as in Rome by the middle of the eleventh century AD, when he wanted to relinquish the bishopric of Ostia because of the unhealthiness of Ostia (see Ch. 8 below). Consequently environmental changes favourable to the mosquito vectors of malaria had already occurred in the vicinity of Ostia *before* the major modern progradation of the Tiber delta. The spread of malaria at Ostia was associated with the filling in of the lagoons behind the ancient coastal barrier after they had become isolated from the sea. Early modern writers unanimously concurred that the area of the notorious Maccarese swamp north of Ostia was virtually uninhabitable.[108] This state of affairs may go back to antiquity in the light of Silius Italicus' description of Fregenae, which can be identified with modern Maccarese.[109]

Just like the lagoons behind the coastal barrier near Ostia, the Pontine Marshes in southern Latium were also cut off from the sea. Pliny the Younger confirms Vitruvius' description of the hydrology of these marshes and indicates that the water table was very high at his villa near Laurentum. *Anopheles* mosquitoes do not lay their eggs in seawater or water with a high salinity level, although Grassi carried out experiments which showed that their larvae can survive in a 2:1 mixture of fresh water: seawater. Similarly Celli noted that *Anopheles* larvae did occur in the weaker sulphurous waters of Sezze, a town whose problems with malaria have already been noted. However, they were not found in the strong sulphurous waters of Tivoli in Latium, the famous *Aquae Albulae* which were reputed in antiquity to be very good for healing wounds, although there must have been mosquito breeding sites somewhere in the neighbourhood, since malaria impeded the operation of the quarry which produced *lapis tiburtina* near Tivoli in the nineteenth

[108] Hare (1884: i. 40–1) wrote as follows: 'the peasants do all their field labour here in gangs, men and women together . . . they have . . . the constantly recurring malaria to struggle against, borne up every night by the poisonous vapours of the marsh, which renders Ostia almost uninhabitable even to the natives in summer, and death to the stranger who attempts to pass the night there', cf. Tomassetti (1910: ii. 496–507). Knight (1805: 100) wrote that 'the air is particularly unhealthy, and the town is chiefly inhabited by galley slaves, who work in the salt mines'. Blewitt (1843: 524) wrote that at Ostia 'during the summer heats . . . the neighbouring coast is severely afflicted with malaria'. Mammucari (1991: 156–7, 162–3) reproduced paintings of the Maccarese forests and marshes by Onorato Carlandi and Cesare Bertolla made before Mussolini's bonifications.

[109] Silius Italicus 8.575: *obsessae campo squalente Fregenae* (Fregenae surrounded by a plain overgrown with weeds through neglect).

century.[110] The precise chemical composition of water is very important.

Hackett commented as follows on the complexity of biological phenomena: 'for the most part the reasons for these secular oscillations in the curve of malaria endemicity are inscrutable, because the internal adjustment of the elements composing a biological situation in dynamic balance is inconceivably complicated'.[111] His words are still as true today as when they were written (see Ch. 9 below for discussion of the idea of 'secular oscillations'). Nevertheless research over the last thirty years has made it absolutely certain that the coastal environments of Italy were not static, but were, rather, changing continuously from antiquity right up to the bonifications of modern times. Writing at the end of the last century, Celli was unable to conceive of major environmental changes in the vicinity of Rome and concluded that the periodic fluctuations which he thought he could discern in the severity of malaria in the Roman Campagna could only be explained in terms of variations in the virulence of *P. falciparum* malaria. However, now that it is known that the physical environment has been changing continuously, it is possible to entertain other explanations for any periodic variations in the degree of endemicity of malaria. It is essential to follow this approach because, as was noted in Ch. 3 above, the most recent scientific research indicates that extreme virulence is adaptive for *P. falciparum*. There is no reason for supposing, *pace* Celli, that its virulence ever diminished in historical times. Moreover, the frequency of malaria could also have been influenced in the past by changes in the balance between different mosquito species. Mario Coluzzi expressed to the author his view that there is intense competition between different species of mosquito and that the balance between different species of mosquito is constantly changing at the local level in Italy. Evidently there could have been countless changes in the balance between different species in the past as well.

Although the details remain obscure, and will probably always be obscure, it is inevitable that major alterations in the habitats available to mosquitoes for breeding purposes will have a huge

[110] Pliny, *Ep.* 2.17.25; Celli (1900: 77, 80); F. Giordano *Condizioni topografiche e fisiche*, in *Monografia* (1881: xxxiv); Vitruvius 8.3.2; Pliny, *NH* 31.6.10; Seneca, *QN* 3.20.4; LeGall (1953: 51); Quilici (1979: 64–5).

[111] Hackett (1937: 4).

impact on species which are so sensitive to environmental parameters. Mosquitoes themselves can sometimes modify their own patterns of behaviour to their own advantage. The contemporary example is the tiger mosquito, *Aedes albopictus*, the vector of the virus of dengue fever in its homeland in south-east Asia. This denizen of tropical rainforests has started to use rubber tyres as a breeding site. It is thought to have been transported around the world in this way and is now spreading in Mediterranean countries, even though it does not fly further than about two hundred metres from its breeding sites. It was first observed in Italy at Genoa in 1990, and has since spread to Campania, Lazio, Tuscany, Veneto and other regions.[112]

Today the various species belonging to the *Anopheles maculipennis* complex prefer fresh water. However, the three anthropophilic species which are dangerous vectors of human malaria in Europe (*A. labranchiae*, *A. sacharovi*, and *A. atroparvus*) have a greater tolerance of slightly brackish conditions than the other, more zoophilic species. *A. sacharovi* can tolerate higher salinity levels than the other two vector species. Lancisi in the eighteenth century reckoned that coastal marshes which sometimes received seawater were particularly dangerous (e.g. at Ostia, Ferrara, and Ravenna).[113] Consequently the anthropophilic species have an adaptive advantage over the zoophilic species in coastal environments, so long as the degree of salinity of the water is not too high. This explains why malaria in Italy tended to have a predominantly coastal distribution. The dangerous anthropophilic species certainly also occurred inland, especially in salty regions such as Diamantina in the Po valley, but faced greater competition there for suitable breeding sites from the harmless zoophilic species.[114]

[112] Sabatini *et al.* (1990).

[113] Missiroli (1938: 14); Lancisi (1717: 21). Sambon reported finding larvae of what was then called *A. maculipennis* very plentiful in brackish water at Ostia, 'amongst large brown clumps of floating algae and seaweed' (Sambon 1901*a*: 198).

[114] Hackett (1937: 26, 60, 106). Koella *et al.* (1998) produced some evidence that malaria parasites can alter the feeding behaviour of mosquitoes by inducing them to bite humans more frequently, another illustration of the complexity of the phenomena under consideration.

4.3 Malaria in Sardinia

On Sardinia *A. labranchiae* exploits a lack of competition to breed in environments, such as mountain streams above 500–1000 metres, where it is rare on the mainland of Italy, since several other species of mosquito (*A. atroparvus*, *A. claviger*, *A. maculipennis s.s.*, *A. subalpinus*, *A. superpictus*) which are common on the mainland of Italy are either rare or absent from Sardinia.[115] This helps to explain the greater intensity of malaria on Sardinia compared to the mainland of Italy in the past. Since the intensity of malaria on Sardinia was already obvious to Roman authors two thousand years ago, it may be inferred that the distribution of mosquito species on Sardinia at that time already matched the modern distribution patterns.[116] Nevertheless the chronology of the introduction of malaria to Sardinia is as controversial as the chronology of its spread in mainland Italy, and even more difficult to resolve, given the lack of evidence. Brown advocated a late-spread theory. He suggested that *P. falciparum* malaria was not significant on the island during the time of the nuraghic culture in the Bronze Age and Early Iron Age, even though he accepted that the malaria vector species *A. labranchiae* has probably been present there for several million years. Brown argued that malaria first became a major problem in the fifth century BC owing to deforestation, a new agricultural system in the plains, and imports of slaves infected with malaria during the period of Carthaginian domination of the island. However, there is no positive evidence for this interpretation of the origin of malaria on Sardinia.[117] It is generally assumed that the nuraghi were designed for defensive purposes. Since the highest densities of nuraghic settlement were in lowland regions with intense malaria until it was eradicated after the Second World War, Brown

[115] Coluzzi and Sabatini (1995); Ramsdale and Snow (2000).

[116] On the unhealthiness of Sardinia see Cicero, *Epist. ad familiares* 7.24.1; Livy 23.34.11; Pausanias 10.17.11; Pomponius Mela, *de situ orbis* 2.123, ed. Parroni (1967): *ceterum fertilis et soli quam caeli melioris, atque ut fecunda ita paene pestilens* (otherwise Sardinia is fertile, with better soil than air, it is almost as pestilential as it is fertile); Silius Italicus, *Punica* 12.371.

[117] Brown's (1984) hypothesis that the distribution and frequency of glucose-6-phosphate dehydrogenase deficiency (see also Ch. 5.3 below) in Sardinia can be explained principally in terms of gene flow during the Carthaginian and Roman periods is rejected by Sanna *et al.* (1997: 300, 313–14), who assign the principal role to the selective pressure of malaria. The absence of the sickle-cell trait (haemoglobin S) from Sardinia counts heavily against Brown's gene-flow hypothesis. [Aristotle,] *peri thaumasion akousmaton*, 100.838[b] recorded the Carthaginian devastation of Sardinia.

assumed that they must have been built before the spread of malaria. He dismissed the idea that the nuraghi might have been a defence against malaria as well. However, it has been frequently been observed that mosquitoes, being weak fliers, are reluctant to fly up to the higher storeys of multi-storey dwellings. At Ostia in the summer of 1900 Sambon observed that 'in human habitations they usually occupy the kitchens and rooms on the ground floor'.[118] The idea that the upper stories of buildings were safer with regard to malaria was in fact widespread both in Italy and elsewhere in premodern Europe. North made the following observations on the Roman Campagna in the last century:

> It is not uncommon to find houses in the Campagna constructed with all the living rooms on the top floor; and it is a matter of universal opinion that the upper storey of a house is safer and healthier, as far as malaria is concerned, than the lower, and practical expression is given to this belief by the method of construction adopted.[119]

Similar beliefs were held by the inhabitants of the Pontine Marshes:

> Any one who visits the Pontine Marshes may see in the open air, at different intervals, platforms erected upon poles four or five metres high on which, in summer, people sleep during the night . . . In fact, what we see done in the Pontine Marshes, by the people who sleep in the open air during the fever season, is repeated, in exactly the same form, in many malarious regions of Greece, and in the jungles of the East Indies.[120]

> In Holland, Pringle . . . noted that the wealthy in 'dry' houses and apartments raised above the ground were least liable to the disease of the marshes and in England 'persons have maintained themselves in good health during sickly seasons, by inhabiting the upper stories of their house.[121]

Herodotus confirms that the idea of the greater safety of the upper storey of a house goes back to antiquity. He states that the inhabitants of some parts of Egypt slept in towers to avoid mosquito bites:

> The inhabitants have devised various means for protecting themselves from the abundant mosquitoes. Those who live upstream of the marshes

[118] Sambon (1901*a*: 199). [119] North (1896: 104).

[120] Tommasi-Crudeli (1892: 136). Celli (1900: 84) observed that the raised sleeping platforms in the Pontine Marshes did not necessarily totally prevent infection, since mosquitoes would make the effort to fly up to them if they were extremely hungry, but they would have reduced the transmission rate.

[121] Dobson (1997: 355).

have towers in which they sleep, since the mosquitoes are prevented by the winds from flying up to the towers.[122]

Consequently it is possible that protection from mosquitoes was one of the purposes of the nuraghi, although there cannot be any proof in view of the complete absence of documentary sources from prehistoric Sardinia.[123] The earliest human skeletal remains from Sardinia which are affected by porotic hyperostosis date to the Late Neolithic period, *c.*4000–3200 BC.[124] It is possible, but not certain, that this condition was produced by *P. falciparum* malaria in the skeletons in question. Nevertheless it is very likely that the frequency of malaria on Sardinia did increase substantially in the second half of the first millennium BC, just as it did on the mainland of Italy. The first report of a Roman army being destroyed by disease on Sardinia dates to 234 BC, just four years after the Romans had gained control of the island.[125] Strabo noted that Sardinia was unhealthy in summer, especially the fertile lowlands from which the Romans wished to export grain to Rome. Since Sardinia, like Sicily, was an important source of grain to feed the population of the city of Rome, there is no doubt that ships returning would have transported both the mosquitoes themselves and people infected with malaria to the city of Rome. Commenting on the difficulty of pacifying the island, he states it was not profitable to maintain army camps continuously in pestilential areas. This was because of the high mortality rate among the Roman soldiers from *P. falciparum* malaria. This passage shows that the Romans included mortality from diseases in their accounting of the profitability of military enterprises.

The island is unhealthy in summer, especially the fertile regions . . . generals sent there sometimes resist [sc. raids by the indigenous tribes dwelling in the mountains], but sometimes they give up the task, since it is

[122] Herodotus 2.95.1: *πρὸς δὲ τοὺς κώνωπας ἀφθόνους ἐόντας τάδε σφί ἐστι μεμηχανημένα. τοὺς μὲν τὰ ἄνω τῶν ἑλέων οἰκέοντας οἱ πύργοι ὠφελέουσι, ἐς τοὺς ἀναβαίνοντες κοιμῶνται· οἱ γὰρ κώνωπες ὑπὸ τῶν ἀνέμων οὐκ οἷοί τέ εἰσι ὑψοῦ πέτεσθαι.* People who actually lived in the marshes of Egypt used mosquito nets instead, according to Herodotus.

[123] For the use of the upper floors of houses for living purposes see Barker and Rasmussen (1998: 156). Tognotti (1996: 73–91) discussed the statistics for mortality from malaria in Sardinia in the nineteenth century; Tognotti (1997).

[124] Sanna *et al.* (1997: 296–7).

[125] Zonaras 8.18.P.I.401a–b, ed. Pinderus (1844), *corpus scriptorum historiae Byzantinae* xxx: *ἐς δὲ τὴν Σαρδὼ τὸν ἀστυνὸμον Πούπλιον Κορνήλιον ἔπεμψαν . . . ὁ γάρ Κορνήλιος καὶ τῶν στρατιωτῶν πολλοὶ ὑπὸ νόσου ἐφθάρησαν* (they sent the praetor Publius Cornelius to Sardinia . . . Cornelius and many of his soldiers were killed by disease.).

not profitable to maintain a military camp continuously in unhealthy areas.[126]

Not surprisingly, the enemies of Gaius Gracchus were delighted when he was sent as quaestor to Sardinia. They doubtless hoped that he would not return. The Roman army with which Gaius Gracchus was serving did indeed suffer severely in the winter. This was probably the result of the synergistic interactions (discussed in detail in Ch. 5. 2 below) of *P. falciparum* malaria with the respiratory diseases of winter.[127] But Gracchus himself did return. A passage in Tacitus also shows that the Roman Senate was well aware that people sent to Sardinia were likely to succumb to the bad air of the island:

The Senate decreed that four thousand freedmen of suitable age, who had been corrupted by this superstition, should be sent to the island of Sardinia to curb bandits there, and if they died owing to bad air, the loss would be of no consequence.[128]

For the poet Martial Sardinia was a synonym for death.[129]

4.4 Malaria, roads, and housing

After this digression on Sardinia, we must return to the environmental factors which influence the distribution of mosquitoes. Besides the distribution and chemical composition of bodies of water, man-made structures undoubtedly also made a significant contribution to the spread of malaria in Italy in antiquity. In the nineteenth century AD it was noticed that malaria tended to spread along the new railway lines that were being constructed in Italy.

[126] Strabo 5.2.7.225C: νοσερὰ γὰρ ἡ νῆσος τοῦ θέρους, καὶ μάλιστα ἐν τοῖς εὐκαρποῦσι χωρίοις . . . οἱ δὲ πεμπόμενοι στρατηγοὶ τὰ μὲν ἀντέχουσι, πρὸς ἃ δ' ἀπαυδῶσιν, ἐπειδὰν μὴ λυσιτελῇ τρέφειν συνεχῶς ἐν τοῖς νοσεροῖς στρατόπεδον.

[127] Plutarch, *Tiberius and Gaius Gracchus* 22.4 and 23.2, ed. Ziegler (1971): ἰσχυροῦ δὲ καὶ νοσώδους ἅμα χειμῶνος ἐν Σαρδόνι γενομένου (there was a severe and unhealthy winter on Sardinia). Cicero, *epist. ad Quintum* 2.3.7 was aware that on Sardinia (in contrast to Latium) there was some risk of transmission of malaria even in winter. Livy 41.6.6 describes the crippling of another Roman army on Sardinia by pestilence in 178 BC. Logan (1953: 176–92) discussed the epidemiology of malaria in Sardinia. Strabo's evidence that Roman commanders were concerned about the mortality from malaria on Sardinia shows that the theme of Curtin (1989) was already being consciously considered (if only in qualitative terms) two thousand years before the period upon which Curtin chose to focus.

[128] Tacitus, *Annals* 2.85.3: *factumque patrum consultum ut quattuor milia libertini generis ea superstitione infecta quis idonea aetas in insulam Sardiniam veherentur, coercendis illic latrociniis et, si ob gravitatem caeli interissent, vile damnum.*

[129] Martial 4.60.

15. Reconstruction of a typical traditional peasant hut in the Pontine region, on display in the Parco Nazionale del Circeo. Spraying of the interior walls of dwellings with DDT broke the malaria transmission cycle in Italy by irritating the mosquitoes and driving them outside, where it was too cold for *P. falciparum* sporogony in the mosquito and frequently too cold for the mosquito itself, according to the explanation given by Mario Coluzzi. The mosquitoes became irritated after about five minutes and flew away before they had absorbed enough DDT to actually kill them (which would have taken about forty-five minutes). Since the irritant effect drove away the mosquitoes before they had absorbed enough DDT to actually kill them, natural selection did not operate on mosquito populations in Italy and they did not develop resistance to DDT. However, the same strategy is less effective in Africa today because both the mosquitoes and the malaria parasites are happy outdoors in the tropical heat.

For example, being sent to work on the forty-four kilometre stretch of railway line between Taranto and Torremare was a death sentence, according to Bonelli. The Fiumicino–Ponte Galera and Rome–Chiarone routes in Lazio ranked among the most lethal railway lines in Italy. It was realized that the construction of embankments and cuttings for railway lines often interfered with natural drainage patterns and altered the level of the water table. In addition, the pits which were excavated to provide earth for embankments often subsequently became filled with water and provided excellent breeding sites for mosquitoes.[130]

In antiquity Strabo explicitly commented on Roman road building in Latium and noted the cuttings through hills and embankments across valleys which Roman engineers designed for their roads. Similarly Pliny noted the roads cut through mountains.[131] Modern experience in Italy in the nineteenth century with railways suggests that Roman (and also earlier Etruscan) road building would have played a significant role in creating favourable new breeding habitats for *Anopheles* mosquitoes. Similarly 'road building was linked intimately with the proliferation of malaria' in Bengal in India during the British rule in the nineteenth century AD.[132] The ancient accounts of his life state that Gaius Gracchus organized a considerable volume of road construction in Italy, after his return from Sardinia. Modern historians have failed to realize the irony of his work. By having roads built, Gracchus unwittingly assisted the spread of malaria in those very same depopulated parts of Italy which he desired to rejuvenate.[133]

The nuraghi of Sardinia served to introduce the question of the design and construction of housing, another very important topic. As Varro put it:

> The situation of villas, the size of the buildings, and the directions in which colonnades, doors, and windows face, are matters of very great interest.[134]

Unfortunately, as has often been observed by modern scholars, the atrium of Roman houses contained a pool of rainwater in the impluvium, a possible habitat for mosquito larvae (so long as there were no fish in it). It is not clear if the presence of the impluvium was important in practice in relation to malaria. Eugenia Tognotti, in her book on malaria in Sardinia, noted that *A. labranchiae* likes houses which are dark inside, providing cover, with small windows,

[130] Bonelli (1966: 667 n. 11), quoting the Inchiesta Iacini; Tognotti (1992: 25); Celli (1900: 147).

[131] Strabo 5.3.8.235C: *ἔστρωσαν δὲ καὶ τὰς κατὰ τὴν χώραν ὁδοὺς, πρόσθεντες ἐκκοπάς τε λόφων καὶ ἐγχώσεις κοιλάδων* (they constructed roads throughout the land, with cuttings through hills and embankments across valleys); Pliny, *NH* 36.24.125: *vias per montes excisas* (roads cut through mountains).

[132] Klein (1972: 140–1).

[133] Plutarch, *Tiberius and Gaius Gracchus* 28, ed. Ziegler (1971); Potter (1979: 79–83, 101–9) on the Roman road network in south Etruria.

[134] Varro, *RR* 1.4.4: *quod permagni interest, ubi sint positae villae, quantae sint, quo spectent porticibus, ostiis ac fenestris*.

a description which fits a lot of traditional housing in Mediterranean countries.[135] Sambon described the habits of what was then called *A. maculipennis* at Ostia at the end of the nineteenth century:

> The adult insects were found in great numbers in the houses and stables of the district. In stables they seemed to rest by preference on the old dusty cobwebs which heavily curtained the ceilings. In the houses they chose the darkest corners, often resting under beds, tables, and chairs, or on dark-coloured clothing, but more frequently on the ceilings, especially when these were begrimed with the smoke of winter fires and well out of the way of danger. In the bedrooms of an inn at Ostia, which had a blue stripe all round their whitewashed ceilings, the *Anopheles* seemed to settle by choice on the dark stripe for protection. It is almost ridiculous how these insects escape detection by those who are not in the habit of looking for them.[136]

A. labranchiae is a non-diapausing species of mosquito. It remains active indoors and continues to bite humans nearly all the year round, although malaria parasites cannot develop inside it in the winter when it is too cold. Consequently it was very vulnerable to the modern malaria-control strategy of spraying the interior walls of dwellings with the insecticide DDT. In contrast the other main vector of malaria in Mediterranean countries, *A. sacharovi*, hibernates outdoors in the winter cold and does not become active until May each year. The northern European malaria vector *A. atroparvus* tolerates cold temperatures well but does not hibernate completely, unlike *A. sacharovi*. Consequently it sometimes bites humans in houses in winter.[137]

Since mosquitoes dislike flying upwards, theoretically the upper storeys of multi-storey buildings in the city of Rome should have been healthier than the ground-floor levels. In the seventeenth century Doni emphasized the importance of building design and town planning.[138] There was a view in early modern literature that tall buildings with narrow streets provided protection against 'bad air'. This point of view had antecedents in antiquity, since Tacitus reports that after the great fire in Rome in AD 64 some people did not like Nero's plan to rebuild the city with lower buildings and wider streets, since they thought that the old layout was healthier:[139]

135 Jones (1908: 534) on *impluvia*; Tognotti (1996: 98).

136 Sambon (1901*a*: 199).

137 Coluzzi (1999); Shute (1951).

138 Doni (1667: 18–23).

139 Grandazzi (1997: 182) on the history of the old layout of the city, attributed in antiquity to the haste with which it was rebuilt after the sack by the Gauls in 390 BC.

However, there were some people who believed that the old layout was more conducive to health because the narrowness of the streets and the height of buildings kept out the heat of the sun; but now the lack of shade in the broad open spaces meant that the summer heat was more intense.[140]

However, people who lived in the upper storeys still had to go out periodically. The evidence of the ancient medical authors (discussed in detail in Ch. 8 below) indicates that malaria was common in the city of Rome both before and after the new town-planning regulations introduced by Nero, in spite of the frequency of multi-storey buildings. The hills of Rome, although healthy for those (the elite) who lived on top of them, probably had an adverse effect on those who lived below them. North made the significant observation that 'experience shows that the benefit obtained [sc. from living above ground-floor level] is not always as great as might be expected, and this is especially the case when the building is sheltered in any way by neighbouring hills'.[141] He collected interesting information on housing and malaria in the Roman Campagna and followed Tommasi-Crudeli and earlier writers such as Knight in concluding that the custom of building houses around the four sides of a square or rectangle, with virtually all the windows opening internally on to the quadrangle, was intended to keep 'bad air' out.[142] Modern experience shows that well-designed housing can help to keep mosquitoes out, although such measures may have little effect if people are in the habit of sleeping outside (at ground level) in hot weather, as frequently happens in the countryside in hot countries, to protect their crops.[143] Consequently the anecdote recounted by Varro in relation to the Pompeian forces on Corcyra during the civil war does have some plausibility, although it also

[140] Tacitus, *Annals* 15.43: *Erant tamen qui crederent veterem illam formam salubritati magis conduxisse, quoniam angustiae itinerum et altitudo tectorum non perinde solis vapore perrumperentur: at nunc patulam latitudinem et nulla umbra defensam graviore aestu ardescere.*

[141] North (1896: 103–5); De Tournon (1831: i. 201–2); Baccelli (1881: 191–2). The advantages of tall buildings against 'bad air' might have been discussed in Rutilius' book *de modo aedificiorum* (Suetonius, *Augustus* 89). However, it should be noted that contrary views were also expressed in antiquity. The medieval Arab writer Ibn Ridwan quoted Rufus of Ephesus as recommending flight from cities with tall buildings and narrow streets because they were unhealthy (Dols (1984: 105)). Similar sentiments were expressed by Sabinus in the second century AD (Nutton (2000*b*: 69–70)).

[142] Knight (1805: 33).

[143] Gamage-Mendis *et al.* (1991). The study of Barber and Rice (1935) in Greece reached inconclusive results in relation to the question of malaria and housing.

indicates that the necessary precautions had not previously been taken on Corcyra (modern Corfu):

> Did not our Varro here, when the army and fleet were on Corcyra and all the houses were full of the sick and dead, make his comrades and servants healthy again by constructing new windows to let in the north wind and excluding the pestilential winds, by changing [the positions of] doors, and by other measures of this kind?[144]

Since it is quite common for blood feeds by female mosquitoes to be interrupted and then finished on another person, it is possible for one mosquito to infect several people in a single household.[145] Certain houses which are particularly badly exposed to mosquitoes may become foci of malarial infection within a community. Households with children are most likely to end up playing this role, since gametocytes (the blood stage of the parasite's life cycle which can reinfect mosquitoes) are mainly found in children in areas where malaria is endemic. The acquired immunity of those adults who survive infection in childhood reduces gametocyte production to insignificant levels in such areas. The dangerous species of mosquito either show a definite preference for human blood (so *A. sacharovi*), or at least are as willing to bite humans as they are to bite other animals (so *A. labranchiae*). These two species enter houses or other man-made structures without hesitation. In contrast, other species of *Anopheles* mosquito in Italy which are not significant vectors of malaria prefer to bite other animals, generally cattle, and show little interest in entering houses. Hackett and his co-workers demonstrated this in their comparison of Val di Chiana in Tuscany, an area of anophelism without malaria in the early twentieth century, with Fiumicino, which had some of the most intense malaria in the world.[146]

It is very important to bear in mind the possibility that the geographical distribution of mosquito species may change over time, following local environmental change. This is doubtless what happened at Ravenna, for example. Consequently regions with anophelism without malaria within the last hundred years were not necessarily like that in earlier periods of history. The southern end

[144] Varro, RR 1.4.6: *Non hic Varro noster, cum Corcyrae esset exercitus ac classis et omnes domus repletae essent aegrotis ac funeribus, immisso fenestris novis aquilone et obstructis pestilentibus ianuaque permutata ceteraque eius generis diligentia suos comites ac familiam incolumes reduxit?*

[145] Conway and McBride (1991).

[146] Missiroli *et al.* (1933); Hackett (1937: 38–41, 75–6, 209–12).

16. The southern end of the Val di Chiana and Lago Trasimeno, viewed from the Fortezza Medicea above Cortona.

of the Val di Chiana (243–60 metres above sea level), particularly in the vicinity of Chiusi, was certainly unhealthy in the medieval and Renaissance periods, as Dante, Boccaccio, and other writers observed. Unfortunately there is no explicit evidence available for the health status of the area in antiquity. Dante bracketed the Val di Chiana with the Maremma and Sardinia as notoriously unhealthy regions:

> As the pain would be, if the diseases of the hospitals of the Val di Chiana, between July and September, and of the Maremma and Sardinia were all together in one ditch.[147]

From the sixteenth century onwards repeated efforts were made to drain the flooded valley, especially by constructing a large canal, the Canal Maestro, to remove water to the Arno river. Leonardo da Vinci was the most famous of the numerous engineers who took an interest in the region's problems. However, these efforts were vitiated for a long time by political rivalry between Rome and Florence as well as by the low gradient of the plain (the same problem as in the Pontine Marshes). Alexander's detailed study of the Val di Chiana reached the conclusion that piecemeal drainage works were doomed to failure; only a grand plan dealing with the entire territory simultaneously would work, and this was not finally achieved until the late eighteenth and early nineteenth centuries by Vittorio Fossombroni. The drainage of the Val di Chiana did not eliminate *Anopheles* mosquitoes, but in some way facilitated a change in the balance between different species so that zoophilic species became prevalent. Similarly Pisa, whose territory suffered from intense malaria during the Renaissance period, had become an area of anophelism without malaria by the end of the nineteenth century, while the coastal region north of Pisa around Viareggio, which eventually became another area of anophelism without malaria, had been described as 'marshy and pestilential' (*paludosa e pestifera*) in the seventeenth century.[148]

[147] Dante Alighieri, *La Commedìa. Inferno. Canto* XXIX.46–9, ed. Lanza (1996): *Qual dolor fora, se delli spedali | di Valdichiana tra 'l luglio e 'l settembre | e di Maremma e di Sardinia i mali | fossero in una fossa tutta insembre.*

[148] Alexander (1984); Luchi (1981: 417–20), on the archaeology of the Val di Chiana in the territory of Chiusi, noted that Livy 5.36.3 indicates that at least part of it was exploited extensively instead of intensively (*latius possideant quam colant*); Dennis (1878: 294); Pinto (1982: 10, 17–18, 30).

4.5 Climatic change

Roads and housing are good examples of factors which were very important at the local level. However, not all factors were so localized in their effects, above all climatic change. Huntington suggested in 1910 that the introduction of malaria to Italy occurred in the late third century BC as a result of increasing aridity (and hence, drier summers) which created more favourable environmental conditions for *Anopheles* mosquitoes. Although that idea was interesting in principle, far less was known in 1910 about climatic change in the past and its causes and consequences than is known today. The question requires a fresh examination. It has already been noted that the earth's average temperature is now approaching levels that were last attained in the Neolithic period, before 3000 BC, probably as a result of anthropogenic global warming in the last few years. In between, the climate was generally cooler, but there were still periodic fluctuations of temperature within these lower levels. The effects of these temperature fluctuations can be analysed by studying periodic advances and retreats of the glaciers in the Alps, which have occurred throughout the Holocene. The time of the Roman Empire was mostly a warm period, relative to the periods immediately before and immediately afterwards. The results from the glaciers can be corroborated by various types of proxy data, for example the spread of viticulture into Roman Britain as demonstrated by the recent archaeological finds at Wollaston in the Nene Valley in Northamptonshire. The time of the Roman Empire was warmer than the period of the 'Little Ice Age', *c.*AD 1500–1800, which encompasses much of the data that are available for studying the distribution of malaria in Italy in the early modern period. Consequently the climate was more favourable for the spread of malaria in Italy during the Roman Empire than it was, say, in 1782, when malaria occurred all over Lazio, except at high altitudes, as shown by Bonelli's map.[149]

Climatic change, then, is a very important factor that creates the expectation of a wider distribution of malaria in Italy during the Roman Empire than during the early modern period. It is not surprising, as has already been noted (see Ch. 4. 2 above), that

[149] Huntington (1910: 672–5); Fraccaro (1919: 66–70); Röthlisberger (1986: 60–1, 70–4); Bianchi and McCave (1999); Brown and Meadows (2000).

P. falciparum malaria occurred in Umbria, far inland, by the fifth century AD. Temperature is very important in relation to malaria because of the requirements of the parasites for sporogony inside the mosquito. This developmental process, which is essential before the mosquito can infect anyone, takes only about 9 days at a mean temperature of 30°C, 10 days at 25°C, but up to 23 days at 20°C, in the case of *P. falciparum*. The time scale in the case of *P. malariae* is even longer, about 20 days at 25°C, and 4–5 weeks at 20°C. Even though on the surface such temperature levels are not maintained for long periods in Europe (taking account of the drop in temperature that occurs every night), nevertheless the longevity of *P. malariae* infections in humans assured its survival until the next favourable transmission period came along, and there are many references to quartan fever in historical sources from Europe. In the case of *P. vivax* the process takes only 9 days at 25°C, but 30 days at 16°C. The slowing down of sporogony caused by low temperatures impedes the transmission of malaria because few adult mosquitoes actually live as long as 3 or 4 weeks. Hackett noted that over 50% of mosquitoes are dead after a week in Italy during the summer.[150]

The scale of the temperature changes in the Roman period can be roughly estimated. One recent study suggested that the mean July temperature in the Arctic about 411 ± 70 years BP (by C^{14} dating), at the peak of the Little Ice Age, was about 0.7°C lower than today. Wider studies have estimated a cooling of about 0.4–0.6°C during the Little Ice Age, explained by periodic variations in annual-mean radiation from the sun.[151] Consequently it is likely that mean summer temperatures in Italy during the Roman Empire were a minimum of about 0.5°C higher (and quite possibly more) than the temperatures of the early modern period, which were already sufficient for *P. falciparum* malaria to be widely distributed in central and southern Italy. A temperature change of this magnitude may appear to be quite modest, but it is well known in ecology that small changes of this kind can have considerable effects on the distributions of living organisms. Moreover the effects of even small temperature changes would be most significant in geographical areas on the periphery of the distribution of *P. falciparum*, such as southern Europe, rather than in the tropics. Modern

[150] Hackett (1937: 67–9); Gilles and Warrell (1993: 111, 126–31).
[151] Havström *et al.* (1995); Wigley and Kelly (1990).

global warming is already creating more favourable conditions for the mosquito vectors of malaria and other diseases in many parts of the world.[152] Some studies have argued that parts of the Roman period were even hotter, up to about 2°C warmer than the temperatures of the Little Ice Age in the early modern period, as well as being wetter than today. If so, the prospects for malaria during the time of the Roman Empire were that much better.[153]

4.6 Agricultural change and deforestation

Increasing temperature favoured the spread of both *P. falciparum* malaria itself and its vector mosquitoes in Italy during the time of the Roman Empire. There were other factors which were also of fundamental significance. Heat is good for malaria, but the mosquitoes still need to find suitable habitats for breeding sites. Human activity in the first millennium BC unwittingly made a crucial contribution to the spread of malaria by altering the hydrology, geomorphology, and vegetation cover of lowland areas on a scale which transcended anything achieved in earlier periods. In Etruria the combination of the different types of evidence yielded by archaeological field surveys (e.g. the Tuscania and Veii surveys), palaeobotany, and palynology indicates that very substantial population growth occurred during the development of the Etruscan cities. This human population growth was supported by Mediterranean polyculture (the triad of cereals, olives, and vines), a new agricultural system which developed in central Italy for the first time in the Early Iron Age. The same sort of intensification of land use occurred in Latium as well.[154] Deforestation of hills and mountain slopes caused increased run-off of rainwater. This raised the water table and increased the chances of flooding in the lowlands and eroded soil to be redeposited as alluvial deposits in the lowlands. These areas of alluvial deposition were very likely to become marshy. This process happened all over Italy. The Greek colony of Metapontum in southern Italy is a well-studied example. Archaeological investigations have shown that the water table rose

[152] Epstein (2000); Patz and Reisen (2001). The alternative view advocated by Rogers and Randolph (2000) seems to totally ignore all the evidence for the existence of *P. falciparum* malaria in the past in southern Europe, for example.

[153] Martinez-Cortizas *et al.* (1999); Reale and Dirmeyer (2000).

[154] Potter (1979: 74) summarized the explosion in site numbers in south-eastern Etruria; Barker (1988); Sallares (1991: 29–34) on the spread of new crops.

17. The Monti Cimini, viewed from the site of the Roman villa at Lugnano in Teverina. Most of the redoubtable ancient forest has now disappeared.

by more than a metre over the whole territory of Metapontum from the sixth to the fourth centuries BC. This was accompanied by extensive alluviation, which created marshy conditions suitable for *Anopheles* mosquitoes. The necropolis at Pantanello, whose very name indicates marshy conditions, outside Metapontum has yielded several skeletons which show signs of thalassaemia, an inherited genetic condition which confers a degree of resistance to *P. falciparum* malaria. This constitutes indirect evidence for the likely existence and activity of *P. falciparum* in southern Italy as well as Sicily during the classical Greek period.[155]

This is not the place for an extensive discussion of deforestation in Italy in antiquity. Suffice it to say that there were massive forests in Italy, which grew during the mid-Holocene climatic optimum, following the end of the last Ice Age. Delano Smith has suggested that even the Tavoliere in Apulia, a semi-arid region today, might have been substantially covered by forest in the early Neolithic period.[156] In western central Italy, which is much better watered than the Tavoliere, the climax vegetation in the absence of human interference undoubtedly would be large forests in many areas. Many of these forests were broken up during the first millennium BC by the demands of an increasing human population for open land for agriculture and by the ever-increasing demand of the Romans for timber. For example, Livy describes the Ciminian Forest. It was said to be so dense and forbidding *c.*310 BC that people were afraid even to approach it. Hardly anything is left of it today.[157] Pliny the Younger described the ancient woods of very tall trees on the Appennine mountains, above his estate at Tifernum in Umbria.[158] Theophrastus described very large forests in Latium at the end of the fourth century BC.[159] These forests were well watered

[155] Henneberg *et al.* (1992: 455) on thalassaemia. Their claim to have also found evidence for treponemal diseases such as syphilis in the skeletal remains from Metapontum remains controversial. Nevertheless malaria probably played a major role in the depopulation of the territory of Metapontum in the third century BC described by Carter (1990).

[156] Delano Smith (1978: 53), cf. Caldara and Pennetta (1996).

[157] Livy 9.36.1–8, discussed by Meiggs (1982: 246) and Cornell (1995: 355–6); Pratesi and Tassi (1977: 49) described the remnants of the Ciminian Forest.

[158] Pliny, *Ep.* 5.6.7: *montes summa sui parte procera nemora et antiqua habent.*

[159] Theophrastus, *HP* 5.8.3 and 2, ed. Amigues (1993): *ἡ δὲ τῶν Λατίνων ἔφυδρος πᾶσα· καὶ ἡ μὲν πεδεινὴ δάφνην ἔχει καὶ μυρρίνους καὶ ὀξυὴν θαυμαστήν· τηλικαῦτα γὰρ τὰ μήκη τέμνουσιν ὥστε εἶναι διανεκῶς τῶν Τυρρηνίδων ὑπὸ τὴν τρόπιν· ἡ δὲ ὀρεινὴ πεύκην καὶ ἐλάτην. τὸ δὲ Κιρκαῖον καλούμενον εἶναι μὲν ἄκραν ὑψηλὴν, δασεῖαν δὲ σφόδρα καὶ ἔχειν δρῦν καὶ δάφνην πολλὴν καὶ μυρρίνους . . . τὸν δὲ τόπον εἶναι καὶ τοῦτον νέαν πρόσθεσιν καὶ πρότερον μὲν οὖν νῆσον εἶναι τὸ Κιρκαῖον, νῦν δὲ ὑπὸ ποταμῶν τινων προσκεχῶσθαι καὶ*

and had taller trees than the forests of southern Italy (although not as tall as those of Corsica). The lowland forests of bay, myrtle, and beech contained old trees tall enough to span the length of the keel of an Etruscan ship, while there were upland forests of fir and silver fir. The extant text seems confused, since beech (*Fagus silvatica*, *ὀξύη*), which dominated the summits of the mountains of Lazio in the early modern period, belongs in the upland forests. If there were any beech forests in the lowlands of Latium *c.*300 BC, they were relics of previous colder periods, which were doomed to extinction during the warmer climate of the Roman Empire.[160]

Theophrastus' description of the region around ancient Circeii shows that he was aware of ongoing environmental change in the form of the alluviation which was thought to have attached Circeii, regarded in antiquity as once having been an island, to the mainland of Italy. Monte Circeo is regarded by modern geologists as

εἶναι ἠϊόνα. τῆς δὲ νήσου τὸ μέγεθος περὶ ὀγδοήκοντα σταδίους . . . τῶν γὰρ ἐν τῇ Λατίνῃ καλῶν γινομένων ὑπερβολῇ καὶ τῶν ἐλατίνων καὶ τῶν πευκίνων—μείζω γὰρ ταῦτα καὶ καλλίω τῶν Ἰταλικῶν. (The whole territory of the Latins is well-watered; the plains contain forests of bay, myrtle, and wonderful beech. They fell timbers of it so long that they span the entire length of the keel of an Etruscan ship. The hills have forests of fir and silver-fir . . . The so-called Circaion is an elevated promontory, but it is densely wooded and has oak trees, a lot of bay, and myrtle. The land surrounding the Circaion has been created recently by sedimentation from certain rivers, but the Circaion was formerly an island. The island was about eighty stades in circumference . . . silver-fir and fir grow extremely tall in Latium and are taller and finer than in southern Italy.).

[160] Quilici (1979: 76–87) on the ancient forests of the Campagna Romana, cf. Pratesi and Tassi (1977: 76); Traina (1990: 16); Grandazzi (1997: 65–73) on the environment of Latium. Meiggs (1982: 219, 243–5) and Fraser (1994: 184–6) discussed Theophrastus on the forests of Latium without considering the problem of the beeches. The inaccuracy of Theophrastus' information (if it is not simply the case that the text has become garbled during manuscript transmission) fits Fraser's emphasis on the paucity of information available to Theophrastus from the western Mediterranean in contrast to the large volume of data yielded by Alexander's expedition into the Persian Empire. The new Budé edition by S. Amigues, with reference to Theophrastus' description of the beech tree in *HP* 3.10.1 (cf. 3.11.5), noted that '*la distinction entre hêtre de montagne et hêtre de plaine n'a pas de valeur scientifique*'. Amigues discussed the ecological adaptability of the beech tree, but did not consider the possibility of climatic change affecting its distribution. Pratesi and Tassi (1977: 38) described '*il faggio*' as '*un albero che, nel Lazio, vive sulle montagne appenniniche a un'altezza variabile tra i 900 e i 1800 metri*', although they noted that it sometimes descends to 400 or 500 metres above sea level in favourable locations, cf. Leonardi and Menozzi (1995); Blasi *et al.* (1999). Bietti Sestieri (1980: 9) suggested that the lower limit of the beech tree has been driven upwards by intensive agriculture in the lowlands. Rendeli (1993: 132) noted finds of beech wood in southern Etruria in Bronze Age levels at Sorgenti della Nova, Grotta Misa, and Lago di Mezzano, and in Iron Age levels at Castro and Acquarossa. These sites are all situated close to suitable uplands for beech forests. Magri (1999: 193) noted that there is fossil evidence for *Fagus* in the lowlands in earlier geological periods at Torre in Pietra, west of Rome. Theophrastus, *HP* 3.17.1 discussed another tree, *Quercus suber*, in Tuscany.

18. The northern slopes of Monte Circeo, with the forest of the Quarto Freddo, viewed from near Torre Paola.

simply an isolated part of the Apennines. It is not now thought to have ever been an island during the Holocene period, but there is no doubt that there was substantial alluviation in the adjoining Pontine plain in classical antiquity.[161] The promontory of Circeii had dense forests of oak, bay, and myrtle. The remnants of the Pontine forest are still visible on the northern slopes of Mt. Circeo itself and in the adjacent Selva del Circeo in the Parco Nazionale del Circeo.[162] Strabo (quoted in Ch. 6 below) shows that the area of the Pontine Marshes in the vicinity of Monte Circeo was severely affected by malaria, although Monte Circeo itself was above the range of malaria in the past, since it reaches an altitude of 541 metres above sea level. Doni regarded Mt. Circeo as healthy in the

[161] The Dutch archaeologists from Groningen identified one specific episode of alluviation (Attema *et al.* (1999)). They found evidence for a mass mud flow from the valley of Vado La Mola into the Pontine plain, near the important proto-historic settlement of Caracupa Valvisciolo near Sermoneta. They attributed this mud flow to 'vegetational denudation of hillslopes'.

[162] Ovid, *Metamorphoses* 15.716–17 described Circeii as surrounded by marshes. Pliny, *NH* 3.5.57–8 simply followed Theophrastus' account of Circeii, cf. Procopius, *BG* 1.11.2–4. Pliny, *NH* 19.40.134 said that the beets of Circeii were particularly noteworthy. [Aristotle,] *peri thaumasion akousmaton* 78.835[b]–6[a] believed that a deadly plant-derived drug could be obtained at Circeii. Pratesi and Tassi (1977: 145–8) and Stanisci *et al.* (1998) described the forests of Circeii as they are today.

seventeenth century, while Martial described Terracina as healthy in antiquity. Demetrius used to hunt wild boar in the forests of Circeii.[163]

By the Late Republic the expansion of the city of Rome required very large quantities of timber for construction and other purposes. Strabo states that the wood for buildings in Rome came mainly from Etruria. It was transported along the Tiber and its numerous tributaries to the city. Pliny noted that the Tiber had forty-two tributaries below its junction with the Chiana. Strabo also mentions the region of Pisa as providing timber for buildings at Rome and for shipbuilding. Rusellae, near Grosseto, was one of the towns which offered timber for shipbuilding to Scipio Africanus in 205 BC for his expedition to Africa. Another cause of deforestation was the requirement for firewood for smelting metals (e.g. around Populonia and in the Colline Metallifere).[164] The breaking up of previously closed forest environments in the lowlands favoured *Anopheles* mosquitoes, some species of which prefer pools of water that are exposed to sunlight for breeding purposes. In the early eighteenth century AD Lancisi observed that stagnant waters, which faced the open sky in summer, were particularly dangerous; such waters had lots of insects and abundant vegetation (which provides cover for mosquito larvae). *A. sacharovi* particularly likes inland waters which are open to sunlight in summer. Lancisi attempted to prove his observations by practical experiments:

It is impossible to ignore the fact that in summer rainwater kept in an open vase becomes polluted with mosquitoes far more quickly and abundantly than anything else.[165]

[163] Doni (1667: 104); Martial 5.1; Polybius 31.14.2–3, ed. Buettner-Wobst.

[164] Strabo 5.2.5.222–3C; Pliny, *NH* 3.5.53–4; A. Betocchi, *Del fiume Tevere*, in *Monografia* (1881: 206–7) listed the tributaries of the Tiber; Livy 28.45.18 on Rusellae; Sallares (1995) and various papers in Frenzel (1994) considered deforestation in antiquity. The demands of 'industry' for timber in the past should not be underestimated. De Felice (1965: 86) gives interesting statistics, which can be scaled upwards for antiquity, about the consumption of charcoal by craft industries in the city of Rome in the eighteenth century, when the city's population was much smaller than during the Roman Empire: '*la sola città di Roma consumava annualmente 12 milioni circa di kg di carbone*'. Meiggs (1982: 218–59) discussed the timber requirements of the city of Rome in antiquity and emphasized the need for charcoal for heating, industry, cremations, and hot water in the public baths, cf. Rausing (1987). Toynbee (1965: ii. 585–99) is still interesting on the question of deforestation.

[165] Lancisi (1717: 58–9, cf. 26–9): *neque vero hic dissimulandum est, aquam pluviam per aestatem, si aperto in vase detineatur, culicibus longe citius, et copiosus quam quaevis alia foedari.* Tommasi-Crudeli (1881*b*) wrote a short article about plant pots inside the house as a source of 'bad air'; Russell (1943: 60).

The first millennium BC witnessed a substantial shift away from the closed forests of the Neolithic period towards the modern open countryside. Dionysius of Halicarnassus described one famous closed forest, the Sila in Bruttium, which he regarded as a source of timber for the whole of Italy.[166] Such forests were under attack in Roman times. Deforestation in upland areas of central Italy led to increased run-off of rainwater. Pliny the Younger noted that at Tifernum in Umbria perennial streams watered beautiful meadows full of flowers, but the ground, because it was sloping, was not marshy, as water drained off into the Tiber. The water ended up elsewhere. A long series of major floods occurred in the city of Rome in antiquity, recalling the catastrophic flood of November 1966 at Florence, Grosseto, and elsewhere in Tuscany, which occurred after forty consecutive days of heavy rainfall. The construction of the Cloaca Maxima suggests that a need for drainage was already felt from the very beginning of Roman history. Strata dating to the imperial period in the Roman Forum are now covered by six or seven metres of alluvial deposits and are themselves several metres above the levels of the archaic period.[167] Pliny the Elder states that the Tiber floods were nowhere worse than in the city of Rome itself, and Pliny the Younger gives a graphic description of the effects of a Tiber flood. Orosius mentions a devastating flood in 241 BC. Cassius Dio recorded that the lower parts of Rome were completely flooded by the Tiber in 54 BC, causing severe damage to buildings. He attributed the flood to very high rainfall upstream, or to the sea driving back the river water. Both explanations are possible. Another Tiber flood made the city of Rome navigable by boat for three days in 23 BC. The following year, Rome was yet again submerged. Tacitus mentioned a severe flood in AD 15, which again caused severe damage to buildings and loss of life, and described an interesting debate in the Senate about these problems. In the end the Senate, whether because of the difficulty of water-management enterprises, or the inevitability of protests from communities liable to be affected by river diversions, or because of superstitious beliefs, decided to do nothing. This illustrates the large degree of helplessness of the Romans in the face of

[166] Dionysius Hal., *AR* 20.15, ed. C. Jacoby (1891): *ὕλη σκιερὸν ἀποτελοῦσα δι᾽ ὅλης ἡμέρας τὸ ὄρος* (the forest keeps the mountain shaded throughout the day). Douglas (1955: 228–30) described the Sila forest as it is now, and Béal (1995) reviewed all the evidence from antiquity.

[167] Quilici (1979: 69–70).

these 'natural' (albeit unintentionally partly man-made) phenomena. The flood in AD 15, the year after the death of the emperor Augustus, shows that the measures which he is said to have taken to control the Tiber were completely ineffectual. Tacitus records another severe flood in AD 69. Terrible floods also occurred in Rome in the reigns of Nerva, Trajan, and Marcus Aurelius. Cassius Dio mentions another flood in AD 217, and there were doubtless others which have gone unrecorded.[168]

The records of the worst floods in Rome during the last millennium show that they principally occurred during the months of September to February. As Rome gradually dried out after these great floods, mosquitoes would have found countless ideal breeding sites within the perimeter of the city of Rome itself. Literature from the early modern period shows that Tiber floods were regarded as a very important factor in the generation of malaria in the city of Rome. The Tiber was not enclosed by the Lungotevere river walls then as it is today. A huge flood in late December 1870, a few weeks after Rome had become the capital of the newly unified Italian state, put the question of taming the river Tiber at the top of the political agenda for the new government. The districts of the city worst affected by malaria were along the river. Floods in September and October increased mosquito populations and the intensity of malaria immediately. Floods later in winter would drench the ground and make it more suitable for mosquito breeding purposes in the following summer. A description of a medieval flood in December AD 791 makes it clear that much water remained in the city long after the Tiber had ceased to flow through it. It was not coincidence that pestilence accompanied the floods of 23–22 BC, according to Cassius Dio, although many other diseases besides malaria would have been active as well, especially waterborne intestinal diseases, which can interact with malaria in ways which will be described later (see Ch. 5. 2 below).[169]

[168] Le Gall (1953: 29–34) discussed the evidence for Tiber floods in antiquity. The following sources are noteworthy: Pliny, *Ep.* 5.6.11–12; Pliny, *NH* 3.5.55; Pliny, *Ep.* 8.17; Orosius, *Hist.* 4.11.5–7, ed. Arnaud-Lindet (1991); Cassius Dio 39.61.1–2, 53.33.5, 54.1.1, also 56.4 for a flooding of the Campus Martius by the Tiber in AD 12, and 79.25.5; Suetonius, *Augustus* 30; Tacitus *Annals* 1.76, 79 (with LeGall (1953: 120–5)); Tacitus *Histories* 1.86; *epitome de Caesaribus* 13.12–13, ed. Pichlmayr (1911); *scriptores historiae Augustae Hadrian* 21.6, *Antoninus Pius* 9.3 and *Marcus Aurelius* 8.4; Claudian, *de bello Gildonico* 39–43; Quilici (1979: 66–8).

[169] Bocquet (1998) described the events of 1870. A. Betocchi *Del fiume Tevere* in *Monografia* (1881: 244–5) listed the heights and months of the worst Tiber floods in the last eight hundred years. Baccelli (1881: 156, 159–60) regarded Tiber floods as very important in generating

Besides floods, heavy rainfall in winter and spring was also beneficial for mosquito breeding. A correlation between heavy rainfall in winter or spring and an elevated frequency of malaria was observed in Rome in the last century. North described as an example the events of 1879, when exceptionally high rainfall in the period from March to May was followed by a severe epidemic of malaria in the summer and autumn of that year. Similarly Bellincioni observed a very close correlation at Grosseto between rainfall levels in the months from September to May and the frequency of malaria in the following summer and autumn over a period of thirty-two years that was studied, from 1900 to 1932. He explained the connection in terms of fluctuations in the level of the water table, which must be linked with fluctuations in the frequency of malaria via fluctuations in the size of mosquito populations, which in turn depend on the size of suitable habitats available to them for breeding purposes.[170] Pliny the Younger observed that, wherever one dug, water was found at his villa near Laurentum, indicating a very high water table.[171] Many of the coastal areas, which were the most severely infested with malaria in the medieval and early modern periods, were expanding in size in Roman times because of alluviation and were prone to flooding. For example, the Etruscan cities of Vetulonia and Rusellae, near the site of modern Grosseto, were much closer to the sea in antiquity than they are today.[172] They were situated by a gulf which in Roman times became a brackish lagoon, the *lacus* (or *amnis*) *Prilius*. Today the area of the former lake forms part of the plain of Grosseto, but it existed into the early modern period as the Lago di Castiglione, a freshwater lake sometimes extending over more than a hundred square kilometres. The history of this area is a classic example of the spread of malaria around the margins of a coastal lake which

malaria in Rome. He reckoned that malaria occurred where the river could deposit sediments on its banks, but not where there were river walls. Davis (1992: 171) and (1995: 84, 179–81, 209–10) recorded the Tiber floods in December 791, November 844, January 856, and October and December 860 AD.

[170] North (1896: 145–7); Bellincioni (1934). Hay *et al.* (2000) observed a three-year cycle of *P. falciparum* epidemics which could not be correlated with climatic trends in a highland region of western Kenya, and suggested that intrinsic population dynamics offer the most parsimonious explanation of the intervals between epidemics. However the evidence from Italy strongly supports climatic explanations for malaria epidemiology in Europe in the past.

[171] Pliny, *Ep.* 2.17.25.

[172] Dennis (1878: 222–34) on Rusellae, which is situated about 170 metres above sea level, while Vetulonia is around 300 metres above sea level.

developed and then gradually became cut off from the sea.[173] The flood plain of the river Ombrone was too flat for drainage purposes, like the Pontine plain. In the early modern period the increasing use of quinine played a more important role in reducing malaria in the province of Grosseto than the bonifications.[174] However, the final blow to malaria in Italy as a whole was delivered by the insecticides DDT (against adult mosquitoes) and Paris Green (against mosquito larvae) during and after the Second World War, for example during the operations to defeat the terrible epidemic in the Monte Cassino region. Consequently the balance of probability is that drainage operations in Roman times, when quinine and DDT were not available, had limited effects on malaria, just like their early modern counterparts. *Anopheles* mosquitoes still exist in the Maremma in spite of the bonifications.[175]

Besides deforestation in the uplands, intensive farming in the vicinity of Rome to feed the burgeoning urban population also played a role in soil erosion, which increased enormously in Roman times. The rate of soil erosion in Latium increased *ten times* in the second century BC compared to its previous rate. This may be attributed to dense settlement around the city of Rome, as suggested by the Capena and Veii archaeological field surveys, and intensive market gardening to produce food for the increasing urban population.[176] We shall see in Chapter 8 below that there was a strong causal connection between gardening and malaria.

[173] Pinto (1982: 13–14).

[174] Ciuffoletti and Guerrini (1989: 67, 95, 136).

[175] Raffaele and Coluzzi (1949); Garaci (1947); Merzagora, Corbellini, and Colluzi (1996). Alberto Coluzzi led the operations against this epidemic. Malaria epidemics are attested in the Monte Cassino region and the valley of the River Liri towards Frosinone as far back as the early medieval period: e.g. *chronica monasterii Casinensis* 1.22, ed. H. Hoffmann (1980), *Die Chronik von Montecassino* (*Monumenta Germaniae Historica. Scriptores,* xxxiv): *Qui videlicet sanctus vir cum depositus fuisset septimo idus Octobris, in loco, quo reconditus est, multos febre detentos diversisque languoribus oppressos, ex fide poscentes ad suos cineres precibus ac meritis suis pristine saluti restituit* (This undoubtedly holy man [sc. abbot Deusdedit], when he was buried on 9 October [834 AD], in the place, in which he rests, restored to their previous good health many people gripped by fevers and oppressed by various kinds of weariness, who in accordance with their faith invoked his ashes with prayers and their own services.); 2.96 *Sed cum predictus apostolicus Romana febre iam dudum langueret, circa ipsam natalis Domini festivitatem adeo graviter infirmatus est, ut pro certo se mori putaret* [December AD 1057] (However since the above-mentioned bishop had already long been severely afflicted by Roman fever, he was so ill about the time of the festival of the birth of Christ that he thought that it was inevitable that he was going to die.), cf. 2.88, 90.

[176] Judson (1968); Potter (1979: 120–37) recorded large numbers of villas by *c.*AD 100 (with slave labour forces), but few significant towns occupied by a free population.

Substantial erosion and redeposition of sediments has also occurred since the classical period. The consequence is that the modern landscape is quite different from the ancient one. Recent research in the Fiora, Marta, Treia, and Valchetta river valleys has drawn a very sharp contrast between the ancient and the modern river systems:

> The sedimentology of the coarse deposits suggests that Roman rivers and floodplains were very different to those existing today. They were characterized by shallow channels, actively migrating, depositing bars of gravel. Some reaches of the contemporary streams are trying to re-establish this condition but only to a limited extent due to confinement by high cohesive sandy-silt banks.[177]

The ancient fluvial regime had very important consequences for malaria. The *laterally mobile* Roman rivers in shallow channels would have been more liable than their modern counterparts in deeper channels to flood the surrounding countryside. As the flood waters retreated, leaving pools here and there, mosquito breeding sites would have been created.[178] Thus it is likely that the rivers of Latium and Tuscany in the Roman period had a greater propensity to create mosquito breeding sites than they do today. Tibullus was right to fear the rivers of Latium and Tuscany in summer.

The overall effect of all the landscape changes which have been described was to provide more breeding sites for mosquitoes in general in Roman times. In coastal areas, if the water was brackish, those species of *Anopheles* mosquito that are the most dangerous vectors of human malaria had an advantage over other species of *Anopheles*. Even in Lazio, suitable breeding sites for mosquitoes can be scarce. In 1928–9 the lake at Nemi was partially drained to uncover Caligula's ships, inadvertently providing new breeding sites for mosquitoes. In 1929 a sudden epidemic of *P. falciparum* malaria infected over half the population of the town, which had no previous history of endemic malaria in its hilly location (320 metres above sea level). Prior to the drainage operations there were not enough mosquitoes around to sustain the transmission of malaria in Nemi, given that the chances against transmission by any individual mosquito are extremely high, since most mosquitoes do not

[177] Brown and Ellis (1995: 69).

[178] An example of periodic flooding at a specific site is the Roman mausoleum at Fosso della Crescenza along the Via Veientana in southern Etruria (S. Judson in Fentress *et al.* (1983: 70–2)). On the rivers of southern Etruria see also Rendeli (1993: 122–5).

live long enough to transmit the disease.[179] *P. falciparum*, the most dangerous species of human malaria, is a very ancient parasite which was probably present in Mediterranean countries on a localized basis from the Neolithic period onwards, as has already been argued. It can certainly continue to exist in very small foci without spreading. It was not a new disease in classical times. Nevertheless the conclusion reached here is that the frequency of all types of malaria increased very substantially in Roman times primarily because of human modifications of the landscape which unintentionally favoured the vector mosquitoes. The demographic effects of this expansion on human populations demand detailed examination now.

[179] Hackett and Missiroli (1931: 64–5) on Nemi.

5
The demography of malaria

5.1 Direct and indirect approaches to the demography of malaria

Bonelli rightly observed that in order to understand the impact of malaria on Italy in the past it is not enough simply to consider its demographic effects in purely quantitative terms.[1] It also influenced the entire lifestyle of people, even if it did not kill them, by forcing them to live away from the fields in which they had to work. In other words, malaria altered settlement patterns.[2] Old Salpi in Apulia was the most dramatic example of this in antiquity (see Ch. 10 below), but malaria also influenced settlement patterns within the city of Rome itself, as will be seen later (Ch. 8 below). Malaria influenced agricultural systems by preventing intensive farming practices (Ch. 9 below). Nevertheless consideration of the demographic effects of malaria in purely mathematical and statistical terms is essential to understand the scale of its impact. The most fundamental weakness of nearly all recent literature on the question of the effects of malaria in Italy in antiquity is the absence of any appreciation in quantitative terms of the demographic effects of malaria on human populations in Europe in the past. This lack of knowledge about the demographic effects of malaria on human populations has permitted many researchers from different branches of scholarship to minimize the importance of malaria.

A good starting-point is the recent debate between Scheidel and Shaw concerning the explanation of excess seasonal mortality in the city of Rome in antiquity, as revealed by funerary inscriptions.[3] Scheidel opted for malaria, in synergistic interactions with other diseases, as the principal cause. Shaw attempted to minimize the role of malaria. It is instructive to consider the flaws in Shaw's argument. Shaw relied on national statistics which show that malaria

1 Bonelli (1966: 662).

2 Pinto (1982: 30) saw malaria as a determinant of settlement patterns in Tuscany in the medieval period.

3 Scheidel (1996); Shaw (1996).

accounted for 2.2% of all deaths in Italy in 1887–9. He concluded that malaria was less important in Italy than in Greece, where 5.6% of all deaths were attributed to malaria as recently as 1921–32.[4] The most detailed statistics can be extremely misleading if they are not handled very carefully indeed. In this particular case, there are two major reasons why these national statistics for cause of death are unlikely to give an accurate estimate of the contribution of malaria to mortality in the city of Rome or in the Roman Campagna in antiquity.

The first rather elementary reason is quite simply that these national statistics lumped together mortality data from localities with intense malaria with data from places where there was no malaria at all to yield meaningless averages which may be completely inappropriate if applied to any particular locality. It is always possible in demography to aggregate data from two or more different regions and calculate the average, but the crucial question is whether the average so obtained is meaningful. As del Panta said in an article on infant and child mortality in early modern Italy:

> No satisfactory explanations can be given for the evolution of child and infant mortality in Italy without considering territorial differences. In fact, national values result from quite different regional and provincial levels.[5]

In localities in Italy where malaria was endemic the proportion of deaths *which were directly attributed to malaria* (the significance of this phrase will be seen shortly) was far higher than the national statistics for mortality indicate. Bonelli gave as examples for 1882 Rossano in Calabria, Grosseto, and Paola in Calabria where 24.8%, 23%, and 19.5% respectively of all deaths were directly attributed to malaria. An earlier, less complete database of causes of death yielded a figure of 19% of all deaths directly attributed to intermittent fevers in Grosseto in 1840–1. This result is of the same order of magnitude as the result for 1882. However, it is probably an underestimate since the surviving records for 1840–1 excluded almost entirely causes of death for infants and children under the age of five, who would be expected to suffer severely from *P. falciparum* malaria when it is endemic.[6] Bonelli stated that 'in the 1880s

[4] Shaw (1996: 133 and note 108); Balfour (1935: 302) on Greece.
[5] Del Panta (1997: 10).
[6] Bonelli (1966: 662); del Panta (1989: 48–9 n. 23), using the statistics of Salvagnoli Marchetti.

it was quite common in the Mezzogiorno for malaria to account for 20–30% of all deaths . . . in numerous other localities malaria accounted for 10–15% of all deaths'.[7]

There are two lessons to be drawn from this. First, in any kind of comparative history it is essential to look for *appropriate* parallels. Since the ancient medical authors Asclepiades and Galen provide positive evidence that *P. falciparum*, the most dangerous species of human malaria, was common in ancient Rome (see Ch. 8 below), the appropriate parallels are places in more recent periods of Italian history where malaria was common, such as Grosseto, not places where it did not occur at all. A good example of a comparison that should be used as a source of *contrasts* with the city of Rome in antiquity, not as a source of *parallels*, is Florence at the time of the famous *Catasto* in 1427.[8] The *Catasto* is of course a very important historical document, to which further reference will be made in Chapter 11 below. However, the demographic situation in Florence then was fundamentally different from the situation in ancient Rome for (at least) two major reasons: (1) Florence in the late medieval period was affected by epidemics of bubonic plague, for which there is no evidence in Rome in antiquity; (2) Florence had no history of endemic malaria.[9] Since there were significant differences in the causes of death between imperial Rome and late medieval Florence, there is no reason whatsoever for expecting the mortality patterns of ancient Rome and late medieval Florence to be similar. It follows that it is essential to investigate the causes of death in detail at the local level, before choosing comparisons for demographic purposes. Shaw did not consider the important evidence of Asclepiades and Galen. He stated that 'it seems clear that it is the factor of temperature variability that marks the main separation between "northern" and "southern" regimes of seasonal mortality', but failed to notice that out of the various diseases which he considered malaria is the only one in fact which is strongly temperature-dependent.[10] Both what he termed 'normal' diseases, such as tuberculosis, and epidemic diseases, such as typhus, flourish equally well in Africa and in northern Europe. In 1998 there were

[7] Bonelli (1966: 662): *negli anni '80 era abbastanza frequente nel Mezzogiorno che il numero dei morti per malaria rappresentasse il 20–30% del totale dei morti . . . numerose altre località presentano una mortalità per malaria compresa tra il 10 e il 15% della mortalità generale.*

[8] Herlihy and Klapisch-Zaber (1985).

[9] Carmichael (1989) on mortality patterns in late medieval Florence.

[10] Shaw (1996: 132).

outbreaks of epidemic typhus in Burundi in Africa and in Russia.[11] Similarly Shaw noted the gradual disappearance of the excess summer mortality in Italy from the 1860s to the 1960s, but did not notice the almost exact correlation of this trend with the gradual eradication of malaria. In contrast Brown found a very strong statistical correlation between mortality trends in Sardinia and malaria eradication over the very same hundred-year period.[12] Del Panta observed that 'the official statistics can only reveal, however, the phase in which mortality from malaria was declining, starting in 1887'. The data for causes of death upon which Shaw relied *postdate* the beginning of the demographic transition towards the modern low-mortality and low-fertility demographic regime in Italy. Consequently these data are of limited value for the pre-modern period. Del Panta stated that the transition towards the modern low mortality demographic regime commenced in Tuscany in the period 1875–80.[13]

The second lesson to be drawn from examining Shaw's use of national statistics is that in demography *all valid studies must commence at the local level*, with, for example, the sort of parish studies which formed the foundation for the monumental population history of England by Wrigley and Schofield. The failure to appreciate the importance of local variation in demography, such as the differences between Grosseto and Treppio noted at the beginning of this book (see also Ch. 5. 4 below), is the single biggest deficiency of the bulk of research in ancient Roman demography carried out over the last thirty years or so. One of the main conclusions reached in this book is that it is in fact impossible to generalize about the demography of a region as small as central Italy in antiquity, never mind the whole Roman Empire.

There is a second very important reason why the national statistics for mortality in 1887–9 in Italy are an unreliable guide to the likely impact of malaria on mortality patterns in antiquity. As a specialist in malariology put it, 'reporting of deaths by cause has been of limited use for the investigation of the impact of malaria and its control on mortality'.[14] The reason for the unreliability of

[11] Raoult *et al.* (1998) and Tarasevich *et al.* (1998) on typhus.

[12] Shaw (1996: 112); Brown (1986: 857).

[13] Del Panta *et al.* (1996: 292 n. 10): *le statistiche ufficiali possono cogliere, purtroppo, solo la fase discendente della mortalità per malaria, a partire dal 1887*; del Panta *et al.* (1996: 152); Sori (1984: 542–3).

[14] L. Molineaux in Wernsdorfer and McGregor (1988, vol. 2, p. 974).

national statistics is that 'medical science shows that for each death attributed to malaria there are several other deaths, which are attributed to other causes, but nevertheless are directly linked to malaria or indirectly caused by the debilitating effects of malaria infections'.[15] The empirical demographic evidence for this conclusion is that it has frequently been observed, both in Italy in the past and in tropical countries today, that after the eradication of malaria the reduction in *total* mortality rates is much larger than the reduction that would have been predicted from the proportion of deaths that were directly attributed to malaria before its eradication. For example, Hackett described the town of Sermoneta on the edge of the Pontine Marshes in 1925, just before eradication started. The population of Sermoneta, which could not reproduce itself, had a crude death rate of 41 per 1,000. All the children had splenomegaly, but only a dozen individuals, mainly children, had acute symptoms of malaria, because almost all adults had developed acquired immunity earlier in life. Only 8% of all deaths were directly attributed to malaria in 1925 (in absolute numbers, three out of thirty-seven). Nevertheless the eradication of malaria in Sermoneta led to a fall in the crude death rate from 41 per 1,000 to 20 per 1,000.[16] Although the problems of Sermoneta in the early twentieth century were a product of the early modern period, there is no doubt that other communities in western central Italy were affected in the same way much earlier. For example, Toubert quoted the decree of Pope Innocent IV in AD 1253 granting permission to the inhabitants of Mozzano to move their village to a new location, because of 'bad air' in summer. This text clearly describes virtually the entire population of Mozzano in the thirteenth century as severely affected by malaria, and shows malaria directly altering human settlement patterns in that period. (Since the town had been built in a place that was so pestilential and unhealthy, owing to bad air, especially in summer, almost all of its inhabitants suffer from severe disease and chronic lethargy . . . we shall allow them to move to the place called Colle Vecchio to live in the territory of the town set aside for them there).[17]

[15] Bonelli (1966: 662): *la scienza medica mostra che per ogni morto classificato come deceduto a causa della malaria ce ne sono parecchi altri classificati come morti per 'altri' eventi morbosi, i quali, peraltro, sono alla malaria direttamente connessi o indirettamente dovuti al processo di debilitazione fisica delle persone colpite.*

[16] Hackett (1937: 237); Molineaux (1997); Brown (1986); Giglioli (1972).

[17] Toubert (1973: i. 363–4 n. 3): *cum castrum in tam pestifero et corrupto sit loco constructum quod*

19. A view of Sermoneta, a hill town dominated by the Castello Caetani, with a history of contact with malaria. The following saying, quoted from the guidebook, *Sermoneta: storia del paese* (1989) by L. Sciotti and A. Nastri, refers to malaria: *Sermoneta che stai ncima a na fossa,* | *ntorno ntorno ci sta l'acqua puzza:* | *a le femmene fa cresce la trippozza,* | *a gli ommeni ce cala la cocozza.*

When malaria eradication caused *a reduction in overall mortality of more than 50%*, as it did in Sermoneta, it seems reasonable to conclude that malaria did in fact dominate the mortality regime before

propter aeris intemperiem, aestivo praecipue tempore, habitatores ipsius quasi omnes infirmitates graves et diutinos languores incurrunt . . . transferendi se ad locum qui Collis Vetulus [modern Collevecchio] *nuncupatur . . . in territorio castri predicti ad inhabitandum inibi . . . concedere curaremus.*

eradication, even if the bulk of its effects were indirect rather than direct. In tropical countries similar results followed the eradication of malaria. One study estimated that in Ceylon the total number of deaths in which malaria played a role was 4.7 times that of the deaths caused directly by malaria, while in the coastal regions of British Guyana the total number of deaths involving malaria was 3.8 times that of those directly attributed to it.[18] The standard view of malariologists is that 'the mortality attributable to malaria . . . was about three times the mortality actually attributed to malaria on the basis of death certification'.[19] For Grosseto, for example, where 23% of all deaths were directly attributed to malaria in 1882, that would imply that well over half of all deaths were in fact linked to malaria, directly or indirectly. Morbidity data, which were collected alongside the cause-of-death data for Grosseto in 1840–41, indicate that about 60% of all recorded illnesses in Grosseto were intermittent fevers.[20] This suggests that malaria might have been more frequent in Grosseto than all other diseases put together.[21] In such contexts, it is easy to understand the equation of 'fever', *πυρετός* or *febris*, with malaria as the disease *par excellence*, as seen for example in the *de medicina* of Celsus. Malaria was the first disease discussed by Celsus in book 3 of his work, when he considered diseases one by one. He explicitly stated that malarial fevers were extremely common, for the benefit of any modern historians who find it hard to believe:

> The next subject is the treatment of fevers, which both affect the entire body and are extremely common. One type of fever is quotidian, the second tertian, and the third quartan.[22]

The data from Grosseto demonstrate the scale of the effect which malaria might be expected to have had on the population of at least some parts of the city of Rome in Galen's time, when it was endemic (see Ch. 8 below). Since the indirect effects of malaria

[18] Newman (1965: 76–9, 158–60). See most recently Jones (2000).

[19] L. Molineaux in Wernsdorfer and McGregor (1988: ii. 976).

[20] Del Panta (1989: 48–9 n. 23). He stated that the effects of malaria were largely indirect as far as adult mortality in Grosseto was concerned. C. Fermi estimated that malaria was implicated in over 50% of all deaths in Sardinia as recently as 1900 (Brown (1986)).

[21] Similarly Desowitz (1997: 195) cited a report from the United States Public Health Service in 1919 which concluded that in the southern states of the USA malaria was more important than tuberculosis, typhoid fever, dysentery, and pellagra put together.

[22] Celsus 3.3.1: *sequitur vero curatio febrium, quod et in toto corpore et vulgare maxime morbi genus est. Ex his una cotidiana, altera tertiana, altera quartana est.*

are so important, indirect methods for estimating its effects on mortality, such as comparisons of overall mortality levels (most simply by crude death rates) or of the age-structures of populations (as between Grosseto and Treppio) are in fact a better guide than direct methods, such as the Italian national statistics for causes of death used by Shaw. Indirect methods are the chosen methods of professional malariologists.[23]

In view of the quantitative importance of malaria in some areas, as shown by the data from Grosseto, it is not surprising that the popular explanations for malaria were sometimes transferred to other diseases, for want of anything better, but this only serves to demonstrate the all-pervasive influence of malaria in those areas where it occurred. Undoubtedly this also happened in antiquity, but the best example is the great epidemic of syphilis which swept across Europe in the years immediately following the return of Columbus from the New World. Leoniceno, in a booklet produced as part of the dispute at the court of Ferrara in AD 1497 concerning the nature of the epidemic, carefully discussed the types of diseases mentioned by classical authors and correctly concluded that the (for some) new disease was quite distinct from the *elephantiasis* or leprosy described in antiquity. Nevertheless he was unable to resist explaining it in Hippocratic terms and associating it with the massive Tiber flood in December 1495, even though he observed that the whole of Italy experienced very high rainfall in that particular year.[24] Similarly Fracastoro, in his poem on syphilis which gave the disease its modern name, advised people to avoid the 'bad air' of marshes and south winds:

First of all I would urge you not to be familiar with all types of air: avoid

[23] Dobson (1997: 134) on the use of crude death rates; L. Molineaux in Wernsdorfer and McGregor (1988: ii. 974).

[24] Leoniceno (1497) added two extra verses to the tetrastichon, which had been composed by another poet about the Tiber flood in 1495, to emphasize the high rainfall all over Europe in that winter: *Tempore Alexandri sexti nonisq; decembris* | *Intumuit thybris bis senas circiter ulnas.* | *Insula quaeque domus facta est. mediisque repente* | *Circunducta viis aequabat cymba fenestras.* | *Deucalion eo vix tantum tempore tellus* | *Diluvium passa est, latuit cum tota subundis.* ((In the time of Pope Alexander VI, on the 5th of December, | the Tiber rose about a dozen arm-lengths | Each house became an island, and suddenly in the middle | of the streets a boat brought around reached the height of the windows. | Scarcely so much land was flooded at the time when Deucalion survived a flood that submerged everything.) On Leoniceno and the medical dispute at Ferrara see Arrizabalaga *et al.* (1997: 59–66, 72–7, also 195–6 on the various epidemics in Rome in the sixteenth century).

winds which always blow from the south, since they are loaded with dirt and the humidity of foul marshes.[25]

Since syphilis occurred in many parts of Europe which had no marshes, no 'bad air', no sirocco wind, and no river Tiber, the environmental aspects of malaria are obviously of no value at all for explaining syphilis. It is testimony to the enormous influence of malaria that ideas for explaining it were transferred so readily to other, utterly dissimilar, diseases, like syphilis. However, malaria did not only interact with other diseases in the human mind at the level of ideas concerning disease causation. The various pathogens also interacted in reality.

5.2 Interactions of malaria with other diseases

It is interesting to go beyond statistics such as those from Grosseto in the nineteenth century to examine in more detail exactly how malaria interacts with other diseases, especially the gastro-intestinal diseases and the respiratory infections which were assigned the primary role in excess seasonal mortality in Rome in the fourth century AD by Shaw. Interactions between different species of pathogens can be synergistic, antagonistic, or neutral in terms, first, of their effects on each other and, secondly, of their effects on the human host. It is also possible, for example, that a human genetic mutation which confers a degree of resistance to one pathogen might also make the host more susceptible to another pathogen at the same time. An example of an antagonistic interaction between two pathogens is that between malaria and syphilis (see Ch. 2 above). The sequencing of the entire syphilis genome has shown that the syphilis spirochaete (*Treponema pallidum*) cannot tolerate the intense body temperatures generated during malarial fevers because it lacks a factor responsible for transcription of heat-shock proteins in other bacteria and so cannot respond to heat shock.[26] The interaction between malaria and syphilis was artificially created in hospitals in Europe and North America as a treatment for syphilis in the central nervous system before the development of drugs against syphilis. However, it is probably not very important in nature, so to speak, in regions with endemic

[25] Fracastoro (1530), *syphilis. sive morbus Gallicus* 2.81–3: *In primis ego non omni te assuescere coelo | Exhorter: fuge, perpetuo quod flatur ab Austro, | Quod coeno, immundaeque grave est sudore paludis.*

[26] Fraser *et al.* (1998).

malaria, since syphilis is predominantly a sexually transmitted disease (although congenital transmission through the placenta also occurs) affecting mainly adults. In holoendemic regions people develop acquired immunity to malaria in infancy and childhood and consequently do not have severe malarial fevers during the years of sexual maturity when they are most likely to encounter syphilis. Whether or not syphilis existed in pre-Columbian Europe is a controversial question which need not be considered here.

A possible example of a 'neutral' interaction, according to the perceptions of contemporary observers, was that between malaria and smallpox in early modern Rome. Lapi wrote that if women with tertian fevers touched or suckled children with smallpox they were liable to develop the relatively mild discrete form of smallpox (rather than the more dangerous confluent form). He maintained that in such cases the two different diseases would run their courses separately without getting confused with each other. Although Lapi seemed to believe that the two diseases were not interacting with each other, it is possible that what happened is that malaria depressed the immune systems of the women to the extent that they could develop secondary infections of smallpox (presumably following earlier primary attacks in their own childhood which generally conferred immunity).[27] Since smallpox certainly arrived in Italy during the Antonine 'plague' in the second century AD, if it was not present earlier, this interaction was possible from then onwards.[28] The focus of the rest of this section will be on definite synergistic interactions between malaria and other pathogens which endanger humans.

The gastro-intestinal diseases were indeed major causes of infant and child mortality in historical populations. In ancient Rome Celsus observed that most of the victims of diarrhoea and dysentery were children up to the age of ten.[29] However, the first point that needs to be made is that in European history populations with endemic malaria had higher overall mortality than populations with no experience of malaria (detailed demographic analysis in Ch. 5. 4 below). This can readily be seen by comparing the population of Florence in the thirteenth to fifteenth centuries with

[27] Lapi (1749: 48); Fenner *et al.* (1988: 51–2) on secondary smallpox infections. Endemic smallpox was finally eliminated from Italy in 1947.

[28] Duncan-Jones (1996) discussed the Antonine 'plague'.

[29] Celsus 2.8.30.

nineteenth-century Grosseto. In Florence, which had no history of endemic malaria, gastro-intestinal diseases, operating principally from July to September inclusive, were indeed the leading cause of infant deaths (outside years of epidemics of bubonic plague), the sort of pattern noted by Shaw. In spite of the effects of gastro-intestinal diseases on children, Herlihy and Klapisch-Zuber reached the conclusion that the average duration of life in Florence in the period in question was as high as forty, if years of major plague epidemics are excluded from consideration.[30] In contrast, life expectancy at birth in Grosseto much more recently was only twenty. This comparison shows that children assaulted by gastro-intestinal diseases alone have better survival chances than when malaria is present as well. It is also important to note that infant mortality is virtually unrepresented in the funerary inscriptions from the city of Rome in the fourth century AD used by Shaw. Since direct mortality from *P. falciparum* malaria principally falls on infants and children where it is endemic, the bulk of its effects in terms of seasonal mortality would not be expected to be visible in those inscriptions in any case.

How does malaria exacerbate the effects of gastro-intestinal infections? *P. vivax* and *P. malariae* undergo the process of schizogony in erythrocytes in the peripheral blood vessels of the human body, but *P. falciparum* merozoites export proteins to the surface of infected erythrocytes which make them adhere to the capillaries of internal organs. Fixation inside internal organs in this way enables the *P. falciparum* parasites to undergo schizogony under a lower oxygen tension, which favours this process in this particular species of malaria. The most severely affected internal organs are the brain (causing cerebral malaria), the kidneys and the heart and the liver, and (most importantly for the discussion at this point), the placenta in pregnant women (especially primigravidae), in whom any acquired immunity to *P. falciparum* malaria tends to break down in the second and third trimesters. Lancisi noted that women were particularly badly affected during the malaria epidemic in Rome in AD 1695.[31] In tropical Africa pregnant women are bitten twice as frequently as non-pregnant women by the mosquito *Anopheles*

[30] Herlihy and Klapisch-Zuber (1985: 83–4, 276–9). They refrained from constructing life tables for the population of Florence for reasons which will be considered in Chapter 11 below.

[31] Lancisi (1717: 210–11).

gambiae, increasing their chances of being infected by malaria, perhaps because pregnant women produce a larger volume of exhaled breath on average.[32] Since mosquitoes are generally believed to locate their prey by detecting chemicals emitted in human breath, European vectors of malaria may also have responded in a similar way to pregnant women in the past (although it is also possible that mosquitoes detect chemicals in human sweat). A new idea which is currently attracting attention among researchers in medicine is that placental malaria is caused by a specific population (or set of haploid clones) of *P. falciparum* with a special affinity for certain chemical receptors generally found only or predominantly in the placentae of pregnant women.[33] The presence of large numbers of plasmodia in the placenta frequently causes miscarriages in non-immune women, or fetal anaemia and intrauterine growth retardation in women with some degree of immunity, leading to low birth-weight infants who are particularly susceptible to diseases in general and gastro-intestinal infections in particular. Desowitz, a specialist in tropical diseases, put it as follows:

> The babies that are born to the malarious usually have a birth weight 200 grams or more below normal. A low-birth-weight baby who doesn't 'catch up' has a puny immune system, and these children frequently die during childhood of all sorts of infections. The death certificate . . . may read diarrhoea or pneumonia, but the real cause of death was malaria of the mother.[34]

This is how malaria can enormously exacerbate the effects of gastro-intestinal diseases on infant and child mortality without even being present in the children. Average birth weight of infants in fact increased significantly in areas of former malaria endemicity following modern eradication campaigns. Maternal infections with *P. vivax* may possibly reduce the severity of subsequent infections with *P. falciparum* during pregnancy, owing to immunological cross-reactions, but *P. vivax* itself causes birth-weight reduction in all pregnancies, not just in primigravidae, in areas with endemic malaria. It has been estimated that up to 50% of low-birth-weight babies in some populations in tropical countries may be caused by

[32] Lindsay *et al.* (2000).

[33] McFalls and McFalls (1984: 101, 107–8); Fried and Duffy (1996), discussed by Matteelli *et al.* (1997); Marchiafava (1931: 50–1) on placental malaria in Italy; Gilles and Warrell (1993: 46); Reuben (1993); Fried *et al.* (1998).

[34] Desowitz (1992: 118); Brabin (1992); Newby and Lovel (1995); and Brabin *et al.* (1996).

maternal malaria.[35] In Sardinia, in areas where the transmission rate of *P. falciparum* malaria was extremely high, fertility rates were higher than in areas where the transmission rate was lower. This proves a degree of adaptation by women to intense malaria, as a result of both acquired and inherited immunity (e.g. thalassaemia and glucose-6-phosphate dehydrogenase deficiency in Sardinia), but it has to be remembered that overall mortality was much higher and life expectancy much lower in the areas with a very high transmission rate. Higher fertility was required to balance higher mortality. Even with such increments in fertility, the mortality profile of populations exposed to endemic malaria was extremely poor.[36]

Besides the indirect effects on infants caused by maternal infection, *P. falciparum* malaria can also be present in infants and children themselves alongside gastro-intestinal infections. In Macedonia during the First World War it was observed that malarial infections readily coexist with typhoid fever, paratyphoid fever, and amoebic dysentery, for example. Of particular interest is the observation that when patients in Macedonia were infected with both typhoid fever and *P. falciparum* malaria, as was proved by examination of blood smears for malaria and microbiological techniques for typhoid fever, the clinical symptoms observed were principally those of typhoid fever. The implication of this with regard to ancient sources is that cases, for example in the books of *Epidemics* in the Hippocratic corpus, which look like cases of typhoid fever, could very easily have been infected with malaria as well, but this would not be apparent from the description given in the ancient text. Such dual infections are very likely to happen in areas where malaria is endemic. Malaria may also directly interact with gastro-intestinal infections, since there is some evidence that malaria suppresses the immune response to typhoid fever and other types of salmonella.[37] Malarial fevers do in any case strongly resemble the

[35] I. A. McGregor in Wernsdorfer and McGregor (1988: i. 757); Brabin and Piper (1997); Nosten *et al.* (1999) on *P. vivax*.

[36] Zei *et al.* (1990) observed that placental malaria is in fact more severe in women in areas of low transmission (and so less acquired/innate immunity) than in areas of high transmission (and so a higher degree of immunity).

[37] Armand-Delille *et al.* (1918: 79). Corvisier (1985: 117) lists six probable cases of typhoid fever in the Hippocratic *Epidemics*; Mabey *et al.* (1987). Urban *et al.* (1999) described one mechanism by means of which *P. falciparum* suppresses the human immune response to infection. Faccini (1984) discussed typhoid fever in early modern Italy.

fever of typhoid in the early stages of infection, before the classic periodicity is established (if it is established), but usually without the severe gastro-intestinal symptoms of typhoid fever. Before the true aetiology of malaria was established, this similarity between *P. falciparum* malaria and typhoid fever led many doctors to assimilate the two in the form of a syndrome, called *typho-malarial fever*, whose reality is no longer accepted by modern doctors. The similarity was noted in Rome, too. Baccelli stated that the malaria of Rome frequently took the form of what he called a *subcontinua tifoide*.[38] He reckoned that Lancisi had observed the same form of the disease in the Trastevere district of Rome during the great epidemic in 1695.[39] This was the most dangerous type of malaria for Baccelli. Despite its similarity to typhoid fever, Baccelli stated that it revealed the true intermittent periodicity of malaria upon careful observation. Moreover it responded to treatment with quinine. These two features prove that the 'subcontinuous typhoid' fevers of Rome were *P. falciparum* malaria. Besides its frequent similarity to typhoid fever, *P. falciparum* malaria occasionally presents itself with gastro-intestinal symptoms similar to those of cholera or dysentery, as was observed in cases at Grosseto and elsewhere. In such cases at autopsy a mass of malarial parasites was observed in the blood vessels of the mucous membranes of the stomach and the small intestine, with relatively few parasites in the rest of the body.[40] Presumably this was caused by a clone targeting a chemical receptor

[38] Smith (1982) on the history of the idea of typho-malarial fever among doctors in the USA; Baccelli (1881: 159–60); Hirsch (1883: 235–6); North (1896: 384–5); Sambon (1901*b*: 316); Marchiafava (1931: 21–2, 41).

[39] Baccelli (1881: 175) employed the definition of a subcontinuous fever given by Francesco Torti. Torti (1755: 190), in his famous book on the use of cinchona bark to treat malaria, defined pernicious periodic fevers (caused by *P. falciparum*) as follows: *Porro generaliter Febris haec Periodica Pernicialis vel talis est, ut perseveranter intermittat, efferamque naturam suam tantum prodat immani quopiam, & peculiari symptomate febrilem Paroxysmum comitante, cuius ferociam exitialem minime tollit intermedia quies, quae caeteroqui securitatem ex Hippocrate pollicetur: vel talis est, ut, intermissione paulatim deperdita, ad Continuam, & Acutam saepius quidem lente, nonnumquam & festinanter tendat, cum extensione gravium quorumdam, variorumque symptomatum ad tempus ipsum turbulentae quietis.* (Furthermore this periodic pernicious fever generally takes one of two forms: 1. there are persistent intermissions, and it prodigiously displays its own savage nature, and is accompanied by the characteristic symptom of a febrile paroxysm, and the rest periods of intermission, which would in other circumstances offer safety according to Hippocrates, have hardly any effect on its destructive nature; 2. the period of intermission gradually disappears, it develops into a continuous fever, frequently becoming acute slowly, but sometimes rapidly, with the extension of a variety of serious symptoms into the turbulent intermission periods.)

[40] Marchiafava and Bignami (1894: 111–12, 151–2); Marchiafava (1931: 31); T. Harinasuta and D. Bunnag in Wernsdorfer and McGregor (1988: i. 726).

found abundantly in the intestinal organs (cf. the explanation of placental malaria given above). In fact, the view has been expressed that a degree of gastro-enteritis occurs in all cases of malaria.[41]

The upshot of the discussion so far is that *P. falciparum* malaria and gastro-intestinal diseases are not alternatives, as Shaw reckoned, but in fact went hand in hand in bringing about high infant mortality.[42] In the city of Rome in antiquity, gastro-intestinal diseases were undoubtedly very common as a result of grossly inadequate hygiene, for example the fact that most habitations used cesspits (in order to recover faeces for use as agricultural fertilizer) for waste disposal and were not actually connected to the city's network of sewers. This has been shown beyond reasonable doubt by Scobie's remarkably detailed account.[43] Nevertheless it remains the case that in historical European populations gastro-intestinal diseases alone had less impact on the mortality regimes of human populations than malaria, where it was endemic. The combination of the two in Rome in antiquity should have generated a very high level of infant mortality.

Two major clinical syndromes, namely *severe anaemia* and *cerebral malaria*, have long been generally recognized and accepted as major manifestations of *P. falciparum* malaria when it attacks children. Both can be aggravated by concomitant bacterial infections, as indicated by indirect methods such as increased levels of leucocytes (white blood cells). Evidence is now emerging from research in Kenya in favour of the recognition of a third major syndrome of childhood malaria, namely *respiratory distress*. The suggestion is now being made that nearly 50% of all children who are diagnosed in hospital as suffering from acute respiratory diseases in that area, the heartland of the evolution of *P. falciparum*, may actually have malaria instead and should be treated with antimalarial drugs. This suggests that the effects in terms of morbidity of *P. falciparum* malaria where it is endemic are even greater than was generally thought until recently.[44]

41 De Korte (1899), cf. Murty *et al.* (2000) for a modern case study. The sort of account given by Wilson (1898) is still highly suggestive, even if Widal's test is no longer believed to be absolutely diagnostic for typhoid fever.

42 Writing about Sardinia, Tognotti (1996: 102) described: *la vera e propria strage degli innocenti che la malaria e le malattie gastro-enteriche provocano nell'isola tra i bambini appena svezzati.*

43 Amulree (1973: esp. 248–9 on malaria) was much less perceptive than Scobie (1986).

44 Modiano *et al.* (2001) on leucocytosis; research at the Wellcome Trust Tropical Overseas Unit at Kilifi in Kenya, directed by K. Marsh, and reported in the Wellcome Trust Newsletter *Q3* (1997: 12–14). James (1920: 158) described cases of *P. falciparum* malaria with

P. falciparum malaria can also directly kill non-immune young adults, such as immigrants to ancient Rome from regions where malaria was not endemic. Those were the cases which were most likely to be noticed by ancient doctors, who on the whole showed relatively little interest in the diseases of infants, judging by extant ancient medical literature.[45] On top of that, *P. falciparum* malaria can attack elderly people, whose immune systems may be weakening. In such cases it is possible to have severe infections marked by a high parasite count in the blood without any obvious fever, which is often suppressed in the elderly. Marchiafava and Bignami made these observations on cases in Rome in the nineteenth century and described in detail as an example the case of a seventy-year-old man, a watchman on the Rome–Tivoli railway line. Alexander of Tralles described a case of tertian fever in an old man in the sixth century AD, while a couple of centuries later Alcuin suffered from *P. vivax* malaria after the age of sixty. W. D. Hamilton, a prominent scientist in the field of evolutionary biology from Oxford, died recently at the age of sixty-three from malaria contracted on a visit to Africa.[46] Besides its own direct effects on elderly people, *P. falciparum* malaria can also strongly exacerbate both the heart diseases and the respiratory diseases whose main effects in terms of mortality are often felt most frequently by elderly age-groups. Marchiafava and Bignami noted several fatal malaria cases in which autopsy revealed not only malaria parasites but also extensive arteriosclerotic changes in the heart. Since they noted that acute dilatations of the heart occur during severe malarial fevers, pre-existing heart disease probably played a synergistic role in the death of these patients.[47] Malaria also had every chance to interact with the respiratory diseases of winter in central Italy in antiquity, since malarial infections often occurred as late as October or even November, as has been seen, after which the disease could take several months to run its course.

symptoms predominantly in the respiratory system. Chalandon and Kocher (2000) described a case of an adult with acute respiratory distress.

[45] Bertier (1990).

[46] Marchiafava and Bignami (1894: 93, 129–31); Marchiafava (1931: 36); Alexander of Tralles 1.5, *περὶ τριταίου*, i. 379, ed. Puschmann (1963): *ἐνδέχεται δ' εἶναι καὶ γέροντα νοσεῖν τριταῖον· ἐγὼ γοῦν αὐτόπτης ἐγενόμην τούτων ἐπί τινος γέροντος* (It is accepted that an old man can become sick with tertian fever; indeed I myself witnessed a case of tertian fever in an old man.); obituary of W. D. Hamilton in *The Times*, 9 March 2000.

[47] Marchiafava and Bignami (1894: 107).

This is clearly illustrated by the chronology of the most detailed malaria cases available from antiquity, namely the cases of Cicero's friend Atticus and his wife Pilia. Cicero's letters suggest that Atticus had contracted quartan fever (*P. malariae*) by 19 September 50 BC, by which time he had an unspecified fever. Although quartan fevers have a longer average duration than other types of malarial fevers, the Horton Hospital experiments showed that *P. malariae* does not manifest the latency and prolonged incubation periods of up to about nine months displayed by some strains of *P. vivax*. Consequently it can be inferred that Atticus was actually infected in August 50 BC. By 25 November it had become clear that Atticus had had a double quartan fever, although one of the two fevers had ceased, and the second fever was reported to Cicero to have become milder by then. Yet the troubles continued. Another letter, dating to the middle of December, shows that Atticus still had the fever, while his wife Pilia had contracted it as well. Eventually Cicero worked out for himself from Atticus' letters the periodicity of his quartan fever and knew on which days Atticus would be suffering. A letter of February 49 BC reports that Atticus' quartan fever had left him. Nevertheless a recrudescence of the illness must have occurred (more likely than a fresh infection at that time of the year), since letters dating to early March 49 show that Atticus was suffering again. A letter dating to 17 March 49 suggests that the fever was easing again. Another letter dating to 10 May 49 states that both Atticus and Pilia had lost their quartan fevers for good by then, although it is quite possible that some parasites persisted for the rest of their lives without causing any subsequent acute clinical symptoms. The case of Atticus, which ran from September 50 BC right through the winter to April 49 BC, demonstrates how easy it was for malarial infections to be running their course at the same time of the year as the respiratory diseases of winter.[48] Atticus' case

[48] Cicero, *Letters to Atticus*, ed. Shackleton-Bailey (1965–70), nos. 123.1 (Atticus had a fever when he arrived in Rome on 19 September 50 BC), 124.1 (by 16 October 50 BC Acastus had reported that Atticus had recovered), 125.2 (by 25 November 50 Atticus had lost one of his two quartan fevers, while the second was milder, while a second report claimed that the second fever had gone as well), 128.1 (Pilia had contracted quartan fever by mid-December 50), 128.3 (Cicero intended to visit a location in the Pontine Marshes at the end of December), 128.5 (Cicero begs Atticus to shake off his quartan fever), 130.3 (on 19 December 50 Cicero wrote that he did not know on which day Atticus' fever was due), 131.2 (by 25–6 December 50 Cicero had found out exactly when Atticus' fever was due), 154.4 (by 20 February 49 BC Cicero had heard that Atticus had lost his quartan fever, but Pilia still had hers), 168 (on 7 March 49 Cicero mentions Atticus' bad day, indicating that he still had the fever after all),

history is an absolutely typical example of the chronology of cases of quartan fever in central Italy in the past. In the early eighteenth century AD Lancisi described as follows the quartan fevers to which those who lived near wetlands were subject:

> The inhabitants of marshes . . . suffer from very prolonged illnesses, especially quartan fevers, which generally persist throughout the winter, and the following spring.[49]

Pliny the Elder made a few comments on the epidemiology of quartan fever:

> For nature has imposed some laws even on diseases: quartan fever never commences at midwinter or in the winter months. It does not occur in some people after the age of sixty, others, especially women, lose it at puberty.[50]

The case of Atticus shows that a quartan fever contracted earlier could run right through the winter, even if a new infection could not be contracted in the middle of winter. This is confirmed by modern research. In considering Pliny's other comments, it is necessary to remember that the periodicity of quartan fever can be concealed by the more powerful rhythms of other species of human malaria, and that once a person has been infected, parasites may survive virtually throughout that person's entire lifetime (Ch. 2 above). Quartan fever is mentioned in historical literature surprisingly often in view of its relative insignificance as an agent of mortality. One reason for this prominence is that it flourished in highly seasonal Mediterranean-climate regions in the past, to which it was highly adapted, more than it does in tropical countries today. Another reason for its visibility in historical literature is that the quartan periodicity is more regular than the periodicities of *P. vivax* or of *P. falciparum*. Celsus noted that quartan fevers were simpler

171.1 (again mentions Atticus' bad day, on 10 March 49), 173.3 and 175.2 (Atticus' bad day is mentioned in both these letters of 12 March and 14 March 49), 200.3 (by 3 May 49 Cicero has learnt that Atticus' fever is easier), 207 (by 10 May 49 both Atticus and Pilia have lost their quartan fevers), 208 (on 14 May 49 BC Cicero again states that Atticus is free of his fever, and a cold as well). Galen 9.561K described quartan fevers contracted in autumn as very long lasting. Atticus was a good example of this dictum.

[49] Lancisi (1717: 46): *paludum habitatores . . . longissimis morbis implicari, maximeque quartanis, quae per universam hyemem, et proximum ver aegros solent exercere.*

[50] Pliny, *NH* 7.50.170: *morbis quoque enim quasdam leges natura inposuit: quadrini circuitus febrem numquam bruma, numquam hibernis mensibus incipere, quosdam post sexagensimum vitae spatium non accedere, aliis pubertate deponi, feminis praecipue.*

than other fevers.[51] Consequently quartan fevers were more easily diagnosed than fevers caused by *P. vivax* or *P. falciparum*, which frequently took a quotidian form that was liable to be confused with typhoid fever, typhus, influenza, hepatitis, and other diseases. Dante mentioned quartan fever in the *Divine Comedy*:

> Like someone so close to the next bout of quartan fever that he already has blue nails, and trembles all over at the mere sight of cool shade, so I became at his words.[52]

The Jewish king Alexander Jannaeus was one individual whose death in 76 BC was associated with an infection of quartan fever lasting for three years, but also with excessive drinking and with severe exertions on military campaigns.[53] Although quartan fevers were generally not regarded as fatal (at least in comparison to other types of malaria), nevertheless there was a persistent view in the past that they were particularly dangerous for the elderly. Sydenham expressed this opinion in the seventeenth century, while a traditional Sicilian saying ran as follows: 'Quartan fever kills the elderly and heals the young'.[54]

Quintus Serenus expressed the opinion that quartan fevers could lead to death and should not be underestimated.[55] Nevertheless quartan fevers were often regarded in antiquity as 'weaker' than benign or malignant tertian fevers, even though they lasted longer on average, simply because quartan fevers only recurred every seventy-two hours.[56] Since Pliny recognized that there was

[51] Celsus 3.3.1: *et quartanae quidem simpliciores sunt. Incipiunt fere ab horrore, deinde calor erumpit, finitaque febre biduum integrum est: ita quarto die revertitur* (Quartan fevers are certainly simpler. They generally commence with shivering, then the heat erupts, and after the fever terminates there is an interval of two days; and so it returns on the fourth day.).

[52] Dante Alighieri, *La Commedìa. Inferno. Canto* XVII.85–8, ed. Lanza (1996): *Qual è colui che sì presso ha 'l riprezzo | della quartana c'ha già l'unghie smorte, | e triema tutto pur guardando il rezzo, | tal divenn'io alle porte parole.*

[53] Josephus, *BJ* 1.105 and *Ant. J.* 13.398; Kottek (1994: 34).

[54] Pitrè (1971: 218): *frevi quartana li vecchi ammazza e li giuvini sana.*

[55] Quintus Serenus, *Liber medicinalis* 48.895–8, ed. Pépin (1950): *nec tu crede levem dilato tempore febrem, quae spatium sibi dat, magis ut cessando calescat: letali quoque grassatur quartana calore, ni medicas adhibere manus discamus et herbas* (Do not believe that this delayed fever is mild, it gives itself a rest in order to return with even greater force: the quartan attacks with a deadly fever, unless we teach you to apply healing hands and herbs.).

[56] Pliny, *NH* 30.30.98–9: *in quartanis medicina propemodum nihil pollet* (in cases of quartan fever medicine has virtually no effect); [Aristotle,] *Problems* 1.56.866[a] εἰ γὰρ μὴ ἦν ἀσθενής, οὐκ ἂν τεταρταῖος ἐγένετο (for if it was not weak, it would not be a quartan fever). Galen 11.18–19K compared the onset of quartan and of tertian fevers. See also Ch. 2 above on quartan fevers. Horace, *Sat.* 2.3.290 also mentioned quartan fever.

no effective herbal remedy or any other cure for quartan fever, he decided to list a series of magical treatments for it.[57] It would not serve any useful purpose here to go through all the references in the works of Pliny and other ancient authors to remedies for malaria, except to stress that their sheer number demonstrates once again the frequency of malaria in antiquity and the difficulty of treating it. A typical example is his reference to an otherwise unknown doctor called Icatidas, who claimed that quartan fevers in men were terminated by sexual intercourse with women who were just beginning to menstruate.[58] Similar beliefs persisted in Italy until recently. In traditional Sicilian folk medicine bathing with the urine of a pregnant woman was considered a remedy for persistent cases of quartan fever. Several early modern Italian writers recommended eating bedbugs (*Cimex lectularius* L.) as a cure for quartan fever, following a tradition stretching back to antiquity. Quintus Serenus had recommended eating bedbugs, with eggs and wine, in cases of both quartan and tertian fevers. Pliny also noted this idea, although he believed that it was useless as a remedy for malaria.[59] Another recommended method was eating the liver of a seven-year-old mouse. A different approach to the problem was the recommendation to arise on three consecutive mornings at dawn, face a window or door, and then shut it suddenly after reciting a particular prayer.[60] These 'remedies' merely serve to show how helpless doctors were in the face of malaria, but they continued trying. Martial wrote an epigram about a doctor who treated cases of quartan fever.[61]

The sophist Favorinus (*c.*AD 85–155) delighted in displaying his skill as a speaker by discoursing on unlikely subjects, according to

[57] Lane (1999: esp. 639–43, 650–1) discussed the role of sympathetic magic in Pliny's remedies for malaria and also provided a list of relevant passages in the *NH*, esp.20.8.15, 26.71.115–17, 28.23.82–6 and 28.25–6.90–1, 28.28.111, 114, 30.30.98–104, and 32.38.113–16. Quintus Serenus, *liber medicinalis* 48.907, ed. Pépin (1950), suggested placing the fourth book of Homer's *Iliad* under those who feared the return of quartan fever, another striking instance of sympathetic magic.

[58] Pliny, *NH* 28.23.83: *Icatidas medicus quartanas finiri coitu, incipientibus dumtaxat menstruis, spopondit.*

[59] Quintus Serenus, *liber medicinalis* 48–9, ed. Pépin (1950); Pliny, *NH* 29.17.63; Dioscorides, *MM* 2.34.

[60] Pitrè (1971: 220–1) on Sicilian folk medicine. Similar beliefs occurred in other cultures, e.g. in Islamic medical literature. Ullmann (1978: 109) quotes the famous doctor Ar-Razi (Rhazes) as saying that 'quartan fever can be cured if the patient wears the unwashed and sweaty shirt of a woman in labour' (note also pp. 1–2 on the importance of malaria in Arabia).

[61] Martial 10.77.

Aulus Gellius. One such topic he chose was to produce a eulogy of quartan fever:

When he sought to praise Thersites and when he eulogized quartan fever, he made many observations on both topics which were charming and not obvious. He has left these comments written in his books. But in his eulogy of fever he even cited Plato as a witness, saying that he wrote that a person who got well and regained his full strength after suffering from quartan fever would afterwards be more surely and more constantly healthy.

Of course, since quartan fever was milder than tertian fevers, and since the advent of quartan fever was regarded in antiquity as a sign of the end of these more serious tertian fevers (in cases of mixed infections—see Ch. 8 below), Favorinus made life easy for himself by choosing a relatively easy subject to display his skill at rhetoric![62]

According to Galen's own account of his career at Rome and the intense rivalry between doctors in the city, his fame there commenced when he correctly diagnosed quartan fever in the case of the Peripatetic philosopher Eudemus, sixty-two years old at the time. This case also shows quartan fever lasting well into the winter, just as in the case of Atticus.[63] Elsewhere in his works Galen observed that quartan fevers could last for as long as two years, and that they were most frequently 'contracted' in the autumn.[64] He also commented that quartan fevers could be dangerous in conjunction with other diseases, especially tuberculosis, and could result in dropsy:

Quartan fevers are difficult to shake off and last for up to two years, longer than the other types of fever . . . some even become dangerous in association with symptoms of other diseases, with the result that they eventually produce tuberculosis or dropsy. Quartan fever is most frequent in autumn

[62] LiDonnici (1998: 85–7) drew attention to Aulus Gellius, *Noctes Atticae* 17.12.2–5: *Cum Thersitae laudes quaesivit et cum febrim quartis diebus recurrentem laudavit, lepida sane multa et non facilia inventu in utramque causam dixit eaque scripta in libris reliquit. Sed in febris laudibus testem etiam Platonem* [*Timaeus* 86a] *produxit, quem scripsisse ait qui quartanam passus convaluerit viresque integras recuperaverit, fidelius constantiusque postea valiturum.*

[63] Galen 14.606–14, 619, 624K, with Nutton's commentary in his edition of Galen's work *On prognosis*.

[64] Celsus 2.8.42 also regarded quartan fevers as prolonged if they appeared in the autumn (presumably new primary infections): *quartana aestiva brevis, autumnalis fere longa est maximeque quae coepit hieme adpropinquante* (Quartan fevers that start in summer are brief, while those that commence in autumn are usually long, and those which begin as winter approaches have the longest duration of all.). In 3.15–16 he gave his recommendations for treating quartan fevers.

and infections at that time of the year are most persistent. However infections in summer are shaken off very easily.[65]

Dropsy as a late manifestation of quartan fever, in other words gross oedema appearing usually after the symptom of fever has ceased to be apparent even if the patient still has a high rate of parasitaemia, is also mentioned in the Hippocratic *Airs, waters, places*. Dropsy in these ancient texts was identified by Kibukamusoke as the nephrotic syndrome of quartan malaria, a severe kidney disease probably caused by an immunological reaction to the parasite.[66]

Tuberculosis, singled out by Galen as a major complication of quartan fever, was the most dangerous of the respiratory diseases. The respiratory diseases were the second category of disease assigned importance by Shaw to explain excess seasonal mortality in ancient Rome. These diseases are indeed very well documented as a cause of morbidity and mortality in the winter months in early modern Italy, for example in the towns of Pontedera, Cascina and Ponte di Sacco in Tuscany in 1610 as described by Cipolla from the records of the Florentine health magistrates.[67] Nevertheless detailed modern studies have demonstrated, just as in the case of the gastro-intestinal diseases, that death rates from respiratory diseases alone are much lower than they are when malaria is present as well. For example, studies in Greece in the 1930s showed that death rates from pneumonia were much higher in villages where malaria was endemic than in otherwise similar villages where malaria was not present at all. Del Panta observed that the Tuscan Maremma in the nineteenth century, in the presence of endemic malaria, had a higher death rate from respiratory diseases than the average rate for the whole of Italy (including regions where malaria did not occur at all). In Guyana following malaria eradication, mortality from both acute (tuberculosis, pneumonia) and from chronic (asthma, emphysema, bronchitis) respiratory diseases dropped significantly, accompanying a reduction in the crude

[65] Galen 7.470K: [*τεταρταῖοι*] *δύσλυτοι καὶ χρονιώτεροι παρὰ πάντας τοὺς τύπους ὥστε καὶ μέχρι διετοῦς προβαίνειν . . . γίγνονται δὲ ἐνίοι καὶ κινδυνώδεις διὰ τὰ πεπλεγμένα αὐτῷ συμπτώματα, ὥστε φθίσιν τὸ τελευταῖον ἢ παρεγχύσεις ὑδρωπικὰς ἀποτελεῖν. πλεονάζει δὲ μάλιστα φθινοπώρῳ καί ἐστι μάλιστα δύσλυτος· ὁ δὲ θερινὸς εὐλυτώτατος.*

[66] Hippocrates, *Airs, waters, places* 10 (*ἐκ τῶν τεταρταίων ἐς ὕδρωπας*) (from quartan fevers to dropsy). Kibukamusoke (1973: 34) defined the nephrotic syndrome of quartan malaria as 'a symptom complex comprised of massive proteinuria, hypoalubuminaemia, gross oedema and hypercholestrolaemia'.

[67] Cipolla (1992: 35–9).

death rate and elimination of the periodic variations which had previously occurred simultaneously in the overall crude death rate and in the mortality rate directly attributed to malaria.[68] The recent research on the syndrome of respiratory distress as a product of *P. falciparum* malaria raises the possibility that some deaths which were ascribed to respiratory diseases in the past might actually have been directly caused by *P. falciparum* malaria. The synergistic interactions of *P. falciparum* malaria with other diseases were observed in antiquity:

> Patients with consumption, and those who suffer from other longer diseases, are very likely to be ill with semitertian fever.[69]

(Likewise Asclepiades said that a persistent quotidian fever is not without danger, and many cases have progressed from it to another disease, such as dissolution of the body or dropsy or whatever occurs through the weakening of the body.)[70]

In early modern Rome the interaction between *P. falciparum* malaria and the respiratory diseases was observed by everyone who did research there. For example, Rey and Sormani, in an article devoted to studying statistics for causes of death in Rome in the years 1874–6, noted that Rome had a higher death rate from various respiratory diseases than other major European cities whose data were considered for comparative purposes. They attributed this excess to the complications of malaria, even at a time when malaria was on the verge of final eradication from the city of Rome, and even though the highest death rates from these respiratory diseases occurred in the months of January to March:

> We cannot distinguish in the cause of death statistics between simple forms and those forms with a special character owing to the influence of malaria; nevertheless the observations which have been made permit an argument for a certain frequency of malarial complications in these disease syndromes.[71]

[68] Balfour (1936: 119) on Greece; Giglioli (1972) on Guyana; del Panta (1989: 48–9 n. 23); Gilles and Warrell (1993: 56) described pneumonia as a familiar complication of *P. falciparum* malaria.

[69] Hippocrates, *Epidemics* 1.24, ed. Littré (1839–61), ii. 674–5: *ἀτὰρ καὶ φθινώδεες, καὶ ὅσοι ἄλλα μακρότερα νουσήματα νοσέουσιν, ἐπὶ τούτῳ* [sc. *τῷ ἡμιτριταίῳ*] *μάλιστα νοσέουσιν.*

[70] Caelius Aurelianus, 2.63, ed. Drabkin (1950): *Item Asclepiades ait cotidianum perseverantem non sine periculo esse, atque multos ex eo in alium morbum induci, hoc est* ⟨*in*⟩ *corporis defluxionem aut hydropem venire et quicquid potest per corporis debilitatem accedere.*

[71] Rey and Sormani (1881: 131–2): '*Non possiamo sceverare quali siano le forme schiette e quali le*

The increased death rate from certain respiratory diseases was a distinctive feature of mortality patterns in the city of Rome, because some other Italian cities which were not affected by malaria, particularly in the north of Italy, had significantly lower death rates from respiratory infections. For example, a comparison of Genoa with London made a few years earlier had shown that Genoa was much healthier with regard to mortality from tuberculosis and chronic respiratory diseases. Consequently the author felt able to recommend travel to certain parts of Italy as desirable for the recuperation of English patients with chronic respiratory infections, although he advised such patients to stay away in the summer from areas affected by malaria.[72] Indeed there was even a school of thought that Rome itself was a desirable place to spend the winter for sick people from England, because of the mildness of its winter climate compared to that of London, but other nineteenth-century authors, noting that respiratory diseases were in fact widespread among the population of Rome in winter, rejected this advice. The respiratory diseases of the Roman winter were frequently attributed to the tramontane wind, just as malaria in the summer was associated with the sirocco.[73]

North wrote as follows:

Chronic malaria is not infrequently associated with a species of chronic pneumonia, which in the experience of the Roman physicians, is often accompanied by the development of tubercle.[74]

After considering the views expressed by more than fifty doctors and scientists on the question of the interaction of malaria and tuberculosis, Collari concluded that tuberculosis struggles to establish itself in a patient already suffering from malaria (perhaps because of the very high fever). However, a malarial infection of a person already suffering from tuberculosis rapidly exacerbates the effects of tuberculosis:

forme che assumono carattere speciale dall'influenza malarica; ciononondimeno, da osservazioni raccolte, ci è permesso di argomentare ad una certa frequenza della complicazione palustre in queste manifestazioni morbose [*sc. pleuro-polmonite e bronchite*].'

72 Chambers (1865); Blewitt (1843: 466).

73 Hoolihan (1989: esp. 472–3, 476–7, 479–82 on malaria) discussed this nineteenth-century debate about Rome as a health resort, cf. Wrigley (2000).

74 North (1896: 273). Sambon (1901*b*: 314–15) expressed the same view: 'in the Roman Campagna the most frequent complication is pneumonia which occurs in the winter or spring months, during relapses of the intermittent fevers'.

When patients with chronic malaria become infected with pulmonary tuberculosis, it assumes a slow course with a tendency towards sclerosis; whereas when a patient with pulmonary tuberculosis becomes infected with malaria, the tuberculosis tends to be aggravated and to assume a course which develops rapidly.[75]

A recent review of the question of the interaction between malaria and tuberculosis concluded that repeated malarial infections, even if asymptomatic, cause both quantitative and qualitative depression of the human immune system and thereby increase susceptibility to tuberculosis as well as the rate of development of tuberculosis infections, reiterating Collari's conclusion seventy years ago. This review considered the possibility that the continuing presence of endemic malaria may be one of the reasons for the persistence of tuberculosis in tropical countries (exacerbated now by its interaction with the HIV virus), in contrast to the gradual disappearance of tuberculosis in temperate countries over the last 150 years.[76]

Baccelli also observed that malaria can aggravate many other diseases.[77] Malarial interference with the T-cell component of the human immune system diminishes the immune response to other pathogens (e.g. the Epstein-Barr virus in relation to Burkitt's lymphoma).[78] Marchiafava and Bignami illustrated a different type of disease interaction with malaria when they described the case of a thirty-three-year-old epileptic man from outside the Porta del Popolo in Rome in whom a malarial infection brought on an epileptic fit. The interaction between malaria and epilepsy has also attracted attention in recent medical research.[79] We can hardly leave the topic of synergistic interactions between malaria and other diseases without briefly mentioning what might well become the most important interaction in tropical Africa, namely malaria's interaction with the HIV virus, even though it is not relevant to antiquity. One study found that 'HIV-1 infection progressively

[75] Collari (1932: 324): *quando la tubercolosi polmonare si impianta nei malarici cronici assume un decorso lento con tendenza alla sclerosi; mentre quando la malaria sopravviene in un malato di tubercolosi polmonare, questa tende ad aggravarsi e ad assumere un decorso rapidamente evolutivo.*

[76] Enwere *et al.* (1999), cf. Hovette *et al.* (1999) for recent research on the malaria–tuberculosis interaction.

[77] Baccelli (1881: 165–6).

[78] Whittle *et al.* (1984).

[79] Marchiafava and Bignami (1894: 120–1); Roy *et al.* (2000).

leads to an increased prevalence and severity of malaria in semi-immune adults'.[80]

Since the evidence of Galen and Asclepiades suggests that malaria was common in imperial Rome (see Ch. 8 below), the balance of probability in the light of modern medical research is that malaria dominated the mortality regime of the population in at least some districts of the city, just as it did in Grosseto, and in the surrounding countryside, even if a large majority of all deaths might have appeared to doctors in antiquity to be the result of other diseases. In the same way, when Corvisier observes that 'fever' (πυρετός) can only be directly connected to malaria in a small proportion of the cases in the Hippocratic *Epidemics*, this is only to be expected under the conditions of endemic malaria, and should not be taken to minimize its importance.[81] The paradoxical yet logical conclusion of modern research is that 'in very highly endemic centres the amount of sickness [sc. in adults] is greatly *reduced* in comparison with epidemic areas', because acute illness is concentrated in infants and children.[82] Nevertheless very highly endemic centres have higher overall mortality (including adult mortality) than areas where malaria has an epidemic character, never mind areas where it does not occur at all. Of course it is quite possible to have excess seasonal mortality patterns without the presence of malaria, but under those circumstances overall mortality for the whole population is lower, as the example of Florence shows.

5.3 Malaria and nutrition

The effects of malaria in antiquity were probably, in their turn, exacerbated by the moderate degree of chronic malnutrition that was arguably endemic among the masses in most if not all ancient populations. If the recent trend towards increasing average height in the populations of modern developed countries is to be attributed to improved nutrition, as seems to be the case, then it is an inevitable conclusion that malnutrition was endemic in historical populations. Specifically in the case of ancient Rome, preliminary reports of research on the skeletal population from Vallerano near

[80] Whitworth *et al.* (2000).

[81] Corvisier (1994: 305–8); contrast Grmek and Gourevitch (1998: 223–5), using the figurines from Smyrna in the Louvre as evidence for virulent *P. falciparum* malaria in the Hellenistic period.

[82] Hackett (1937: 174).

Rome, dating to the second century AD, have revealed a significant frequency of porotic hyperostosis attributed to iron-deficiency anaemia. Together with palaeodemographic evidence for low life expectancy (unreliable in detail, yet probably still reasonably accurate in respect of the overall impression given), and better-known literary evidence such as Soranus' comments on the frequency of rickets in the city of Rome (caused by vitamin-D deficiency), it suggests a rather low standard of life in the suburbs of Rome itself with repeated infections and widespread chronic malnutrition, especially of infants and children. Such problems continued, incidentally, throughout the history of the city of Rome. The explanation of Soranus' evidence was provided by Lapi in the eighteenth century. He admitted that rickets was common in Rome in his own time, even though he argued that Rome was healthier than its reputation suggested. Lapi states that rickets manifested itself in babies in Rome between the ages of nine months and two years. He attributed the prevalence of rickets in Rome to the custom of keeping infants inside rooms, with the unintended consequence that they were never exposed to ultraviolet radiation in sunlight, which converts the sterol 7-dehydrocholesterol in skin into cholecalciferol, vitamin D_3.[83] We may infer that infants were kept indoors because of the widespread fear of 'bad air' among the Roman population. Evidently their diet did not include fish-liver oils, the most important potential dietary source of vitamin D, and was inadequate to compensate for the lack of exposure to sunlight, but an inadequate diet was not the only reason for rickets in the Roman population, both ancient and early modern.

Malnutrition of the host adversely affects the parasite as well as the host. At the most extreme level, it has been suggested that severe malaria is rare in children suffering from the worst forms of protein-energy malnutrition, but the most recent research indicates that protein-energy malnutrition is indeed associated with increased morbidity and mortality from malaria.[84] A considerable body of research has found that deficiencies of several different vitamins reduce the reproduction rate of malarial parasites, leading to lower parasite counts in the blood of patients. For example, a

[83] Ricci *et al.* (1995); Soranus, *Gynaecology* 2.43–4; Lapi (1749: 75): *il tenere i bambini a marcire nelle camere lontanissimi dal sentire l'alito dell'aria esterna*; Levi (1945: 34, 76) on the association of rickets, general malnutrition, malaria and trachoma in Lucania; Davidson *et al.* (1979: 121–4).

[84] Shankar (2000) gives a detailed survey of all facets of the malaria-nutrition problem.

shortage of vitamin E, an antioxidant, predisposes erythrocytes to oxidant-induced premature lysis, rupturing the red blood cells before the parasites have completed their development inside. Deficiency of vitamin C has been reported to have the same effect in experiments on monkeys. Other experiments have shown that a diet deficient in a nutrient essential for the malaria parasite, para-aminobenzoic acid, suppresses infections of rats with the malaria species *Plasmodium berghei*. Para-aminobenzoic acid is a precursor of the important coenzyme folic acid. It has been suggested that a diet of pure breast milk, which contains a very small proportion of this chemical, may increase resistance to malaria among very young human infants, although there is no experimental proof, and human malaria parasites do appear to have some capacity to produce it themselves. Iron deficiency is inimical to the parasites, although its effects on the chances of the host's developing malaria are unclear; different studies have yielded conflicting results in both humans and animals. Nevertheless iron supplements to the diet do appear to increase the risk and severity of attacks of malaria. Studies in India have shown that a deficiency of riboflavin (vitamin B_2) *in vivo* results in a reduced parasite reproduction rate. The best sources of riboflavin are milk, eggs, and liver. It is relatively scarce in cereals, especially if they are highly processed.[85]

These are all deficiencies in the diet of the human hosts. Natural selection for resistance to malaria can also favour human genetic mutations that produce an *inherited* reduction in the uptake of essential nutrients, even if the nutrients are abundant in the diet. Some recent research in biochemistry at the hospital in Grosseto has produced very interesting results. It has been shown that there is a high frequency of familial flavin-deficient erythrocytes in Grosseto and in Ferrara in the Po delta (which had endemic malaria in the late medieval and early modern periods), but not in Florence, a city with no history of *P. falciparum* malaria. This inherited genetic condition causes a reduced uptake of riboflavin by red blood cells even if it is abundant in the diet. It is a product of natural selection for resistance to malaria under conditions of extreme pressure and illustrates the importance of malaria in the past as an agent of natural selection.[86]

[85] Das *et al.* (1988), with Davidson *et al.* (1979: 140–2); Gilles and Warrell (1993: 64); Har-El and Chevion (1997); Dobson (1997: 336–8).

[86] Anderson, *et al.* (1994), cf. Anderson *et al.* (1995).

Nevertheless, even with the help of this trait conferring a degree of resistance to malaria, life expectancy at birth in Grosseto in the nineteenth century was still only twenty (see Ch. 5. 4 below). In other parts of Italy, especially in the Mezzogiorno, Sicily, and Sardinia, where there was also intense pressure from malaria, other genetic traits conferring degrees of resistance to it attained high frequencies, notably glucose-6-phosphate dehydrogenase (G6PD) deficiency and thalassaemia. Research in Sardinia by Siniscalco and colleagues first provided strong support for Haldane's hypothesis, proposed in 1949, that heterozygotes for thalassaemia have increased resistance to *P. falciparum* malaria. Although that research was later criticized because of problems concerning the geographical origin of some of the populations of the villages which were studied, the new techniques of molecular biology have not only confirmed Haldane's idea over the last few years, but have also shown that the statistical correlation between high frequencies of thalassaemia mutations and the presence (past or present) of endemic malaria is valid not just in the Mediterranean, but all over the world wherever *P. falciparum* malaria occurs. Grmek has comprehensively studied the evidence for the history of thalassaemia, G6PD deficiency, and favism (which is associated with G6PD deficiency) in antiquity.[87] G6PD deficiency reduces the activity of a gene that plays a critical role in a biochemical cycle that eliminates oxidizing agents from erythrocytes. It is thought, in general terms, that this results in the premature lysis of red blood cells before malaria parasites inside have completed their development, although the precise mechanism remains unclear. Thalassaemia (predominantly β-thalassaemia in Mediterranean populations) is caused by mutations in the globin genes which lead to an imbalance in the correct synthesis of the α- and β-globin chains of the haemoglobin molecule. Malarial parasites digest haemoglobin to obtain amino acids for protein synthesis.

Thalassaemia and G6PD deficiency are very common in the modern populations of areas in the Mediterranean which were colonized by Greeks and Phoenicians in antiquity. They also occur

[87] Siniscalco *et al.* (1961); Weatherall (1997), Grmek (1983: 355–407), Ruwende and Hill (1998), Astolfi *et al.* (1999), and Vezzoso (1946) on thalassaemia; Greene and Danubio (1997) and Battin (1998) on G6PD deficiency. Lieber (1973) suggested that the Pythagorean communities in the cities of Magna Graecia arose from 'a society of favism sufferers'. This hypothesis is not impossible, but cannot be proved or disproved given the lack of contemporary evidence for the origin of these communities.

but are not so frequent in Latium and Tuscany. The problem arises of whether thalassaemia was introduced into Italy by Greek colonists in the eighth century BC or alternatively had been present in human populations in Italy since the Neolithic period.[88] These two possibilities are not necessarily mutually exclusive, since it is now known that numerous independent mutations for thalassaemia (and G6PD deficiency) in response to malaria have occurred in many different parts of the world.[89] Nevertheless, since high frequencies of thalassaemia in mainland Italy are mainly concentrated in regions that were colonized by Greeks, it is likely that Greek colonization did indeed play a critical role in the spread of thalassaemia in Italy. In view of Ampolo's convincing arguments about the free movement of individuals (e.g. Demaratus of Corinth) and groups from state to state in archaic central Italy, there is little doubt that there were plenty of opportunities for gene flow between populations in the archaic period.[90] Nevertheless the fact that different genotypes conferring degrees of resistance to malaria attained high frequencies in different regions demonstrates that Latium and Tuscany had a different population history in antiquity from the other areas in question, never having been colonized by Greeks or Phoenicians. Presumably the original Greek colonists of Magna Graecia brought common mutations for thalassaemia and G6PD deficiency with them from Greece. It has been suggested that the two commonest mutations for β-thalassaemia in Mediterranean populations were both spread by colonization. According to this hypothesis the β+IVS nt 110 mutation occurred in Greece and was then spread to southern Italy by Greek colonists, while the $\beta^{\circ}39$ mutation originated in the Levant and was carried westwards by Phoenician colonists to North Africa, Sardinia, and the Iberian peninsula. McCormick provides an interesting discussion of alternative hypotheses. The suggestion that thalassaemia was brought to the Mediterranean by the Mongols or Huns is in fact quite impossible because the thalassaemia mutations of East Asian populations are quite different from those of Mediterranean populations (this was not known at the time the idea was proposed because DNA sequencing was not yet possible at that time). How-

[88] Ascenzi and Balistreri (1977) discussed this question inconclusively.

[89] Weatherall (1997). About 200 different thalassaemia and 120 different G6PD mutations are now known.

[90] Ampolo (1976).

ever, the idea that thalassaemia might have been brought to Italy during the Byzantine period, as part of the internal diaspora of the Byzantine Empire which is the subject of the book containing McCormick's article, is more plausible. Nevertheless it remains the case that there were substantial population movements in Europe before the Byzantine period, and malaria was active in both Greece and Italy before the Byzantine period. Consequently it is virtually certain that the human genetic response to malaria commenced before the Byzantine period.[91]

A skeleton with a probable diagnosis of heterozygosity for β-thalassaemia was excavated at the Roman villa of Settefinestre. This skeleton might have belonged to an imported slave and is not a direct proof of the presence of malaria there, since thalassaemia is an inherited condition. Nevertheless it is a sign that the slave labour force of the Roman villas in western central Italy was in contact with malaria during the time of the Roman Empire. Marsh vegetation first appears in the palaeobotanical record at Settefinestre in the third century AD. However this alone cannot be used to date the spread of malaria at Settefinestre because *Anopheles* mosquitoes do not necessarily require large marshes for breeding, as has already been seen (Ch. 4. 2 above).[92] The commonest DNA mutation for G6PD deficiency in Mediterranean populations has been identified in the human skeletal remains from the infant cemetery at Lugnano in Teverina in Umbria, dating to the fifth century AD, using ancient DNA (see Ch. 4. 2 above).[93] Undoubtedly over the next few years the application of the techniques of molecular biology to human skeletal remains excavated on archaeological sites will greatly increase our knowledge of the history of these human genetic adaptations to malaria in antiquity.

Both dietary and genetically determined nutritional deficiencies occurred in the past in western central Italy. Both interacted with malaria. The aforementioned work on dietary deficiencies and

[91] Cao *et al.* (1989); McCormick (1998: 25–31). We can invisage three phases in the spread of thalassaemia and G6PD mutations in Italy: 1. archaic Greek colonization (particularly important in southern Italy, less important in northeastern Italy); 2. further immigration from the eastern Mediterranean in the Byzantine period (probably particularly important in northeastern Italy, around Ravenna); 3. the indigenous spread of antimalarial mutations owing to the pressure of natural selection by *P. falciparum* malaria *in situ* (in southern Italy since the fifth century BC at least, in northeastern Italy since the medieval period).

[92] Mallegni and Fornaciari (1985) on the skeleton number 26.203 from Settefinestre, a young woman nearly seventeen years old, diagnosed as suffering from thalassaemia; Celuzza (1993: 25–6, 230).

[93] Sallares, *et al.* (2002).

malaria was principally directed at the effects of malnutrition on the malaria parasite, without considering its effects on the human host. Thus there was a tendency in some medical literature to argue that malnutrition in the host reduced the severity of malaria infections. It may well be true that the severity of clinical symptoms is reduced if the host is significantly malnourished, because the reproduction rate of the parasites is reduced. However, it is undeniable that malnutrition is bad for the host, and any malaria infection is also bad for the host.[94] Recent re-evaluations of this problem suggest that the combination of malnutrition and malaria does increase human morbidity and mortality, even if the parasites suffer as well from malnutrition. Zurbrigg argued that acute hunger (as indicated by elevated grain prices) was statistically significantly associated with recurrent severe malaria epidemics in the Punjab between 1868 and 1940. The correlation was strongest in areas of the Punjab where crop failure was mainly caused by drought, thus bearing the closest resemblance to the conditions of semi-arid Mediterranean climate regions. She also argued that a link between severe malaria and starvation was frequently observed in the Punjab. It is likely, even if there is no specific evidence for it, that a similar link occurred in the famines that certainly occurred sometimes in Italy in antiquity, for example the great famine during the Gothic Wars in the sixth century AD described by Procopius, which forced people to eat bread made from acorns and to resort to cannibalism.[95]

Tognotti studied the diet of people who lived in areas of holoendemic malaria on Sardinia. The diet of such people was frequently short of meat, fish and dairy products, which often ended up in the towns even where animal husbandry was important. The fundamental component of the diet was bread, accompanied by prickly pears (not available in antiquity), other fruit, legumes, and mushrooms. Researchers on Sardinia felt that malnutrition was positively, not negatively, correlated with malaria.[96] Similarly researchers who worked in Rome and the Roman Campagna generally reckoned that poor malnutrition was associated with

[94] I. A. McGregor in Wernsdorfer and McGregor (1988: i. 753–67).

[95] Zurbrigg (1994) and (1997); Procopius, *BG* 2.20.15–33.

[96] Tognotti (1996: 106) quoted a doctor who said that: *ad Orosei…la frequenza dei casi di malaria era in 'ragione diretta della scarsa alimentazione'*. Levi (1945: 19) described the diet of the inhabitants of a region with endemic malaria in Lucania.

malaria. For example, Celli thought that peasants in the Roman Campagna in the nineteenth century had a very poor diet, eating a lot of maize (not available in antiquity), but not much else, although he thought that shepherds had a somewhat better diet, including both wheat and milk.[97] Other researchers and travellers reached similar conclusions. Gregorovius wrote as follows:

> If you live among them, you will see, too often, hunger-stricken human beings coming out of this paradise to meet you . . . [the peasant] would starve if it were not for the meal of the Indian corn [sc. maize], which is his sole nutriment.[98]

North carried out a short experiment which suggested to him that 'a few ounces of well-cooked red meat, and a liberal allowance of good red wine, will have an effect, equal, if not superior, to a large dose of quinine'.[99] North's experiment was not a double blind test, as is generally expected in modern medical research, and his conclusion undoubtedly understates the seriousness as a disease of malaria in non-immune individuals. In fact, the belief in the value of red meat and red wine against malaria, a disease of red blood (cells), was ultimately yet another instance of sympathetic magic. Other similar experiments yielded completely different results. For example, in 1897 Cirio, who had made his fortune in the fruit-canning industry, brought a colony of non-immune farming families from the Veneto in the north of Italy to the Pontine territory and provided them with very large rations of meat, wine, and other commodities to test this theory.[100] Although the results of the experiment were disastrous, they do not necessarily exclude the possibility that malnutrition might exacerbate the severity of malarial infections, perhaps particularly in individuals with some degree of immunity. The increasing use of quinine, especially after the Italian government made it available to all free of charge by

[97] Celli (1900: 170–2); Mallegni and Fornaciari (1985) found that the skeletons from Settefinestre had a high zinc content and a low strontium content, indicative of a diet rich in meat and short of vegetables. They rightly interpreted these results in terms of a pastoral economy in the Maremma in late antiquity. Ciuffoletti and Guerrini (1989: 97–100) described the traditional diet of the inhabitants of the Maremma. Similarly Arlacchi (1983: 176–9) commented on the very poor nutritional state in the nineteenth and early twentieth centuries of the inhabitants of the Crotonese, a population severely affected by malaria. He noted the consequence that the average height of these people was 10 cm less than the regional average, cf. Douglas (1955: 130).

[98] Gregorovius (1902: 82).

[99] North (1896: 161).

[100] Snowden (1999: 33–4); Hackett (1937: 28).

a series of laws passed in the years 1900–4, a few years after North's research, was probably the most important single factor in the reduction of mortality from malaria in Italy.[101] Nevertheless North's primitive experiment and the general experience of observers at the time indicate how important malnutrition may have been in the past. De Felice, after considering comments on the matter in the writings of the early modern Roman agronomists, concluded that animals were better fed, on the lush pastures of Latium, than most of the local inhabitants![102]

Of course the early modern period had its own peculiar problems, which were not necessarily shared by antiquity. Gregorovius attributed the poor diet of peasants in Latium to the economic effects of high taxation. Reliance on maize, imported from the western hemisphere after Columbus, introduced the possibility of pellagra. This was not a problem in antiquity.[103] Nevertheless the general impression given, namely that malnutrition did significantly aggravate the effects of malaria in the Roman Campagna in the early modern period, is very important. The balance of probability is that the sort of malnutrition now being revealed by the Italian studies of the Vallerano skeletal population in the second century AD increased both mortality and morbidity from malaria in western central Italy in Roman times. One vital but imponderable question about antiquity is the question of how well fed were slaves. There is no way of knowing if the recommendations for rations given by the ancient Roman agronomists were widely followed in practice, but even if they were, slaves might still have had an impoverished diet. In his recent discussion of this topic, de Martino concluded that the recommendations of the agronomists would have given slaves a very poor diet:

It can be inferred, based on the sources, that there was without doubt a

[101] Florence Nightingale noted how it emerged during a papal visit to the Santo Spirito hospital in Rome in January 1848 that patients were actually only being given half the quantities of drugs prescribed to them in order to save money, in spite of the hospital's enormous endowments (Keele (1981: 183)). The fact that drugs were known does not necessarily mean that they were available in the right quantities (and at the right price) to those who needed them. That is why the laws of 1900–3 were so important. Corso (1925) gives the text of these laws. Pope Innocent III founded the Santo Spirito hospital near Castel S. Angelo in 1198 (*Regula ordinis S. Spiritus in Saxia*, ed. Migne, *Pat. Lat.* vol. 217, cols 1130–57).

[102] De Felice (1965: 96): '*Per tutto il Settecento e buona parte dell'Ottocento si può dire che in gran parte del Lazio il bestiame era meglio alimentato della massa dei contadini*'.

[103] Livi-Bacci (1986) on pellagra.

great scarcity of animal protein, insufficient fats and a lack of very important vitamins, C and D, with A being very rare.[104]

A clinical trial in Papua New Guinea concluded that symptomatic episodes of *P. falciparum* malaria were about 30% less frequent in young children who received vitamin-A supplements than in those who received placebos.[105] Much older writers also raised the question of the importance of nutrition in relation to malaria. Carmichael described one case that was reported in the *Necrologi* (or death registers) of Milan, in which the death of a fifty-year-old man on 7 August AD 1479 was attributed by one doctor to 'simple tertian fever with a bad regimen'. A second doctor who also examined this case concluded that the poor diet must have played a significant role, since tertian fevers alone were usually not fatal.[106] At the end of the eighth century AD Alcuin gave the following advice to a disciple travelling to Italy:

> Italy is an unhealthy country. It provides harmful foods. Consequently exercise extreme caution with regard to what, when, or what sort, or which foods you eat; and above all avoid being constantly drunk, since it is from the heat of wine that intense fevers tend to strike the unwary.[107]

The urban poor in Rome in antiquity faced food shortages, certainly from time to time, and perhaps chronic food shortages as well. The 'Mediterranean diet', whose health advantages have attracted so much publicity in recent years, is of course a modern invention. As has been seen already, peasants in many parts of early modern Italy relied heavily on foods like maize and prickly pears which were not available in Europe in antiquity.[108] Even aspects of the ancient diet apparently conducive to good health probably made little difference to mortality and morbidity from

[104] De Martino (1993: 422): '*Da tutto quel che precede si desume che stando alle fonti, vi era senza dubbio grande scarsità di proteine animali, grassi insufficienti e mancanza di vitamine molto importanti, la C e la D, scarsissima la A*'.

[105] Shankar *et al.* (1999).

[106] Carmichael (1989: 39).

[107] Alcuin, *epistolae* 281, ed. Duemmler (1895), *Monumenta Germaniae Historica. Epistolae*, iv. 439: *Italia infirma est patria et escas generat noxias. Idcirco cautissima consideratione videas, quid, quando, vel qualiter, vel quibus utaris cibis; et maxime ebrietatis assiduitatem devita, quia ex vini calore febrium ardor ingruere solet super incautos.*

[108] Ferro-Luzzi and Branca (1995) defined 'the Mediterranean diet' as the diet of southern Italy in the 1960s. If defined as such, it is of course a legitimate object of research, but it must be recognized that the subject as defined has little relevance to antiquity. Ferro-Luzzi and Branca noted, for example, the importance in 'the Mediterranean diet' of the tomato, which was not available in Europe before Columbus.

infectious diseases like malaria. A good example is emmer (*Triticum dicoccum*), the most important type of wheat cultivated in Latium and Tuscany in the Iron Age and the early stages of Roman history, as shown both by palaeobotanical remains and literary sources. Emmer comprised 58% of the cereals from excavations of the archaic layers of the Roman Forum; einkorn (*T. monococcum*) comprised 10%, barley (*Hordeum vulgare* 32%), and there was no naked wheat at all. Research at Etruscan sites such as Acquarossa and Podere Tartuchino is producing broadly similar results, sometimes with a greater importance of barley over all types of wheat. Rations of emmer are mentioned in the *Twelve Tables*, confirming its importance in the fifth century BC. By the Roman Empire cultivation of emmer in Latium had declined in favour of poulard wheat (*T. turgidum*), even though emmer was suitable for the wet conditions of Latium and contains a higher proportion of protein than modern varieties of bread wheat (*T. aestivum*), but it continued to be important in more mountainous regions such as Umbria. By the early modern period cultivation of emmer (*farro*) had decreased to the point that statistics for its production were not recorded in the documentary investigations into Latin agriculture of that period, such as the *Inchiesta Iacini*. Nevertheless it continued to be grown by a handful of farmers and data survive for emmer prices on the markets of Rome in the nineteenth century, allowing its price ratio with respect to naked wheats to be firmly established. Within the last twenty years emmer has been rediscovered by Italian botanists being cultivated on a few farms in isolated areas of the Apennines, after it was thought to have become extinct in Italy. It is now sold and marketed as a health food in Italy (*farro perlato*) because some research has suggested that consumption of emmer reduces the risks of heart disease and cancer of the colon, perhaps because of its high fibre content. However, these diseases attain their highest frequencies among elderly people. Population age-structures produced by endemic malaria show that most people would have been killed by infectious diseases before they became old enough for intestinal cancers, for example, to become a major cause of death. Consequently it is unlikely that consumption of emmer in western central Italy in antiquity did significantly improve the health of the population in practice.[109]

[109] De Martino (1979); Ampolo (1980: 15–19); Hjelmqvist (1989); Perkins and Attolini (1992); Rendeli (1993: 140); *Twelve Tables*, 3.4; Pliny, *NH* 18.19.83–4; Sallares (1991: ch. 3, esp.

Before leaving the topic of the interaction of malaria and malnutrition in humans, it is important to remember that other parasites may also figure in this equation. For example, the presence of intestinal worms may help to cause malnutrition in cases of malaria. Some research in Madagascar suggests that treatment with antihelminthic drugs considerably reduces the frequency of severe malaria attacks.[110]

5.4 Comparative demography of malaria in Italy and England

A fully comprehensive population history of Italy in more recent times, based on local studies (akin to the English parish studies) of both mortality and fertility covering a long period of time from all over the country, has yet to be produced by Italian demographers. To see how endemic malaria drastically altered demographic patterns at the local level against the background of a historical situation where large parts of the population of a country as a whole were quite healthy, it is necessary to turn to Britain and consider the sort of data that were used in Wrigley and Schofield's *Population History of England 1541–1871* and in subsequent research. Although England is too cold for *P. falciparum* to have ever become endemic in the past, it is warm enough for *P. vivax*. *P. vivax* only requires a temperature of 15–16°C to complete sporogony inside the mosquito in summer, and many of its strains in temperate climate regions have developed a certain tendency in the direction of avirulence to enable it to survive long, cold winters in northern Europe inside humans.[111] *P. vivax* existed in Britain in the past in the Westminster

481 n. 101); Strabo 5.2.10.228C noted the predominance of emmer over naked wheats in the mountains of Umbria in his own time: [ἡ Ὀμβρική] ἅπασα δ' εὐδαίμων ἡ χώρα, μικρῷ δ' ὀρειοτέρα, ζειᾷ μᾶλλον ἢ πυρῷ τοὺς ἀνθρώπους τρέφουσα (the whole of Umbria is prosperous, but rather hilly; it feeds men with emmer rather than wheat); De Felice (1965: 121); ch. on *Movimento dei prezzi delle derrate alimentari*, in *Monografia* (1881: 350, 354–6); Toubert (1973: i. 244) noted references to *far* in the *Statuti della Provincia Romana* from the thirteenth and fourteenth centuries AD; Perrino and Hammer (1984).

110 Cited by Mutapi *et al.* (2000), who observed themselves that there appear to be immunological cross-reactions between malaria and schistosomiasis.

111 Malaria parasites generally overwinter in human hosts rather than vector mosquitoes (Hackett (1937: 209–12)) because sporozoites tend to degenerate after about a month inside the salivary glands of mosquitoes (Garnham (1966: 369)). This traditional view has been confirmed and reinforced by recent research employing the new techniques of molecular biology (e.g. Babiker *et al.* (1998) and (2000), Hamad *et al.* (2000)) which has shown that subclinical asymptomatic infections do persist in some people, during seasons of the year when

and Lambeth districts of London, in the coastal marshes of Kent and Essex, the East Anglian Fens, parts of the south coast, possibly also Bridgewater in Somerset and the Ribble valley in Lancashire, and probably as far north as the East Lothian area of Scotland. Robert Hamilton described the course of the typical epidemics of vivax malaria at King's Lynn in the late eighteenth century.

> if a very wet winter and spring are succeeded by a very hot and dry summer, in which the ditches and marshes are nearly dried up, it is generally epidemical, and spreads widely around us. It most commonly appears about the middle of August, and lasts till the ditches are filled with water, the marshes somewhat covered, which, with a frost, usually puts a period to its raging in that form, for that season; for it now generally changes to the type of a genuine intermittent. This is it's [*sic*] common mode of termination, as the winter advances; but when it rages with extensive violence, during the autumnal months, it puts on a variety of morbid degeneracies, many of which, by persons unaccustomed to its Proteus-like changes of type, would be taken for a very different disease.[112]

Hamilton's description illustrates in a historical context the very important conclusion reached in Chapter 2 above about the importance of quotidian fevers. It was only in the final stages of the annual epidemic that the tertian periodicity manifested itself. Until then the fevers of vivax malaria generally took a quotidian form. Similarly Sydenham stated that epidemical agues in the autumn were at first accompanied by a continual fever.[113] Hamilton emphasized the association of *P. vivax* malaria with marshes which tended to dry up during the summer, an association also found in Italy. He observed that what he called the 'marsh remittent fever' of England was the same disease as the tertian fever of Minorca. Hamilton also noted that during the epidemic of 1783, a very hot year, many agricultural labourers were attacked during the harvest. In addition, he made interesting observations about the possibility of contagion at a time when the miasmatic theory of 'bad air' still prevailed. He commented that the marsh fever was observed to spread through large families, starting with one or two cases,

mosquito activity is low, at levels undetectable by microscopic examination of blood smears, not only in the case of *P. vivax* but also in the case of *P. falciparum*, even in geographical regions with low levels of transmission of malaria (traditionally thought to be an impediment to the development of acquired immunity). *P. falciparum* malaria now seems to be in many cases a more chronic disease than generally used to be thought, cf. Garnham (1966: 413).

112 Hamilton (1801: 27–8).
113 Meynell (1991: 124).

'which looked very much like the effects of contagion'. The use of 'Peruvian bark' (cinchona) as a treatment was also discussed. This probably played a major role in the decline of vivax malaria in England.[114]

The last major epidemic of malaria in England occurred in 1857-9, during two very hot summers, but three-quarters of the population of the Isle of Grain in Kent suffered from malaria in 1876. Cases of malaria occurred as recently as 1921 in that locality, following the reintroduction of *P. vivax* by soldiers returning from the campaign in the Balkans in 1916. The possibility of the reintroduction of malaria to the Isle of Grain was a matter of concern to the local public-health authorities in Kent as recently as 1952–4.[115] Malaria could have been transmitted in England by *Anopheles atroparvus* and *A. plumbeus*.[116] *P. vivax* malaria is generally regarded in modern medical literature as a considerably milder disease than *P. falciparum*. It seldom kills well-nourished, otherwise healthy people by itself. The Hippocratic *Epidemics* noted that tertian fever was not dangerous (see Ch. 2 above). More recent historical evidence from Italy supports this view. For example, Cipolla described the reaction of Alessandra Macinghi Strozzi, who in 1459, upon learning that her son in exile at Naples had tertian fever, 'took comfort because you do not die of tertian fever, unless other illnesses intervene'. The last four words are crucial, because her son did die after all.[117] The evidence from the English parish studies suggests that in historical contexts where it could operate in synergy with other infectious diseases, and where its targets probably suffered from malnutrition, *P. vivax* malaria produced extraordinary changes in the mortality regimes of human populations.[118] Sydenham observed the association in infants of rickets and 'coughs and other symptoms of being in a consumption' alongside autumnal

[114] Hamilton (1801, 39, 43, 73ff.).

[115] Dobson (1997: 320–7, 349); Smith (1956).

[116] Snow (1990) described the mosquitoes of England. Shute (1951) described the laboratory culture of *A. atroparvus*. He noted that to breed it one only needs some grass with some soil attached to the roots in a basin of rainwater about two feet in diameter.

[117] Cipolla (1992: 69); Garnham (1966: 139) stated that he had observed fatal cases of *P. vivax* malaria in young children.

[118] Modebe and Jain (1999) described a recent case of severe complications caused by *P. vivax* malaria. Dobson (1989: 269) concluded that vivax malaria had less effect on colonists in the United States than it did in England because of a relative shortage of other diseases in North America, even though *P. vivax* malaria was probably imported from England (Kukla (1986)).

intermittent fevers, although he noted that ague was more dangerous to the elderly than to infants.[119] There is no doubt that *P. vivax* was indeed responsible for the demographic patterns found in the English marshlands, because the parasites were found in the blood of the last few people to have indigenous English malaria, in the early years of the twentieth century. In addition, quinine, which would not have substantially helped sufferers from other diseases, relieved the symptoms.

Important research by Mary Dobson discovered that before the nineteenth century crude death rates were as low as 20–30 per 1,000 in many rural parishes of south-east England, but in the marshy areas of Kent and Essex crude death rates were over 50–60 per 1,000, sometimes as high as 80 per 1,000. It is very important to appreciate that the excess mortality produced by malaria is not a marginal phenomenon. The differences in overall mortality levels between the parishes most severely afflicted by *P. vivax* malaria and the healthiest parishes in the same area were *quite literally of the order of 300–400%*. Similarly, comparing fifteen marsh and fifteen non-marsh parishes between 1551 and 1837 in the same parts of England, Dobson found that crude burial rates in the marsh parishes *exceeded 100 per 1,000* in about 11% of the years, while such high burial rates were only attained in non-marsh parishes about once every two centuries on average. These staggeringly high mortality rates occurred in the malarial districts at a time when the population of the rest of England was increasing and was quite healthy. Life expectancy at birth was slashed in the malarial regions. Dobson reported that in three North Shore malarial parishes in north Kent it was 33 years, compared to no less than 58 years in four parishes in the East Downs where *P. vivax* was not endemic, in the early nineteenth century.[120] The difference between the life

119 Meynell (1991: 122, 135).

120 Dobson (1997) is fundamental on malaria in England, esp. pp. 133–49 and 172 on local variations in death rates. Many of the results of her long book are summarized in her (1980) and (1994) articles. See also Reiter (2000). One might also compare the situation around Valencia in Spain in the eighteenth century (Palmero (1994)). Palmero and Vega (1988,: 351) translated and quoted the following comments of Francisco Llansol, written in 1797: 'the dwellers of the Upper Riverside in certain towns like, for example, Cárcer Valley, Castellón, Alberique and so on, are likely to have poor health. They are pale yellow-skinned, there are many women with swollen bodies, and people living in these areas, in general, are likely to have a short life . . . when people die, they are mostly between forty and fifty years of age'. Jagailloux (1986: 262) regarded the debilitating effects of *P. vivax* malaria as an important factor in mortality in Egypt.

expectancy of 33 in malarial parishes in England and the life expectancy at birth of 20 in Grosseto only a few years later represents the difference between *P. vivax* and the more virulent *P. falciparum* (see also discussion below). However, *P. vivax* was also very common in Mediterranean countries in antiquity and will have made its mark on mortality patterns there as well. Where both species of malaria coexist in an endemic form, as in western central Italy in the past, *P. falciparum* often tends to outcompete *P. vivax* because of its higher rate of reproduction, especially in very hot years when environmental conditions are most favourable for it.[121]

Some recent research in Vanuatu in the Pacific has generated the hypothesis that prior infections with *P. vivax* may confer some immunity to subsequent infections with *P. falciparum*. The modern experience that *P. vivax* is a relatively mild disease is then invoked to suggest that cross-immunity could give rise to a low incidence of severe malaria even under holoendemic epidemiological conditions. It is not clear if these results can be generalized. The artificial infection experiments at Horton Hospital in England yielded different results, suggesting that *P. vivax* is unable to prevent subsequent infections with *P. falciparum*, although *P. falciparum* does inhibit *P. vivax*.[122] In any case this particular idea does not seem relevant to European historical populations, such as Grosseto and Croton (see below), where both *P. vivax* and *P. falciparum* were undoubtedly present yet the demographic effects of malaria as a whole on the human population were very severe. Mathematical modelling of the interaction of *P. falciparum* and *P. vivax* in the human bloodstream yields complicated results depending on the relative timing of the various infections. An existing *P. vivax* infection can reduce the parasite load in the blood of a subsequent *P. falciparum* infection by as much as 50%, but on the other hand, a subsequent *P. vivax* infection or even relapse can actually exacerbate an earlier low-level, asymptomatic, *P. falciparum* infection. In

[121] Gill (1938: 36–9) noted that in northern Italy *P. vivax* infections in autumn tended to produce acute attacks immediately after the normal incubation period. In other words there was no delay of the primary attack until the spring as in Holland, for example. Consequently the spring wave of *P. vivax* malaria in northern Mediterranean countries was probably mainly composed of relapses, not primary attacks. The hotter the year, the more likely it was that *P. falciparum* would overshadow *P. vivax* and *P. malariae* in the late summer and autumn in Mediterranean countries. Sorgoni (1832) noted that pernicious symptoms were more frequent around Narni the greater the difference between the daytime and the night-time temperatures.

[122] Maitland *et al.* (1997); contrast Covel and Nicol (1951) and Shute (1951).

the case of simultaneous infections with the two different species, *P. vivax* often fares poorly.[123] It is difficult to generalize about the demographic consequences at the population level of the *P. vivax*–*P. falciparum* interaction because of the complicated results found in individuals. Nevertheless the fact remains that the evidence from more recent periods of European history discussed in this chapter suggests that being infected with *P. vivax* in the past was not necessarily any better in the long run than being infected with *P. falciparum*. As far as antiquity is concerned, Galen's comments in the second century AD indicate that *P. falciparum* infections tended to occur at an early age then (Ch. 8 below). This suggests a different epidemiology from that described recently in Vanuatu. This Pacific island group seems to lack the full range of genotypes of *P. falciparum* found in Africa and Eurasia, as is suggested by a greatly reduced range of polymorphism in the merozoite surface protein genes.[124] Presumably a large proportion of the organism's range of genetic polymorphism failed to make it across the ocean during the human population movements which colonized the Pacific islands. Alternatively they might have been eliminated when the human population of Vanuatu passed through a severe bottleneck within the last two hundred years. Either way, the evolution of malaria in Vanuatu, an example of evolution in an isolated island population, is not directly relevant to the historical situation in Europe, although it is certainly of considerable intrinsic interest.

In passing, it should be noted that *P. vivax* probably already existed and operated in the way described by Dobson in Britain in classical antiquity. The disease of the marshes that severely affected the army of Septimius Severus in Scotland in AD 208 may well have been *P. vivax* malaria, as Bordier suggested a long time ago.[125] In the seventeenth century Doni expressed the opinion that quartan fever was unknown in Scotland, implying that he believed that tertian fever did occur there.[126] An inscription, now lost, from Risingham

[123] Mason and McKenzie (1999). Bruce *et al.* (2000) suggested that in tropical regions where malaria is continuously active there is density-dependent regulation of infections that transcends species as well as genotype, resulting in non-independent sequential episodes of infection with each species.

[124] Maitland *et al.* (2000).

[125] Bordier, cited by Fraccaro (1919: 86 n. 2), drew attention to Cassius Dio 77.13.2: ὑπὸ τῶν ὑδάτων δεινῶς ἐκακοῦντο (they were badly affected by the waters). Herodian 3.14.6–8 emphasized the marshiness of Britain in the early third century AD.

[126] Doni (1667: 7): *in Scotia quartanam febrim ignotam esse credi potest.* It will be remembered that the British mosquito vector *A. atroparvus* is a poor carrier of *P. malariae* (Shute (1951)), although it could have been transmitted by *A. plumbeus* instead.

(Roman Habitancum), a Roman fort north of Hadrian's Wall, has been frequently cited as a dedication to the goddess of tertian fever. Unfortunately this reading of the text is a guess made in the early seventeenth century. It appears to be unreliable.[127] Dobson noted that the opium poppy was widely cultivated in East Anglia in the early modern period to provide opium, which was used to relieve the symptoms of *P. vivax* malaria. It did not create addiction under those circumstances. Archaeobotanical finds of opium poppy (*Papaver somniferum*) from Iron Age–Roman archaeological sites in East Anglia show that it was already being cultivated there by Roman times, probably for the same reason. Localized extreme variation in mortality patterns caused by malaria was probably already occurring in Roman Britain.[128]

Although there is no direct evidence available, owing to the shortage of written sources for Roman Britain, the balance of probability is that the constant movements of soldiers, merchants, slaves, and administrators between Britain and other parts of the Roman Empire introduced malaria to Roman Britain, if it was not already present. As was seen earlier, the evidence of Gregory of Tours shows that malaria was frequent and familiar in France in the sixth century AD (Ch. 4. 1 above). Moreover Pliny mentions tertian fever in the territory of the Tungri in Belgium and Holland in the first century AD.[129] *P. vivax* malaria was present in these areas by then, only a short distance from Britain. Alcuin in the late eighth century AD is a specific case of an individual who travelled from Britain to Rome, became infected with 'Roman fever', and brought the parasites back to northern Europe with him. He contracted malaria during his visit to Rome in 798 and was severely affected by it thereafter. Alcuin presumably had mixed infections,

[127] The text *Deae Tertianae sacrum Ael(ia)* (*CIL* 7.999) was accepted by Weinstock in Pauly-Wissowa *RE* s.v. *Tertiana* (vol. v A.1 (1934), column 822), Schaffner in Cancik and Schneider (1998), s.v. *Febris*, and Burke (1996: col. 455, p. 2269). However, it was rejected in favour of the alternative reading (*Deae Dianae sacrum Aelia Timo posuit votum solvens laeta libens merito*) found in the manuscript tradition by Collingwood and Wright (1995: 397 no. 1209), who rejected the lectio difficilior. The inscription *CIL* 12.3129 is a dedication to quartan fever in the third century AD from Nemausus in Gallia Narbonensis (*quartanae votum reddet libens merito Byrria Severilla*).

[128] Dobson (1997: 304–6); Pryor (1991: 130); Cameron (1993: 10, 54–5) described malaria as common in Anglo-Saxon England; the *lencten-ádl* of Old English texts probably signified spring relapses of *P. vivax* malaria, according to Bonser (1963: 403–5); Darby (1983: 52, 95, 107, 112, 146, 150–2, 176) on malaria in the East Anglian fens and its disappearance in the nineteenth century; Nicholls (2000).

[129] Pliny, *NH* 31.8.12.

since he emphasizes that he had quotidian fevers. The timing of one episode of fever, after Easter 801, sounds like a typical spring relapse of vivax malaria, but it is possible that he contracted falciparum malaria as well in Rome.[130] There were undoubtedly other such individuals, since Bede and Paulus Diaconus both commented on the popularity among the Anglo-Saxons of pilgrimages to Rome in the early medieval period.[131] More than one Anglo-Saxon king died in Rome. Bede related the story of the miracle of a young boy who was cured of a long-running intermittent fever by standing on the tomb of St. Oswald, king of Northumbria (633–642), at Bardney Abbey in Lincolnshire. This text constitutes some direct evidence for malaria in England *c.*AD 700 (at that time in the same monastery a little boy was severely affected by a prolonged fever. One day he was awaiting the hour of the attack,when one of the brothers entered and said to him: 'my son, shall I teach you how to cure yourself from the trouble of this debilitating disease? Get up, enter the church, and go to Oswald's tomb, remain there, stay quiet and remain by the tomb. Make sure that you don't leave the church, or move from the spot, until the hour when your fever is scheduled to leave you. Then I will enter the church, and lead you away.' The boy followed the brother's instructions. While he sat by the tomb of the saint the disease never dared to touch him; indeed it was so terrified that it flew away, and did not dare to touch him on the second day, or the third day, or ever again.')[132]

[130] e.g. *febrium flagellatione . . . remanet cotidianus labor eiusdem castigationis*; *tamen febrium castigatio cotidianis diebus nos non reliquit* (By the lashing of fevers . . . the daily labour of the very same chastisement continues; the daily chastisement of fevers does not leave me.) Alcuin, *Epistolae* 218, 221, ed. Duemmler (1895), *Monumenta Germaniae Historica. Epistolae*, iv. 362, 365, cf. *Epistolae* 146, *febris et infirmitas me fatigatum habet* (fever and weakness keep me tired), and 149 (*febricitantem*); Gaskoin (1904: 99, 110, and 124). Peter of Blois is another example of a person who returned to northern Europe after contracting malaria in Italy. He developed semitertian fever in Sicily in AD 1169, was treated at Salerno, and then returned home with a detailed knowledge of malaria to the Loire valley region of France, where in a letter to his friend Peter *medicus* written *c.*1170–5 he described another case of semitertian fever in the knight Geldewin, which may also have been imported—Peter of Blois, *Letter* 43, discussed by Holmes and Weedon (1962).

[131] Bede, *Historia Ecclesiastica*, 5.7, ed. Plummer (1896); Paulus Diaconus 6.37.

[132] Bede, *HE* iii.12: *tempore fuit in eodem monasterio puerulus quidam longo febrium incommodo graviter vexatus: qui cum die quodam sollicitus horam accessionis exspectaret, ingressus ad eum quidam de fratribus: 'Vis,' inquit, 'mi nate, doceam te quomodo cureris ab huius molestia languoris? Surge, ingredere ecclesiam, et accedens ad sepulcrum Osualdi, ibi reside, et quietus manens adhaere tumbae. Vide ne exeas inde, nec de loco movearis, donec hora recessionis febrium transierit. Tunc ipse intrabo, et educam te inde.' Fecit ut ille suaserat, sedentemque ad tumbam sancti, infirmitas tangere nequaquam praesumpsit; quin in tantum timens aufugit, ut nec secunda die, nec tertia, neque umquam exinde eum auderet contingere.*

In the late medieval period there continued to be regular contact between England and Rome. The resident English community in Rome suffered from malaria there as well as the numerous pilgrims, the so-called *Romipetae*. Gervase, a monk in Canterbury, described a severe epidemic of 'bad air' in Rome in AD 1188. It badly affected both visitors from England and the Roman cardinals who were patrons of the Canterbury church. It started its ravages in July, but continued to claim victims as late as October in that particular year. ('For a terrible epidemic, arising from the excessive heat of summer and atmospheric conditions which appeared after the festival of St John the Baptist, devastated the Roman people to such an extent, and especially foreign visitors, that several thousand of the clerics and people died. Indeed the cardinals who were the patrons of the Canterbury church were killed by this abominable pestilence, as well as five monks who were companions of the prior and many of the servants. All the others were so ill that no one was able to pass on a drink of cold water to anyone else. However the prior Honorius, who was already on the point of death, was taken, through the good offices of the bishop of Ostia, to a mountainous location in the province of Velletri so that he could be cured by breathing purer air. Nevertheless that execrable poison of bad air, now occupying his vital organs, finally killed him on 21 October . . . Other monks, who had died in July, were buried in various churches.')[133] A noted English doctor, Hugh of Evesham, was elevated to the status of cardinal of San Lorenzo in Lucina by Pope Martin IV (1281–5) to protect him from malaria, but Hugh himself died from Roman fever.[134] In view of these contacts it is

[133] *The historical works of Gervase of Canterbury*, ed. Stubbs (1879) i.: *The chronicle of the reigns of Stephen, Henry II and Richard I*, 42: *Horrida enim pestilentia ex ardore aestatis nimio, et diversis aeris passionibus quae post festum Sancti Johannis Baptistae emerserunt, Romanum adeo vastavit populum et maxime peregrinos, ut non nulla milia cleri et populi spiritus exhalerent. Ex hac pestilentia detestanda cardinales quidem Cantuariensis ecclesiae patroni extincti sunt, et ex sociis prioris monachi quinque et plurimi servientes. Caeteri omnes adversa valitudine adeo detenti sunt, ut nec unus alteri vel aquam frigidam valeret propinare. Prior autem Honorius iam fere praemortuus, beneficio episcopi Hostiensis in montana Velletrensis provinciae absportatus est, ut ibidem liberiori refectus aere respiraret. Sed illa corrupti aeris detestanda infectio, iam ipsius occupans vitalia, ad extrema perductum XII° Kalendas Novembris compulit exspirare . . . Alii vero monachi, qui mense Julio mortui sunt, in diversis ecclesiis sepulti quiescunt.*

[134] Brentano (1974: 50, 89). For the history of medieval pilgrimage to Rome and malaria see Birch (2000: esp. 56–8), citing numerous sources, e.g. Peter the Venerable, abbot of Cluny, Letter 118, in *The Letters of Peter the Venerable*, ed. Constable (1967) (= *Harvard Historical Studies*, 78) i. 311: *mortem ipsam, quam Romanus aer nostratibus celeriter inferre solet* (death itself, which the Roman air is accustomed to bring rapidly to our colleagues). Peter suffered from malaria himself and made several other references to the unhealthiness of the Roman air in his letters written in the twelfth century (Constable, (1967) ii. 247–51).

likely that *P. vivax* malaria in Britain was regularly replenished and refuelled directly from Rome during the Roman and medieval periods, in exactly the same way that during the First World War the return of infected British soldiers from Greece led to a resurgence of malaria in the English marshlands. Rome exported diseases.

Dobson's demographic data from the Kent and Essex marshlands can be directly compared to the data from Grosseto studied by del Panta to illustrate the profound deviations in the age-structure of mortality produced by malaria. Del Panta compared the population of Grosseto to Coale and Demeny Model South Level 2 (for males) because of the similarity in infant mortality in the first year of life.[135] He pointed out that adult mortality, especially in the age-group 20–50, was much higher in Grosseto relative to the (high) level of infant mortality than the model life-tables predict (Table 3).

Table 3. Probability of death (qx) at various ages (in %)

Interval	Grosseto	Treppio	South 2	South 1	East 1
1q0	31.7	19.6	31.1	33.6	50.5
5q1	34.0	16.5	31.6	34.7	24.7
50q20	60.0	26.5	43.1	46.0	46.3
e^0	20.0	37.0	22.3	19.9	17.4

The data in Table 3 show that the effect of malaria on the population of Grosseto was to produce a much higher level of adult mortality between the ages of 20 and 50 than even the 'worst' model life-tables used by demographers (and Coale and Demeny Model East Level 1 is a theoretical construct). In plain language, conditions in Grosseto were so bad that adult mortality went right off the bottom end of the scale generally used by demographers. This is the full magnitude of Varro's 'reckoning with death', *ratio cum orco* (see Ch. 9 below). Historians who have attempted to minimize the role of malaria in Italian history have completely failed to appreciate the magnitude of the 'reckoning with death'. Del Panta, a leading Italian historical demographer, stated that numerous places in Italy, especially in the Mezzogiorno, had demographic patterns similar to those of Grosseto.[136] One example from the

[135] Del Panta (1989: 22). [136] Del Panta (1989: 23).

Mezzogiorno is the territory of the Crotonese. Arlacchi described the excess adult mortality: [sc. in the early twentieth century] 'for every 100 deaths in the Crotonese 15 befell persons between the ages of 20 and 40, compared to 7 to 8 for Calabria and 6 to 7 for Italy as a whole'.[137] According to Bonelli 12.3% of all deaths in the Crotonese in 1882 were directly attributed to malaria. This was substantially less than the direct mortality from malaria at Grosseto in the same year. Nevertheless Arlacchi's description shows that malaria had severe effects on the entire population of the Crotonese. This once again demonstrates that the overall effects of malaria stretch far beyond the proportion of deaths directly attributed to it. In the nineteenth century the crude death rate reached 60 per 1,000, while as recently as 1890 life expectancy at birth in the Crotonese was no higher than 20. It is likely that this was the fate of the once prosperous populations of the great coastal cities of Magna Graecia, such as Croton and Metapontum, during the Hellenistic and Roman periods following the spread of malaria.[138]

Table 4. Probability of death (qx) at various ages (in %)

Interval	Treppio	South 8 (Females)	South 9 (Males)
1q0	19.6	18.5	19.0
5q1	16.5	18.5	16.2
50q20	26.5	26.5	27.0
e^0	37.0	37.5	38.5

Incidentally, the data for the age distribution of mortality of the population of Treppio, the Appennine community located at high altitude to which del Panta compared Grosseto, are very similar to model life-tables with similar levels of life expectancy at birth (Table 4). This shows that at the very same time when some Italian populations had severely atypical age-structures as a result of

[137] Arlacchi (1983: 182).

[138] Arlacchi (1983: 176–83) on the Crotonese; Bonelli (1966: 662 n. 5). On malaria in Calabria see also Douglas (1955: 293–300), a perceptive account by a traveller who realized that the physical environment has changed substantially over the last two thousand years and appreciated the importance of these changes in relation to malaria. He reached the following conclusion: 'Malaria is the key to a correct understanding of the landscape; it explains the inhabitants, their mode of life, their habits, their history' (p. 300). Levi (1945: 156–7) described the effects of malaria in Lucania. Genovese (1924: 56–126) described the distribution of malaria in Calabria in recent times.

malaria, other populations in Italy not affected by malaria had quite normal patterns.

The population of Grosseto had three distinctive features: (1) much lower life expectancy at birth; (2) much higher overall mortality; (3) an unusual and distorted age-specific distribution of mortality. The third feature merits some further analysis. Table 5 shows that age-specific mortality was higher than predicted in Grosseto from age 5 to 9 and from 20 to 50. These characteristics of age-specific mortality emerge not only from the comparison with the communities of Stia and Pratovecchio in the Casentino given by del Panta, but also from the comparison with model life-tables.[139]

Table 5. Number of deaths per person-years lived between age x and x+n (m(x))

Age-group	Grosseto (Males)	South 2 (Males)	Grosseto (Females)	South 2 (Females)
0–4	16.5	18.0	17.7	17.3
5–9	**2.3**	1.5	**3.0**	1.7
10–19	1.2	0.9	1.0	1.1
20–9	1.8	1.6	1.5	1.6
30–9	**3.0**	1.7	**2.2**	0.9
40–9	**3.5**	2.3	**2.8**	1.9
50–9	**5.9**	3.6	**6.8**	3.0

Note: Bold type indicates items which deviate significantly from the values predicted by the model life-tables.

Del Panta was undoubtedly right to explain the excess age-specific mortality in the 5–9 age group in Grosseto as a direct consequence of *P. falciparum* malaria, as in tropical African countries today. Since direct mortality among adults from malaria was low in Grosseto, del Panta explained the excess adult mortality in terms of synergistic interactions with respiratory and gastro-intestinal diseases. Very high mortality rates required very high fertility rates if the population was to have a chance of reproducing itself. Consequently populations badly affected by malaria, such as Grosseto and the Sardinian populations mentioned earlier, had both higher mortality and higher fertility levels than other populations. Del Panta showed that the marriage patterns of Grosseto favoured very

[139] Del Panta (1989: 21); del Panta (1997) on infant mortality.

high fertility levels. Elsewhere he has described the coastal regions of central and southern Italy with intense malaria as characterized by neolocal marriage, with simple nuclear families and a predominance of agricultural wage labour.[140] Gregorovius made the following observation in Latium:

They marry very early in these parts—a young fellow of twenty one chooses frequently a girl who has only numbered fifteen summers.[141]

Table 6 demonstrates that an age-specific mortality pattern with some similarities to the data from Grosseto can be identified in the malarial parishes in the marshlands of south-east England.[142]

Table 6. Number of deaths per person-years (m(x)) for various age-groups

Age-group	Marsh parishes	Model West 6 (Females)
0–4	9.5	10.0
5–9	0.9	0.9
10–14	**1.1**	0.7
15–19	**1.3**	1.0
20–9	**2.0**	1.3
30–9	**2.7**	1.6
40–9	**4.2**	1.9
50–9	**4.7**	2.9
60–9	5.9	5.7

Note: Bold type indicates items which deviate significantly from the values predicted by the model life-tables.

The demographic pattern found by Dobson in the English marsh parishes is not dissimilar to the pattern of Grosseto, but with differences in detail; this is not surprising taking account of the fact that *P. falciparum* malaria was absent from England, not to mention numerous other environmental differences between England and Italy. In the English marsh parishes there was no deviation of the mortality level from the model's expectations in the 5–9 age group. This is comprehensible, since no significant degree of mortality produced directly by *P. vivax* in this age-group is to be expected. *P. vivax* does not produce death directly itself in the same way that

140 Del Panta *et al.* (1996: 162–4); Livi-Bacci (2000: 98–9, 145–6).

141 Gregorovius (1902: 90).

142 Data for the parishes of Canewdon, South Benfleet, Burnham and Tollesbury, which Dobson (1997: 169) compared to Coale and Demeny Model West Level 6.

P. falciparum does among children in tropical Africa today. The deviation in the English marsh parishes from the model pattern started at age 10, not 20, as in Grosseto, and steadily increased from the age of 30 onwards. Coale and Demeny Model West Level 6 gives a very good fit to English data up to the age of 20. However, Table 7 shows that this comparison is unsatisfactory from age 20 onwards.

Table 7. Number of people aged 20+ who die between ages x and y

Interval	Marsh parishes	West 6	West 2	West 1
20–9	18.3	14.1	19.1	20.7
20–39	36.8	28.8	37.7	40.4
20–49	58.6	44.1	53.5	56.7
20–59	75.9	61.2	69.9	73.0
20–69	87.4	80.3	87.0	89.1

Table 7 shows that from age 20 onwards the mortality rates predicted by Model West Level 6 are far too low. The attested rates of attrition are roughly consistent with Levels 1 and 2, with a life expectancy at birth of between 20 and 22.5, rather than 32.5 as in Level 6. In so far as the Coale–Demeny models are of any relevance at all, the English data indicate a drop from Level 6 mortality in the first ten years of life to a lower level from ages 10 to 20, followed by a sharp drop down to Level 1 or 2 from age 20 onwards. Consequently life expectancy at birth in the English marsh parishes was probably rather lower than 33, the figure suggested by Level 6. This would not be surprising in view of the exceedingly high crude death rates for the marsh parishes, up to 80 per 1,000. Nevertheless a more important conclusion, for the purposes of this chapter, is that when all the obvious environmental differences between the English marshlands and western central Italy are considered, the mortality patterns produced by *P. vivax* in England and the combination of *P. falciparum* and *P. vivax* in western central Italy were remarkably similar. Both were characterized by very excessive age-specific adult mortality relative to the prevailing levels of infant mortality.

Similarly Tognotti described deviations in the age-structure of mortality on Sardinia, which had some of the most intense malaria in the western Mediterranean. In Sardinia infant mortality in the first year of life was actually below the average of all the various regions of Italy (including regions where malaria did not occur at all).[143] In fact, infants in the first few months of life seem to be less severely affected by malaria than older infants. A variety of possible explanations have been offered for this phenomenon.[144] One possibility is that infants sleeping alongside their mothers have a much smaller surface area than their mothers, and move around more even when asleep, and so are less likely to attract mosquito bites. Infants may also be carrying antimalarial antibodies derived from their mothers in the first few weeks after birth, although this may simply indicate a high transmission rate of malaria and have little effect on infections. Malarial parasites grow much more slowly in erythrocytes with foetal haemoglobin than in cells with the adult form of haemoglobin. Another possible explanation, noted in Chapter 5. 3 above, is that human breast milk contains an extremely low concentration of para-aminobenzoic acid, a chemical required by malaria parasites. These factors probably all interacted to reduce mortality and morbidity from malaria in very young infants on Sardinia. Nevertheless after the first year of life on Sardinia, the risk of mortality increased progressively until in the 10–15 age-group (normally the healthiest segment of any human population) mortality was higher in Sardinia than in any other part of Italy. The mortality regime as a whole of the human population of Sardinia was worse than that of any other region of Italy. The situation on Sardinia was fundamentally the same as in Grosseto and the English marshlands, namely that infant mortality was not a reliable guide to mortality levels in older age-groups. Human populations which are severely affected by either *P. falciparum* or *P. vivax* or both under the transmission rates and seasonality typical of temperate to subtropical climates exhibit distinctive and much more severe adult-mortality patterns which distinguish them from populations unaffected by any species of malaria. Demographic regimes in history characterized by excess adult mortality relative to infant mortality can also be produced by causes of death other than malaria. The recently published family reconstitution studies of English parishes have shown that until the eighteenth century the English population *as a whole* had adult mortality levels higher

[143] Tognotti (1996: 81–2 n. 11).

[144] Brabin *et al.* (1990); Riley *et al.* (2001) surveyed the possibilities.

than those predicted by the Coale–Demeny model life-tables for the prevailing levels of infant mortality:

> Viewed in terms of the Princeton North or West model life-tables adult mortality was far too high relative to rates in infancy and childhood in the seventeenth century. If the only information available were the adult rates, and one were to extrapolate from them to estimates of expectation of life as a whole, using the Princeton tables, the result would be a radical underestimate of expectation of life at birth.[145]

Nevertheless it must be remembered that mortality as a whole was lower in non-marsh parishes in England than in the marsh parishes ravaged by *P. vivax*. Malaria was the most powerful cause of these atypical patterns—atypical by modern, but not necessarily by pre-modern, standards. In the pre-modern world infectious diseases were vastly more important than they are today. The Coale–Demeny life-tables, which assume that decreasing levels of life expectancy at birth can be explained above all in terms of increasing levels of infant mortality, fail to pay enough attention to additional adult mortality caused by infectious diseases in historical populations. Similar patterns of excess adult mortality relative to infant mortality have also been observed in the historical demography of India. It has been suggested that tuberculosis was the most important cause of the atypicality in India, but malaria (especially *P. vivax*) has been very important historically in many parts of India. Learmonth noted the striking correlations in Bengal until recently between, first, areas with intense malaria and areas with static or decreasing populations, and, secondly, districts with little or no malaria and districts with growing human populations. Malaria undoubtedly interacted with tuberculosis in India.[146] These atypical mortality patterns have had a wide geographical spread in recent times: England, Italy, India, and East Asia. It is a reasonable

[145] Wrigley *et al.* (1997: 349, cf. 261–3, 284–5).

[146] Mari Bhat (1989) on Indian demography, and Learmonth (1988: esp. 5–7, 206–7) on malaria in India. Even if the Sanskrit texts mentioned in Chapter 3 above do not definitely associate malaria with mosquitoes, other Sanskrit texts do describe malaria itself (a demon called *takmán* frequently found on low-lying land) very clearly, differentiating quotidian, tertian and quartan fevers: Zysk (1985: 34–44); Raina (1991: 1–4). Hirsch (1883: 204–7) described the distribution of malaria in India in the nineteenth century, and Klein (1972) its devastating effects in Bengal. Mari Bhat (1989: 110–11) also suggested, using the Barclay data, that the age-structure of mortality of traditional Chinese populations diverged from the model life-tables even more than that of Indian populations did, extending the patterns under discussion here even further.

hypothesis that they also have a long history. The balance of probability is that human populations that were affected by malaria in Latium and Tuscany in antiquity also shared these atypical patterns with high infant mortality but even higher adult mortality. Modern quantitative knowledge of the extreme effects of malaria on human demography indicates that Toscanelli was right to suggest in 1927 that the spread of malaria from *c.*300 BC onwards did play a major role in the decline of the southern and coastal Etruscan cities, in exactly the same way that malaria led to the depopulation of the Pontine Marshes. From a methodological viewpoint, the conclusions reached here suggest that it is a mistake for ancient historians to assume that the model life-tables necessarily encompass the entire range of possibilities as far as the demography of human populations in antiquity is concerned.[147] It is now time to investigate the operation of some of the general principles which have been discussed so far in detail at the local level in the various environments of western central Italy. Let us start with the most notorious focus in Latium, the Pontine Marshes.

[147] The fact that extrapolations from data for adult mortality in historical populations often yield underestimates of life expectancy at birth is relevant not only to Roman demography, but also to the demography of classical Athens. Although this cannot be explored in detail here, it is worth noting in passing that the ratio between the ephebes and the arbitrators in Athens in the fourth century BC (a measure of adult mortality), which has often been used to yield very low estimates of life expectancy at birth following comparisons with model life tables, probably underestimates e_o, in the light of the present discussion. This provides further support for the view advocated by Sallares (1991: 113–14) that life expectancy *at birth* in classical Athens has been underestimated. If infant and juvenile age-groups were in fact healthier in classical Athens than is generally supposed by historians, this helps to explain many important problems of Greek history; for example, how the Athenian citizen population was apparently able to recover very rapidly from repeated military catastrophes (as well as the 'plague of Athens' in 430 BC) during the period of the fifth-century empire (cf. Sallares (1991: 95–9)).

6

The Pontine Marshes

The Pontine Marshes have attracted little attention in modern historiography. The most comprehensive twentieth-century accounts of their ancient history were written by Bianchini, a rare book which attracted little attention owing to its publication at the beginning of the Second World War, and Hofmann, a very long Pauly-Wissowa article described by Brunt as 'remarkable for its ready acceptance of annalistic details and lack of scientific data'.[1] Early modern descriptions of the region are very important.[2] In fact, virtually all the historical questions considered by twentieth-century historians had already been debated by writers in the eighteenth century. In the year 1800 Nicola Maria Nicolai published a very substantial work on the Pontine region consisting of four books. The first two of these books provide an extremely detailed survey of the literary and documentary evidence for the history of the Pontine Marshes from antiquity onwards, as a prelude to a description of the bonifications of Pope Pius VI in the last two books. In view of the scarcity of twentieth-century literature on the subject, it is still well worth reading Nicolai's books today. The main contribution of modern research has come from archaeology rather than history. Field surveys by Dutch and Italian archaeologists have recently added important new data. Collari described the history of bonification attempts in the Pontine Marshes.[3]

It is difficult to imagine now what the Pontine Marshes were like before Mussolini's bonifications. Some parts of the marshes were permanently submerged, while other areas dried out in the summer each year. There were flooded forests in winter. In the early modern period, maize was planted in June and harvested in November in some parts of the Pontine Marshes which were submerged under water in winter.[4] It was these seasonal, open marshes

[1] Bianchini (1939); Hofmann (1956); Brunt (1987: 349 n. 6).

[2] e.g. De Tournon (1831: i. 112–39, 319–21, ii. 213–37); Hare (1884: ii. 245–63).

[3] Voorips *et al.* (1991); Attema (1993); Collari (1949).

[4] De Felice (1965: 55–7, 108). D'Erme *et al.* (1984) shows numerous photographs of early modern paintings of the Pontine region.

Map 4. Southern Lazio

which were so lethal as a source of malaria, as Palladius understood. The interior of the Pontine forest itself, although visually intimidating, was still dangerous with regard to malaria, but not quite so dangerous. Only a small fraction of the marshes survived Mussolini's attentions. What is left is preserved today in the Parco Nazionale del Circeo. Tito Berti, who travelled in August and commented that bad air (*aria cattiva*) began at Cisterna, described the Pontine forest in 1884 as follows:[5]

The Pontine forest creates fear and horror. Before entering it cover your neck and face well, because swarms of large bloodsucking insects are waiting for you in this great heat of summer, between the shade of the leaves, like animals thinking intently about their prey . . . Trees of every species bow towards you, stand erect in front of you, prevent you from passing: a dense network of shrubs, plants, leaves, forces you to stop: you make a path with an axe, knocking down the obstacles; and here you find a green

[5] Attema (1993: 36–41) discussed Berti's journey through the Pontine region.

20. The Centro culturale polivalente, Via Cavour 23, in Pontinia, another of Mussolini's new towns in the Pontine region. It houses the Museo *La malaria e la sua storia*, which documents the campaigns to eradicate malaria from the region in the 1930s.

zone, putrid, nauseating, where thousands of insects move around, where thousands of horrible marsh plants grow under a suffocating sun.[6]

This was the landscape, so close to Rome itself, which the Romans were unable to master even when they had conquered most of the rest of the then known world. To gain an idea of what that landscape was like it is necessary to resort to more recent descriptions of it, like Berti's, because it is not described in ancient sources. From this omission significant conclusions may be drawn. Pliny the Elder (quoted below) did indeed use the word *miraculum*, a marvel, in connection with the Pontine Marshes. Yet he failed to describe this marvel, even though it was so close to Rome. Pliny in his *Natural History* gives us countless bits of information about

[6] T. Berti (1884), *Le Palude Pontine*, quoted by Pratesi and Tassi (1977: 137–40): *Il bosco pontino mette paura e ribrezzo. Prima di penetrarvi copritevi bene il collo e la faccia, perché nuvoli di grossi tafani vi aspettano in questa caldura, fra il rezzo delle foglie, come animali pensanti intenti alla preda . . . Alberi d'ogni specie s'incurvano verso di voi, vi spiccano dritti, vi chiudono il passo: una fitta rete d'arboscelli, di piante, di foglie, vi obbliga a fermarvi: vi fate strada con l'accetta, abbattendo gli ostacoli; ed ecco vi si presenta una zona verde, putrida, nauseante, ove corrono migliaia di insetti, ove crescono sotto un sole soffocante migliaia di orribili piante palustri.*

21. View from the northern slopes of Monte Circeo of the Lago di Sabaudia o di Paola, the most southerly of the four lakes stretched along the coast of the Pontine region behind the coastal dunes, and the Selva di Circeo. Domitian's villa is located on the eastern shore of the lake. Hare (1884: ii. 275) made the following observations on these lakes: 'they are much frequented by the peasants for the fishing they afford, but few strangers will venture into this plague-stricken region'.

22. The interior of the ilex-oak (*Quercus ilex*) forest on the relatively cool northern slopes (the Quarto Freddo) of Monte Circeo. Another species of oak tree (*Quercus cerris*) predominates in the Selva di Circeo further north in the plain.

individual plants, animals, and minerals which were of use or interest to man. However, he had no conception whatsoever of a biological environment as a community of living organisms, even though Theophrastus had already shown some insights in that direction. Moreover Pliny the Elder had less talent than his nephew, the younger Pliny, for writing about the natural landscape. Pliny the Younger described beautifully the marshes around the Lago di Bassano (*lacus Vadimonis*), but it is clear that his visit there was brief; he did not live in such environments himself.[7] The *Natural History* would have been a much better work if it had been written by Pliny the Younger instead of by his uncle. Pliny the Elder had great opportunities to provide posterity with detailed accounts of very interesting ancient ecosystems like the Pontine Marshes, which he completely squandered. The question arises of why he and most other ancient writers showed so little interest. A lot of recent scholarship on Roman attitudes to marshes and other hydraulic phenomena has attempted to extract positive attitudes

[7] Pliny, *Ep*. 8.20.

towards marshes from the ancient sources and, furthermore, to outline an ancient ideology of hydraulic management as a source of power. It is essential to ask the question of who created this ideology. It is suggested here that in so far as any positive attitudes towards marshes did exist in ancient mentalities, they were created by outsiders, people who did not live in the marshes themselves, had no first-hand experience of the extreme environmental conditions of marshlands, and consequently did not suffer from the endemic malaria whose enormous demographic impact on human populations living in marshland environments is now well known to specialists in historical demography (Ch. 5. 4 above). It is because the ideology of the management of wetlands was created by outsiders that we cannot hope to find in ancient sources the level of detail, found in more recent descriptions such as Berti's, which would suggest anything much in the way of personal acquaintance with life and environmental conditions in marshlands. At least the description of a painting of a marsh given by Philostratus may have some literary merit, even though its failure to allude in any way to 'bad air' demonstrates its fundamental lack of realism. The writing about marshes of the late Roman author Vibius Sequester is so impoverished that it hardly merits quotation.[8]

The extreme poverty of his text, a brief list of names and locations with a handful of extremely short notes of mythological interest, scarcely needs any commentary. Let us return to the early modern descriptions. Different visitors arrived at different times of the year and saw different parts of the Pontine region. Thus it is possible to find quite different accounts of the area. Gregorovius provides an interesting contrast to the already quoted passage from Berti:

He who has traversed the Pontine Marshes as far as Terracina by the Via Appia will have a most mistaken idea of them if he imagines that they are loathsome swamps. Morasses and ponds do exist, but they lie hidden away in the woods, where the hedgehog, the stag, the wild boar, the

[8] Vibius Sequester, *de fluminibus fontibus lacubus nemora paludes*, etc., ed. Parroni (1965): *5. PALUDES*, 1 *Ambracia Achaiae.* 2 *Asia Asiae, cui Caystros prope est.* 3 *Camerina nunc, ante Hyperie dicta, Syracusis.* 4 *Lerna Arcadiae, unde hydra centum capitum, quam Hercules occidit.* 5 *Maeotis Scythiae.* 6 *Pomptinae Tarracinae, Foro Appi.* 7 *Padu⟨s⟩ae Galliae a Pado dictae.* 8 *Styx inferorum a Styge Oceani filia.* 9 *Satura inter Antium et Cerce⟨i⟩os, eadem Stura.* 10 *Strymon Thraciae.* 11 *Salpina in Hadriatico.* 12 *Triton Thraciae, in quo se novies merserit in avem convertitur.* 13 *Tyraca Syracusis.* Traina (1986) and (1988: 107, 112) on Vibius Sequester; Leveau (1993) and Purcell (1996) for the ideology; Philostratus, *imagines* 1.9, ed. Kayser (1871).

buffalo, and the half-wild cattle may still be found. In May and June this Pontine territory is a sea of flowers, poured out, as far as the eye can reach, over this whole land. In the heat of summer, it is true, it becomes a Tartarus, where pale fever creeps around to torture the poor herdsman or labourer, who must earn his bread in suffering, and cannot fly from its pestilential air.[9]

Tartarus! A far cry from the idyllic view of Mediterranean wetlands found in the writings of some modern historians. Gregorovius, unlike Berti, does not describe the Pontine forest. He also travelled around 1860 in summer (at a time when most travellers to Rome went there between November and April[10]) and saw the region at the time of year when large areas, which were flooded in winter, had dried out for summer. Nevertheless Gregorovius was right that the areas which dried out seasonally were the ones which were most dangerous with regard to malaria. They were the breeding sites of the mosquito species *Anopheles labranchiae*, which was extremely common in this area, while the forested areas and the brackish lakes along the coast were the domain of *A. sacharovi*, another very dangerous vector of malaria. A third mosquito species, the zoophilic *A. messeae*, also occurred in some of the same localities as *A. labranchiae*, but in much smaller populations. Doni also regarded coastal forests as unhealthy in the seventeenth century.[11]

Hans Christian Andersen described the Pontine Marshes as follows:

Many people imagine that the Pontine Marshes are only marshy ground, a dreary extent of stagnant, slimy water, a melancholy road to travel over: on the contrary the marshes have more resemblance to the rich plains of Lombardy; yes, they are like them, rich to abundance; grass and herbage grow here with a succulence and luxuriance which the north of Italy cannot exhibit . . . the immense plain stretches itself out with its tall grass, and its fresh, green marsh-plants. Canals cross one another, and drain off the water which stands in ponds and lakes covered with reeds and

[9] Gregorovius (1902: 279).

[10] A more typical example of the early modern travellers was the famous nurse Florence Nightingale, who arrived in Rome in early November 1847 and departed at the end of March 1848 (Keele (1981)). She toured the hospitals of Rome, including the Santo Spirito hospital which accommodated patients with malaria, and noted the atrocious conditions prevailing in them. Blewitt (1843: 466) noted that few travellers stayed in Rome during the summer.

[11] De Muro (1933); Doni (1667: 101).

23. The extremely flat Pontine plain, viewed from Sermoneta.

broad-leaved water-lilies . . . I met a peasant, whose pale, yellow, sickly exterior contradicted the vigorous fertility which the marshes presented.[12]

Another traveller, an Englishman, H. Matthews, had yet another different perspective:

The Pontine Marshes, of which one has heard such dreadful accounts, appeared to me to differ but little from many parts of Cambridgeshire, though the livid aspect of the miserable inhabitants of this region is a shocking proof of its unwholesomeness. The short but pathetic reply, made to an inquiring traveller, is well known. 'How do you manage to live here?' said he, to a group of these animated spectres. 'We die!'[13]

Given what is now known about the demographic effects of malaria on the inhabitants of the marshlands of early modern England, the comparison to 'many parts of Cambridgeshire' (before the draining of the East Anglian Fens) is entirely apposite.[14] Nevertheless all the early modern travellers tended to give partial accounts of the Pontine region. For a more comprehensive description, it is necessary to turn to different types of source, for example the description of the region, concentrating on its forests, in an official Italian-government publication dating to the late nineteenth century.[15] This description, which puts the beech trees in their proper position on the hilltops, explicitly compares the Pontine forest to the tropical forests of equatorial regions, a description which is justified, since the flooded Pontine forest undoubtedly

[12] Andersen (1845: ii. 1–3).

[13] Matthews (1820: 167–8).

[14] Nicholls (2000).

[15] Chapter in *Monografia* (1881) entitled *Sulle condizioni dell'agricoltura e pastorizia della provincia di Roma*, pp. xcix and cx–cxi: '*Questo regione non apparisce che come un vasto terreno paludoso, intersecato qua e là, segnatamente verso il mare, da selve annosissime, che la credenza sulla loro efficacia per diminuire il flagello delle malarie, o piuttosto le difficoltà dei trasporti, riparmiarono fino a qui . . . Queste piante* [sc. *il pistacchio lentisco, il ramerino, la Daphne collina, la filaria e il mirto*] *unite insieme formano* [sc. on the sandy soils closest to the sea] *talora dei macchioni densissimi che diventano anche pressochè insuperabili, quando ad essi si aggiungono formando quasi un graticulato di liane, le smilaci, le viti selvatiche e le clematidi. Più dentro terra, ma sempre in grande vicinanza del mare, e qualche volta anche in immediato contatto di questo, si hanno selve di alto fusto costituite da cerri, da quercie peduncolate, da olmi e da frassini. Le più grandi di queste selve sono rimaste nella striscia di terra, che fiancheggia il mare nelle palude Pontine, e non di rado anche queste rimangono impenetrabili a cagione delle acque che invadono il suolo. Non sappiamo se altrove, in Italia e fuori, si possa avere una immagine degli smisurati boschi delle regioni equatoriali, migliore di quella che offrir possono i boschi Pontini . . . nelle parti ondulate e nelle colline si hanno i boschi cedui semplici ed i boschi cedui con sgamolli o capitozze. Le specie dominanti in questi boschi cedui sono quasi sempre quercie rovere e quercie peduncolate con mistura di lecci e di arbusti, come l'albero di Giuda, il corniolo, il nocciolo, ecc. Se dalla pianura e terreni adiacenti si risale ai monti, si trovano qua e là boschi di quercie e di castagno, a ceduo od a fustaja, e poi finalmente, verso le sommità dei monti, il faggio, il quale rappresenta in questi luoghi, come nelle rimanenti parti dell'Appennino, l'albero più diffuso*'. Cf. Quilici (1979: 77).

resembles, on a much smaller scale, some of the rain forests in South America, for example.

Having gained some impressions of this environment in more recent times, it is necessary to consider whether the Pontine environment was the same in antiquity. There are indeed various indications that the Pontine Marshes might once not have been quite so intimidating as Berti's description suggests, or at least not have occupied as extensive a geographical area as they did in the early modern period. Pliny the Elder described the Pontine Marshes as an area in which there were once twenty-four cities, suggesting that there had once been considerable human occupation of the area:

Another marvel, next to Circeii, is the Pontine Marsh, where there were twenty four cities according to Mucianus, three times consul.[16]

The archaeologists who are surveying the Pontine area believe that these lost cities were mainly situated in the region immediately south of Velletri, following Nicolai's interpretation two hundred years ago, in other words they were not actually located in the marshes themselves, although the wetlands were certainly exploited. In the seventeenth century the marshes proper stretched from Cisterna to Terracina, according to Doni.[17] The most famous of these lost cities was Suessa Pometia, which gave its name to the whole Pontine region. It vanished so completely after its destruction by the Romans that even its precise location is not known for sure (perhaps at ancient Satricum, or near modern Cisterna).[18] Atina, east of the marshes, is explicitly linked to death from disease by Servius, the ancient commentator on Virgil:

Powerful Atina. This city-state was situated near the Pontine Marshes. It was named Atina after the diseases, called *atai* in Greek, which are caused by the proximity of the marsh.[19]

The disappearance of these communities recalls the disappearance

[16] Pliny, *NH* 3.5.59: *aliud miraculum a Cerceis palus Pomptina est, quem locum XXIV urbium fuisse Mucianus ter consul prodidit*; *NH*, 3.5.70: *ita ex antiquo Latio LIII populi interiere sine vestigiis* (thus fifty-three people from Old Latium have disappeared without trace); Quilici (1979: 128–30).

[17] Nicolai (1800: 9–14); Doni (1667: 133–41).

[18] Nicolai (1800: 1–7, 14–18); Dionysius Hal. *AR* 4.50.2–5.

[19] *Servii Grammatici qui feruntur in Vergilii carmina commentarii*, ed. Thilo (1923), ii., on Virgil, *Aeneid* 7.630: *ATINA POTENS civitas haec iuxta Pomptinas paludes, dicta Atina a morbis, qui graece atai dicuntur, quos paludis vicinitas creat.*

of other early human communities in Latium Vetus, recorded by Pliny the Elder.[20] In the Early Republican period the area of the Pontine Marshes, which was seized by the Volsci in the early fifth century BC, was a potential source of grain for Rome whenever there were food shortages. Thus Roman officials were sent to buy grain from the Volsci in 508 BC. They tried again unsuccessfully in 492 BC to buy grain from the Volsci and the Pomptini. In fact it is not unreasonable to suggest that control of the Pontine plain, which was potentially one of the richest (per unit area) if not the richest agricultural land in Italy, was the first major objective of Roman imperialism. This objective dominated Roman foreign policy for about two centuries, from the short-lived expansion in the late sixth century BC under Tarquinius Superbus as far as Circeii (which is said to have been colonized) and throughout the Volscian wars of the fifth and fourth centuries. Polybius' account of the first treaty between Rome and Carthage, whose historicity is now widely accepted, implies that Rome, under Tarquinius Superbus, controlled the whole coast of southern Latium as far as Terracina in 509 BC. The Pontine territory was highly desirable as late as 386, when a tribune of the plebeians brought the subject up for discussion, shortly after the Romans had gained complete control over the territory. Mommsen maintained that the 'definitive occupation and distribution of the Pomptine territory' by the Romans was one of the two reasons for the breakdown of the alliance between Rome and the Latins (the other being the temporary weakness of Rome caused by the Celtic attack). According to the annalistic tradition as presented by Livy, rich Romans quickly moved in to divide up the land to their own advantage. This could be an anachronistic retrojection of the conditions of the Late Republic on to the fourth century BC, but, on the other hand, it is not impossible, since large landowners have regarded the Pontine territory as highly suitable for animal husbandry throughout

[20] Ogilvie (1976: 106) believed that malaria had significant effects in Latium as early as the fifth century BC. He argued that it explained the disappearance of some low-lying Latin communities in that period, such as Longula and Pollusca, which are said to have been recovered by the Volsci from the Romans in 488 BC (see Dionysius Hal. *AR* 6.91.2–3, 8.36.1–2 and Livy 2.39.2–4 for their history). Tomassetti (1910: i. 35) placed Longula at Buonriposo and Pollusca at Casal della Mandria. Nicolai (1800: 31–4) had already discussed their location. The precise locations of Longula and Pollusca are still uncertain, according to Attema (1993: 58). Attema (1993: 60–4) also discussed de la Blanchère's view that the 'lost cities' were situated in the region between Anzio and Velletri, not in the heart of the Pontine Marshes. Doni (1667: 35–41) had already discussed the lost cities of Latium, in the seventeenth century.

history (see Ch. 9 below). In 383 BC a board of five (*quinqueviri*) was appointed to divide up the Pontine territory. Two new tribes of Roman citizens, the *tribus Pomptina* in 358 and the *tribus Ufentina* in 318 (centered on Privernum), were created to exploit the southern half of the Pontine territory, the *ager Pomptinus*. The impression given is of a flourishing agricultural economy, of land that was worth having. This tradition could not have been invented by Livy or any other annalistic writer in the Late Republic, because by then the Pontine Marshes had become one of the deadliest places on earth for humans (at least in summer and autumn). It must be a genuine archaic historical tradition, and it is corroborated by archaeological evidence. Cancellieri and Quilici Gigli have both noted the centuriation scheme still visible on the terrain, dating to the fourth century BC. The cuniculi of the Pontine region can also be attributed to this phase of activity. The archaeological evidence proves that the Pontine territory really was divided up in the fourth century. The evidence of the annalistic tradition does not prove that malaria was completely absent from the area in the fifth and fourth centuries BC, but it probably indicates that malaria was not quite as widespread and intense then as it became later. A *pestilentia ingens* severely affected the Volsci in 492/1 BC, according to the annalistic tradition, but did not reach as far as Rome. It cannot be securely identified, but it is conceivable that it was an epidemic of malaria, a disease which tends to be highly localized.[21]

It is important to remember that mosquitoes like well-watered lands for breeding purposes, and well-watered lands are also the best for arable farming and animal husbandry. Strabo noted the connection of malaria with the best agricultural lands on Sardinia (Ch. 4. 3 above). He also commented (quoted below) that Latium, with its high water table, was very fertile and produced everything. Since poor people have to make a living, it is commonly observed in the historical record that they are attracted to areas where malaria is endemic, since these areas offer the best prospects for agriculture. Mediterranean wetlands are extremely productive

[21] Livy 1.53.2, 1.56.3, 2.9.6, 2.34.3–5, 6.5.1–5, 6.6.1, 6.21.4, 7.15.12, 9.20.6; Polybius 3.22; Mommsen (1894: 447); Cancellieri (1990); Quilici Gigli (1997); Traina (1990: 22–3); De Felice (1965: 93–4) for the maintenance of very large herds of animals in winter and spring in the Pontine Marshes in the early modern period; Cornell (1995: 268, 304–9, 323–4). For the Roman colonization of Circeii see also Dionysius Hal. *AR* 4.63.1, 8.14.1–2, and Plutarch, *Coriolanus* 28. Dionysius Hal. *AR* 2.49.4–5 records a strange tradition of a Spartan colonization enterprise in the Pontine region in the archaic period.

today. For example, the agricultural zone of the Ombrone river valley within the Parco Regionale della Maremma, near Grosseto, yields some of the highest levels of agricultural productivity in Tuscany today. However, in the past in order to access this wealth it was necessary to risk one's life. The nineteenth century Italian proverb quoted by George Dennis encapsulates the situation: 'In the Maremma one becomes rich in a year, one dies in six months.'[22] Mammucari commented on the situation in the Roman Campagna as follows:

> Between the certain death from starvation and the probable death caused by the *Anopheles* mosquito, the latter was almost always preferred . . . men defied death in order to make a living.[23]

Similarly agricultural land in the territory of the former Pontine Marshes is extremely productive today. De Tournon noted that the depopulation of the Volscian territory must be ascribed to *mal'aria* because the land was extremely fertile.[24] He observed that the fertility of the parts of the Pontine Marshes which had been drained by Pope Pius VI in the late eighteenth century was so great that wheat could be grown several years in succession, without any need for fallow periods.[25] Mediterranean wetlands were surely equally potentially productive in antiquity, even though the ancient Romans and Greeks failed to figure out the best way of exploiting their economic potential, namely rice cultivation. Although very attractive for economic reasons, malaria turned many European wetlands in the past into death-traps. In early modern England agricultural labourers were constantly attracted to the marshes of Kent and Essex because of their great economic potential, but suffered very high mortality from *P. vivax* malaria (see Ch. 5. 4 above). Similarly in late medieval Italy there was a tendency towards migration, within the territory controlled by Florence, from the uplands towards the Maremma of Pisa and Volterra,

[22] Dennis (1878: 205): *in Maremma s'arricchisce in un anno, si muore in sei mesi.*

[23] Mammucari (1991: 66): *tra la morte certa per inedia e quella probabile a causa della zanzara anofele, quasi sempre veniva preferita quest'ultima...l'uomo sfidava la morte per guadagnarsi la vita.*

[24] De Tournon (1831: i. 117) on the territory of ancient Corioli: *Maintenant il est absolument désert . . . deux maisons délabrées que pendant l'été habitent quelques pauvres fiévreux représentent quatre villes puissants remplies d'une population vigoureuse. Ainsi sans cesse nous voyons les effets terribles du climat, car ce n'est pas la fertilité qui manque aujourd'hui à ces belles plains, où les blés les plus épais alternent avec les pâturages les plus abondans, et où succèdent le maïs, le riz, l'avoine et les fèves.*

[25] De Tournon (1831: i. 320): *Les terres à froment pourraient être semées plusieurs années de suite, tant est grande la fécondité de cette alluvion.*

which was intensely infested with malaria at the time. The attractions of marshlands for economic reasons explain why some people would always migrate there in the past in spite of their dreadful reputation for malaria. Migration can explain how areas where death rates persistently exceed birth rates remain populated.[26]

The upshot of all this is that the fact that the region of the Pontine Marshes apparently had a flourishing agricultural economy in the fifth and early fourth centuries BC does not prove that *P. falciparum* malaria was completely absent from the scene, since the area was very attractive for economic reasons. Unfortunately, little is heard thereafter about the *Ager Pomptinus* in literary sources for a period of about two centuries, a period for which detailed information would be extremely useful. Appius Claudius constructed the Via Appia from Rome through the Pontine Marshes to Capua in Campania in *c.*312 BC. Quilici Gigli observed that certain details of the road's construction imply that cuniculi over which it passed were still operational, and Nicolai argued that the construction of the road implies that the region through which the road was to run was not already filled with marshes then. Traina's argument that the region did not receive the name of *Pomptinae paludes* until the first century BC, having previously been called *ager Pomptinus*, also deserves to be noticed, although there is a shortage of relevant literature antedating the first century BC. Nevertheless there is no doubt that the construction of the Via Appia altered natural drainage patterns and so created suitable conditions for the spread of the mosquitoes which transmit malaria. The account of the Via Appia given by Diodorus Siculus lays stress on the cuttings and embankments constructed by Appius Claudius, features whose construction is known from modern experience to create mosquito breeding sites.[27] Horace observed the abundance of mosquitoes in

[26] Dobson (1980), (1994) and (1997); Herlihy and Klapisch-Zuber (1985: 112); Sallares (1991: 22–4) on rice in antiquity.

[27] Diodorus Siculus 20.36.2: *τῆς ἀφ' ἑαυτοῦ κληθείσης Ἀππίας ὁδοῦ τὸ πλεῖον μέρος λίθοις στερεοῖς κατέστρωσεν ἀπὸ Ῥώμης μέχρι Καπύης, ὄντος τοῦ διαστήματος σταδίων πλειόνων ἢ χιλίων, καὶ τῶν τόπων τοὺς μὲν ὑπερέχοντας διασκάψας, τοὺς δὲ φαραγγώδεις ἢ κοίλους ἀναλήμμασιν ἀξιολόγοις ἐξισώσας* (He paved with solid stones most of the Appian Way, which was named after him, from Rome to Capua, the distance being over a thousand stades, and he dug through elevated places and levelled the way across gullies and valleys with remarkable fills.); cf. Livy 9.29.6, Lucan, *de bello civili* 3.85: *et qua Pomptinas via dividit uda paludes* (and where a wet road divides the Pontine Marshes); G. Radke in Pauly-Wissowa, *RE* suppl. xiii (1973: cols. 1494ff.); Nicolai (1800: 67–74); Quilici Gigli (1997: 197); Traina (1988: 113).

the Pontine Marshes during his famous trip along the Via Appia in 36 BC, heading for Brundisium.[28]

The Via Appia was subsequently rebuilt by Nerva and Trajan. Procopius was impressed by the state of the Via Appia as late as the sixth century AD and described the road as one of the wonders of the world, although it is striking that Justinian's general Belisarius chose not to march along it during the Gothic Wars. Both Strabo and Procopius mentioned the Decemnovium, a canal that ran alongside the Via Appia for nineteen miles through the Pontine Marshes, usurping the function of the road.[29] The construction of the canal is surely an admission that by the first century BC the Pontine territory was permanently marshy. It was not normal Roman practice to build a canal alongside a road. The Pontine territory probably required little encouragement to become marshy. It is a very low-lying land which receives up to about 900 mm of rainfall annually. In addition, it received water from a number of rivers: De Tournon listed eight in the nineteenth century: from north to south, the Tepia, Ninfa, Cavatella, Cavata, Ufente, Amazena, Scaravazza, and Pedicata.[30] Of course the river system has changed since antiquity in the Pontine region as elsewhere in western central Italy. Nevertheless the Ufente and the Amazena were probably particularly important with respect to the amount of water brought in. Since these rivers originated in the hills of Latium, breaking up by deforestation of the upland forests described by Theophrastus (Ch. 4. 6 above) would have increased the flow of water to the Pontine territory. Nicolai argued that as late as the time of Strabo only the rivers Ufente and Amazena (or Amaseno) contributed water to the region of the marshes proper. He suggested that the other rivers only started to drain into the marshes during the time of the Roman Empire.[31] This question requires more research by geologists. Similarly de la Blanchère argued that the marshes occupied a smaller area in the archaic

[28] Horace, *Sat.* 5.14–15: *Mali culices ranaeque palustres avertunt somnos.*

[29] Procopius, *BG* 1.14.6–11; 1.11.2; Strabo 5.3.6.233C; di Vita Evrard (1990) studied the inscriptions recording the work of Nerva and Trajan on the Via Appia, also recorded by Cassius Dio 68.15, (*τά τε ἕλη τὰ Πομπτῖνα ὡδοποίησε λίθῳ* (and he built a stone road across the Pontine Marshes), cf. Galen 10.633K; Nicolai (1800: 93–101) on the activities of Nerva and Trajan in the Pontine Marshes.

[30] De Tournon (1831: ii. 221); Cancellieri (1986); Festus, p. 212L, noted that the *tribus Ufentina* was named after the River Ufente.

[31] Nicolai (1800: 101), cf. Quilici (1979: 65).

period. He maintained that they only expanded after the extermination of the Volscian population by the Romans.[32]

Nevertheless there had probably always been some marshes. Livy described Terracina (the former Volscian city of Anxur) as surrounded by marshes in 406 BC. This was probably true, even though Terracina was able to flourish later in Roman times because the ancient settlement lay on the side of a hill, a reasonably healthy location, above the modern town.[33] However, human activity of all sorts in the surrounding region gave the marshes and mosquitoes all the encouragement they needed to spread. Besides road building and deforestation in neighbouring areas, it is conceivable that farmers deliberately attempted to fill in some low lying parts of the Pontine Marshes by diverting rivers or streams to bring in alluvial sediments and so silt up the land. This interpretation, as colmatage deposits, of some of the alluvial sediments in the Pontine territory was given by the team of Dutch archaeologists from Amsterdam who carried out the *Agro Pontino* survey.[34] The consequence is that some land, which was previously permanently flooded, might subsequently have only been flooded seasonally, principally in winter, making it more useful for the mosquitoes. Livy records that a plague of locusts occurred in the *Ager Pomptinus* in 173 BC. Similar events frequently occurred in Latium in the early modern period, for example in 1758, 1807/8, 1810/12, and almost continuously for a dreadful eighteen-year period from 1767 to 1784. The build up of locust populations was favoured by a system of extensive cultivation with long fallow periods, which encouraged locusts to lay eggs.[35] This extensive pattern of land use was imposed

[32] de la Blanchère (1884: 48–50). He attempted to explain the origin of the marshes in the Maremma in the same way, by the destruction of the Etruscans by the Romans.

[33] Livy 4.59.4: *Anxur fuit, quae nunc Tarracinae sunt, urbs prona in paludes*; Nicolai (1800: 52–4) on Terracina; De La Blanchère (1884) catalogued all the documentary evidence for the history of Terracina in antiquity.

[34] J. Sevink *et al.* in Voorips *et al.* (1991: 41). Attema (1993: 106) observed that there is no evidence that colmatage/sedimentation in the Pontine plain was ever *deliberately* provoked by man in antiquity. However, Alexander (1984) emphasized the importance of colmatage in the early modern drainage of the Val di Chiana. It is not clear when the technique originated.

[35] Livy 42.2.5: *Pomptinum omne velut nubibus lucustarum coopertum esse* (it is said that the whole Pontine plain was covered by clouds, as it were, of locusts); De Felice (1965: 36 n. 14) on locusts in Lazio. Cassius Dio 56.24.3 mentioned locusts in Rome in AD 9. Paulus Diaconus, *Historia Langobardorum*, iv.2, ed. G. Waitz (1878), *Monumenta Germaniae Historica*, xlviii (*Scriptores* 7) described a plague of locusts in AD 591–2: Davis (1995: 299, 307) mentions plagues of locusts during the reign of Pope Hadrian III in the 880s AD. See also Sallares (1991: 27–8) on locusts in antiquity.

24. View of the southern end of the Pontine plain, looking from San Felice Circeo (80 metres above sea level) in the direction of Terracina and the Monti Ausoni.

upon farmers in the region by malaria. Long fallow periods were certainly not necessary for arable farming in the very fertile Pontine territory. However, once malaria had a grip on the region, intensive agriculture became exceedingly difficult, as will be seen later (Ch. 9 below). The next major recorded event in the history of the Pontine Marshes was the drainage scheme of M. Cornelius Cethegus in 160 BC.[36]

The brief notice of this drainage operation in the summaries of the lost books of Livy presents it in a matter-of-fact way as if it was a routine operation which was completely successful. It has indeed frequently been taken at face value by modern historians. However, a more profound examination of it is essential to determine its role in the historical development of the Pontine Marshes. Sources dating to the Late Republic and the age of Augustus, such as Vitruvius, state that the Pontine Marshes were pestilential, owing to malaria, at that time. That suffices to make it clear that Cethegus' operation did not prevent malaria at all. In fact, it is quite conceivable that it had the opposite effect, and that partial drainage might have expanded suitable breeding habitats for *Anopheles* mosquitoes. Of course eliminating malaria was not necessarily Cethegus' intention, since the literary sources available for the period before the Late Republic do not furnish any direct information on the chronology of the spread of malaria in the Pontine Marshes; he probably simply wished to make more land available for agriculture. It is difficult to make any further progress using literary sources alone.

However, the Dutch archaeological surveys have provided new and very interesting data. The area has long been occupied by humans. The discovery in 1939 of a Neanderthal skull in the Grotta Guattari at the foot of Monte Circeo extended human occupation of the area back to about 65,000 years ago. After that there is evidence for the activity of early modern humans, followed by Mesolithic, Neolithic, and Bronze Age activity. However, the evidence of the Amsterdam field survey indicates that there was a considerable increase in the number of sites in the seventh century BC in the Pontine territory as elsewhere in western central Italy. Substantial occupation continued during the Volscian period in the

[36] Livy, *Periochae* 46: *Pomptinae paludes a Cornelio Cethego cos., cui ea provincia evenerat, siccatae agerque ex his factus* (The Pontine Marshes were drained by the consul Cornelius Cathegus, to whom this province had been allotted, and turned into arable land.).

fifth century BC (Attema's 'Post-Archaic' period *c.*500–350 BC[37]) and into the Roman occupation in the fourth and third centuries BC, to which period belong the largest proportion of the Roman finds, as well as an extensive centuriation scheme. This shows that the Romans did indeed attempt to make intensive use of the territory after gaining control of it, as Livy's account suggests. There was a lot of human activity there in the fourth century BC. However, by the first century BC the Pontine region had become very unhealthy and was thinly populated, as is suggested by the literary sources discussed below. Moreover the data of the Amsterdam field survey indicate that there was a complete collapse of the population.[38] It is difficult to date the population decline or describe its progress in detail in view of the scarcity of evidence, but it clearly happened between the fourth and the first century BC. Given that the land was fertile and the area was firmly under Roman control and not threatened by anyone else, this population decrease surely was the result of the spread of malaria. This provides a context for the drainage scheme of Cornelius Cethegus. It was an attempt to remedy an environmental disaster which had already happened, or which was in progress at the time. It is quite possible, and indeed very likely, that human disturbance of the environment during the phase of intense activity in the fourth century BC following the Roman conquest actually made the situation worse rather than better and created more breeding sites for *Anopheles* mosquitoes. The Pontine Marshes were a remarkable assignment as a consular province, at a time when Rome was well on the way to conquering

[37] Attema (1993: 25).

[38] The second Dutch archaeological team from Groningen wish to minimize the amount of demographic change in the Pontine region and are reluctant to interpret in purely demographic terms (a common tendency among classical archaeologists without any foundation in population studies) the shift in settlement patterns which they discerned in north-eastern sectors of the Pontine region from a large number of small farmsteads to a smaller number of larger sites. However, there is no problem in relating the shift from peasant smallholdings in the proto-historic period to the Roman imperial economy of large villas based on slave labour to the spread of malaria, as will be seen later (Ch. 9 below). The Groningen archaeologists acknowledge that in some of their survey zones pottery sherds later than the Roman Republic do not occur in the sediments (Attema (1993: 103)). The prosperity of the Roman colonies at Cori, Norba, and Setia (upon whose hinterlands the Groningen surveys concentrated), as well as Terracina, is not surprising, since they were all situated at altitude (e.g. Attema (1993: 82–3) noted that Cori is 405 metres above sea level, a geographical position which reduced or eliminated malaria). However, the fact that hilltop settlements prospered does not in any way exclude the possibility of intense malaria in the Pontine plain below the hills, a phenomenon explicitly attested by ancient sources such as Vitruvius and Strabo.

most of the then known world, probably the nastiest job ever assigned to a Roman consul.

It is impossible to quantify the collapse of the *free* population (the significance of slavery in this region will be discussed in Chapter 9 below), but later parallels offer stark illustrations of malaria's capabilities in that part of the world. A misguided drainage scheme in the late eighteenth century, which blocked a river and in so doing created a large marsh right underneath the town, introduced malaria to Sermoneta (257 metres above sea level), which had previously been free of it. That brought about a substantial reduction of 50% or more in the population of the town, which fluctuated considerably over the decades. That is the likely scale of the collapse of the free population in the Pontine region after the fourth century BC. The Amsterdam field survey suggested that there was no subsequent general recovery in Roman times, even if Cethegus was responsible for the handful of settlements which sprung up sometime along the Via Appia: namely ad Medias, Tres Tabernae, Tres Pontium, and Forum Appii.[39] Consequently our conclusion must be that Cethegus' operations were a complete failure, like numerous other ancient (and more recent) drainage schemes. In fact North made the correct interpretation of the value of Cethegus' work as long ago as 1896, without the benefit of the archaeological data which have only become available in the last few years. He made the acute observation that if Cethegus' work was completed in such a short space of time as a single year, during his consulship in 160 BC, it could not have been *serious*. Drainage is not a trivial business. In fact this interpretation had already been debated by the eighteenth-century historians. Nicolai discussed Corradini's theory that Cethegus carried out his drainage works not in his official capacity as consul, but as a private individual (as Decius did in late antiquity—see below). He proposed this hypothesis, which requires an unnatural, metaphorical interpretation of the text of the summary of Livy, in order to free Cethegus from the temporal constraints of a consulship lasting a single year. Since the objective of Corradini's line of argument was to reach a conclusion, namely that Cethegus' works were a great success, for which there is no evidence nor any probability, his argument is unnecessary.[40]

[39] C. W. Koot in Voorips *et al.* (1991: 125–30); Nicolai (1800: 38–44) on the settlements along the Via Appia. North (1896: 24) gave data for birth–death ratios in Sermoneta for the crucial period from 1779 to 1869.

[40] North (1896: 79, 124); Nicolai (1800: 74–9).

The Pontine region undoubtedly suffered severely during the civil war between Marius and Sulla, described by Appian, when Norba, Setia, and many other towns in Latium and Etruria were sacked by one side or the other. Nevertheless the devastation caused by the war does not explain why there was no subsequent recovery in an extremely fertile land. For that, a different sort of explanation is required. Archaeological and literary evidence combine to suggest that the Pontine Marshes remained a very large expanse of marshland which was intensely infested with malaria for the rest of antiquity, and indeed thereafter until Mussolini, despite the attention of numerous statesmen over the intervening two thousand years. Julius Caesar presumably gained first-hand experience of the region's problems in about 67 BC, while curator of the Via Appia.[41] Nothing came of Caesar's subsequent plan, noted earlier (Ch. 1 above), to drain the Pontine Marshes. Anthony tried to revive it after his death.[42] A scholiast on a corrupt line of Horace claims that Augustus also drained the Pontine Marshes and made them productive for agriculture.[43] The evidence for this particular attempt at drainage operations is very thin, but if it did take place it was certainly not fruitful, since contemporary sources leave no doubt that malaria was endemic at that time. Strabo's testimony confirms the evidence of Vitruvius on the Pontine Marshes quoted earlier:

The whole of [Latium] is prosperous and produces everything apart from a few districts along the coast, the marshy and unhealthy areas, such as the territory of Ardea[44] and the land between Antium and Lanuvium[45] as far

[41] Plutarch, *Julius Caesar* 5.9, ed. Ziegler (1971): *ὁδοῦ τῆς Ἀππίας ἀποδειχθεὶς ἐπιμελητὴς πάμπολλα χρήματα προσανάλωσε τῶν ἑαυτοῦ* (After being appointed curator of the Appian Way he spent a lot of his own money on it.).

[42] Cassius Dio 45.9.1: *χώραν ἄλλην τε πολλὴν καὶ τὴν ἐν τοῖς ἕλεσι τοῖς Πομπτίνοις, ὡς κεχωσμένοις ἤδη καὶ γεωργεῖσθαι δυναμένοις, κληρουχθῆναι διὰ Λουκίου Ἀντωνίου ἀδελφοῦ δημαρχοῦντος ἐσηγήσατο* (Through his brother Lucius Antonius, a tribune, he proposed a law to divide and allot a lot of other land as well as the Pontine Marshes, since they had already been filled in and cultivation was possible.).

[43] Horace, *de arte poetica* 65–6, ed. Brink (1971), with his commentary ad loc; Nicolai (1800: 81–9) and de la Blanchère (1884: 102–3) on the Pontine region in the time of Augustus.

[44] Blewitt (1843: 531) described Ardea in the nineteenth century as follows: 'the malaria is so severe in summer that the village is almost deserted', cf. Hare (1884: ii. 278): 'desolate and forlorn as it is now, and almost totally deserted by its plague-stricken inhabitants during the summer months, Ardea was once one of the most important as well as one of the wealthiest cities of Latium' (according to Dionyisius Hal. *AR* 4.64.1 and Virgil, *Aeneid* 7.411–13), cf. Tomassetti (1910: ii, 446–61, esp. 447). Seneca, *Epist. Mor.* 105.1 hinted at the unhealthiness of Ardea during the Roman Empire, cf. Martial 4.60.

[45] Blewitt (1843: 531) described Pratica di Mare as follows: 'the place is heavily afflicted

as the Pontine region and some parts of the territory of Setia as well as the area around Terracina and Circeii.[46]

Next are the plains, some of which adjoin Rome and its suburbs, while others lie towards the sea. Those which face the sea are less healthy, but the others are easily cultivated and decked out in the same way [sc. as the foothills of Mt. Albanus and Tusculum].[47]

In interpreting these two texts, it is very important to realize that the coastal districts of Latium listed by Strabo, such as the Pontine Marshes, were not the only places where malaria occurred; they were simply the areas with the greatest intensity of malarial transmission and infection. This point becomes clear when the evidence of the medical writers, from Asclepiades to Galen, is considered (see Ch. 8 below). The medical writers show that *P. falciparum* malaria was common in at least some districts of the city of Rome itself even though Strabo does not mention the city of Rome as one of the unhealthy areas. The districts listed by Strabo correspond to the areas of Latium which were the most severely affected by malaria in 1782, but Bonelli's map shows that malaria was not confined to those coastal areas but occurred all over Lazio at that time, except at high altitude. Similarly the reports of the Florentine health magistrates in the first half of the seventeenth century show that malaria (especially *P. vivax*) occurred in many inland parts of Tuscany, besides the Maremma where *P. falciparum* malaria was intense.[48]

Cicero described the Pontine region as 'neither pleasant nor healthy' and did not show any appreciation whatsoever of this

with malaria, of whose fatal influence the countenances of the inhabitants bear a melancholy proof'.

[46] Strabo 5.3.5.231C: *ἅπασα δ' ἐστὶν εὐδαίμων καὶ παμφόρος πλὴν ὀλίγων χωρίων τῶν κατὰ τὴν παραλίαν, ὅσα ἑλώδη καὶ νοσερά, οἷα τὰ τῶν Ἀρδεατῶν καὶ τὰ μεταξὺ Ἀντίου καὶ Λανουίου μέχρι Πωμεντίνου καί τινων τῆς Σητίνης χωρίων καὶ τῆς περὶ Ταρρακίναν καὶ τὸ Κιρκαῖον.*

[47] Strabo 5.3.12.239C: *ἐφεξῆς δ' ἐστὶ πεδία, τὰ μὲν πρὸς τὴν Ῥώμην συνάπτοντα καὶ τὰ προάστεια αὐτῆς, τὰ δὲ πρὸς τὴν θάλατταν· τὰ μὲν οὖν πρὸς τὴν θάλατταν ἧττόν ἐστιν ὑγιεινά, τὰ δὲ ἄλλα εὐάγωγά τε καὶ παραπλησίως ἐξησκημένα.* One possible example of a healthy inland plain was that occupied by the Roman town of Privernum, constructed on the plain of the upper Amaseno river valley, separated from the Pontine plain by hills (Cancellieri (1997)). The modern town of Priverno lies on the slope of a hill adjoining the plain. A canalized, covered waterway ran right through the centre of the Roman city, which was clearly subject to flooding. The ground level has risen by 2.5 metres since antiquity. The construction of the town on a plain may imply that the plain was thought to be healthy then.

[48] Cipolla (1992: 49–51, 68–70, 79–80).

fascinating environment.[49] Silius Italicus also described the Pontine Marshes as pestilential, and mentioned the huge amount of alluvium which was being brought down by the river Ufente.[50] Virgil also described the river Ufente.[51] Nero had the idea of driving a canal through to lake Avernus from the Tiber delta, connecting all the lakes along the coast of Latium. Of course it was a complete failure.[52] Quintilian, as part of his advice on oratory, described the question of whether the Pontine Marshes could be drained as a matter of *conjecture*. He was not sure that it could be done.[53] Pliny the Elder, in the course of a wild attack on Asclepiades for his handling of herbal remedies, described the Pontine Marshes as land that was lost to Rome.[54] Juvenal shows that by the first century AD the thinly populated Pontine Marshes already had the reputation as a haven for brigands and highwaymen which it possessed in the early modern period.[55] Nevertheless the Romans never gave up. Even in the twilight of late antiquity they still kept on trying to drain the Pontine Marshes, an enormous task which was often reduced in practice to the more restricted aim of keeping open the Via Appia, upon which the marshes continuously encroached. Cassiodorus records one final attempt by the patrician Decius on behalf of king Theodoric in AD 507/11.[56]

49 Cicero, *de oratore* 2.290: *Pomptinum . . . neque amoenum neque salubrem locum.*

50 Silius Italicus, *Punica* 8.379–82: *et quos pestifera Pomptini uligine campi, | qua Saturae nebulosa palus restagnat, et atro | liventes coeno per squalida turbidus arva | cogit aquas Ufens atque inficit aequora limo* (and the Pontine Marshes which emit pestilential vapours, where the misty swamp of Satura inundates the land, and the Ufens forces its waters, discoloured by dark mud, over neglected fields, and dyes the sea with mud).

51 Virgil, *Aeneid* 7.801–2: *qua Saturae iacet atra palus gelidusque per imas | quaerit iter vallis atque in mare conditur Ufens* (where the black marsh of Satura is situated and the cold Ufens makes its way through the bottoms of the valleys and reaches the sea).

52 Tacitus, *Annals* 15.42; Le Gall (1953: 125–6); Quilici (1979: 66).

53 Quintilian 3.8.16: *cum autem de hoc quaeritur, coniectura est . . . an siccari palus Pomptina.*

54 Pliny, *NH* 26.9.19: *siccentur hodie meroide Pomptinae paludes tantumque agri suburbanae reddatur Italiae* (Let the Pontine Marshes be drained today by the plant *merois* and so much land near the city be recovered for Italy.) *Merois* is an unidentified plant that was supposed to have magical properties from the Kingdom of Meroe in Sudan.

55 Juvenal, *Sat.* 3.305–8. There is even a museum in the area today devoted to this subject, the Museo del Brigante at Fienili di Sonnino, cf. Staccioli (1996).

56 The inscriptions *CIL* X.6850–1 provide further evidence for this attempt to drain the Pontine Marshes, giving the usual misleading impression that it was a complete success; cf. Cassiodorus, *Variae* 2.21 for similar activity at Spoleto. Nicolai (1800: 101–4) discussed Theodoric's bonifications. Marshes in general were regarded as suitable places for rubbish disposal (see e.g. Tacitus, *Histories* 4.53 for disposing of the ruins of an old temple, and *Annals* 15.43 for disposing of rubbish from the great fire of Rome in AD 64, in the marshes around Ostia.

> The magnificent patrician Decius . . . has promised to drain the marsh of Decemnovium, which devastates the vicinity like an enemy, by opening up channels. That notorious desolation of the age, through a long period of neglect, has established itself as a marshy sea, hostile to farming, which pours out a flood with its water that covers both arable land and quivering woods.[57]

Needless to say, this attempt, like all the others until Mussolini, was a failure in the long run. Doni made the following simple comment on the Via Appia in the seventeenth century: 'Wherever anyone rests, disease arises.'[58]

[57] Cassiodorus, *variae* 2.32.3, ed. A. J. Fridh (1973), *Corpus Christianorum Ser. Latina*, xcvi: *magnificus atque patricius Decius . . . paludem Decemnovii in hostis modum vicina vastantem fovearum ore patefacto promisit absorbere, illam famosam saeculi vastitatem, quam diuturnitate licentiae quoddam mare paludestre consedit cultisque locis inimicum superfundens unda diluvium terrenam gratiam silvestri pariter horrore confudit.*

[58] Doni (1667: 115): *ubi quis quieverit, morbus exsurgat.*

7
Tuscany

The situation north of the Tiber in Etruria during the Late Republic was broadly similar to the situation south of the Tiber in Latium, which was considered in the previous chapter. A fragment of Cato provides the earliest definite evidence for endemic malaria in a specific place in western central Italy in antiquity. Of course this text simply yields a *terminus ante quem*, since there are no relevant earlier extant contemporary Latin sources for the Middle Republic:[1]

From Pliny in the *Natural History* and Cato in the *Origins* we learn that Graviscae is unhealthy, pestilential, if *unhealthy* is taken to mean *lacking a moderate climate*, in other words a calm climate; for according to Cato Graviscae is so called because it supports bad air.[2]

Unfortunately the text of Pliny to which Servius also refers is not extant. The etymology that Cato offers for the name of Graviscae, the port of Tarquinia, may be worthless, like most ancient etymologies. Nevertheless the logic of Cato's argument implies that by the time of his death in 149 BC Graviscae was notorious for 'bad air', (i.e. malaria), even though it was the location of a Roman colony which had been founded as recently as 181 BC. Doni noted in the

[1] Out of the sources which are usually discussed in relation to this problem, Plautus, *Curculio* 17, *caruitne febris te heri vel nudiustertius* (Were you free from fever yesterday or the day before?), and Terence, *Hecyra* 357, *quid morbi est? febris. cottidiana? ita aiunt* (Which disease is it? A fever. A quotidian fever? So they say), the latter dating to 165 BC, may simply have been translating their Greek originals. Nevertheless these texts presuppose that a Roman audience would have understood these terms. Pliny, *NH* 7.49.166 states that the consul Q. Fabius Maximus lost a quartan fever in battle on 8 August 121 BC in the south of France, *Q. Fabius Maximus consul apud flumen Isaram . . . febri quartana liberatus est in acie* (The consul Q. Fabius Maximus was liberated from quartan fever in the battle at the river Isara.). Festus, 343. 30–32, ed. Lindsay (1913), followed Paulus in quoting the lines of the second century BC poet Lucilius, *iactans me ut febris querquera* (tossing me like a *querquera* fever) and *querquera consequitur capitisque dolores* (a *querquera* follows and headaches) , where *querquera* is a malarial fever accompanied by shivering.

[2] Cato, *origines* 2.17, ed. M. Chassignet (1986) [= 46 P] *ap.* Servius, *ad Verg. Aen.* 10.184: *Intempestas ergo Graviscas accipimus pestilentes secundum Plinium in Naturali Historia et Catonem in Originibus, ut intempestas intellegas sine temperie, id est tranquillitate: nam ut ait Cato, ideo Graviscae dictae sunt, quod gravem aerem sustinent.* Fraccaro (1928) discussed this text.

Map 5. The Maremma and Valdichiana

seventeenth century that Graviscae was located only two thousand paces from the left bank of the river Marta, one of the malarious river valleys of western central Italy. Moreover the site of the Greek trading settlement or *emporion* and the adjacent Roman colony is located only a few metres away from salt pans today. These *saline* were constructed out of a salt marsh in the nineteenth century. Doubtless in antiquity this area of marshland provided a breeding habitat for the deadly anthropophilic species of mosquito *A. labranchiae*.[3] In that context, the famous observations made by Tiberius

[3] Livy 40.29.1; Velleius Paterculus 1.15.3; Doni (1667: 77); Gianfrotta (1981) discussed [*cont. on p. 196*]

25. Some of the ruins of the Roman colony founded in 181 BC at Graviscae, the port of Tarquinia. This was the location of the earliest endemic malaria in mainland Italy attested by a contemporary ancient source.

26. A few metres beyond the remains of the Roman colony of Graviscae are the modern *saline*, which were created from a salt marsh in the nineteenth century. This was the breeding habitat where *A. labranchiae* flourished to create the earliest endemic malaria recorded for mainland Italy in antiquity by a contemporary source.

Gracchus in 137 BC on his journey through Etruria to join the Roman army at Numantia in Spain are plausible:

His brother Gaius wrote in a book that Tiberius, travelling through Etruria on his way to Numantia, saw the desolation of the countryside and observed that the farmworkers and shepherds were imported slaves and barbarians, and it was at that moment that the policy which brought them countless misfortunes entered his mind.[4]

Tiberius Gracchus' observations of the depopulated state of southern Etruria (depopulated apart from gangs of barbarian slaves) led him to believe that it was essential, for the sake of maintaining Roman military manpower (according to Appian's account), to introduce a scheme for the redistribution of public land (*ager publicus*) which had been taken over by the rich. This scheme had fateful consequences for the stability of the Roman Republic.[5] His observations of the state of the countryside are hardly surprising given that malaria was already endemic at Graviscae, as has just been seen. Nevertheless it is arguable that Tiberius Gracchus' analysis of the causes of the situation, blaming it on the avarice of the rich, was inadequate. The undesirable state of coastal and southern Etruria had much deeper causes than that. It is not surprising that neither the colony of 181 BC nor the colony or individual allotments of land subsequently made by Augustus at Graviscae prospered.[6]

The coast of Etruria continued to be severely afflicted with malaria for the rest of antiquity. There are fewer texts that refer to the state of the coastal region north of the Tiber than to the coastal areas south of the Tiber. It is well known that much of the coastal

some of the archaeology of the Etruscan coast; Cristofani (1983: 122–4). In a related context Varro, *de lingua latina* 5.26 gave a false etymology of the word *palus*, marsh, cf. Traina (1988: 62–3, 73). See also Shuey (1981).

4 Plutarch, *Tiberius Gracchus* 8.9, ed. Ziegler: ὁ δ᾽ ἀδελφὸς αὐτοῦ Γάιος [HRR I^2 119] ἔν τινι βιβλίῳ γέγραφεν, εἰς Νομαντίαν πορευόμενον διὰ τῆς Τυρρηνίας τὸν Τιβέριον καὶ τὴν ἐρημίαν τῆς χώρας ὁρῶντα καὶ τοὺς γεωργοῦντας ἢ ἐπεισάκτους καὶ βαρβάρους, τότε πρῶτον ἐπὶ νοῦν βαλέσθαι τὴν μυρίων κακῶν ἄρξασαν αὐτοῖς πολιτείαν.

5 5 Appian, *Civil Wars* 1.7–11; Barker and Rasmussen (1998: 272–3) on T. Gracchus' journey in 135 BC.

6 *Liber coloniarum* i, 220, ed. Lachmann (1967), in *Die Schriften der Römischen Feldmesser*: *colonia Graviscos ab Augusto deduci iussa est.* Harris (1971: 308) regarded this entry in the *Liber Coloniarum* as a mistake, but he did not consider all the evidence for the state of Graviscae in antiquity. As a result of depopulation by malaria, Graviscae may well have been regarded in the time of Augustus as a locality that had room for fresh colonists. Virgil, *Aeneid* 10.184 also described Graviscae as unhealthy (*intempestaeque Graviscae*).

region north of the Tiber, especially the once great Etruscan city of Vulci, failed to make any significant contribution to the Roman war effort against Carthage in 205 BC, and was presumably incapable of being taxed.[7] In spite of the scarcity of references, the evidence provided by Pliny the Younger is explicit enough. He reassured his friend Domitius Apollinaris that he did not intend to spend the summer at his villa at Laurentum, close to the *vicus Augustanus Laurentium* (a small seaside town which belonged to the emperor) and modern Castel Fusano in Latium, by the unhealthy and pestilential Tuscan coast. Instead he intended to spend the summer at another villa far inland at Tifernum in Umbria, about eight kilometres north of Tifernum Tiberinum (modern Città di Castello), in the vicinity of the very healthy Appennine mountains.[8] The stretch of coast that Pliny regarded as unhealthy presumably included Graviscae, but it is not clear how much further north it stretched. Nevertheless Pliny's descriptions, to which several references are made in the course of this book (especially in Ch. 11 below), of his two villas, are very important evidence for the contrasting state of the geography, hydrology, and climate of two localities in central Italy with completely different pathocoenoses and mortality regimes. The former was an example of a place in a region where malaria was endemic, while the latter was a locality where there was no malaria at all. The demographic consequences of these differences in the physical environment will be highlighted later on (see Ch. 11 below). Pliny's response to malaria was the standard response of members of élites to pestilence throughout history: flight from the pestilential area, leaving those who had to work there for a living to their fate. Similarly in early modern England the aristocracy and the clergy took care to avoid the regions dominated by *P. vivax* malaria.[9]

The poet Rutilius Claudius Namatianus described the desolation of the coast of Etruria, including Graviscae, in AD 416:

> Next we see the scattered roofs of Graviscae,
> Which are often oppressed by the stench of the marsh in summer;
> But the neighbourhood, full of woods, is verdant with dense groves
> And the shade of the pines wavers at the edge of the sea.

[7] Livy 28.45.

[8] Pliny, *Epist.* 5.6.2: [Laurentum] *gravis et pestilens ora Tuscorum, quae per litus extenditur . . .* [Tifernum] *hi procul a mari recesserunt, quin etiam Appennino, saluberrimo montium.*

[9] Dobson (1997: 298–9); Leach (2001).

We see the old ruins, guarded by no one,
And the disintegrating walls of abandoned Cosa.
The ridiculous reason for its abandonment should not be recorded in serious
Accounts, but it would be undesirable to conceal a funny story.
The citizens are said to have been forced to move away,
Abandoning their homes infested with rodents.[10]

Again, the observation of desolation is more convincing than the explanation of the population explosion of mice or rats offered for it in the case of the abandoned town of Cosa. True plague (*Yersinia pestis*), which is transmitted principally by rat fleas, did not appear on the scene until the reign of the Byzantine emperor Justinian in the sixth century AD. Celli argued that there was no endemic malaria on the Tuscan coast in the early fifth century AD because Rutilius does not mention it. Celli's 'argument from silence' is untenable because the reference in line 282 to the smell of the marshes of Graviscae in summer is a very explicit reference to 'bad air', (i.e. *mal'aria*). Consequently it is extremely probable that the depopulated condition of Graviscae in the early fifth century AD was caused by malaria.[11] Rutilius' words can be compared to the famous invocation of the same stretch of coast by Dante in the *Divine Comedy*.[12] Dante himself died of fever at Ravenna in 1321. Again, as has already been seen in the case of Pliny the Elder, Rutilius showed no interest whatsoever in describing the natural, as opposed to the human, environment for its own sake.

The Maremma continued to be infested with malaria until modern times.[13] Malaria generated acquired immunity in those

[10] Rutilius Claudius Namatianus, *de reditu suo sive Iter Gallicum*, ed. Doblhofer (1972), ll. 281–90: *Inde Graviscarum fastigia rara videmus, | quas premit aestivae saepe paludis odor; | Sed nemorosa viret densis vicinia lucis | pineaque extremis fluctuat umbra fretis. | Cernimus antiquas nullo custode ruinas | et desolatae moenia foeda Cosae. | Ridiculam cladis pudet inter seria causam | promere, sed risum dissimulare piget. | Dicuntur cives quondam migrare coacti | muribus infestos deseruisse lares.*

[11] Celli (1933: 48–9), contrast Scullard (1967: 61); Sallares (1991: 263–71) and the papers in the forthcoming publication of the conference on the plague of Justinian at the American Academy in Rome (2001) on true plague; Dennis (1878: 194–211) described the condition of the Maremma in the nineteenth century.

[12] Dante Alighieri, *La Commedìa: Inferno. Canto* XIII.1–9, ed. Lanza (1996): *Non era ancor di là Nesso arrivato, | quando noi ci mettemo per un bosco | che da neun sentiero era segnato. | Non fronda verde, ma di color fosco; | non rami schietti, ma nodrosi e 'nvolti; | non pomi v'eran, ma stecchi con tòsco. | Non han sì aspri sterpi né sì folti | quelle fiere selvagge che 'n odio hanno | tra Cecina e Corneto i luoghi cólti.*

[13] Ciuffoletti and Guerrini (1989: 86) quoted the following traditional Italian song: *Tutti mi dicon Maremma Maremma | E a me mi pare una Maremma amara | L'uccello che ci va perde la penna | Io ci ho perduto una persona cara | Sia maledetta Maremma Maremma | Sia maledetta Maremma e chi l'ama | Sempre mi trema il cor quando ci vai | perché ho paura che non torni mai.*

27. The maintained wetland which is displayed to visitors to the Parco Naturale della Maremma, photographed at the end of July in an extremely hot summer (daytime temperature approaching 40°C). Parched vegetation is visible in the foreground, as the wetland desiccates during the summer. The national park guide told the author that the water in these wetlands is not completely fresh but brackish, although the salt content is very low. These conditions favoured those species of *Anopheles* mosquito which were important vectors of malaria in Italy in the past. The cattle in the background belong to the breed indigenous to the Maremma.

who survived childhood in the Maremma just as it did in the region of Ravenna (see Ch. 4. 2 above). Consequently it was possible for the local inhabitants to deny that malaria was a serious problem, as those questioned by the English novelist D. H. Lawrence at Montalto di Castro, near Vulci, did during his visit to Tuscany in April 1927, the healthiest time of the year. However, Lawrence was perceptive enough to understand the reality of the situation. He also noted that malaria was a severe problem for early modern archaeologists attempting to explore ancient Etruscan sites.[14] One of the disease's victims was Alessandro François, discoverer of the famous François tomb at Vulci.

As a postscript, it should not be forgotten that malaria is spreading again in developing countries, following the evolution of

[14] Lawrence (1986: 121–3, 129, 132).

resistance to antimalarial drugs by the parasites and resistance to insecticides by the mosquitoes.[15] In spite of all the bonifications of the twentieth century, the potential for malaria to return to western central Italy in the future still exists. This potential does not reside so much in modern *tropical* strains of *P. falciparum*, to which Italian mosquitoes are refractory, as Coluzzi has argued, as in *P. vivax*.[16] In August 1997 an Indian girl, who had moved to the Maremma from the Punjab and was infected with *P. vivax* malaria, was bitten by an Italian mosquito (probably *A. labranchiae*), which then transmitted the disease to an Italian woman resident in a sparsely populated area of the Maremma.[17] This case shows how easily a single infected individual can spread malaria over large geographical distances. There were close political relations and commercial links between the Etruscan city-states and Carthage (i.e. North Africa) in the middle of the first millennium BC. This is shown by the Phoenician–Etruscan bilingual texts excavated at Pyrgi, the port of Caere (modern Cerveteri), and Aristotle's comments on the close political relations between Carthage and the Etruscan city-states.[18] Later on in Roman times North Africa was an important source of grain and other commodities for the city of Rome. Consequently it was inevitable that malaria would be introduced to central Italy in antiquity directly from Africa, as well as from southern Italy, Sardinia, Sicily, Greece, and the Near East. It became endemic in central Italy as soon as localized (and frequently anthropogenic) environmental change created suitable breeding sites for the mosquito vectors.

[15] Krogstad (1996); Marsh (1998) on the recent upsurge of mortality directly caused by *P. falciparum* malaria in Africa following the development of resistance to the drug chloroquine.

[16] Coluzzi (1999).

[17] Baldari *et al.* (1998), cf. Castelli *et al.* (1993); Sabatinelli *et al.* (1994); Romi *et al.* (1997).

[18] Aristotle, *Politics* 1280ᵃ35–7.

8

The city of Rome

The city of Rome itself is obviously of particular interest. It requires discussion on its own, since it constituted a distinctive environment, as far as malaria is concerned, which must be considered separately from the Campagna Romana, the Pontine Marshes, and the Tuscan Maremma. Cicero gave credit to the legendary Romulus for choosing a healthy spot in a pestilential region for the site of the city:

> He chose a site which both has abundant sources of water and is healthy, in a pestilential region, for there are hills[1]

Similarly Livy spoke of the 'very healthy hills' of Rome.[2] He put these words into the mouth of Furius Camillus in a speech supposedly delivered *c.*386 BC, following the siege of Rome by the Gauls, in the context of a proposal to move the entire population of Rome to the healthier site of Veii. The statements of Cicero and Livy are admissions that the areas surrounding the hills of Rome were unhealthy in their own time. (Whether Livy's statements actually tell us anything about the fourth century BC is a separate question.) During his description of the Gallic siege Livy had earlier described an outbreak of disease among the Gauls (exacerbated by food shortage). This epidemic was attributed to the unhealthy location of their camp on low ground between hills.[3] Such localities were evidently regarded as unhealthy in Livy's own time. Malaria is the only major disease that has this precise ecological requirement in Mediterranean environments, because the low ground is where mosquitoes breed. The Gallic siege may be the earliest attested example of the devastating malaria epidemics destroying foreign armies attacking Rome that occurred in so many later

[1] Cicero, *de republica* 2.6.11: *locumque delegit et fontibus abundantem et in regione pestilenti salubrem; colles enim sunt.*

[2] Livy 5.53.4: *saluberrimos colles.*

[3] Livy 5.48.1–3: *urgebat, Gallos pestilentia etiam, cum loco iacente inter tumulos castra habentes,* (Pestilence was also affecting the Gauls, since their camp was situated in a place between hills.).

historical episodes, and this could be the reason why the Gallic sack of Rome apparently did little damage to the city, according to the results of recent archaeological research. Unfortunately no description of the symptoms is provided by Livy.[4]

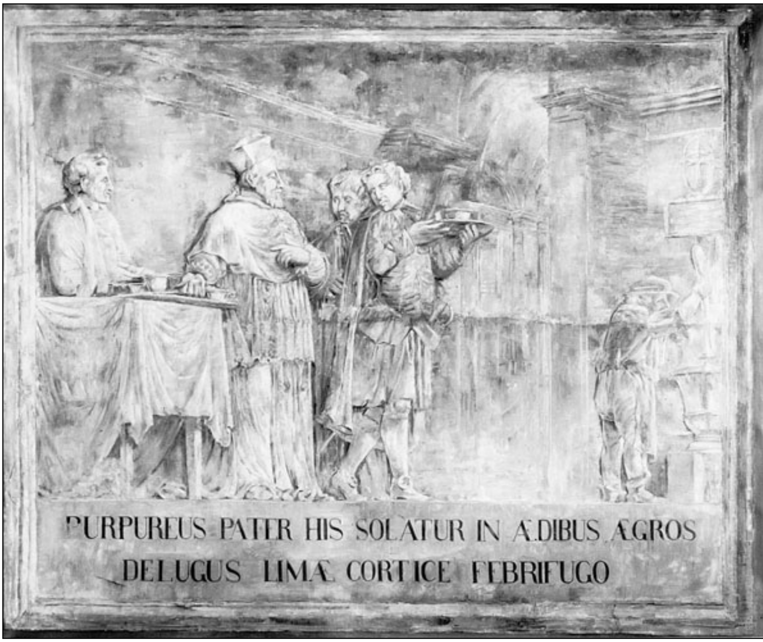
Livy's comments illustrate the close juxtaposition of healthy and unhealthy areas that was characteristic of malaria in Italy in the past. In the early modern period the incidence of malaria in the most densely populated districts of the city of Rome itself on the hills was also often described as relatively light. For example, Bonelli described 'light malaria' in the city of Rome in 1782. Bercé, writing about the sixteenth and seventeenth centuries AD, stated that 'the city of Rome was not regarded as really dangerous, except for the hot months in some districts exposed to Tiber floods'.[5] Nevertheless the description of how the cardinals, who assembled in the Vatican following the death of the pope on 8 July 1623 to elect a new one, were decimated by malaria by 6 August suggests that it was essential (especially for non-immune visitors) to be very careful indeed which districts of Rome they entered. Eight cardinals and thirty other officials died and numerous others became ill. The new pope Urban VIII fled for his life from the Vatican to the Quirinal (61 metres above sea level), which was thought to be safer. Subsequent papal elections were less lethal because of the increasing use of quinine, which was brought back to Rome in 1632 from South America in the bark of the cinchona tree by the Spanish priest Alonso Messias Venegas. It became popular after a successful trial in the Santo Spirito hospital in Rome organized by Cardinal Juan de Lugo in 1643.[6]

The artificial infection experiments at Horton Hospital in England demonstrated that by the twentieth century infections with Italian strains of *P. falciparum* required much larger doses of quinine for treatment than infections with African or Indian strains. This may be evidence for the evolution of a degree of resistance to quinine by *P. falciparum* strains in Italy between the seventeenth and the

[4] About four years earlier, according to the annalistic tradition (Livy 5.31.5), a very hot and dry summer had caused disease and famine in the vicinity of Rome, preventing the Romans from sending out an army against Volsinii. This might be an even earlier malaria epidemic, but there is no description of the symptoms.

[5] Bonelli (1966: map on pp. 678–9); Bercé (1989: 241): *la ville de Rome n'était d'ailleurs pas réputée vraiment dangereuse, avec l'exception des mois chauds dans les quelques quartiers accessibles aux débordements du Tibre.*

[6] Celli (1933: 130); P. F. Russell (1955: 93).



28. Cardinal Juan de Lugo (1583–1660) orders the use of cinchona bark to treat patients with intermittent fevers. Reproduction of an oil painting by a Roman painter in the Ospedale di Santo Spirito in Rome. The Wellcome Library, London.

twentieth centuries.[7] However, there were no effective remedies for malaria in Europe in antiquity. The papal election in 1623 demonstrates how devastating *P. falciparum* malaria sometimes was in Rome before the increasing use of quinine moderated its effects both in Rome in particular and more generally in Europe as a whole. The records of the *Listae status animarum almae urbis Romae* indicate a crude death rate for Rome of 43.1 per 1,000 in 1623, a bad year for malaria. This figure may be compared to the normal crude death rate of slightly over 30 per 1,000 estimated for Florence, a city unaffected by *P. falciparum* malaria, during the early seventeenth century by Cipolla, as an indication of the excess mortality that might be produced in Rome by an epidemic of malaria.[8]

[7] Covel and Nicol (1951).

[8] Schiavoni and Sonnino (1982: 107) record that the crude death rate in Rome in the pre-

To understand the demographic evidence from the periods studied by Bercé and Bonelli for the purposes of comparison with the evidence of the ancient medical authors which will be considered shortly, it has to be remembered that the population of the city of Rome during those periods was very approximately an order of magnitude smaller than it was during the time of the Roman Empire. The *Listae status animarum almae urbis Romae* recorded a population of slightly more than 90,000 people at the end of the sixteenth century, perhaps very roughly a tenth of the population of imperial Rome.[9] Consequently the low-lying, frequently flooded areas along the Tiber, in the valleys between the various hills, as well as the lower slopes of the hills, the most dangerous areas in terms of the risk of malaria and densely occupied during the time of the Roman Empire, had a much smaller human population during the periods studied by Bercé and Bonelli. The popes from Sixtus V in the late sixteenth century onwards had instigated a deliberate policy of shifting settlement from the low-lying areas to the

vious year, 1622 (an even worse year for malaria), was 54.1 per 1,000. They note (p. 105) that the pontifical statisticians kept these demographic records precisely so as to be able to make *les nombreuses observations que l'on peut faire sur la qualité de l'air.* Cipolla (1992: 78) on Florence; del Panta and Rettaroli (1994: 35–7). Spigelio (quoted by Corradi (1865: ii. 39)) described the disease of 1622 as *febbre semiterzana maligna*. Corradi also quoted Doni on this year: *A. MDCXXII aestas atque autumnus magnum proventum malignarum febrium attulerunt, quae paucis mensibus multa hominum milia, ad vicena, vel tricena ferme atque ex his plurimos nobiles atque illustriores oppresserunt* (In the year 1622 the summer heat and the autumn brought a great crop of malignant fevers, which in a few months killed many thousands of men, up to twenty or nearly thirty thousand, including many of the nobles and more illustrious men.). Compare Cagnati's (1599) description of the year 1593 in Rome (discussed by Corradi (1865: ii. 684–6): *abortis tertianis praesertim, quas duplices vocant, quartanis, dysenteriis, fluoribus ventris, et acutis febribus, quae aliquos interficere* (Particularly common were failed tertian fevers, which they call double tertians, also quartan fevers, dysenteries, diarrhoea, and acute fevers, which caused some fatalities.). Cagnati then went on to give a detailed description of the symptoms of the intermittent fevers of that year. Corradi (1865: i. 640) summarized 1581 as follows, a mixture of different diseases: *Mali assai perniciosi furono nell'estate in Roma, dove pure, siccome in altre parti d'Italia, caddero strabocchevoli pioggie. Erano febbri terzane, quartane, continue con esanthemi, cioè petecchie e dissenteria.*

[9] Schiavoni and Sonnino (1982: 97–100) record a population for the city of Rome of 90,455 in AD 1598. By 1699 it had climbed to 135,099. By 1797 the city's population had increased to about 160,000, although it dropped to 112,000 by 1814, as a result of the two periods of French occupation. J. C. Russell (1985: 1–25) and Storey (1997) attempted to revise the population of the city of Rome during the period of the Roman Empire downwards to about 450,000, on the basis of the density of houses in Ostia and Pompeii. Such arguments do not take account of the evidence of ancient authors indicating that ancient Rome had large numbers of multi-storey dwellings (e.g. Aelius Aristides, *Orat.* 14 p. 324, ed. Dindorf; Aulus Gellius *NA* 15.1.2; Dionysius Hal. *AR* 10.32.5; Vitruvius 2.8.17; Strabo 5.3.7.235C; Herodian 7.12.5–7; Cicero, *de lege agraria*, 2.96), and so a higher population density.

healthier hills.[10] (Human settlement was perforce concentrated in low-lying areas for much of the medieval period because of the need for drinking water, following the breakdown of most of the aqueducts, which had brought water to the city of Rome during the time of the Roman Empire.[11]) As Delumeau put it in his monumental study of the city of Rome in the sixteenth century:

It is for reasons of health that the popes now took an interest in the zone of the hills: in the summer they fled the heat and the pestilential air of the lower town.[12]

The danger of malaria was mitigated in medieval and early modern Rome by extreme avoidance behaviour (see also Ch. 11 below). For example, a substantial proportion of the population went away from the city during the dangerous period of late summer and early autumn. In the seventeenth century those who left Rome for the mountains during the summer would not return to the city before the Ides of October at the earliest.[13] Such customs would be expected to reduce both morbidity and mortality from malaria. Presumably the very considerable extent of temporary migration during the summer away from dangerous areas, such as Rome and Grosseto, explains why the recorded crude death rates from such areas in early modern Italy often seem to have been, if anything, lower than the crude death rates in the English marshlands (see Ch. 5. 4 above), even though the combination of *P. falciparum* and *P. vivax* in Italy was more dangerous than *P. vivax* alone in the marshlands of England. In Italy in antiquity, members of the élite had the option of moving to villas in healthier areas during the summer and autumn, as the Younger Pliny did when he went to Tifernum in Umbria. However, it is not obvious that the bulk of the mass of the urban plebeians in antiquity had anywhere to go during the dangerous season, and slaves had no say in the matter.

More detailed accounts of the medical geography of the city

[10] Finding safe locations for the pope and his court during the dangerous season was indeed a constant preoccupation long before the period studied by Delumeau. Toubert (1973: i. 363–4, ii. 1051–3) wrote about the eleventh and twelfth centuries as follows: *les sources narratives et les pérégrinations anciennes de la cour pontificale à travers le Latium illustrent, en tout cas, cette recherche constante de l' 'aria buona' dont les malariologues ont confirmé le bien-fondé.*

[11] Procopius *BG* 1.19.28 noted that the Romans relied on wells for their drinking water during the siege by the Goths in the sixth century AD.

[12] Delumeau (1957: i. 311): *C'est pour des raisons de salubrité que les Papes s'intéressent désormais à la zone des 'monts': l'été ils fuient la chaleur et 'l'air pestiféré de la ville basse'.*

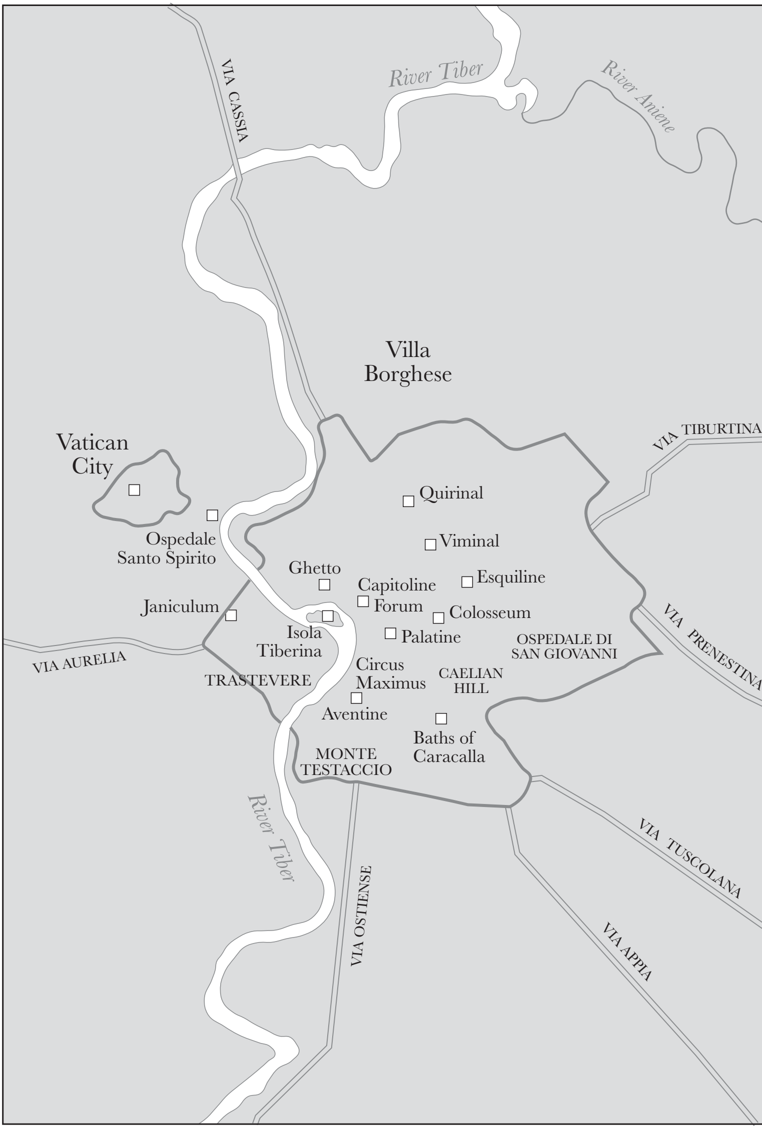
[13] Doni (1667: 114).

of Rome show that the distribution of malaria within Rome was as complicated as the topography of the city, with its numerous hills and valleys. Some districts were quite safe, while others were dangerous in the summer and autumn. Baccelli provided interesting information in a very useful but propagandistic article about malaria in the city of Rome, which was published by the Ministry of Agriculture in 1878, as part of a massive book (a goldmine of information) intended to help to justify the choice of Rome as the capital of the recently unified Italian state. Baccelli had the task of arguing that Rome was healthier than its reputation for bad air, especially among English writers and travellers, suggested. His task was in fact fairly easy by then. Extensive drainage schemes, filling in and paving over of low-lying areas, and substantial construction work all over the city, leading to the conquest of the lower land from the hills (the inverse of the movement in the sixteenth century described by Delumeau), were indeed well on the way by then to eliminating malaria from the city of Rome. Indeed the situation improved so drastically that Mendini was able to describe Rome as now the healthiest of the large Italian cities, in his hygienic guide to Rome to which Baccelli contributed a preface.[14] Nevertheless Baccelli still had extensive information available about the situation before the modernization of Rome commenced:

> We find that on the right bank of the Tiber the centre of the Leonine city can be said to be immune to fevers; on the other hand more or less unhealthy are the side streets, Porta Angelica, the Vatican hill; the Janiculum and the entire area from the Janiculum to Porta Portese is unhealthy. On the left bank of the Tiber the unhealthiness of the vicinity of Monte Testaccio, of Porta and Via Ostiense and of Porta San Sebastiano is well known; the same may be said of the low-lying plain between the Caelian and Palatine hills, of the Aurelian wall, of Porta Metronia, of Via Ferratella until the Lateran hill and of the surroundings of Santa Croce in Jerusalem. Other more elevated localities, even if they cannot be regarded as completely immune to fevers, are sufficiently more healthy.[15]

[14] Pesci (1971: 596–7); Mendini (1897: 83–100).

[15] Baccelli (1881: 156): *Troviamo che sulla destra del Tevere la città Leonina, nel suo centro, può dirsi immune dalle febbri; più o meno malsane sono invece le vie laterali, Porta Angelica, il Monte Vaticano; malsani sono il Gianicolo e tutto quel tratto che si estende dal Gianicolo fino a Porta Portese. Sulla sinistra del Tevere è nota l'insalubrità delle adiacenze di Monte Testaccio, di Porta e via Ostiense e di Porta San Sebastiano; così pure dicasi del basso piano compreso tra il Celio e il Palatino, del recinto Aureliano, di Porta Metronia, di via Ferratella fino al colle Laterano e dei dintorni di Santa Croce in Gerusalemme. Altri punti più elevati, se non possono dirsi immuni, sono assai più salubri.*



Map 6. The city of Rome

29. The vicinity of Monte Testaccio was one district of the city of Rome that was dangerous with regard to malaria in the past. The hill is about 45 metres above sea level and is composed entirely of broken pots, which had been thrown away from the port facilities of ancient Rome on the River Tiber nearby. It is now overgrown with vegetation.

Information is also given on districts that had been afflicted by malaria before the construction work mentioned above, for example Piazza Barberini, Via Quattro Fontane, San Nicola da Tolentino, Via Urbana, and the vicinity of the Baths of Diocletian. The drainage of the lake at the entrance of the Villa Borghese eliminated malaria from that particular district. Celli wrote that 'it was sufficient in those days only to ride in the evening through the Villa Borghese in order to catch the fever'.[16] Other writers also gave detailed accounts of the medical geography of the city of Rome with reference to malaria. One of the earliest such works was the pioneering book on the medical geography of malaria in the Roman Campagna written by Giovanni Baptista Doni, who has already been mentioned several times in passing, *de restituenda salubritate Agri Romani*, published in Florence in 1667. Doni began by observing that various countries were noted for particular diseases. He gave as one example the 'sweating sickness' in England, a

[16] Celli (1933: 131), referring to the first half of the nineteenth century.

phenomenon of that period which has puzzled medical historians ever since. The causative pathogen might have been a hantavirus, according to the most recent research. Doni explicitly compared the *Ager Romanus* as a whole to southern Sardinia, and then concentrated on malaria in the city of Rome. He reckoned that the most heavily built-up areas of the city were healthier, also buildings facing north and east, and the districts further away from the Tiber, while areas close to the Tiber, and buildings facing south and west, and buildings in low-lying locations, particularly in the valleys, were more dangerous.[17]

He singled out the areas of the Campus Martius, between the Aventine and the Palatine hills, and the area between the Tiber and the Aventine as particularly dangerous (although the summit of the Aventine hill itself was healthy), as well as the area of the Ostian Gate, although the Leonine region was the worst of all. Doni had no difficulty recognizing the continuous and semitertian fevers described by Asclepiades and Galen (quoted below) as the cause of the problems in his own time.[18] The view expressed by Doni, Donatus, and later writers such as Lancisi, de Tournon, Colin, and North that a dense human population reduces the frequency of malaria is an instance of a correlation that does not necessarily indicate causation.[19] Of relevance here is the standard view in statistics that the fact that two sets of data are correlated does not prove that one of them is causing the other.

Since most people in the early modern period chose, if possible, to live in relatively healthy areas, most areas of dense habitation

[17] Doni (1667: 8–9): *Quaecunque loca crebris aedificiis ambiuntur, atque editiora sunt, et in Septentrionem, atque Orientem spectant, et longius a Tiberi absunt, salubriora: vice versa quae seiuncta sunt, et remota a frequentioribus tectis, situque sunt humili, ac maxime in convallibus; tum propiora Tiberi, in Meridiem, atque Occasum solis spectantia, minus salubria a peritioribus habentur.*

[18] Doni (1667: 6). Doni's work was partly written in response to the sixteenth century book of Alessandro Petronio (translated into Italian by Paravicini (1592)), a doctor from Cività Castellana who worked in Rome. He acknowledged that quotidian fevers and lethargy were common in Rome (*si vedano spesso*—Paravicini (1592: 200)), although he thought that semitertian fevers were rare, but nevertheless suggested that fevers as a whole were much less frequent in Rome than the ailments upon which he wished to concentrate, namely excess of humours in the head (*capiplenio*) and indigestion! He wished to concentrate on ailments which could possibly be influenced by his focus on diet, lifestyle, and exercise. Of course headache and indigestion are much commoner than major infectious diseases in all human populations, but the fact remains that only major infectious diseases have significant demographic consequences!

[19] e.g. Donatus (1694: bk iii. ch. 21, pp. 273–4): *Quaedam alia de Vaticano memorantur, haud sane firmis auctoritatibus nixa, praeter frequentia in eo campo sepulchra, et insalubre Coelum, quod noster aetas propter Civium, tectorumque frequentiam salubrius experitur.*

30. Via della Reginella, connecting Via del Portico d'Ottavio to Piazza Mattei, is a relic of the old Jewish Ghetto in Rome, a district that was walled until 1848. Despite its location, close to the River Tiber, and the poor living standards of its inhabitants, there was little or no malaria there. This may be attributed to the densely packed houses, with no gardens between them, and so a lack of mosquito breeding sites.

were fairly healthy. However, that does not prove that a high human population density by itself is enough to defeat malaria, and the comments of the ancient medical writers (to be discussed shortly) indicate that that was not the case in ancient Rome. The classic example given in early modern discussions of malaria in Rome was the Jewish ghetto. This district remained walled until 1848. It had a high population density and was free of malaria even though it was situated close to the Tiber, in the vicinity of Isola Tiberina. The key to understanding the situation in the ghetto is not the human population density as such, or the height of the buildings in it, but the absence of gardens in between the buildings. Irrigated gardens where Romans grew vegetables during the heat of the Mediterranean summer made a significant contribution to feeding the population of the city. However, they also furnished ideal breeding sites for mosquitoes, and this was explicitly noted in both ancient and early modern literary sources. For example, the anonymous author of a discourse on *mal'aria* written near the end of the eighteenth century observed that gardens were one of the deadliest producers of 'bad air' and noted the abundance of mosquitoes in gardens.[20] Similarly in antiquity Pliny the Elder noted the abundance of mosquitoes (*culices*) in well-watered gardens and recommended measures to try to drive them away.[21] This is a crucial piece of evidence because it identifies irrigated gardens, particularly those in which trees or bushes provided resting and hiding places for mosquitoes, as important breeding sites for mosquitoes in and around the city of Rome.[22] The elimination of gardens from many parts of Rome during the development of the modern city, as it changed in the direction of the modern situation in which most people live in blocks of flats without gardens, was an important factor in the eradication of malaria from Rome.

The observations of the early modern authors as a whole prove the importance of malaria not necessarily as a regular direct agent of mortality (although there certainly were some major epidemics from time to time), but as a determinant of settlement patterns

[20] Anon. (1793: 56): *zanzare, e tutti gli animali indicatori e propagatori della corruzione.* Tommasi-Crudeli (1892: 127) discussed the connection between malaria and market gardening in Rome.

[21] Pliny, *NH* 19.58.180: *infestant et culices riguos hortos, praecipue si sint arbusculae aliquae; hi galbano accenso fugantur* (Mosquitoes also infest irrigated gardens, especially if there are some shrubs; they are driven away by burning the resin of galbanum.).

[22] Pliny, *NH* 36.24.123 noted the abundant supplies of water to gardens in Rome.

in the city of Rome (at a time when the urban population was much smaller than during the Roman Empire). For example Gian Girolamo Lapi argued in the eighteenth century that intermittent fevers were no more frequent in Rome than in many other Italian cities and that it was safe to visit Rome in summer, even though he acknowledged that the air of the Roman Campagna was very unhealthy. However, even Lapi admitted that a majority of the citizens of Rome (*la maggiore parte*) were afraid of 'bad air', being unwilling to sleep in the villas in and around the city or even to move from one district of the city to another.[23] Malaria forced people to congregate in the healthier districts of the city, at a time when the unoccupied sections of the city amounted to about two thirds of the area within the Aurelian walls. Ellis Cornelia Knight mentioned a law in early modern Rome banning landlords from expelling tenants during the summer, so that no one should be forced to end up living in the dangerous parts of the city in summer. Her words clearly show malaria acting as a determinant of settlement patterns even though she believed, like Lapi, that those parts of the city where people congregated were safe.

> Seldom any rain falls during the months of July and August, and the air is perfectly calm . . . mephitic exhalations abound at this season of the year in the neighbourhood of any stagnant waters, and in the unfrequented parts of Rome, particularly over the catacombs. The few inhabitants who remain there are subject to fevers and agues, but their number is very inconsiderable; and no danger is to be apprehended where fires are kept up by any considerable number of houses. For this reason the cottagers of the Campagna usually leave their dwellings during summer, and sleep, either at Rome under the porticoes of the palaces and public edifices, or in the towns nearest to their little possessions. If they persist in remaining too long they get agues; and the greatest number of patients in the Roman hospitals, for the months of July, August, and September, consists of peasants from the circumiacent fields . . . During this month [sc. September], and the two preceding it, noone can be compelled to change his dwelling; as there is a law to that effect, for the purpose of preventing the pernicious consequences supposed to ensue, from the necessity of leaving a well-inhabited part of the town for one less salubrious.[24]

Many later authors followed Doni's approach to medical geography. Léon Colin produced a map of the frequency of malaria among the French troops stationed in various quarters of Rome in

[23] Lapi (1749: 11–16). [24] Knight (1805: 4).

31. The Colosseum lay in a valley between the Esquiline, Palatine, and Caelian hills in Rome. Such low-lying localities were favourable to malaria in the past.

1864.[25] Celli cited the work of the doctor Maggiorani, who as recently as 1870 'considered not only the valleys of Rome, such as the Forum, the Colosseum, the Prati di Castello and the villa Borghese, to be centres from which arose pestiferous exhalations, but also declared that the populated hills of Rome were not immune from fever'. Celli also drew attention to a map of malaria in Rome in 1884 produced by two doctors, Lanzi and Torrigiani, who listed 'even the quarters of Trastevere, Pincio, Viminale, Esquilin, Celio, Testaccio, Palatine' as malarious.[26] This all too brief survey of literature on the medical geography of the city of

[25] A. Gabelli, *Prefazione* in *Monografia* (1881: l–li); North (1896: 238–42); Colin (1870: 88–9); Marchiafava and Bignami (1894: 23–7) on Colin's classification of the malarial fevers which he observed in Rome. Beauchamp (1988: 258) made the observation that malaria is spreading today in developing countries which are experiencing rapid urbanization.

[26] Celli (1933: 167); Pinto (1882: 19–24) also described the healthy and unhealthy parts of Rome.

Rome proves that numerous parts of the city were affected by malaria in the fairly recent past. If we return to reconsider the already quoted text of Cicero, *de republica*, on the healthy location of Rome, it becomes evident that Cicero, in spite of his attack on Rullus for wanting to settle army veterans in the pestilential territory of Salpi in Apulia (see Ch. 10 below), was really no more interested in the health of the masses than he was in any other aspects of their welfare. When he described Rome as healthy, he was only thinking of the hilltop districts where the aristocracy lived, and ignored the low-lying areas where many poor Romans lived and worked.[27] This conclusion, at least, should not surprise historians with more conventional interests in political history.

To evaluate Cicero's statement, it also must be remembered that owing to sediment deposition in the intervening valleys by Tiber floods and deliberate infills in both antiquity and modern times, the hills of Rome were more impressive as hills in the early stages of Roman history than they are today.[28] The Esquiline, the highest of the seven hills of Rome, is only 65 metres above sea level, although the Janiculum (usually not counted among the seven hills) reaches 82 metres above sea level. Baccelli categorized the unhealthy lowland areas as having a topsoil which was always damp, though not actually waterlogged, with evaporation from the surface, overlying a stratum of impermeable *cappellaccio*, with substantial run-off of water from the hills of Rome, in other words a geology resembling that in areas of the Campagna Romana where cuniculi were constructed in antiquity.[29] In the early eighteenth century Lancisi had already noticed a correlation between certain types of soil and unhealthy locations. Scobie pointed out that the streets of ancient Rome were wet owing to the overflow from fountains and public water basins. This probably also created breeding sites for mosquitoes right inside the city. Moreover it is easy to underestimate the number of lakes inside the city. The lake which Nero constructed for his Golden House (*Domus Aurea*) should not be allowed to distract attention from all the other numerous bodies of water within the limits of the city, including for example the Velabrum, which was still navigated by boat at the end of the first century BC, and

[27] Galen noted that at Pergamum in Asia Minor the rich lived on the hill (Nutton (2000*b*: 70)).

[28] Ammerman (2000).

[29] Baccelli (1881: 156–7).

Table 8. Distribution of lakes within the city of Rome

Region number	Name of region	Number of lakes
1	Porta Capena	81
2	Caeleomontium	65
3	Isis et Serapis	65
4	Templum Pacis	71
5	Exquiliae	74
6	Altosemita	73
7	Via Lata	76
8	Forum Romanum Magnum	120
9	Circus Flaminius	120
10	Palatium	90
11	Circus Maximus	20
12	Piscina Publica	80
13	Aventinus	89
14	Transtiberim	180

Source: *Curiosum urbis Romae regionum, xiiii. Libellus de regionibus urbis Romae,* ed. Nordh (1949). There are minor discrepancies in the figures between the *Curiosum* and the other list, the *Notitia*, and the repetition of certain figures may also raise some doubts about the accuracy of the data, but there is no doubt about the overall impression.

the *lacus Caprae* in the Campus Martius.[30] According to late antique catalogues of the features of the fourteen regions of the city of Rome, there were no less than 1,204 lakes within the city.

Hirsch in his monumental pioneering book on disease epidemiology was correct to state that 'the Campagna di Roma . . . together with the city of Rome, forms one of the chief seats of the disease', although it was on its way out of the city by then. By the end of the nineteenth century it was thought that infection no longer occurred within the walls of Rome itself, although numerous cases were still brought to hospitals in the city, such as the Santo Spirito, from the Roman Campagna, where it was still endemic. As recently as 1886, 66% of the communities of Latium were still classified as suffering from endemic malaria.[31] Perhaps the most interesting account of a specific malaria epidemic in early modern Rome was given by Lancisi. In the second book of his famous work, published in 1717,

30 Varro, *de lingua latina* 5.43; Quilici (1979: 72–5).

31 Hirsch (1883: i. 214); Celli (1900: 86); the Inchiesta Jacini gave detailed information on the distribution of malaria in Latium.

32. Ospedale di Santo Spirito, the main hospital in Rome which received cases of malaria in the past. Also visible are the Lungotevere in Sassia river walls. The construction of effective river walls in the nineteenth century prevented malaria by stopping the River Tiber from flooding surrounding areas and so creating mosquito breeding sites.

he described at length the severe malaria epidemic which reached its height in August–September 1695. It affected principally the districts of the city closest to the Tiber, such as Trastevere and the Vatican. Lancisi mentioned all the main factors which have already been noted as prerequisites for malaria epidemics in the city of Rome (heavy rainfall which increased the volume of the Tiber, a Tiber flood, south winds, water overflowing from fountains, etc.). He noted that visitors to Rome were particularly badly affected, and described in detail the symptoms of the malarial fevers observed in that year.[32] During the time of the Roman Empire the district of Trastevere, where the port facilities of ancient Rome along the Tiber have recently been discovered, according to newspaper reports, was intensively occupied. Procopius states that the Romans constructed so many houses in Trastevere that the

[32] Lancisi (1717: esp. 193–7, 204–7, 244–6). Corradi (1865: ii. 278–84) reckoned that the epidemic of 1695 was a combination of malarial and petecchial fevers, and followed Haeser's description of it as *febbre intermittente gastrico-tifico* (on which see Ch. 5. 2).

33. The Roman Forum was another low-lying district of the city of Rome, where there was a risk of malaria infection according to Horace.

River Tiber appeared to be in the middle of the city, instead of marking the boundary with hostile Etruscan territory as it had done in the earliest stages of Roman history.[33]

In the light of the evidence of the medical geography of early modern Rome, it is not surprising that Rome was also troubled in antiquity. The Roman Forum was a dangerous place in antiquity, just as it was in 1870 according to Maggiorani. Horace described it as a place where one was likely to be infected with malaria in summer.[34] Similarly Juvenal testifies to the prevalence of malaria in Rome.[35] His evidence suggests that mixed infections with three different species of human malaria in the same person at the same time were common in ancient Rome, just as they were in those parts of Italy in more recent times where malaria was endemic. The importance of this piece of information is that it indicates a very

[33] Procopius, *BG* 1.9.10: *οἰκίας συχνὰς ἐν χωρίῳ τῷ ἀντιπέρας δειμάμενοι μέσον τῆς πόλεως τὸ τοῦ Τιβέριδος πεποίηνται ῥεῦμα.* Dionysius Hal. *AR* 4.13.3–5 described the great extent of the suburbs of Rome.

[34] Horace, *Epist.* 1.7.8–9: *officiosaque sedulitas et opella forensis adducit febris et testamenta resignat* (and courteous officiousness and work in the Forum bring on fevers and open wills).

[35] Juvenal, *Sat.* 4.56–7: *iam letifero cedente pruinis autumno, iam quartanam sperantibus aegris* (Already deadly autumn is giving way to winter frosts, and sick people are now hoping for a quartan fever.), cf. Juvanal, 10.221.

high transmission rate of malaria. Ill people in ancient Rome *hoped* for a quartan fever in late autumn because it signified a return to good health. Quartan fevers caused by *P. malariae* outlast more dangerous infections with *P. falciparum* and *P. vivax*, when all three are present at the same time in the same person, even though the quartan periodicity is masked by the more powerful rhythms of *P. falciparum* and of *P. vivax*, which both invade a larger proportion of erythrocytes than *P. malariae* does.

Mathematical models of the interaction of *P. malariae* and *P. falciparum* in the human bloodstream suggest that *P. malariae* struggles to establish itself if *P. falciparum* is already present in an individual. This explains the situation in tropical countries today. *P. malariae* has often been judged to be quite rare in environments where *P. falciparum* is active all the year round, using the traditional diagnostic technique of microscopic examination of blood smears on slides (although the modern techniques of molecular biology now suggest that it is in fact commoner even in tropical environments than used to be thought). However, the same mathematical models also yield the very important result that if a *P. malariae* infection occurs before an infection with *P. falciparum*, then *P. malariae* can establish itself, very significantly reduce the severity of a subsequent infection with *P. falciparum* because of cross-species immunological reactions, and outlast *P. falciparum*.[36] The interaction of the two diseases is very significant. Livy tells us that many of the survivors of an epidemic (doubtless involving other diseases as well as malaria) in 174 BC ended up with quartan fever.[37] This constitutes evidence for the presence of endemic quartan fever in Latium by then. It is likely that frequent infections with *P. malariae* earlier in that particular year reduced the severity of a major epidemic of falciparum and vivax malaria in the late summer and autumn of that year. The survivorship rate might have actually *increased* in the short term, contrary to what would have been expected if *P. malariae* had not been present at all. However, it must be remembered that malarial infections as a whole did substantially reduce life expectancy in European historical populations in the long run (see Ch. 5. 4 above). Galen observed that quartan fever generally followed other

[36] Mason *et al.* (1999) wrote a very interesting article on the epidemiology of *P. malariae* and its interaction with *P. falciparum*.

[37] Livy 41.21.5: *qui superaverant, longinquo, maxime quartanae, implicabantur morbo* (the survivors were ill for a long time, particularly with quartan fever).

fevers instead of occurring on its own. This statement can only mean that multiple infections were normal.[38]

> for the most part quartan fever does not appear immediately at the beginning of the illness, but occurs after other fevers have manifested themselves[39]

Cicero gives a specific example of this phenomenon, namely the case of Tiro:

> since the essence of the disease has changed into a quartan fever (for so writes Curius), I hope that you [Tiro], with due diligence, will be even stronger[40]

This letter is dated 12 January 49 BC, precisely the right time of year for that development. Scepticism is always possible with regard to the value of the evidence provided by an author like Juvenal, although in this particular case his words make perfectly good sense in the light of modern medical knowledge. Recent research in tropical countries employing the techniques of molecular biology to detect very low population densities of malaria parasites has shown that mixed infections (as well as subclinical chronic infections) are more frequent than was often thought previously when examination of blood smears under a microscope was the only means of detecting parasites. The ancient medical writers provide very important evidence confirming that *P. falciparum* malaria was indeed common among the population of the city of Rome from the second century BC to the second century AD. Caelius Aurelianus quoted Asclepiades of Bithynia, a Greek doctor who enjoyed great success at Rome (in spite of Cato's condemnation of Greek medicine) in the late second century BC, according to

[38] Other ancient texts which mention this phenomenon include: Hippocrates, *Airs, Waters, Places* 10: *τούς τε περιγενομένους ἐς τεταρταίους ἀποτελευτᾶν* (the survivors ended up with quartan fevers); [Aristotle,] *Problems* 1.19.861^{b} *τεταρταῖοι γίνονται τοῖς σωζομένοις* (those who were saved had quartan fevers); Galen 11.114K: *ἔστι δ' οἷσιν οὐκ ὀλίγοισιν ἐξ ἄλλων πυρετῶν καὶ νοσημάτων ἀποστάσιες ἐς τεταρταίους ἐγίνοντο* (in many cases there was a transition from other fevers and diseases to quartan fevers). Galen is quoting Hippocrates *Epidemics*, 1.6. Mixed infections were the norm in the town of Sermoneta in the Pontine region in the early twentieth century, according to Hackett (1937: 243). Similarly mixed infections were common in Greece (Balfour (1935: 312)). Galen recognized mixed infections and wrote about them e.g. 7.464–5K and 9.646K.

[39] Galen 11.18K: *μηδ' εὐθὺς ἀπ' ἀρχῆς τὰ πολλὰ τὸν πυρετὸν τοῦτον* [sc. *τεταρταῖον*] *εἰσβάλλειν, ἀλλ' ἑτέρων προσηγησαμένων συμπίπτειν.*

[40] Cicero, *Epist. ad familiares* 16.11.1: *cum in quartanam conversa vis est morbi (sic enim scribit Curius), spero te, diligentia adhibita, etiam firmiorem fore.*

Rawson's redating of his floruit. Asclepiades may have invented the idea of seeds of disease that was employed by Lucretius.[41]

> Asclepiades states that a persistent quotidian fever is not without danger . . . at Rome, he says, we notice that these fevers with a violent seizure of the body and mind, resembling lethargy, are frequent . . . he writes similar comments about these fevers, not once but frequently, saying that for a certain reason this seizing of the mind occurs in attacks of intermittent fevers, and that this is common at Rome.[42]

Asclepiades states that quotidian fevers, the most dangerous manifestation of *P. falciparum* malaria, were common in Rome, frequently exhibited the symptoms of cerebral involvement called catalepsy or lethargy by ancient medical writers, and could be fatal. He made these remarks repeatedly, emphasizing the importance of the phenomena under discussion. Similarly, Marchiafava and Bignami noted that 'lethargic and comatose "complicated" fevers' with cerebral symptoms were the forms of *P. falciparum* malaria most frequently encountered by doctors in hospitals in Rome in the nineteenth century. Baccelli also noted that lethargy was a dangerous condition in some forms of the disease.[43] Francesco Torti, the author of an important treatise on (the use of quinine in) cinchona bark, described lethargy as one of the seven symptoms of pernicious periodic fevers that were particularly liable to lead to death, and noted that it did not occur in tertian fever (caused by *P. vivax*).

> Finally the seventh lethal symptom of any intermittent pernicious fever, not characteristic of a simple tertian fever, is an extremely sleepy state of mind, or deep lethargy, which very frequently tends to accompany the febrile paroxysms . . . if it is neglected, and its progress is not inhibited, I would almost say that lethargy, if not conquered by any medical art, will be fatal, like a major stroke, during one or other of the periodic episodes of fever. When this state of mind commences, the patient first falls into a deep sleep. If he is awoken, he immediately goes back to sleep. Shortly afterwards he cannot remember what had happened immediately before. Consequently he frequently asks for a pot, then forgets to pass urine, and

[41] Rawson (1982) and the speculative arguments of Polito (1999); Nutton (1983: 10–11).

[42] Caelius Aurelianus, *On acute diseases* 2.63–4, ed. Drabkin (1950): *Item Asclepiades ait cotidianum perseverantem non sine periculo esse . . . apud Romam vero, inquit, frequentare advertimus has febres cum corporis atque mentis oppressione in similitudine lethargiae . . . item similia de his scribit, et non semel sed frequenter, dicens certa ratione mentis apprehensionem typorum in accessionibus fieri, atque hoc apud Romam frequentare.*

[43] Marchiafava and Bignami (1894: 93, 123–6, 150–1); Baccelli (1881: 180). Caelius Aurelianus II.65–6 described catalepsy as a condition predominantly occurring in the autumn.

is drowsy in the meantime. Sometimes he answers a question, but is unable to express himself coherently. It may be the case that he understands his own error, but nevertheless cannot correct himself, or continue, but babbling instead, he either cuts short his words, or uses the wrong word, just as if he were affected by a slight stroke causing paralysis of the tongue. Eventually, as his drowsiness intensifies, he is completely immobile, and snores through his nostrils. He cannot be awakened by any sound, physical force or contact, ligatures or tourniquets, affixing of cupping-glasses or of vesicants, or even fire at any time whatsoever, and if he does become conscious for a time, he immediately relapses into the same sleep, or falls into an even deeper coma, and does not begin to awaken until the periodic attack of fever is coming to an end. Even if he begins to awaken after the first or second period of fever, it is always with a little more difficulty, and if spasmodic gasping is added to the lethargy, he succumbs to his inevitable fate during the third or fourth periodic attack of fever at the latest.[44]

The fact that lethargy was frequently a term applied in antiquity to cerebral malaria caused by *P. falciparum* is demonstrated by a text of Aetios of Amida, quoting Archigenes and Poseidonius.[45] Aetios states that lethargy could arise in various ways, but goes on to say that it was a common effect of quotidian and semitertian fevers. It was also possible in quartan fevers, according to Aetios. However, it is significant that he does not mention tertian fever (caused by *P. vivax*) here. *P. vivax* does not cause cerebral malaria because it does not (unlike *P. falciparum*) induce cytoadherence of parasitized erythrocytes to the endothelium of capillaries in the brain.[46]

[44] Torti (1755: 195–6): *Septimum denique lethale symptoma Perniciosae cuilibet Intermittenti, non uni Tertianae familiare, est gravis affectus soporosius, seu profundus Lethargus, qui paroxysmos febriles saepe-saepius comitari consuevit . . . si negligatur, nec inhibeatur progressus, Lethargum una, vel altera accessione mortiferum, ac omni arte invincibilem, fortis Apoplexiae instar, fere dixerim certo portendit. Cum huiusmodi affectus incipit, aeger primo est in soporem pronus, a quo excitatus, statim in sommum relabitur; paulo post fit immemor rerum immediate ante gestarum, unde non raro matulam poscit, deinde mingere obliviscitur, atque interim dormitat; nonnumquam obloquitur, nec suos conceptus valet exprimere; & licet sui erroris sit compos, se tamen nequit corrigere, aut continere: immo quandoque balbutiens, vel verba mutilat, vel unum pro alio profert, non secus ac si levi Apoplexia in linguae paralysim degenerante foret detentus. Ingravescente tandem sopore omnino iacet, ac stertit naribus, neque ulla voce, ulla vi, frictione, ligatura, cucurbitularum, aut vesicantium appositione, immo nec igne quandoque actuali valet excuti; & siquidem excutiatur aliquantisper, statim in eumdem soporem, immo in profundiorem recidit, nec nisi declinante accessione incipit expergisci. Quod si una, vel altera vice resipiscat quidem, sed semper paulo difficilius, aut si soporosae affectioni adjungatur singultus, tertia ad summum, vel quarta accessione, inevitabili fato succumbit.* Marchiafava and Bignami (1894: 13–18, 96 n.1) discussed Torti's classification of intermittent fevers.

[45] Aetios of Amida 6.3: [ὁ λήθαργος] ἐνίοτε δὲ καὶ ἐπὶ τῶν χρονίων πυρετῶν συμβαίνει κατὰ περίοδον βαπτίζεσθαι αὐτοὺς τῷ ὕπνῳ, οἶον πολλάκις γίνεται ἐπὶ ἀμφημερινῶν πυρετῶν καὶ ἡμιτριταίων, ἔστι δ᾽ ὅτε καὶ ἐπὶ τεταρταίων.

[46] This is the conventional explanation of the pathology of severe *P. falciparum* malaria. An

The situation described by Asclepiades lasted throughout the Principate (and most probably throughout late antiquity as well), since Galen made very similar comments in the second century AD. Galen wrote pages and pages on forms of 'fever' (*πυρετός*) that can now be identified as malarial fevers. Since it would take a very long time to scrutinize all his writings on the subject in detail, it is only possible to mention a few of the most important points here. Galen described semitertian fevers as very common in Rome, more familiar to men in the capital of the Roman Empire than anywhere else.[47] This passage also shows clearly that Galen recognized that different places had different pathocoenoses, and this implies a diversity of mortality patterns in different parts of the Roman Empire.

That there is such a fever, as I have stated, does not require the evidence of Hippocrates or anyone else as a witness, since we observe it every day, especially at Rome. For just as other diseases are common in other places, so this evil is frequent in this city.[48]

The fever arising from yellow bile on its own is called tertian, but the fever which requires an equally strong share of the raw humour is strictly called semitertian. It is most frequent at Rome, being very familiar to men in the city.[49]

He explicitly states that semitertian fevers were extremely dangerous, much more dangerous than tertian fevers: 'this type of fever [semitertian] is malignant and extremely dangerous';[50] 'Semitertian fever . . . is . . . much worse than tertian fever.'[51] Galen also discussed mixed infections, which are only to be expected where malaria is endemic, as noted above. His comments on the various

alternative view, expounded most recently by Clark and Schofield (2000), is that the severe pathological effects are the result of an inflammatory state caused by a toxin released by the malaria parasite.

[47] Martial 2.40 and 4.80 also mentioned semitertian fevers, cf. 2.16 and possibly 3.93 for less specific references to fevers. Rodrígues (1985/6) and Wittern (1989) discussed Galen on fevers.

[48] Galen 7.435K: *ὅτι γὰρ καὶ τοιουτός τις γίνεται πυρετὸς, ὁποῖον εἶπον, οὐκέτ' ἐν τῷδε μάρτυρος οὔθ' Ἱπποκράτους οὔτε ἄλλου τινὸς ὁ λόγος χρῄζει, μόνον οὐ καθ' ἑκάστην ἡμέραν ὁρώντων ἡμῶν αὐτὸν, καὶ μάλιστα ἐν Ῥώμῃ. ὥσπερ γὰρ ἐν ἄλλοις ἄλλα χωρίοις, οὕτως ἐν τῇδε πόλει πλεονάζει τὸ κακὸν τοῦτο.*

[49] Galen 17A.121–2K: *ὁ μὲν οὖν ἐπὶ μόνῃ τῇ τοιαύτῃ* [sc. *ξανθῇ χολῇ*] *συνιστάμενος ὀνομάζεται τριταῖος, ὁ δὲ καὶ τὸν ὠμὸν χυμὸν ἰσοσθενῆ προσλαβών, ἀκριβὴς ἡμιτριταῖος γίνεται, πλεῖστον ἐν Ῥώμῃ γινόμενος, ὡς ἂν τῶν κατὰ τὴν πόλιν ἀνθρώπων οἰκειότατος ὤν.*

[50] Galen 7.467–8K: [*ὁ ἡμιτριταῖος*] . . . *ἄγριός τέ ἐστι καὶ κινδυνοδέστατος οὗτος ὁ τύπος.*

[51] Galen 17A.235K: *ὁ δ' ἡμιτριταῖος . . . ἔστιν . . . πολὺ χείρων τοῦ τριταίου.*

age-groups, which were characteristically targeted by different types of malarial fevers, are of great significance for establishing the epidemiology of malaria in the second century AD. Galen says that semitertian fevers struck men in the prime of life in autumn, when it was very dangerous, while tertian fevers attacked young men, and quotidian fevers, the most dangerous of all, attacked young children in particular.[52]

Tertian fever, caused by *P. vivax*, becomes a disease of childhood when *P. vivax* is hyperendemic, as it was on Sardinia, for example, in the nineteenth century. However, to interpret all these texts it is necessary to remember that ancient Rome (like early modern Rome) was constantly receiving large numbers of adult immigrants who would have been vulnerable (see Ch. 11 below). All the literature on malaria in early modern Rome states that adult immigrants or visitors were more vulnerable than people who had been born and had lived all their lives in Rome.[53] This was because the indigenous inhabitants knew what had to be done in the way of avoidance behaviour, as will be seen later (Ch. 11 below). They might also have had acquired immunity following childhood infection, or even inherited innate immunity. Galen's observation on the epidemiology of quotidian fevers is extremely important because it shows that *primary* attacks of *P. falciparum* malaria frequently occurred in infancy or early childhood in the second century AD.[54]

[52] Galen 7.468K: [ὁ ἡμιτριταῖος] . . . πλεονάζει δὲ ἐπὶ μὲν τῆς φύσεως τῆς κατὰ τοὺς ἄνδρας, ἡλικίας δὲ τῆς κατὰ τοὺς ἀκμάζοντας, ὥρας δὲ μᾶλλον τῆς φθινοπωρινῆς, ὅτε καὶ λίαν κινδυνώδης τυγχάνει ([semitertian fever] . . . is common in men, particularly those in the prime of life, most frequently in autumn, when it is exceedingly dangerous); 17B.642 [τριταίοι] . . . οὗτοι γὰρ χολωδέστατοί τε πυρετῶν ἁπάντων εἰσὶ καὶ πλεῖστοι τοῖς νεανίσκοις γίνονται . . . οἱ πρεσβῦται τῶν νέων τὰ μὲν πλεῖστα νοσέουσιν ἧττον ([tertian fevers] . . . are the most bilious of all fevers and most frequently occur in young men . . . in most cases old men are less affected than young men); 11.23K: παῖδες δὲ καὶ μάλιστα οἱ μικρότεροι καὶ ὅσοι τῶν τελείων φλεγματικώτεροί τέ εἰσι καὶ τὴν ἕξιν τοῦ σώματος παχεῖς καὶ ἀργὸν τὸν βίον ἔχοντες ἐν πλησμοναῖς καὶ μέθαις καὶ λουτροῖς συνεχέσι καὶ μάλιστα τοῖς ἐπὶ τροφῇ ἀμφημερινοῖς εὐάλωτοι (children, especially younger children, and adults who have more phlegm and are fat and lead an idle lifestyle with excessive eating and drinking and continuous bathing, and most of all those who are being cared for by a nurse, are easily affected by quotidian fevers).

[53] e.g. Aitken (1873); Baccelli (1881); Rey and Sormani (1881); North (1896); Bercé (1989). Similarly Dobson (1994: 47) and (1997: 318)) noted that *P. vivax* malaria was more dangerous to immigrants than to the indigenous inhabitants of the English marshlands.

[54] M. Greenwood (1921) considered Galen as an epidemiologist. In many other instances, for example in relation to the Antonine plague, Galen's epidemiology turns out to be very disappointing. Grmek (1994: 4) accepted Galen's epidemiological evidence, speaking of *une expansion hyperendémique aux temps de Galien*. However, the idea of an *expansion* in Galen's time does not take account of the earlier evidence of Asclepiades.

The inference is that the transmission rate of *P. falciparum* malaria was very high; high enough to create a situation in which acute clinical illness and direct mortality as a result of malaria was concentrated among children. In relation to the fact that the Romans continued to use the Greek word *semitertian* and had not coined a specific Latin word for the disease, Quintus Serenus stated that mothers did not want to use a specific word for it for fear that by speaking of it it would be attracted to their own children. This fascinating observation confirms that *P. falciparum* malaria was regarded as typically a disease of childhood during the time of the Roman Empire. It also illustrates the importance of sympathetic magic in Roman popular thought:

> more deadly is the fever which is called semitertian in Greek; no one, I think, could have named it in our language and mothers would not have wanted to[55]

Acquired immunity to the strains present in such a locality is gradually built up by survivors of primary attacks, in response to repeated infections. The result is that episodes of acute clinical illness become less frequent with increasing age. Under such circumstances the bulk of severe illness is concentrated among children. Severe illness among adults is only observed among immigrants, who do not have any acquired immunity. After the city of Rome became the centre of Christianity during the period of the Roman Empire, Christians migrating to or visiting Rome were particularly susceptible to the scourge of 'Roman fever'. The cases of St. Augustine and Alcuin have already been mentioned, as well as the English monks mentioned by Gervase in AD 1188. Hyperendemic malaria was the pattern over much of the Campagna Romana throughout the medieval and early modern periods. Under such circumstances *acute* infections of indigenous adults were less frequent. Epidemics of malaria among adults were only observed when large groups of people who were not native to the area appeared on the scene, for example French and German armies. Many historians have observed that malaria acted as a protection for Rome from foreign invaders. This viewpoint had already been explicitly articulated by Godfrey of Viterbo as early as AD 1167, when he recorded in verse the destruction of the army of Frederick

[55] Quintus Serenus, *liber medicinalis* 51.932–4, ed. Pépin (1950): *mortiferum magis est quod Graecis hemitritaeos | vulgatur verbis; hoc nostra dicere lingua | non potuere ulli, puto, nec voluere parentes.*

Barbarossa. It can be surmised that the rainfall during the summer storm mentioned by Godfrey created mosquito breeding sites in the vicinity of Barbarossa's camp.

The hot Dog Star is accustomed to give men's bodies fever. | This heat tends to kill men at Rome, | and often inflicts pains through countless fevers; | now it produced more than usual. | When Rome cannot protect itself by the sword, | fever can be seen as an ally, a means of salvation: | the soldier dies of fever, which he feared yesterday. | Those whom Rome could not destroy were annihilated by the wind, | at whose arrival the German youth were killed: | thus when Rome is silent, our imperial glory lies in ruins, | alas, because the lord [sc. Frederick] of the city and the world is vanquished and stopped | by the diseases of Romulus in a short span of time; | he whom sea and land fear groans at the heat of the fever. | All of Rome had sworn an oath at Caesar's will. | A wind came from the southern zone with thunder and lightning, | and the storm hit the camp. | Every man was drenched as the heat of the sun decreased, and became ill with a terrifying fever following the shivering. | The soldiers ached with pain in their heads, as is to be expected, and internal organs and legs. All of them were now injured by the wounds of fever.[56]

Malaria was almost certainly already playing that role in late antiquity, when Alaric died from a disease contracted during the siege of Rome in the summer of AD 410, while Attila's failure to march on Rome in 452 was probably motivated at least partly by the threat of pestilence as well as famine in Italy.[57] However, that epidemiological situation had arisen long before the fifth century. Tacitus describes an episode during the short-lived occupation of Rome by Vitellius in AD 69 that sounds very similar to the numerous catastrophes which befell French and German armies attacking Rome in the medieval and early modern periods, as catalogued

[56] Gotifredus Viterbiensis, *de gestis domni Friderici Romanorum imperatoris*, sec. 27, ll. 625–46, ed. G.H. Pertz (1870), *Monumenta Germaniae Historica. Scriptores Rerum Germanicarum*, xxx, 24–5: *Fervida stella poli canis est coniuncta leoni, | Ordine zodiaci connectens sidera soli, | Datque calore poli corpora febre mori. | Hoc solet ardore sol perdere corpora Rome, | Febribus innumeris infligere sepe dolores; | Nunc dedit ex more deteriora fore. | Dum nequid in gladio se maxima Roma tueri, | Febris ab auxilio poterit salvanda videri: | Miles febre perit, quem metuebat heri. | Quos non Roma potest, potuit disperdere ventus, | Cuius in adventu cecidit Iermana iuventus: | Sic ubi Roma tacet, gloria nostra iacet. | Heu quia Romuleis modico sub tempore morbis | Vincitur et premitur dominator et Urbis et orbis; | Febre calente gemit, quem mare terra tremit. | Cesaris ad libitum iuraverat omnia Roma. | Venit ab australi ventus cum fulgure zona, | Castraque precipitant ventus et aura tonans. | Omnis homo madidus, solis fugiente calore, | Leditur orribili febri, veniente rigore. | Et caput ex more, viscera, crura dolent. | Omnia iam fuerant febrili vulnere lesa.*

[57] Romer (1999); Olympiodorus *ap.* Photius, *bibliotheca*, ed. Henry (1959), i. 168–9 and Jordanes, *de origine actibusque Getarum*, 157–8, on Alaric's death; *novellae divi Valentiniani*, 33 ed. Meyer and Mommsen (1905).

by Celli, Celli-Fraentzel, and more recently Bercé. The German and Gallic troops of Vitellius, like Julius Caesar's army after it had spent years in Gaul in the previous century (see Ch. 10 below), were not accustomed to the *P. falciparum* malaria of Mediterranean countries and had no acquired (or innate) immunity to it. This episode shows that the Vatican district was extremely dangerous in summer in the first century AD, just as it was during the papal election in 1623:[58]

Finally, not even caring about life, many of them camped in the unhealthy Vatican district, as a result of which there were many deaths among the rabble. The Tiber was near by, and the Germans and Gauls, whose bodies were already liable to disease, were weakened by their lack of tolerance for the heat and their desire for the river's water.[59]

Medieval accounts of the perils of the areas of the city close to the river Tiber are more detailed. For example, Godfrey of Bouillon, the Duke of Lower Lorraine who later became one of the leaders of the First Crusade, was infected near the Tiber with quartan fever during the siege of Rome in AD 1083 and vowed that he would go to Jerusalem if God cured him. He survived the siege, although one strand of tradition suggests that a recrudescence of quartan fever played a role in his death in Jerusalem in AD 1100, but many of his colleagues were killed by malaria during the siege of Rome.

Advancing to storm Rome, he was the first to break through that part of the wall which had been allotted to his own section of the army, opening a large window to make an entry. Sweating very heavily,and panting as his blood was so hot, he entered an underground store-room which he found by chance as he moved around there: when he had satisfied his excessive thirst by drinking too much wine, he developed a quartan fever. Some say that he was infected by poisoned Falernian wine, because the Romans, and the men of that land, are accustomed to pour poisons into

[58] Bercé (1989: 239–40); Celli (1933: 73–82, 95); Celli-Fraentzel (1932); Scheidel (1996: 128–9); Lapi (1749: 17–18) noted that foreigners such as Germans who visited Rome in the eighteenth century were particularly likely to become ill. Even a severe disease like malaria could sometimes be evaluated positively, cf. P. F. Russell (1955: 244) noting that some Africans regarded malaria as an ally against European colonists. Jarcho (1945) drew attention to a German propaganda exercise in the Second World War. It attempted to induce American soldiers in Italy to believe that getting infected with malaria was *desirable* in order to be invalided out of military service and so avoid death in battle.

[59] Tacitus, *Hist.* 2.93: *Postremo ne salutis quidem cura infamibus Vaticani locis magna pars tetendit, unde crebrae in vulgus mortes; et adiacente Tiberi Germanorum Gallorumque obnoxia morbis corpora fluminis aviditas et aestus impatientia labefecit.* Alexander Donatus (1694: iii.21, p. 274) in the seventeenth century believed that the 'Vatican district' included the Ianiculum in Tacitus' eyes.

whole casks of wine. Others say that by chance he had been allotted that section of the walls where the current of the Tiber in the morning exhales deadly mists, which were the cause of death of all but ten of his own soldiers. He himself lost his hair and nails and recovered with difficulty. Nevertheless in truth it is agreed that, whatever the reason, he was never free from the inconvenience of a continuous but slow fever until, having heard of the crusade to Jerusalem, he vowed that he would go there if God graciously bestowed good health upon him . . . the story is that the king's old fever revived because he was unaccustomed to leisure.[60]

In the following century Bishop Otto of Freising gave a detailed description of the first destruction by malaria at Rome of an army belonging to Frederick Barbarossa in AD 1155.

For the unhealthy climate and the heat at that time, especially around the city, had more power to hurt our men than the weapons of the Romans . . . the rising of the sparkling Dog Star at the morbid foot of Orion was imminent, and all the air in the vicinity became dense with misty vapours arising from the neighbouring swamps and caverns and the ruined places around the city, air that was pestilential and lethal for mortals to breathe. The citizens in the city, accustomed to take refuge in the mountains at that time of the year, and the soldiers in the camp, who were not accustomed to such bad air, were both afflicted with this disease . . . As innumerable men developed very severe illnesses as a result of this corruption of the air, the prince, although chagrined and unwilling, was forced to transfer the tents of the camp to the neighbouring mountains to gratify his own men . . . but as the rage of the Dog Star upon the army grew even hotter, and there were hardly any men left who were not debilitated by the seething heat and the bad air, and as many soldiers had also been injured and some killed during the storming of cities, castles, and towns, he was forced, not without feeling bitter about it, to go back across the Alps again.[61]

[60] William of Malmesbury, *gesta regum Anglorum*, iv.373, ed. T. D. Hardy (1840), pp. 573–5: *Ad oppugnandam Romam profectus, eam partem muri quae vigiliis suis observabatur primus prorumperet, magnam fenestram irrupturis aperiens. Ita potissimum sudans, et praefervidis venis suspiriosus, cellarium subterraneum, quod forte se discursanti obtulerat, ingressus est: ibi, cum nimio vini haustu intemperantiam sitis placasset, febrim quartanam iniit. Dicunt alii venenato Falerno infectum; quod soleant Romani, et illius terrae homines, totis infundere toxica tonnis. Alii, ei partem illam moenium sorte obtigisse ubi Tiberis influens mane saevas exhalat nebulas, quarum pernicie omnes milites eius praeter decem interiise; ipsum, amissis crinibus et unguibus, dubie convaluisse. Veruntamen, quodlibet horum fuerit, constat eum nunquam continuae sed lentae febris incommodo vacasse; donec, audita fama viae Ierosolymitanae, illuc se iturum vovit si Deus propitius ei salutem largiretur . . . fama est regem otii desuetudine febrim antiquam nactam fuisse.*

[61] *Ottonis et Rahewini gesta Friderici I. Imperatoris*, ii.33–4, 37, ed. de Simson (1912): *plus enim nostros intemperies caeli estusque illo in tempore maxime circa Urbem inmoderatior quam Romanorum ledere poterant arma . . . iam tempus imminebat, quo Canis ad morbidum pedem Orionis micans exurgere deberet, e vicinis stagnis cavernosisque ac ruinosis circa Urbem locis tristibus erumpentibus et exhalantibus nebulis totus vicinus crassatur aer, ad hauriendum mortalibus letifer ac pestifer. Urgebatur hoc incommodo in Urbe civis,*

Otto clearly describes the custom of Rome's inhabitants of fleeing the city for the mountains each summer, during the dog-days, in the medieval period.[62] This was also a custom in antiquity, at least for the élite, as Pliny the Younger, when he went to Tifernum Tiberinum, and Horace, when he went to his farm in the Sabine territory, prove.[63] Celsus recommended flight from the scene of pestilence. Since he specifies that his recommendations particularly apply to pestilences brought on by the south wind and to travel in unhealthy regions and during the unhealthy season of the year, it is clear that in this case at least the word *pestilentia* does include malaria.[64]

The extant ancient sources are less detailed than the medieval ones, but there is no reason for supposing that the situation with regard to the unhealthiness of the Tiber valley was fundamentally different in antiquity. Martial clearly described the conditions that created mosquito breeding sites in the Tiber valley. He stated that Ladon's property near the Tiber was frequently flooded, turning the fields into a lake in winter. As the year progressed the fields near the river would gradually dry out, creating breeding sites for mosquitoes.[65] One of the letters of Pliny the Younger confirms that the banks of the Tiber were unhealthy in the first century AD, even though his uncle had said that there were more villas lining the Tiber than all the other rivers of the world.[66] The letter describes the activities of Regulus who, among numerous other faults,

hoc tempore ad montana consuetus fugere, in castris miles, tanto desuetus aeris intemperie . . . Verum innumeris hac caeli corruptione in morbos gravissimos incidentibus, princeps dolens ac nolens suisque tantum morem gerens ad vicina montana transferre cogitur tabernacula . . . Verum excandescente amplius in exercitum Canis rabie vixque aliquibus residuis, qui estus fervore et aeris intemperie corruptionem non sentirent, sauciatis quoque de civitatum, castellorum, oppidorum expugnatione pluribus nonnullisque extinctis, non sine cordiis amaritudine ad Transalpina redire cogitur.

[62] Krautheimer (1980: 317) noted that in medieval Rome in the twelfth century 'the hills were comparatively healthy; the low parts of the *disabitato* were not to be trusted', and were abandoned by everyone who could afford to move away in summer.

[63] The context of the phrase *rabies Canis* in Otto's account enables us to understand its full significance when it appears in the verses of Horace, *Epist.* 1.10.15–17: *Est ubi plus tepeant hiemes, ubi gratior aura | leniat et rabiem Canis et momenta Leonis* (It is a place where the winters are milder, where a rather agreeable wind softens both the fury of the Dog Star and the violent movements of Leo). Cf. *Sat.* 2.6.18–19: *nec mala me ambitio perdit nec plumbeus Auster | autumnusque gravis, Libitinae quaestus acerbae* (and no ruinous ambition destroys me there, nor the oppressive south wind and the noxious autumn, a source of gain to the severe goddess of the dead).

[64] Celsus 2.10.1–4; Seneca, *QN* 6.1.6: *in pestilentia mutare sedes licet* (it is permissible to change one's dwelling place during a pestilence); Snowden (1999: 37–8).

[65] Martial, *Epig.* 10.85.

[66] Pliny, *NH* 3.5.54.

irritated people by insisting that they visit him in his villa alongside the Tiber at the unhealthiest time of the year:

He stays in his gardens across the Tiber, where he has filled a very large area with huge colonnades and covered the river bank with his statues, since he is extravagant despite his avarice, and a braggart in spite of his bad reputation. Consequently he irritates the citizens at the most unhealthy time of the year and derives satisfaction from annoying people.[67]

Frontinus, writing towards the end of the first century AD, confirms that Rome had a reputation for 'bad air'.[68] He claimed that water-management operations under the emperor Nerva had solved the problem, but Galen's later observations show that the problem had not been solved at all. Since the frequency of malaria fluctuated depending on numerous variable environmental parameters (such as the amount of rainfall, the height of the Tiber, the temperature, etc.), some mild years might have occurred by chance immediately following Nerva's operations. That would explain Frontinus' comments. Celli and several other writers expressed the view that epidemics of malaria occurred in Rome and the Roman Campagna every five to eight years on average in the early modern period.[69] It could also simply be the case that Frontinus had no option but to praise the emperor:

Not even waste waters are lost: the causes of the rather unhealthy atmosphere have been eliminated, the appearance of the streets is clean, the air is purer, and the bad air for which the city was always notorious, according to older writers, has been removed.[70]

The argument so far has shown that *P. falciparum* malaria was not

[67] Pliny, *Ep.* 4.2.5–6, ed. Schuster (1958): *Tenet se trans Tiberim in hortis, in quibus latissimum solum porticibus immensis, ripam statuis suis occupavit, ut est in summa avaritia sumptuosus, in summa infamia gloriosus. Vexat ergo civitatem insaluberrimo tempore et, quod vexat, solacium putat.*

[68] Jordan (1879) discussed the corrupt text of Frontinus. Seneca, *Epist.* 104.6 also mentioned the *gravitatem urbi*. In this passage Seneca described another notable feature of the city of Rome in antiquity, atmospheric pollution. The air of Rome was unhealthy not only because of mosquitoes carrying malaria and of airborne pathogens such as tuberculosis, but also because of the high level of pollution caused by burning wood, oil, and other materials for industrial and domestic purposes. Capasso (2000) noted that the Grotta Rossa mummy, the only mummy found in Rome so far, shows severe anthracosis even though the individual in question died young.

[69] Corti (1984: 638).

[70] Frontinus, *de aquae ductu urbis Romae* 88.3, ed. Kunderewicz (1973): *Ne pereuntes quidem aquae otiosae sunt: ablatae causae gravioris caelii munda viarum facies, purior spiritus, quique apud veteres se⟨mper⟩ urbi infamis aer fuit est remotus.*

confined to the Pontine Marshes, its most notorious focus, but was also endemic in at least some districts of the city of Rome itself, and extended inland into Umbria, during the period of the Roman Empire. This geographical distribution resembles that of the early modern period, when the Tiber valley was severely affected along most of its course, far into Umbria. By the first century AD there had already been created in and around the city of Rome a distinctive disease community or pathocoenosis, to use Grmek's concept, which was dominated by *P. falciparum*, the most dangerous species of malaria. That was a distinction for which the city of Rome was to be famous over the succeeding 1900 years or so, as the home of 'Roman Fever', the title chosen by North for his book on a disease which was certainly not confined to Rome yet was more characteristic of Rome than of other major European cities. Before leaving the city of Rome to examine some aspects of the medical situation beyond the suburbs of the city, in the Roman Campagna, let us glance at a few more of the later literary references to malaria in Rome (out of a vast corpus of literature which could be quoted). These sources and numerous others show that malaria remained a major problem in and around Rome throughout the medieval and early modern periods.

First, Pope Gregory the Great, who himself suffered from malaria, mentioned a great epidemic of fever at Rome in August AD 599. He states that there were reports every day of high mortality in neighbouring towns (and also reports of plague epidemics in the eastern Mediterranean):[71]

For every day I am weak and in pain and sigh, waiting for the remedy of death. Assuredly among the clergy of this city and people there are so many cases of lethargy and fever that hardly a single free man or a single slave remains, who is fit for any office or ministry. However, from neighbouring towns I receive reports every day of the carnage of death.[72]

[71] Gregory himself spoke of suffering prolonged slow fevers (in addition to other health problems) in the prefatory letter to his commentary on Job, ed. Migne (1844–90), *patrologia Latina*, lxxv, col. 515, ch. 5: *Multa quippe annorum iam curricula devolvuntur, quod crebris viscerum doloribus crucior, horis momentisque omnibus fracta stomachi virtute lassesco, lentis quidem, sed tamen continuis febribus anhelo* (Now many periods of years roll by, because I am racked by frequent pains inside my body, I am weary at all hours and times because the habit of good digestion has been broken, and I gasp for air because of fevers which are certainly slow, but nevertheless continuous.). His biographers also noted this problem, e.g. John the Deacon, *Sancti Gregorii magni Vita*, 1.30, ed. Migne, *patrologia Latina*, lxxv., col. 75: *cum ergo Gregorius validissimis febribus aestuaret* (since Gregory was burning with very powerful fevers).

[72] *Gregorii I Papae registrum Epistolarum*, ed. Ewald and Hartmann (1899), ii.IX.232: *Cotidie*

Secondly: St. Peter Damian, Bishop of Ostia, composed a tetrastichon about Roman fever in a letter to Pope Nicholas II datable to December AD 1059–July 1061:

> Rome, devourer of men, tames the erect necks of men:
> Rome, fruitful in fevers, is very rich in the harvest of death.
> The Roman fevers are faithful to a constant law.
> Once they have assailed a person, they seldom leave him
> while he is still alive.[73]

Thirdly: another medieval cleric, Atto, stated that scholars and men of learning were reluctant to come to Rome as teachers *c.*AD 1080 because of its unhealthiness:

> I know, most esteemed brothers, that there are two reasons for your ignorance: first, the unhealthiness of the place does not allow foreigners to live here to teach you[74]

The malaria of Rome was sometimes portrayed as a dragon. Indeed the dragon was the object of a pagan Roman cult. A legend is preserved that Sylvester, the pope under whom the emperor Constantine converted to Christianity in the early fourth century AD, brought under control (but, significantly, did not kill) a terrible dragon living in a cave underneath Rome which breathed out 'bad air', a synonym for malaria throughout history.[75] The binding of

enim in dolore deficio et mortis remedium expectando suspiro. In clero vero huius urbis et populo tanti febrium languores inruerunt, ut paene nullus liber, nullus servus remanserit, qui esse idoneus ad aliquod officium vel ministerium possit; de vicinis autem urbibus strages nobis cotidie mortalitatis nuntiantur.

[73] *Monumenta Germaniae Historica. Die Briefe der Deutschen Kaiserzeit,* iv. *Die Briefe des Petrus Damiani*, ed. Reindel (1988) ii. 344 (no. 72): *Roma vorax hominum, domat ardua colla virorum:* | *Roma ferax febrium, necis est uberrima frugum.* | *Romanae febres stabili sunt iure fideles.* | *Quem semel invadunt, vix a vivente recedunt.*

[74] *Attonis cardinalis presbyteri Capitulare seu breviarium canonum*, ed. Mai (1832), *Scriptorum veterum nova collectio e vaticanibus codicibus* (vi. 60), Rome: *Scio, dilectissimi fratres, quod duae causae ignorantiae vestrae: una quod aegritudo loci extraneos qui vos doceant hic habitare non sinit, alia quod paupertas vos ad extranea loca ad discendum non permittit abire: quibus compellentibus causis factum est ut paenitentiale romanum apocryphum fingeretur, et rusticano stilo; ut illi qui authenticos canones nesciunt, et litteras non intelligunt, in his fabulis confidant; atque tali confidentia sacerdotium, quod eos non debet, arripiant; et caeci duces cum sequacibus suis cadant in foveam.*

[75] Pohlkamp (1983) discussed Sylvester and the dragon. The legend of Sylvester and the dragon is portrayed in the famous thirteenth-century frescoes in the chapel of St. Sylvester in the church of Santi Quattro Martiri Coronati in Rome. Celli (1933: 101) mentions a painting of a dragon said to live in the marshes outside Rome in 1691. The dragon could be associated with diseases other than malaria, for example bubonic plague, according to Gregory of Tours, *History of the Franks*, x.1, Paulus Diaconus, *S. Gregorii Magni Vita* 1.10 and John the Deacon, *S. Gregorii Magni Vita*, 1.36, ed. Migne (1844–98) *Patrologia Latina,* lxxv. cols. 46 and 78 respectively. These sources claim that a huge dragon was washed down the Tiber with

demons, especially demons responsible for fever, to bring them under control was a common motif in late antique texts about magic. It is also now attested archaeologically. Burial no. 36 in the infant cemetery at Lugnano in Teverina was weighted down to the surface on which it lay, a crude 'bed' consisting of soil, stones, and tile fragments, according to the excavators, David Soren and his

rubble from the city by a great flood in November AD 589, two months before the outbreak of a plague epidemic. However, there is no doubt that the dragon was most closely associated with malaria in Italy.

34. Front (p. 232) and side (this page) views of the monument of Leopold II di Lorena in Piazza Dante in Grosseto, commemorating his attempts to eradicate malaria from the Maremma by bonifications in the nineteenth century. The grand duke is portrayed protecting the Maremma, depicted as a woman with her children, from the dragon of malaria.

colleagues. Stones had been placed on top of both the left and the right hands of this 2–3-year-old infant, while a tile covered its feet. It is precisely this infant which has yielded some ancient DNA belonging to *P. falciparum* malaria. Its corpse was weighted down to prevent the demons of malaria from escaping and wreaking any more havoc on the population.[76]

[76] Dickie (1999); D. Soren, T. Fenton, and W Birkby in Soren and Soren (1999: 508) on infant burial no. 36 at Lugnano in Teverina.

Sylvester . . . is said to have gone down the hundred steps into its lair to face the deadly dragon of Rome, a creature of enormous size, hiding in the secret cave of the crypt. It was causing terrible problems for the miserable population, corrupting the air with its poisonous jaws and pestilential breath, and the pagans were deceived into offering the filthy sacrifices of frenzied purification to calm the madness of its fury. Sylvester disciplined for ever the dragon with the punishment of eternal vengeance by restraining it with a collar from which it cannot escape.[77]

The earliest dragon cult in ancient Latium seems to have been located in Lanuvium. From there it was transferred to Rome sometime.[78] In the medieval period the swamps at Maccarese near Ostia were supposedly the home of a dragon, which was killed by a knight from the Anguillara family, to which the territory was awarded as a result. Tomassetti linked this legend to attempts at bonifications to improve health in the area.[79] A dragon that represents malaria is still visible today on the marble monument in Piazza Dante in Grosseto. It was carved by Luigi Magi in 1846. This monument commemorates the efforts of Leopold II di Lorena 'Canapone', the last grand duke of Tuscany, to rescue the Maremma and its inhabitants from the scourge of malaria.[80] Similar monuments were constructed in other towns that were affected by malaria. For example, Cisterna erected in its main square a sculpture by Ernesto Biondi to commemorate the triumph of health over disease. It won the *grand prix* at the Paris Exhibition of 1900.[81]

77 St. Aldhelm, *de laudibus virginitatis*, xxv, ed. J. A. Giles (1844): *Sancti Aldhelmi opera quae extant*: *Sylvester . . . ad letiferum Romae draconem in clandestino cryptae spelaeo latitantem, qui virulentis faucibus et pestifero spiritus anhelitu aethera corrumpens miserum populum atrociter vexabat, per centenos latebrarum gradus introrsum descendisse fertur, et eandem mirae magnitudinis bestiam, cui paganorum decepta gentilitas ad sedandam furoris vesaniam, fanaticae lustrationis spurcalia thurificabat, inextricabili collario constrictam perpetuae ultionis animadversione perenniter mulctavit, et Romam fallacis idololatriae cultricem a funesto, victimarum ritu Evangelicis assertionibus et segnis pariter coruscantibus correxit.*

78 Aelian, *On animals* 11.16; Propertius, *Elegies* 4.8.3–14, ed. Fedeli (1984). There is no sign of an association with disease in these texts. The dragon cult is presented as an agricultural fertility rite by Propertius.

79 Tomassetti (1910: ii. 497). A modern painting in the church of St. George in Maccarese portrays the saint slaying a dragon. Levi (1945: 96–7) and Douglas (1955: 102–7) discussed dragons in Lucania and Calabria, while Horden (1992) considered the dragon motif in relation to malaria in the lives of the saints in early medieval France.

80 Santi (1996: 126).

81 Tomassetti (1910: ii. 390–1).

9
The Roman Campagna

The countryside immediately surrounding the city of Rome, the Campagna Romana, requires attention now. In view of the warm climate for most of the period of the Roman Empire (see Ch. 4. 5 above), malaria was probably even more widespread then than it was in the early modern period, when Giordano described the region as follows:

> The Tiber and its tributaries, which flow across it sunk into deep channels, have cut into the uneven surface of this plain, which is almost everywhere uncultivated, with only natural pastures, bare of trees and property, the home of malaria in summer.[1]

Tomassetti, an expert on the Roman Campagna, wrote about its fauna as follows:

> The very common fly (*Musca domestica*) and the mosquito (*Culex pipiens*) . . . the one by day, the other by night, are the greatest nuisance to visitors to the Roman Campagna in summer.[2]

Even in the vicinity of Rome as recently as the nineteenth century, it could be difficult to obtain precise and trustworthy information about the distribution of malaria. Tommasi-Crudeli, for example, observed that there were many reasons for people to tell lies about malaria:

> Sometimes they imagine that you are a collector of taxes, and tell you that a place is pestiferous, although it is not, in order that you may not be induced to raise their assessment. At other times they take you for a would-be purchaser, and assert that the place is healthy, even when it is extremely malarious, in order to induce you to buy. Cases are known in

[1] F. Giordano, chapter entitled *Condizioni topografiche e fisiche di Roma e Campagna Romana* in *Monografia* (1881: p. ii): *Questa planizie di superficie ineguale, incisa dal Tevere e dai suoi influenti che vi scorrono incassati entro profondi solchi, presentasi quasi ovunque incolta ed a soli pascoli naturali, nuda d'alberi e di cose, sede di mal'aria in estate.*

[2] Tomassetti (1910: i. 16): *La volgarissima mosca (Musca domestica) e la zanzara (Culex pipiens) . . . l'una di giorno, l'altra di notte, formano la più grande molestia di chi frequenta in estate la campagna romana.* Blewitt (1843: 534) mentioned the abundance of mosquitoes along the direct road from Rome to Anzio (ancient Antium).

which they will tell you a falsehood, rather than speak the truth, for fear of ruining their trade.[3]

In the same decade in which he wrote the original Italian version of his book, the Italian government in fact made a great effort to gather information about the distribution and frequency of malaria in every district of Italy for the monumental *Carta della malaria dell' Italia*, inspired by Luigi Torelli. This map, completed in 1882, was apparently so large and detailed that it would cover a town square if all the sheets were laid out on the ground side by side. After considering all the difficulties, Tommasi-Crudeli went on to reach the following conclusion:

We must admit that malaria prevails throughout the whole extent of the Campagna, although there are abundant reasons for believing that some localities are much more malarious than others, and that some are entirely free from it.

Obviously it is far more difficult to obtain information now regarding the situation two thousand years ago than it was to assess the then current situation little more than a hundred years ago. However, bearing in mind the evidence of ancient medical writers that malaria was frequent within the city of Rome itself and the statements of Cicero and Livy, implying that Rome was situated in an unhealthy region, the balance of probability is that many of the low lying rural districts of Latium and southern Etruria were also affected by malaria during the time of the Roman Empire just as they were in more recent times. It is worth describing some features of the ecology of Latium in Roman times to show how it fits this suggestion. Pliny the Younger described the countryside along the roads from Rome to Laurentum in the first century AD. These roads passed through woods, which provided plenty of firewood (though Pliny does not mention timber good enough for construction purposes in Rome), and extensive meadows where there were numerous flocks of sheep and herds of cattle and horses which were driven down from the mountains in winter to pasture on the well-watered meadows overlying the very high water table. Indeed these pastures were so rich that elephants were kept in the region between Laurentum and Ardea in readiness for the circuses in Rome.[4]

3 Tommasi-Crudeli (1892: 86), cf. Levi (1945: 32, 74) on taxes and lies.

4 Pliny, *Ep.* 2.17.3; the inscription *CIL* VI.8583, *procuratoris Laurento ad elephantos* (procurator

[*cont. on p. 238*]

35. Luigi Torelli's *Carta della malaria dell'Italia*, completed in 1882. Geographical areas with *P. falciparum* malaria have dark shading, areas with only *P. vivax* malaria have light shading.

These meadows were natural meadows, not artificial ones, just as in Lazio in the nineteenth century, since the Roman agronomists in antiquity did not have any conception of the complicated crop rotation systems required for artificial meadows. In any case the forage crops of artificial meadow systems, such as lucerne, grew naturally in such a well-watered (in winter) environment. According to the early modern Roman agronomists stall feeding of stabled animals was disliked in Lazio because it was felt that animals tended to become infected with diseases if they were not allowed to roam freely. In 1813 33% of the total value of all agricultural production in Lazio came from animal husbandry. This demonstrates in quantitative terms the importance of animal husbandry to the agricultural economy, and explains why the élite in Rome throughout history took such an interest in it.[5] In the sixth century AD Procopius noted that the invading Gothic army chose to set up a camp at Regata near Terracina because the Goths observed that the lush Pontine plain was very suitable for feeding the horses of their cavalry.[6]

However, the agricultural system of Latium in antiquity was one in which animal husbandry was not integrated with arable farming. Pliny took transhumance for granted as the basic pattern of animal husbandry. This traditional system continued from antiquity up to and throughout the nineteenth century. It can be inferred that shepherds in antiquity were as vulnerable to infection with malaria when they came down from the mountains in late autumn as Marchiafava noted they were in the nineteenth century. The poem *Culex* in the *Appendix Vergiliana* tells a fable about a shepherd sleeping out in the countryside who was about to be attacked by a poisonous snake when he was woken up and saved by a mosquito biting him. The ungrateful shepherd killed the mosquito, which descended to the underworld and then reappeared to him in a

for elephants at Laurentum) and Juvenal, *Sat.* 12.102–5 record the presence of elephants in this region.

5 Sallares (1991: 382–4) on meadows in antiquity; De Felice (1965: 38–40, 89–104) on meadows and animal husbandry in early modern Lazio; Gabba & Pasquinucci (1979) and Garnsey (1988*b*) on antiquity.

6 Procopius, *BG* 1.11.1 (cf. 2.3.10–11 for the vicinity of Rome itself). Nicolai (1800: 42–3) discussed eighteenth-century opinions on the location of Regata or Regeta. He noted Cluverius' textual emendation of the name to Pineta and Olstenius' emendation to Trajecta, but followed Corradini's view that Regata was situated between Forum Appii and ad Medias along the Via Appia.

dream.[7] This tale evidently lacks realism in more ways than one. It shows no awareness at all of the danger of mosquito bites and the link between mosquitoes and malaria. Nevertheless it is quite realistic in suggesting that being bitten by mosquitoes was an occupational hazard for shepherds in the Roman Campagna.

However, the question of animal husbandry and agricultural systems has a wider significance in relation to malaria. It was noted earlier that species of mosquito may be anthropophilic, or zoophilic, or indifferent with regard to their choice of prey. In the Campagna Romana in the 1930s the important malaria vector species *A. labranchiae* certainly occurred inland but was most abundant along the coast, from Palidoro to Ardea. Its larvae seemed to require a certain degree of salinity in the water. Fluctuations in the size of populations of *A. labranchiae* were correlated with fluctuations in the frequency of malaria. Away from the coast in the 1930s the zoophilic *A. typicus* was commoner, while another zoophilic species, *A. messeae*, was very rare. Zoophilic female mosquitoes prefer cattle, but may also dine on pigs or horses instead. They are not so keen on sheep, whose woolly fleece provides protection from mosquito bites. Consequently a system of arable farming, using cattle to pull the plough, may sometimes deviate some species of mosquitoes away from humans towards cattle, especially if fodder crops alternate with cereals, increasing the number of animals that can be kept on the arable farm in summer, the crucial time of the year.[8] This raises many important questions about the nature of ancient agriculture in Mediterranean-climate regions, such as the question of the prevalence or otherwise of fallow in arable farming, or that of the scale of cultivation of fodder crops, or of the extent to which animals were actually maintained permanently on farms. These issues cannot be explored in detail here, beyond expressing general agreement with the analysis of Roman agriculture made by Ampolo and his use of comparative material from the early modern period.[9]

In contrast, a dominance of transhumant animal husbandry, especially if it concentrates on sheep, may have the effect of driving mosquitoes towards humans. In addition, a critical feature of transhumance is that the animals are absent from the parched lowlands

[7] Marchiafava (1931: 52); *Culex* 182–9.
[8] Hackett (1937: 89); Missiroli *et al.* (1933); Sandicchi (1942).
[9] Ampolo (1980).

during the summer heat, which is precisely the time of year when adult female mosquitoes are searching for prey to bite.[10] In the early modern period transhumance commenced in the Pontine region in May each year, earlier than in the Roman Campagna, because of the greater intensity of malaria in the Pontine Marshes. The system of land use along the road from Rome to Laurentum, described by Pliny the Younger, probably increased the intensity of transmission of malaria to humans in the countryside of Latium in antiquity in summer by deviating mosquitoes from animals to humans. Similarly, Bercé thought that an increasing interest in animal husbandry on the part of rich absentee landowners, to supply the urban market in Rome with meat and wool, which commanded higher prices than cereals, was correlated with an intensification of malaria in the sixteenth and seventeenth centuries AD. Celli had already noted the debates in the Gracchan period in the second century BC, concerning the appropriation of public land (*ager publicus*) by rich Romans and its exploitation for animal husbandry, which cannot be considered in detail here. Suffice it to say that this development was correlated with the spread of malaria in central and southern Italy, although it is difficult to specify cause and effect. The history and consequences for the Roman Republic of the Gracchan attempts at agrarian reforms are well known. It is only worth observing here that the question of appropriation of land by the rich for pastoralism was a perennial problem throughout the agrarian history of western central Italy. It was as prominent an issue in Lazio in the eighteenth century AD as it was in Latium in the time of the Gracchi in the second century BC. The comparison with detailed accounts of the very same phenomenon in much more recent and better-documented times shows that

[10] The only large domesticated animal (leaving aside the elephants) whose entire population spent the whole year in the lowlands of Latium in the pre-modern period was the water-buffalo (the source of mozzarella cheese), first mentioned in Italy by Paulus Diaconus, *historia Langobardorum*, iv.10, ed. G. Waitz (1878), *Monumenta Germaniae Historica*, xlviii (*Scriptores* 7) in the late sixth century AD: *tunc primum cavalli silvatici et bubali in Italiam delati, Italiae populis miracula fuerunt* (At that time wild horses and water-buffaloes were brought to Italy for the first time, marvels for the peoples of Italy). However it should be noted that there is some uncertainty about the identification of the *bubali* in the text of Paulus Diaconus: the aurochs is another possibility (White 1974). Toubert (1973: i. 268–9) suggested that water-buffaloes (*bubali*) might have served to deviate mosquitoes away from humans. This was certainly a possibility, but since malaria remained endemic in Lazio until Mussolini's bonifications, there were probably never enough buffaloes around to make a real difference. Hare (1884: ii. 271) described water-buffaloes in the Pontine Marshes. These animals have their own specific species of malaria, *Plasmodium bubalis* (Garnham (1966: 494–9)).

Appian's account of the behaviour of the rich in Roman Italy has an air of realism about it.[11]

This leads us on to the vexed issue of latifundia in Roman Italy. Pliny claimed that the latifundia had ruined Italy.[12] Recent discussions of this question have emphasized that use of the term is restricted in extant literature to a fairly short period, the first century AD. Moreover it did not have any precise meaning and could be applied to property holdings of quite different sizes.[13] However, there is no reason why the term should have had any very precise meaning; this requirement on the part of modern historians stems from an excessive preoccupation with legalistic issues. The debate should focus instead on the degree of fragmentation of large property holdings and on their internal organization. At the end of the fourth century AD Olympiodorus of Thebes stated that rich Roman families drew annual monetary incomes from their properties of about four thousand pounds of gold, not to mention the wheat, wine, and other produce which was worth about a third of this amount. Even if we did not have such explicit evidence, it would be foolish to deny that there were very large property holdings in the Roman Empire, and that the immense wealth of members of the Roman élite was indeed derived from large property holdings, regardless of what term(s) were used to designate large estates.[14] The argument that follows proceeds from these assumptions. In more recent times regions of Italy, like Lazio, which were dominated by malaria, were indeed characterized by very large estates, with small permanent populations in the pestilential lowlands, while the bulk of the population lived in towns on more healthy hills, or in mountainous regions. Celli summarized the situation as follows:

> Large estates and malaria usually go together, because man, in certain months of the year, cannot live in intensely malarious regions where, therefore only cultivation on an extensive scale is possible, and hence the large estates.[15]

[11] Bercé (1989: 241); Celli (1933: 26–7); De Felice (1965: 92–3), Burke (1996: 2278); Appian, *BC* 1.7.

[12] Pliny, *NH* 18.7.35: *latifundia perdidere Italiam.*

[13] Martin (1995).

[14] Olympiodorus *ap.* Photius, *bibliotheca*, ed. Henry (1959), i. 185–6 used the rather unspecific word κτήματα for the properties in question.

[15] Celli (1900: 144). See also De Clementi (1989, 45–9) for the effects of malaria on the early modern latifundia of Lazio. One of the anonymous referees pointed out the

Of course malaria was not confined to large estates. It could equally well occur in areas of smallholdings, as we have already seen in relation to market gardening in and around the city of Rome. Nevertheless malaria was strongly associated with large estates. Leading Italian writers such as Francesco Ciccotti and Giustino Fortunato attributed to malaria a considerable role in explaining the underdevelopment in recent times of the Mezzogiorno, relative to northern Italy.[16] The role of malaria is a constant undercurrent to the story of Carlo Levi's *Christ stopped at Eboli*, one of the most famous works of modern Italian literature. Eboli overlooks the intensely malarious plain in which ancient Paestum was situated. The close link between malaria, large estates, agricultural wage labour, and demographic regimes characterized by both high mortality and high fertility has been reaffirmed by the most recent research in Italian historical demography.[17] Similarly in Spain a very close correlation has been noticed between the distribution of malaria and of *latifundios*.[18] It cannot be stressed too much that there was a universal consensus among people who studied the situation in Lazio in the early modern period that the presence of endemic malaria made intensive agriculture virtually impossible in practice, however desirable it might have been in theory. The evidence from the Roman agronomists suggests that the situation was fundamentally exactly the same in antiquity by the time of the Late Republic. Perhaps the simplest way of demonstrating this is to juxtapose quotations from the ancient Roman agronomists with quotations from modern writers to show the similarity between conditions in antiquity and conditions in the early modern period, before the eradication of malaria:

> Spring-sown wheat remained essentially confined to limited areas. It was considered impossible to cultivate it in a large part of the domains of the Papal State, in the Roman Campagna and the Pontine Marshes, because it reached maturity in the season in which the air was more pestilential and in which it was liable to cereal rust.[19]

significance of the book by Antonio Monti (1941), an account of the work of Luigi Torelli, in relation to the mentality of large landowners and malaria. Unfortunately it was not possible to obtain a copy of this rare book.

16 Snowden (1999).

17 Del Panta (1989: 28) on the *latifundia* of Grosseto, also *Agricoltura e società* (1980); Arlacchi (1983, chapter 3) on the *latifundia* of the Crotonese; del Panta (1996, 141); Corti (1984, 643–7).

18 Beauchamp (1988: 258–9).

19 De Felice (1965: 55): *Il grano marzajolo rimase sostanzialmente circoscritto a limitate superfici,*

However, the most profitable land is land which is healthier than elsewhere, since there the proceeds are certain: however, on land that is pestilential, no matter how fertile it is, disaster does not allow the farmer to achieve a profit. For, where the reckoning is with death, not only is the profit uncertain there, but even the lives of the farmers are at risk. In an unhealthy location farming is a lottery in which the life and possessions of the owner are in danger.[20]

Those cultures, for instance viticulture, which require repeated care and labour even in the summer, can only be practised in localities with healthy air that are consequently somewhat elevated. Consequently in the Alban hills, very rich in vineyards, the curious phenomenon is observed that the lower limit of these vineyards signals almost exactly the upper limit of malaria, reigning in lower regions.[21]

In a pestilential locality, where work is impossible in summer, the honourable master will add a fourth part to the fee for the work [sc. the construction of a villa].[22]

The rarity of maize cultivation in the plains is explained readily when one remembers, on the one hand, the persistent aridity which usually prevails in the summer, and then the labour shortage, owing to malaria, which is observed in the season in which the vegetative growth of this plant occurs.[23]

However, I have a general principle, like a witness, which should be declared more frequently. M. Atilius Regulus, a very renowned general during the First Punic War, is said to have enunciated this rule: that not even the most fertile estate should be bought if it is unhealthy . . . Atilius gave this opinion to farmers in his own time with greater authority as it

ritenendosi impossible coltivarlo in gran parte del Patrimonio, dell'Agro e delle Palude Pontine dato che giungeva a maturazione nella stagione in cui l'aria vi era più 'pestilenziale' ed era pertanto soggetto alla 'ruggine'.

[20] Varro, *RR* 1.4.3: *Utilissimus autem is ager qui salubrior est quam alii, quod ibi fructus certus: contra in pestilenti calamitas, quamvis in feraci agro, colonum ad fructus pervenire non patitur. Etenim ubi ratio cum orco habetur, ibi non modo fructus est incertus, sed etiam colentium vita. Quare ubi salubritas non est, cultura non aliud est atque alea domini vitae ac rei familiaris.*

[21] F. Giordano, *Condizioni topografiche e fisiche . . .* in *Monografia* (1881: lix): *Talune di queste colture, come per esempio la vite, che esige ripetuta cura e lavorazione anche nella state, non può praticarsi che nei siti di aria sana e perciò alquanto elevati, e perciò vedesi il curioso fenomeno dei monti Albani ricchissimi di vigneti, dove il limite inferiore di questi segna presso a poco il limite della malaria regnante nelle regioni inferiori.*

[22] Cato, *de agr.* 14.5: *Loco pestilenti, ubi aestate fieri non potest, bono domino pars quarta preti accedat.*

[23] Author of the chapter entitled *Sulle condizioni dell'agricoltura e pastorizia della provincia di Roma*, in *Monografia* (1881: ci): *La scarsezza di cultura del granturco nelle pianure si spiega agevolmente quando si pensa da un lato, alla insistente siccità che non di rado vi domina nella estate, e poi al difetto di braccia che si verifica, a cagione della malaria, nella stagione appunto in cui si svolgono le fasi vegetative di questa pianta.*

was based on experience, for works of history say he farmed a tract of land in Pupinia that was pestilential.[24]

Malaria prevents changes in the agricultural system, and this in turn maintains malaria. A vicious circle from which it is impossible to escape, except with an expression of energy and with an enormous and prompt expenditure of money which could only be expected from an energetic and wealthy government . . . but the current state of the finances of the Italian government . . . would not permit such a heroic remedy.[25]

The accounts of early modern Lazio show that in the lowlands which were dominated by malaria it was virtually impossible to cultivate any crop which required attention in the summer and autumn (i.e. during the season of danger from malaria), such as spring-sown wheat, maize, or, most significantly given its importance in the economy, the vine. Viticulture ended at the altitude, going down the Alban hills, where malaria started.[26] In antiquity Cato states there were pestilential places where work was impossible in summer, just as in the early modern period. It is interesting that this was already the case by Cato's time in the first half of the second century BC. In view of his writing about Graviscae (see Ch. 7 above), there is no doubt whatsoever that Cato knew all about endemic malaria.[27] In the passage quoted here, which deserves more attention than it has received, Cato gives an indication of the additional cost to the Roman economy of the mortality and morbidity arising from malaria, stating that the cost to a contractor of

[24] Columella, *RR* 1.4.2–3: *In universum tamen quasi testificandum atque saepius praedicandum habeo, quod primo iam Punico bello dux inclitissimus M. Atilius Regulus dixisse memoratur: fundum sicuti ne fecundissimi quidem soli, cum sit insalubris . . . parandum; quod Atilius aetatis suae agricolis maiore cum auctoritate censebat peritus usu, nam Pupiniae pestilentis . . . agricultorem fuisse eum loquuntur historiae.*

[25] F. Giordano *Condizioni topografiche e fisiche . . .* in *Monografia* (1881, LXII): *'La malaria impedisce il mutare sistema di cultura, e questo viceversa mantiene la malaria. Circolo terribile dal quale è ben difficile escire, salvo con un atto di energia e con una ingente e pronta spesa che soltanto potrebbero attendersi da un governo energico e ricco di mezzi . . . Ma lo stato attuale delle finanze del Governo italiano . . . non consentirebbero ora un rimedio cosi eroico'.*

[26] Columella *RR* III.2.16 said that the Eugenian vines of the Alban Hills in antiquity were adapted to a cold and damp climate. Evidently these vines were cultivated on the higher slopes of the Alban Hills. Pliny, *NH* 14.8.64 described the wine produced in the Alban Hills as very sweet. Knight (1805: 62) observed that since Albano is elevated, peasants from the surrounding area stayed there from July to September in the early nineteenth century to avoid ' "the malaria', which is the name they give to the pernicious dews which fall in summer'. The Alban Hills reach altitudes of over 900 metres. Werner Sombart (1888) wrote a treatise about the peculiar economic problems of the Roman Campagna.

[27] North (1896: 74) reached an erroneous conclusion because he was not aware of the fragment of Cato on Graviscae, cf. Celli (1933: 26–7). Pliny, *NH* 14.8.67 mentioned the wine of Graviscae.

building a villa was likely to rise by 25%. That such an estimate of the economic effects of malaria is quite realistic is shown by the report to President Roosevelt in 1938 of the National Emergency Council on economic conditions in the south of the United States, cited by Desowitz. This report estimated that malaria had reduced the industrial output of the southern states of the USA by about a third.[28] Of course, for the slaves actually doing the work envisaged by Cato, who were killed or whose health was ruined by malaria, the cost could not be evaluated in purely financial terms. In order not to end up owning areas with such enormous economic problems (imagine what a sudden increase in labour costs of 25% would do to business in the economy of any modern developed country), the Roman agronomists essentially recommended avoidance behaviour. One should refrain from buying pestilential land, such as the notorious *ager Pupinius* (or *regio Pupiniae*) towards Tusculum, where the Roman consul Regulus had a farm in the middle of the third century BC. Both Columella and Pliny record that Regulus already advised against the purchase of unhealthy farms, even if the soil was very fertile, as early as the third century BC. It is interesting that there was already intense malaria in at least part of the Roman Campagna at that time, moreover in an inland plain rather than the coastal plains.[29] As has already been observed, the distribution of malaria is always discontinuous and highly localized because of its very complicated ecological requirements. As Cicero put it:

> let us return to the snares of Chrysippus: first of all certainly let us answer him on the question of contagion, and let us deal with other matters afterwards. We see how much difference there is in the nature of different places: some are healthy, others pestilential.[30]

[28] Desowitz (1997: 197). Livadas and Athanassatos (1963) described the economic benefits of malaria eradication in Greece. McCarthy *et al.* (1999) found a statistically significant negative association between higher malaria morbidity rates and per capita GDP growth rates in tropical countries today.

[29] On the *ager Pupinius* see also Cicero, *de lege agraria* 2.35.96 and Varro, *RR* 1.9.5. On Regulus see also Pliny, *NH* 18.6.27: *Atilius Regulus ille Punico bello bis consul aiebat neque fecundissimis locis insalubrem agrum parandum* (Atilius Regulus, consul twice during the Punic War, said that an unhealthy estate should not be acquired even in the most fertile locations.); Valerius Maximus 4.4.6.

[30] Cicero, *de fato* 4 ed. Giomini (1975): *ad Chrysippi laqueos revertamur; cui quidem primum de ipsa contagione rerum respondeamus, reliqua postea persequemur. Inter locorum naturas quantum intersit videmus; alios esse salubris, alios pestilentis.*

It was always possible to find localities which were free from malaria, especially on raised land. Just to give one small example here, a nineteenth-century travel handbook noted that on the Via Cassia leading north from Rome the first inn after Veii, Baccano near the Lago di Bracciano, was situated in an unhealthy area, but the next inn along the road, Monterosi, was healthy because of its higher altitude (276 metres above sea level).[31] Sometimes modern historians use the localized distribution of malaria to argue that because it did not occur everywhere it was not very important. Brunt, for example, advocated this view, while accepting that malaria had probably always been present in Italy. The error in this view is that it overlooks the fact that the localities where malaria occurred were the localities with the best agricultural land, i.e. valleys and well-watered lowlands. Consequently malaria had a much greater impact on the economy than its localized distribution might suggest. In the early modern period about one-sixth of the area of the Roman Campagna was regarded as being good, fertile farmland. It was naturally located in the lowlands. That means that malaria only had to cover that same sixth of the Roman Campagna to devastate the agricultural economy. Under those circumstances the type of animal husbandry described by Pliny the Younger along the road from Rome to Laurentum was logically the best way of exploiting the land.

It is impossible to consider here in detail the question of latifundia in relation to the results of archaeological field surveys in Italy, beyond recalling briefly the well known results of the surveys conducted by the British School at Rome which revealed a decline in the number of occupied sites of about 80% from the first to the fifth century AD in southern Etruria.[32] Field surveys in various other parts of Italy have shown that the countryside was certainly not deserted in the last two centuries BC, following the devastation which it is frequently assumed that Hannibal caused during the Second Punic War. However, the archaeological evidence on its own has and always will have, two fundamental weaknesses. First, it cannot tell us anything about the nature of land ownership, for example about the possibility of multiple sites being owned by a single owner. Secondly, the field surveys cannot tell us anything about the composition of the labour force (i.e. whether farms were

[31] Blewitt (1843: 246).
[32] Potter (1979: 138–46), cf. Liverani (1984).

worked by owner-occupiers, tenants, or slaves). For that we need documentary evidence.

Consequently it is still worth paying attention to Brunt's treatment of the problem of 'the desolation of Italy' (*Italiae solitudo*) as it appears in literary sources for the Republican period, even though it was written before archaeological field surveys became fashionable. He concluded that 'the existence of so many small towns in south Etruria is a strong indication that the free agricultural population held out better there than in some other parts of Italy'.[33] Even if this is true for the Republic, the field surveys suggest a steady decline in south Etruria during the Empire. Most of the major towns of the region in antiquity were eventually either abandoned or moved to new sites. With respect to Latium Brunt's conclusion was rather different: the population was mainly composed of slaves on 'a land of estates owned by the few'.[34] If Brunt's conclusion about Latium is correct, it shows that the system of land ownership characteristically associated with malaria in recent periods of history was already in place in Latium by the end of the Republic. It also raises another fundamental question about the agricultural system in Latium in the later stages of the Republic, namely the question of the nature of the agricultural labour force.

The population of the city of Rome, perhaps 750,000–1,000,000 people by the end of the first century BC, required very large quantities of food to sustain itself. Latium was renowned in particular for its wines, especially Caecuban wine, the product of a variety of vine which was very well adapted to the wet environmental conditions of the coastal region in the vicinity of modern Fondi.[35] The existence of such varieties of domesticated vine is not at all surprising when one recalls, from the descriptions of the Pontine forest quoted earlier (Ch. 6 above), that wild vines flourished in the Pontine Marshes. Setian wine, the favourite of the emperor Augustus, was also very highly rated. The example of Setian wine is particularly

[33] Brunt (1987: 353).

[34] Brunt (1987: 50).

[35] The Caecuban vine was actually cultivated in marshes: Pliny, *NH* 14.8.61: *in palustribus populetis sinu Amyclano* (in marshy poplar woods on the bay of Amyclae), cf. Theophrastus *HP* 4.1.1 for poplars liking marshy ground; Martial, *Epig.* 13.115: *Caecuba Fundanis generosa cocuntur Amyclis, vitis et in media nata palude viret* (The generous Caecuban vine is ripened at Amyclae near Fondi, and the green vine is born in the middle of the swamp.). Columella, *RR* 3.8.5 also mentions the Caecuban vine. Strabo 5.1.7.214C noted that vines grew very rapidly (with the inevitable corollary of a short life span) in the marshes of Ravenna. See Fregoni (1991: 33–5, 88–144) on the wild vine in Italy and on ancient Roman viticulture.

striking because Strabo singled out Setia as a pestilential district, a reputation that it retained until very recently, when Celli considered its problems at the end of the last century. Strabo described Setian wine as expensive. The price reflected the cost of producing it in the presence of endemic malaria as much as its intrinsic value.[36] Similarly viticulture was a major component of the agricultural system in Lazio in the early modern period, principally on the hills above the altitude reached by malaria. It was more important than olive cultivation, which was also confined to the hills but was frequently badly affected by severe frosts during the climatic conditions of the 'Little Ice Age'. Early modern Rome was not self-sufficient in olive production even when the urban population was no more than 200,000 people or so; the same was doubtless true in antiquity.[37] If one assumes that the free population declined substantially during the Late Republic and the Empire, following Brunt's conclusions, then a large slave-labour force on the land of Latium and southern Etruria is the main alternative, as Tiberius Gracchus observed on his way to Numantia. Cornell has recently summarized the population history of Latium as follows:

> The mass emigration of tens of thousands of poor peasant families must have led to a gradual depopulation of the old *ager Romanus*—a phenomenon that is in fact referred to in the sources of the classical period—and implies a radical change in the organization of landholdings and the manner of their exploitation. What must have happened is that the land was concentrated into larger holdings, which were worked by slaves who were brought in to replace the former peasant smallholders. The model therefore implies a continuous exchange of populations; poor Roman citizens were sent away to colonize lands whose original inhabitants were brought back to Roman territory as slaves. The process was complicated by a change in the relative distribution of the inhabitants in the old *ager Romanus*, with a greater proportion than before living in the city, and a corresponding reduction in the population of the countryside.[38]

As far as it goes, this analysis is quite logical, in accordance with the totality of the evidence, and perfectly plausible. The people

[36] Pliny, *NH* 14.8.61 on Setian wine, the favourite of the emperors, states that it grew *above* Forum Appii (*nascitur supra Forum Appi*), on the hills flanking the Pontine Marshes, the Monti Lepini, cf. 16.67.173; Martial, *Epig.* 10.74.10–11: *nec quae paludes delicata Pomptinas ex arce clivi spectat uva Setini* (nor the tender grape of Setia which from the hill slope overlooks the Pontine Marshes) and 13.112; Strabo 5.3.10.237C. The Monti Lepini reach altitudes of over 1500 metres.

[37] De Felice (1965: 70–82).

[38] Cornell (1995: 393–4).

who ended up in colonies in other parts of Italy must have come from somewhere. The large numbers of slaves generated by Roman imperialism, most notably those from the Second Punic War and those from Epirus in 167 BC, must have been put to work somewhere. However, it leaves one fundamental issue unresolved; namely, what was the motivation for Romans and Latins to leave the countryside of Latium in the first place? Cornell considered that the peasants of the *ager Romanus* were impoverished, had inadequate landholdings, and consequently were ready to emigrate. However, some parts of the old *ager Romanus* were potentially very good for farming (about a sixth), especially the valleys, as well as (potentially!) the coastal plains. Latium yielded everything in the way of agricultural produce, according to Strabo. It was also a well-watered lowland territory, an attribute that was rather unusual in relation to many other lowland Mediterranean regions characterized by a semi-arid climate.[39] In terms of its agricultural potential, Latium was surely much better off than Attica in Greece during the period of the Athenian empire in the fifth century BC, yet Thucydides noted that most Athenians still lived in the rural demes of Attica at the beginning of the Peloponnesian War. In addition, Latium produced prize wines. Why should peasants in an agrarian society have wanted to emigrate from the district that produced the emperor Augustus' favourite wine?

The answer to this question is clearly given by Strabo: because the district of Setia was pestilential. Setia had very rich agricultural land, the Campi Setini. However, it was always portrayed by the ancient sources as suffering from a shortage of manpower. This complaint was already made in 379 BC, according to Livy.[40] In 209 BC Setia (along with other communities in the region such as Circeii and Ardea) was one of the rebellious Latin colonies which informed the Roman consuls that they were unable to supply soldiers for the war against Hannibal. The long-running manpower shortage at Setia in antiquity was almost certainly a consequence of malaria, which probably had a long history in at least some corners of the Pontine region.[41] Livy wrote that Roman soldiers were reluctant to

[39] Garnsey (1988*a*) on the effects of the Mediterranean climate on agriculture.

[40] Livy 6.30.9: *Eodem anno Setiam ipsis querentibus penuriam hominum novi coloni adscripti* (In the same year new colonists were sent to Setia, whose people were complaining themselves about a shortage of manpower.).

[41] Livy 27.9.7 and 29.15.5 for the events of 209 BC; Livy 41.8.7 for the movement of Latins

return home after the siege of Capua in 342 BC because their land in Latium was pestilential.[42] Dionysius of Halicarnassus also stated that one of the attractions of life in Campania for the Romans was the healthiness of the plain for farmers.[43] Those Roman soldiers were simply following the sort of advice already given by the consul Regulus in the third century BC and by the later agronomists, namely to avoid pestilential land (see Ch. 11 below on other aspects of avoidance behaviour in relation to malaria). The unhealthiness of Latium was to remain a major aspect of its history for well over two millennia. Delumeau suggested that a recrudescence of malaria in the sixteenth century helped to explain migration from the countryside to the city of Rome in that period.[44]

The agricultural potential of their land was certainly a consideration, but it was not the only important consideration in the minds of the peasants who formed the backbone of the Roman army, when they chose to emigrate from the Latin countryside. The final proof comes from a consideration of the fortunes of colonies in different regions and environments. Inland colonies were generally very successful. However, colonies located on the coast, including both the Latin colonies of Cosa and Paestum (founded in 273 BC) and several small Roman colonies (besides Graviscae), were usually unsuccessful. The case of Cosa (modern Ansedonia), whose problems have already been noted in connection with the description of the Maremma by Rutilius Namatianus (see Ch. 7 above), is particularly striking. The town occupied a fine site, but required more colonists in 197 BC, less than a century after its foundation. Its

from the countryside of Latium to the city of Rome. The two doctors, Quinctius Theoxenus and Gaius Licinius Asclepias, who are recorded as having lived in Setia undoubtedly had plenty of work to do (*CIL* X.6469 and 6471). On Setia see also Attema (1993: 87–9). Setia was a site of triumviral colonization, according to the *Liber Coloniarum*, i. 237–8, cf. Cicero, *de lege agraria* 2.25.66. Nicolai (1800: 42–3) described early modern Setia as rich in olive trees, but very rich in vines.

42 Livy 7.38.7: *pestilenti et arido circa urbem solo*.

43 Dionysius Hal. 15.3.4: *Καμπανίαν . . . πρὸς ὑγίειαν ἀνθρώποις γεωργοῦσιν ἀρίστην οὖσαν*. Cicero, *de lege agraria* 2.35.96, Pliny, *NH* 3.5.60 and Strabo 5.4.2.242C also praised the Campanian plain. Presumably the reference is mainly to the interior plain around Capua, since there certainly were some unhealthy parts of Campania, such as the coast around Paestum. For the general idea of disease forcing people to migrate see also Seneca, *ad Helviam matrem de consolatione* 7.4, ed. Hermes (1905).

44 Delumeau (1957: i. 220): *Mais si Rome s'accroît entre 1527 et 1600 de quelque 50,000 habitants, ne serait-ce pas aussi aux dépens de la campagne voisine où les moissons diminuent et où la malaria multiplie ses ravages?*

subsequent history was rather disjointed.[45] The failure of repeated attempts to colonize coastal areas can be attributed to malaria.

In the Renaissance period Niccolò Machiavelli claimed that unhealthy areas could be made healthy if they were colonized by a large body of men, but this was wishful thinking on his part.[46] The healthiness of Venice is to be explained in other ways; in antiquity it was undoubtedly part of the region of anophelism without malaria which also included Ravenna (see Ch. 4. 2 above). Subsequently, however, Venice did not dry up and suffer the same environmental changes as the coast around Ravenna. Pisa's problems have already been noted. Machiavelli understood the importance of colonization for the success of Roman imperialism in antiquity, but his argument misses the point that short-term colonization cannot ensure long-term population stability in the face of malaria. The Romans in antiquity were unable to populate *in the long run* those areas with the most intense malaria. The rulers of Florence in Machiavelli's own time were no more successful, since the detailed evidence available to modern historians shows that in the late medieval and Renaissance periods the Maremma only had a population density of about 5–10 people per square kilometre, in contrast to population density levels of about 150 per square kilometre in the immediate vicinity of Florence itself. Many men were driven by dire necessity to seek seasonal employment in agriculture in the Maremma, but the bulk of those people chose not to reside permanently and work and die under the conditions of endemic malaria.[47] Although slavery had not yet completely disappeared, the economy of Renaissance Florence was not based on mass chattel slavery. The difference in antiquity was that ancient Rome was a society with the potential for massive chattel slavery as the basis of the labour force and the slaves had no choice over where to live and die.

[45] On Cosa see Celuzza (1993: 227–34); Fentress (1994: 281) concluded that 'the only "continuity" evident at Cosa is the continual difficulty of keeping its inhabitants for more than a few generations'.

[46] Niccolò Machiavelli, *Istorie fiorentine*, ii.1 ed. Carli (1927): *I paesi male sani diventano sani per una moltitudine di uomini che ad un tratto gli occupi; i quali con la cultura sanifichino la terra e con i fuochi purghino l'aria; a che la natura non potrebbe mai provedere. Il che dimostra la città di Vinegia, posta in luogo paduloso e infermo: nondimeno i molti abitatori che ad un tratto vi concorsono lo renderono sano. Pisa ancora, per la malignità dell'aria, non fu mai di abitatori ripiena, se non quando Genova e le sue riviere furono dai Saraceni disfatte; il che fece che quelli uomini, cacciati da' terreni patrii, ad un tratto in tanto numero vi concorsono, che feciono quella popolata e potente.*

[47] Herlihy and Klapisch-Zuber (1985: 35, 49); Pinto (1982: 44, 53–4, 66); Bueti and Corti (1998).

Finley emphasized how rare mass chattel slavery has been in human history: there have only been five major cases in recorded history, namely the United States, the Caribbean islands, and Brazil, after 1492, and ancient Rome and Greece (and a few other minor cases which he did not consider). There was a fundamental difference between the classical Greek city-states and the other four cases in respect of the scale of slavery, as in respect of the scale of everything else, which sets apart classical Athens from the other four. The origins of the slave trade to the western hemisphere are well known and have been described by numerous historians: the European conquerors initially tried to put the indigenous Amerindians to work, but they were decimated by diseases introduced by the colonists, as part of the Columbian exchange which has been so well described by McNeill and Crosby. Subsequently there was a tremendous shortage of labour to work the plantations, a gap which was filled by importations of Negro slaves from Africa, who were more resistant to European diseases than the Amerindians but nevertheless suffered extremely high mortality rates, and who had the virtue (for their buyers) of being cheap and readily available in large numbers. Benjamin Franklin in 1751 concluded that the reason why estate owners in the United States turned to slave labour was simply a question of labour costs: imported slaves were much cheaper than hired labour from the thinly scattered white population.

The reason for the genesis of an economy based on mass chattel slavery in western central Italy (and large parts of the south of Italy) in antiquity is fundamentally exactly the same as the reason why it arose in the western hemisphere after Columbus. A spreading disease (in this case *P. falciparum* malaria) gradually, by a slow process of attrition, either killed or forced to emigrate the bulk of the indigenous farming population in Latium and southern Etruria, thus providing the manpower for Roman colonization elsewhere. That, in turn, created a vacuum, a massive labour shortage, on fertile agricultural land where free men were reluctant to work because of the disease. That labour shortage could only be filled by importing large numbers of chattel slaves. Even though the later slave revolts in Italy led by Spartacus and in Sicily have attracted much more attention from modern historians, it is very striking that the first attested slave revolt in Roman Italy occurred precisely in the Pontine Marshes, in 198 BC. Livy records that slaves, acquired as part of the proceeds of the Second Punic War, in the territories of Setia, Norba, and Circeii conspired with the slaves of Carthaginian hostages who were being held at Setia to attack these towns. Military action was required to suppress the revolt. Viewed in the light of the analysis given here, the location of this first slave revolt was not an accident. After the Second Punic War and such later acts of Roman aggrandisement as the destruction of Epirus in 167 BC, slaves were extremely cheap. Their owners need not worry if the gangs of slaves employed on the land, such as those seen by Tiberius Gracchus, suffered extremely high mortality rates from malaria; slaves were very cheap and easy to replace. For as long as the slave trade to the western hemisphere continued, slave owners there took exactly the same attitude, tolerating very high mortality rates among their slave labour forces and assuming that imported slaves would not live more than a few years on average. Yet they were able to make large profits under those circumstances. The slaves who ended up in Setia were brought there because of the manpower shortage noted earlier. The slave revolt there in 198 BC shows that the slave economy witnessed by Tiberius Gracchus was already taking root in western central Italy two generations before his excursion through south Etruria which had such catastrophic consequences for the Roman Republic. The demand for labour preceded and called forth supply in Roman Italy, exactly as it did in the United States, according to the arguments of Benjamin Franklin. What happened in Setia was a microcosm of what happened throughout western central Italy and in large parts of southern Italy as well. The slaves who were brought to Latium and Etruria were forced to constitute the labour forces of the Roman villas which came to populate the landscape, villas such as Settefinestre, according to the villa-based slave mode of production characteristic of these regions during the Roman Empire, as described by Carandini.[48]

To replace the concept of the latifundium, which he maintains lacks clarity, Carandini postulated a typology of two types of Roman villas. He distinguished the *villa centrale* from the *villa periferica*. He suggested that the *villa centrale* was characteristic of the *suburbana regio Italiae*. It was relatively small and practised intensive

[48] Franklin (1751); Livy 32.26 for the events of 198 BC; also 33.36.1–3 for another slave revolt in Etruria a couple of years later; Carandini (1985).

agriculture using mainly slave labour. All this is acceptable. The point at issue here is the assertion that the *villa centrale* was found on fertile lands and in a healthy environment.[49] In contrast the *villa periferica* was found mainly in more outlying, isolated regions, located on less fertile land and in less healthy conditions.[50] Extensive agriculture which required a smaller labour input was the norm. That labour was supplied principally by serfs or tenants rather than slaves. This typology implies that unhealthy conditions were to be found mainly on the fringes of the agricultural landscape of central Italy in Roman times. However, there is plenty of evidence, as this book demonstrates, for malaria right at the heart of the Roman world, even in the city of Rome itself. There were villas in the extremely fertile territory of Setia, which undoubtedly employed the slaves attested during the slave revolt of 198 BC and later supplied wine for the personal consumption of the Roman emperors. Not a fringe area. Yet the land of Setia was pestilential. This example alone wrecks Carandini's typology in so far as it concerns healthy/unhealthy conditions. Moreover, as we have already seen, in general it was fertile lowlands in particular that were likely to be unhealthy, while less fertile mountainous regions were usually healthy. The argument proposed here instead is that it was precisely because much of the best agricultural land of central Italy was unhealthy, owing to malaria, that the Roman élite was forced to import large numbers of slaves in order to get the land worked. Mass chattel slavery was an adaptation to malaria.

One of the plays of Plautus explicitly mentions the idea of slaves dying rapidly in summer after being forced to perform agricultural labour on pestilential estates. The six months' life expectancy on farms where malaria was endemic recalls the six months' life expectancy mentioned in the traditional Italian proverb about the Maremma quoted in Chapter 7 above. Of course Plautus' comments on a particularly undesirable farm, where everything that could go wrong did go wrong, were intended to be funny, but it was a type of comedy which could only be enjoyed by slave owners. Nevertheless it shows that the type of analysis advocated here was well within the consciousness of ancient Romans:

moreover none of the Syrian [sc. slaves]- the most enduring of men—who

[49] Carandini (1995: 33): *Si trova su terreni fertili e in ambiente salubre.*
[50] Carandini (1995: 34): *È posta su terreni meno fertili e in condizioni meno salubri.*

lived there for six months, is alive: all of them were killed by the disease that strikes at the summer solstice[51]

There was an alternative, or at least a possible supplement, to slave labour which deserves some attention, bearing in mind that Mediterranean agriculture requires a lot of labour during harvesting, in the summer, which is not required for the rest of the year. The alternative is the employment of hired labour from seasonal migrant workers. Varro's recommendation, quoted earlier (Ch. 4. 2 above), that hired labour should be employed in unhealthy regions, rather than slaves, should be recalled. In the early modern period a considerable proportion of the labour input was provided by free labourers who migrated from the uplands of Abruzzo and Marche to gather in the harvest in the Roman Campagna, and from Liguria and Emilia to Tuscany, and also from Abruzzo to the Tavoliere. Bercé described how in 1593, for example, forty thousand labourers arrived in the vicinity of Rome, first to reap wheat and barley, then to thresh it, and afterwards to harvest the grapes.[52] Those labourers were prepared to take the risk of catching malaria, sleeping out in the fields in the summer, because it was the only way in which they could make a living. External colonization gave poor Romans alternatives in antiquity during the Republic. The employment of hired labourers inevitably meant that large landowners did not have to bear the costs if the labourers died from malaria. Cipolla described from the reports of the Florentine health magistrates how seasonal workers who had gone from Liguria to work in the Tuscan Maremma had become ill in early autumn at Bibbona in 1614 on their way home and died during the winter months. In this way malaria was able to influence the demography of parts of Italy in which it did not occur. Del Panta attributed the fact that the territory of the Senese had very high mortality levels in the early modern period, even though it was a considerable distance from the coast, to the effects of malaria on labourers who migrated seasonally to the Maremma.[53] The

[51] Plautus, *Trinummus* 542–4: *tum autem Surorum, genus quod patientisumumst | hominum, nemo extat qui ibi sex menses vixerit: | ita cuncti solstitiali morbo decidunt.*

[52] Bercé (1989: 241), citing Paolo Paruta; Delano Smith (1978: 145); Sorcinelli (1977: 95–6) linked malarial fevers in the Marche to seasonal migrations of farm labourers, and also to the construction of the Bologna–Ancona railway line.

[53] Cipolla (1992: 51–3); del Panta *et al.* (1996: 193–6); Scheidel (1994*a*: 175, 187–8, 216) discussed wage labour in *gravia loca*.

combination of slaves for the permanent labour forces of villas with seasonal labour for the harvest and associated tasks explains how the Roman élite was able to extract a substantial amount of agricultural production from a land which was shunned by free peasants because of the 'reckoning with death', *ratio cum orco*, mentioned by Varro. The reckoning with death from malaria was exactly the same in the Roman Campagna in the early modern period as it was in antiquity: the difference was that early modern Rome was not a slave society:

> The workman does not languish voluntarily where the cause of illness and death is close by and powerful.[54]

As was noted earlier, Celli advocated 'the theory that . . . periods of prosperity coincided with periods of attenuation in the severity of the malarial fever'.[55] He knew that many Roman villas were constructed in the Roman Campagna, above all in the period from Augustus to the Antonines, and thought that the economic prosperity indicated by these villas could only be explained on the assumption that malaria, which was certainly present, was less virulent at that time. Celli proposed a cycle of fluctuations of virulence of *P. falciparum* malaria in the Roman Campagna throughout history. The idea was accepted by other leading Italian malariologists, such as Missiroli for example, and by medical historians like Bercé and North. It has in fact never been subsequently seriously reexamined.[56] Yet the whole theory is quite weak. Of course Celli, writing at the end of the last century, had no direct scientific evidence for fluctuations in the virulence of *P. falciparum*, and there is little available today; as was observed in Chapter 3 above, current scientific research into parasite evolution and epidemiology suggests that extreme virulence is adaptive for *P. falciparum*. Moreover the modern populations of regions with endemic malaria in the past tend to have high frequencies of human genetic mutations which give some resistance to malaria (see Ch. 5. 3 above, and the discussion of Ravenna in Ch. 4. 2 above). This implies intense pressure by severe malaria as an agent of natural selection on

[54] F. Giordano, *Condizione topografiche e fisice . . .*, in *Monografia* (1881: lxiii): *dove è prossima e forte la causa di malattia e di morte, non si perita volentieri il lavoratore.*

[55] Celli (1933: 109).

[56] North (1896: 86); Missiroli (1938: 5–6); Bercé (1989); Hofmann (1956: cols. 1203–6) on Celli's theory of cycles of malaria as applied to antiquity.

human populations in Italy in the past and contradicts Celli's theory of mild malaria.[57]

Celli's evidence was entirely indirect, basically the remains of villas in the Early Empire (and churches in the Late Empire) as signs of prosperity. A typical example is Cicero's villa at Astura on the coast of southern Latium, a beautiful location. However, it must be noted that Virgil hinted that the marshes of Astura were unhealthy.[58] Moreover, according to his letters, Cicero stayed in his villa at Astura principally in the spring—the season of the year when transmission of malaria ceased or was very low. After the end of the Republic most of the villas on the coasts of Etruria and Latium eventually became the emperor's property and probably rarely saw their owner. Domitian's villa by the side of the Lago di Paola in the Pontine Marshes has left very imposing archaeological remains which have recently been restored. However, it appears to have been a single-phase site which was neglected after Domitian's death. The letter of Pliny the Younger quoted earlier (Ch. 8 above) about the villa of Regulus on the Tiber confirms that some Roman villas were located in areas which were known to be unhealthy. Moreover Celli did not consider who built these villas, or ask who were the people who formed the labour force working out of these villas afterwards. He did not consider the importance of the fact that these villas had a labour force made up of slaves. He did not pay any attention, as a possible parallel, to the slave societies of the western hemisphere, where plantation owners were quite happy to make big profits by employing large numbers of slaves with a low life expectancy in very unhealthy environments.[59] He did not pay

[57] In using this line of argument it is necessary to take account of human population movements and migrations. The modern populations of some of the regions of Italy which formerly had endemic malaria have moved there recently from other areas. For example, the modern population of the new towns of the Pontine plain is largely descended from colonists sent there from the north of Italy by Mussolini in the 1930s (Gaspari 1985). Under such circumstances it would obviously be foolish to use the genetics of the modern population of this region to attempt to shed light on ancient malaria. Similar considerations apply to the population of the city of Rome itself, which has been a magnet for migrants not just in modern times but throughout history (see Ch. 11 below).

[58] Cicero, *Letters to Atticus*, 257, ed. Shackleton-Bailey (1965–70) (written on 14 March 45 BC) described Astura as a *locus amoenus* (a pleasant place) (unlike the Pontine Marshes); Virgil, *Aeneid* 7.801.

[59] Giglioli (1972) studied the large reductions in mortality following the eradication of malaria from the sugar plantations of Guyana. For comparative evidence from North America see also J. F. Smith (1985: 7, 136–7); Joyner (1984: 35–7, 70); Savitt (1978: 17–35); Merrens and Terry (1984); Dubisch (1985); Duffy (1988); Dobson (1989); Dusinberre (1996); Rutman and Rutman (1997).

enough attention to the fact, accepted by all historians writing about the Roman Campagna from Ashby to Brunt, that there were very few significant towns or villages in Latium populated by free people during the Roman Empire. Free people had a choice of where to live, but slaves did not have any choice. The verdict of free people is much more significant in assessing the problem of the desirability of living in Latium. Above all, Celli, surprising as it may seem in a work of medical history, did not pay enough attention to one crucial category of literary evidence from antiquity, namely the evidence provided by the medical writers. It is worth quoting one paragraph from the English translation of Celli's book to illustrate the problem:

> The best description of the character of the different forms of fever is given by Galenus; he . . . describes vividly the . . . aestivo-autumnal fevers again recurrent in our days and which in those days were called 'Emitritea fevers', and were widely spread in Rome in summer and in autumn. The heavy occurrence of jaundice and dropsy could be daily observed, symptoms undoubtedly produced by malaria. This disease was widely spread at a time when we know from many signs and proofs [sc. villas, etc.] that the pest was diminishing in virulence.[60]

The massive problem with this line of argument is that Galen does not say anything whatsoever about the pest diminishing in virulence! On the contrary, Galen explicitly described the semitertian fevers, which were so common in Rome, as extremely dangerous (*κινδυνοδέστατος*), as has already been seen (Ch. 8 above). Moreover the symptoms of jaundice and dropsy noted by Celli himself indicate a severe disease. The direct testimony of Galen with regard to the virulence of the disease is much more significant than the extremely indirect evidence of villas which were largely populated by slaves. Celli's argument for an attenuation of the severity of malaria during the Roman Empire, as a cyclical downturn after the ravages which he argued it caused during the Late Republic, is very weak. There is no space to examine here in detail the possibility of fluctuations in the virulence of malaria in the Roman Campagna during more recent periods of history. That would require another book, which would have to be based on extensive research in archives and libraries in Italy, but the weak-

[60] Celli (1933: 47, 111–17).

ness of Celli's arguments about antiquity suggests that the enterprise would be worth undertaking.

There is only space here to note that some of the evidence presented by Celli himself for later periods contradicts his own theory in exactly the same way that Galen contradicted it in antiquity. For example, Celli argued, again on the basis of construction work (analogous to the villas of antiquity), that another period of attenuation of the severity of malaria occurred from the mid-fourteenth to the seventeenth century AD. However, he noted that the leading seventeenth-century historian of the city of Rome, Father Alexander Donatus, observed that the villas of that period were built in hilly locations precisely because the lowlands were unhealthy:

> The reason is to be sought in the unhealthy and noxious wildness of the air. For the opinion of the doctor Alexander Petronius, expressed in notable works, is confirmed by experience, with everyone's agreement: the summer residences of the citizens in the vineyards around the city are unhealthy, and are not far away from the danger of ill-health. Consequently very few villas can be counted not only on the land along the Tiber, but even on the land around the city, despite the presence of so many noblemen and the abundance of wealth. The villas are located instead a little further away, on the ridges of Tibur, Tusculum, and Mt. Albanus.[61]

Donatus' evidence undermines Celli's own theory. It is very revealing to compare Donatus' account with the archaeological evidence for the distribution of ancient Roman villas around Praeneste, for example, as described by Andreussi:

> All these villas arose either on the flat summits of hills separated by deep ravines, or on the southern slopes of the same hills, with a good aspect and view.[62]

The similarity to the situation described by Donatus in the seventeenth century is obvious.[63] It is likely that Donatus was right,

[61] Donatus (1694: bk iii. ch. 21, p. 272): *Causa rejicienda est in aëris intemperiem insalubrem, et gravem. Nam quod Alexander Petronius Medicus insignis typis evulgavit, omnium assensu, et experientia comprobatur; insalubres esse Civibus circum Urbem aestivas in vineis stationes, nec procul a periculo valetudinis abesse. Itaque non modo secundum Tiberim, sed etiam in agro suburbano, in tanta Principum et divitiarum copia, paucissimae numerantur Villae, quae paulo remotiora Tiburis, Tusculi et Albae juga insederunt.*

[62] Andreussi in Giardina and Schiavone (1981), i. 351: *tutte queste ville sorgevano o sulle sommità piatte di colli separati da profondi burroni, o sui pendii meridionali dei colli stessi, con buona esposizione e vista.*

[63] Note also the comments of Thomas and Wilson (1994: 173) on the location of Roman

and the lowlands were always very unhealthy (from at least *c.*200 BC onwards) because of malaria. Equally, there were always some healthy locations available for villas, especially on the slopes and summits of hills, during both the time of the Roman Empire and all subsequent periods. Humans continuously made efforts to reclaim the lowlands, for example the *domuscultae* of Pope Zacharias (AD 742-752), but they were always beaten back by malaria until modern times.[64] In so far as there were any periodic variations in the distribution and/or frequency (transmission rate) of malaria, these are much more likely to have been caused by local environmental change affecting the breeding habitats of mosquitoes, a question which Celli did not consider at all. The modern areas of anophelism without malaria were probably created by the modernization of Italian agriculture with the integration of arable farming and animal husbandry (replacing traditional transhumance) in a way that favoured zoophilic over anthropophilic species of *Anopheles* mosquito. There seems to be little evidence in fact that any of the regions of anophelism without malaria considered by Fantini actually existed before the nineteenth century. Pisa, for example, has already been considered. Its territory was unhealthy during the Renaissance period. Similarly the Val di Chiana, where Hackett performed some of his famous studies, and other areas of anophelism without malaria in Tuscany in the late nineteenth century such as Fucécchio and Altopáscio, were extremely unhealthy in the eyes of late medieval and Renaissance historians. Herlihy and Klapisch-Zuber, for example, described these areas as 'fever-ridden sinks'.[65] The vicinity of the southern end of the Val di Chiana continued to suffer from malaria into the nineteenth century, since Cesare Massari, a doctor from Perugia who pub-

villas. On the Via Praenestina east of Rome at Ponte di Nona a mid- to late Republican healing sanctuary was excavated. Many terracotta votive offerings were found. Wells (1985) interpreted the large number of terracotta heads found at this site as connected with cerebral malaria. Grmek and Gourevitch (1998: 347–8) described Wells's analysis as an example of 'overinterpretation'. It is certainly true that there are many other possible causes of pain in the head besides cerebral malaria. Consequently no individual terracotta head can be conclusively associated with malaria. However, given the sanctuary's geographical location, it is likely that some of the votive offerings were the result of malarial infections, although there is no way of knowing which ones.

[64] Tomassetti (1910: i. 110–12) on the *domuscultae*, which he described as a *villaggio sparso*, wrote as follows: *la durata di esse fu di circa trecento anni; la decadenza ne fu rapida e l'abbandono fu assai dannoso*.

[65] Fantini (1994); Herlihy and Klapisch-Zuber (1985: 34).

lished a history of that town's experiences of epidemic disease in 1838, recorded the establishment of a hospital in about 1816 at Corciano specifically to handle cases of malaria among the inhabitants of the region of Lake Trasimene.[66] This proves that the region's status as an area of anophelism without malaria was a modern development. Besides the drainage scheme that was mentioned earlier, it is also likely that increasing usage of quinine in the hospital during the nineteenth century played a significant role in the defeat of malaria in that region.

[66] Massari (1838: 144–5): *Nè deve sotto silenzio passarsi il provvedimento preso in quel tempo di stabilire uno Spedale nella terra di Corciano, distante sei miglia al ponente di Perugia, per la via di Toscana, a racchiudimento di tutte que' febbricitanti i quale dalle vicinanze del Trasimeno, per le cattive arie d'estate ed autunno, entravano ammorbati tra noi. E là dovevano essere medicati que' laghegiani, cui la continua o la intermittente paludosa febbre avesse colto.*

10
Apulia

Although the focus of this book is on western central Italy, Latium and Etruria, it must not be forgotten that much of southern Italy was also severely affected by malaria, as Alcuin commented in AD 801 upon hearing of the intentions of the army of the Frankish king Pipin:

I have heard that you are about to go to devastate the land of Beneventum. Ensure that you have maximum knowledge of the danger awaiting you there because of the pestilential air of that land.[1]

The Samnite and later Roman city of Beneventum occupied a plateau (135 metres above sea level) between two rivers, the Sabato and the Calore. The site of the city itself was healthy, as Eustachius emphasized in his account of the air of Beneventum published in AD 1608. He acknowledged that some diseases entered the city at the time of the rising of the dog-star and the Etesian winds and noted that some patterns of autumn weather could produce 'bad air' at Beneventum. Nevertheless he maintained that the respiratory diseases of winter were more important than summer diseases at Beneventum (see Ch. 5. 2 above for the relationship between the two) and that the inhabitants of the city as a whole were healthy. However, river valleys always had potential as far as malaria was concerned. Some parts of the region had a reputation for malaria throughout the medieval and early modern periods. Doni noted that there were unhealthy localities near Beneventum and Telesia in Samnium in the seventeenth century. More recently the distribution of malaria extended from Campania across the provinces of Benevento and Campobasso towards the Adriatic coast.[2] Con-

[1] Alcuin, *Epistolae*, 224, ed. Duemmler (1895), *Monumenta Germaniae Historica. Epistolae*, iv. 367: *Audivi vos ituros esse ad vastandam Beneventanam patriam. Scis optime, quale periculum ibi imminet tibi propter pestilentem illius terrae aerem.*

[2] Doni (1667: 87); Eustachius (1608: 56–7, 89). North (1896: 24, 100). The early medieval life of St. Barbatus, Bishop of Beneventum, identified fevers with paganism and sin: *peccatorum febribus* (fevers of sinners) (*vita Sancti Barbati Episcopi Beneventani*, iii, ed. Waitz (1878), *Monumenta Germaniae Historica. Scriptores Rerum Langobardicarum*, ii. 557–8).

Map 7. Salpi and Apulia

sequently we may need to look no further to explain the significance to the Romans of Beneventum's original name which was transcribed into Latin as Maleventum ('bad wind'), the name changed by the Romans to the more auspicious Beneventum ('good wind') when they founded a colony there in 268 BC.[3] The demography of malaria was widely distributed in the southern half of Italy as well as in western central Italy. Doni noted that acute

[3] Livy 9.27.14; Pliny, *NH* 3.11.105; Velleius Paterculus, 1.14.7; Procopius, *BG* 1.15.4–7 attributed its original name to a stormy wind from Dalmatia which blew over the area.

fevers caused thousands of deaths in Apulia and Campania in 1607, a very hot, dry year.[4]

There is definitely evidence that this was already the situation in classical times. The marsh of Salpi (*Salpina palus*) in Apulia, close to Old Salpi (or Salapia) on the gulf of Manfredonia on the Adriatic coast of Italy, was notorious for malaria.[5] During the Second Punic War Hannibal decided that Salpi, which he held for six years, was a good place in which to spend the *winter*, because of the lush pastures for his cavalry. Hannibal was too smart to spend the summer in an area subject to intense malaria if he could avoid it.[6] The landscape changes which affected the vicinity of the old town, as described by Delano Smith, were typical of those undergone by coastal habitats which were being seized by malaria.[7]

The Lago di Marana adjoining the old town at Torretta dei Monaci was a small shallow lagoon originally connected to the much larger Lago Salpi on its southern side. Lago Salpi was a large lake running parallel to the sea but separated from it by a narrow strip of land, like the Lago di Paola and the other lakes along the Tyrrhenian coast next to the Pontine Marshes. To the north of Salpi lay Lago Salso, a large lake which was drained under Mussolini in the 1930s. The presence of these large lakes suggests that at least some parts of Apulia were wetter during the Iron Age than they are today. Some palaeobotanical research has reached this conclusion for Arpi, which was linked to Salpi by a waterway.[8] The Lago di Marana next to Old Salpi was cut off from Lago Salpi by alluviation caused by intensive farming and gradually turned into marshes. Once the marshes were cut off from the sea they were generally filled with fresh water, but their history created slightly brackish conditions. The whole region, from Manfredonia in the north to Margherita di Savoia in the south, is responsible for about three-quarters of modern Italy's total salt production. Inevitably it was highly attractive for those species of mosquito which transmit malaria and are tolerant of brackish conditions. Di Biase pointed out that evidence for salt production in the area goes back to Roman times, as shown by the name *Salinis* given to Salpi in the

[4] Doni (1667: 177–8).

[5] Lucan, *de bello civili* 377 mentioned the *Salpina palus*, as did Vibius Sequester (see Ch. 6 above).

[6] Livy 24.20.15, cf. 26.38.6–14 and Valerius Maximus 3.8.*ext.*1, on Hannibal.

[7] Delano Smith (1978: 82–91, 154–7, 165–9).

[8] Sanpaolo (1995: 85–7) on the palaeobotany of Arpi.

Roman itineraries. This is yet another illustration of the fact that the areas infested by malaria were frequently areas of great economic importance. The historical geography of the entire region recalls Vitruvius' comments, with reference to the Pontine Marshes, about the unhealthiness of coastal marshes which were or became isolated from the sea. Vitruvius explicitly states that Old Salpi, a once prosperous Daunian city located in a grain-exporting region, according to Strabo, was abandoned because it was unhealthy. The landscape changes described by Delano Smith, a geographer, are extremely important for understanding the creation of suitable breeding habitats for *Anopheles* mosquitoes leading to intense malaria:[9]

> The town of Old Salpi in Apulia . . . had been established in places like that [sc. stagnant marshes cut off from the sea], as a result of which the inhabitants were ill every year, until they eventually approached M. Hostilius with a request in public and persuaded him to search for and choose a suitable place for the transfer of their fortified town. He did not delay, but immediately after making very shrewd investigations he bought some land in a healthy location near the sea and asked the Senate and Roman people for permission to transfer the town . . . he cut a channel to link a lake to the sea and made a harbour from the lake for the town. Consequently the people of Salpi now live in a healthy place six kilometres from the old town.[10]

Vitruvius states that the inhabitants were moved at their own request by M. Hostilius (whose identity is uncertain) to a healthier location on a small hill (il Monte) about six kilometres away from the old town, beyond the usual flight range of mosquitoes. This was a triumph for Roman town planning in the face of malaria, but it also shows malaria directly altering human settlement patterns. It is a very good illustration of how localized endemic malaria can be. This episode cannot be closely dated, but archaeological evidence

[9] Delano-Smith argued that Old Salpi was abandoned because of the silting up of a canal leading to the sea which had been used for grain exports. Strabo 6.3.9.283–4C described Salapia as the seaport of Argyrippa, but only mentioned exports from Sipontum, not from Salapia. He regarded Argyrippa as less important than Canusium in his own time.

[10] Vitruvius 1.4.12: *in Apulia oppidum Salpia vetus . . . in eiusmodi locis fuerat conlocatum, ex quo incolae quotannis aegrotando laborantes aliquando pervenerunt ad M. Hostilium ab eoque publice petentes impetraverunt, ut his idoneum locum ad moenia transferenda conquireret elegeretque. Tunc is moratus non est, sed statim rationibus doctissime quaesitis secundum mare mercatus est possessionem loco salubri ab senatuque populoque R. petit, ut liceret transferre oppidum . . . lacum aperuit in mare et portum e lacu municipio perfecit. Itaque nunc Salpini quattuor milia passus progressi ab oppido veteri habitant in salubri loco.*

suggests that habitation continued at Old Salpi into the second century BC. Gabba suggested that the refoundation of Salpi occurred after the Social War in 89 BC and should be interpreted as one small aspect of the integration of the Italians into the Roman state after that conflict.[11] Nevertheless the area remained notorious, since Cicero accused Rullus of wishing to lead Roman veterans into the pestilential territory of Salpi.[12] Di Biase proposed the alternative interpretation that the foundation of Roman Salpi should be dated to the Augustan period. Salpi was one of the districts chosen for the Gracchan land distributions in the second century BC. The choice of such unfavourable localities (cf. Graviscae) shows how difficult it was to find suitable land for distribution.[13]

The new Roman town of Salpi flourished and continued to thrive into the late medieval period, but in time the mosquitoes caught up with it and the new town was eventually abandoned in turn in the seventeenth century, after which modern Manfredonia became the most important town in the region. Malaria was certainly one of the reasons for this second abandonment (*pace* di Biase), since the records of the Dogana of Foggia speak of bad air there in AD 1603.[14] Given the existence of foci of intense malaria such as Salpi, it is not surprising that Julius Caesar's army, coming from Gaul, was severely affected by the severe autumn in Apulia, in the same way, perhaps, that the Gauls themselves besieging Rome in *c.*386 BC were affected (see Ch. 8 above):

> The noxious autumn in Apulia and around Brundisium brought ill health to the whole army, which had come from the very healthy regions of Gaul and Spain.[15]

The problems of Caesar's army recall the misfortunes of the army assembled for the First Crusade when it moved from Rome to southern Italy. Similarly Cicero wrote a couple of letters at

[11] Gabba (1983); for other literature on Salpi see Marin (1970), Mazzei (1984) and Volpe (1990).

[12] Cicero, *de lege agraria* 2.27.71, ed. Marck (1983) *in Salpinorum pestilentiae finibus Rullo duce collocari.*

[13] *Liber Coloniarum*, i. 210 and ii. 261, ed. Lachmann (1967), in *Die Schriften der Römischen Feldmesser*.

[14] Delano Smith (1978: 168, 174): *ci parla di aria cattiva*; Di Biase (1985: 37–50).

[15] Julius Caesar, *BC* 3.2: *gravis autumnus in Apulia circumque Brundisium ex saluberrimis Galliae et Hispaniae regionibus omnem exercitum valetudine temptaverat.*

Brundisium to Atticus, significantly in August–September 47 BC, in which he clearly mentioned its unhealthiness (*loci gravitas*).[16] Malaria was certainly one of the reasons for Apulia being the least densely populated part of Italy, as described by Cicero. Extensive cereal cultivation occupied a large area of land and the whole region had a reputation for grain production and exports both in antiquity and in subsequent periods. Olive cultivation and viticulture were also widespread in Apulia. Nevertheless it is clear that transhumant animal husbandry began to operate on a large scale in the Tavoliere after the unification of Italy by the Romans just as it did in the coastal regions of Latium (see Ch. 9 above). Varro mentioned the annual migration of the animals from Apulia to the mountains of Samnium for the summer. The documentary evidence for transhumance has been supplemented by archaeological research recently at Tiati (Teanum Apulum).[17]

Falleroni described the epidemic of malaria during the First World War, in 1915–16, around modern Trinitapoli in the vicinity of ancient Salpi. Many of the malarial infections were acquired by agricultural labourers during the harvest, a common pattern observed all over the world (see Ch. 2 above). Although the élite always had the option of flight to safe areas, it would have been virtually impossible for peasants in antiquity to avoid malaria in areas where it was endemic. However, direct mortality from malaria at Trinitapoli was concentrated among children; over two-thirds of the dead were young children. The epidemic coincided with an explosion in mosquito population size. Falleroni reckoned that *cave di prestito* (pits) were important breeding sites for mosquitoes during this epidemic. He noted that the large-scale transhumance for which Apulia was famous offered no protection at all against

[16] William of Malmesbury *Gesta Regum Anglorum*, 4 .545, ed. Hardy (1840): *pars pro intemperie soli morbo defecit* (part of the army perished from disease because of the unhealthy climate). Elsewhere (4.572) William, commenting upon the bravery and heroism of the Crusaders, put the risk of their dying from bad air on the same level as their risk of being killed by the Saracens: *ubi vel pestifero afflarentur aere vel Saracenica occiderentur rabie.* In most military campaigns throughout history more soldiers died from disease than were killed by the enemy. In another passage (4.547), on the foundation of Constantinople, William noted that the emperor Constantine sought a healthy location for his new city because he could not tolerate the Mediterranean sun, having been born in Britain. Cicero *Letters to Atticus* 236.2–237.2, ed. Shackleton-Bailey (1965–70); Celli (1933: 82).

[17] Cicero *Letters to Atticus* 153.4: *Apulia delecta est, inanissima pars Italiae*; Varro, *RR* 2.1.16 and 2.9; Sanpaolo (1995: 87–91) on the archaeology of transhumance; Compatangelo-Soussignan (1994) on crop production in Apulia.

malaria in the lowlands, since the animals went into the hills in summer, the time of the year when female mosquitoes are searching for prey. However, he believed that the maintenance of domestic animals in close proximity to the human agricultural population in the lowlands could reduce malaria by deviating mosquitoes away from humans.[18]

[18] Falleroni (1921).

11

Geographical contrasts and demographic variation

The comprehensive evidence of the English parish studies discussed in Chapter 5. 4 above confirms the evidence derived from scattered local studies in Italy, such as the comparison between Grosseto and Treppio first mentioned in Chapter 1 above. Malaria, even the relatively mild *P. vivax*, enormously increased mortality levels, sharply reduced life expectancy at all ages, and significantly altered the age-structures of human populations in Europe in the past, wherever it became endemic. However, occurrences of malaria tended to be highly localized because of the very complicated ecological requirements of the disease, as, for example, at Old Salpi, where just by moving a few kilometres away the environment became much healthier. Consequently malaria generated enormous regional variations in demographic patterns in early modern Europe. In view of the compelling evidence from ancient sources for the endemicity in large areas of central and southern Italy of all three species of human malaria under consideration here, the comparative evidence from early modern Europe suggests that such major regional variations in demographic patterns should also have occurred in Roman Italy. There is no doubt whatsoever that that is exactly what happened. Pliny the Younger testifies to it, in a fundamental text whose neglect by those historians who have chosen to specialize in studying the demography of the ancient Roman world simply demonstrates their failure to understand the demography of Roman Italy. It is necessary to return again to the comparison of Pliny's villas near Laurentum in Latium and near Tifernum in Umbria. Laurentum was uncomfortably close to some of the most malarious places on earth.[1] Not far away

[1] It is quite possible that there were healthy localities in the vicinity, bearing in mind the description of Laurentum in the late second century AD given by Herodian 1.12.2, since the distribution of malaria was always highly localized. Nevertheless Pliny's own comments on the *gravis et pestilens ora Tuscorum* (oppressive and pestilential coastal region of Tuscany) leave no doubt that Laurentum in his own time was not far from extremely unhealthy areas. Blewitt (1843: 529) described the Laurentine forest in the nineteenth century. He noted that 'the proper season for enjoying a residence at Castel Fusano is the spring; in summer it

lay the *silva Laurentina*, doubtless in parts a flooded forest in winter like the Pontine forest further south along the coast, since ancient authors describe it as a large marsh, the haunt of wild boars.[2] Almost certainly it was a malarial marsh. If it had not been so, Vitruvius would have cited it instead of Ravenna as a case of a healthy marsh much closer to the city of Rome than Ravenna. The presence of intense malaria explains the virtual abandonment of Laurentum during the time of the Roman Empire, a state of affairs that lasted right through to the end of the nineteenth century AD.[3] In contrast, Tifernum, as described by Pliny, was cold and frosty in winter, with a temperate and windy climate in summer.[4] It was too cold for the olive tree, whose geographical distribution corresponds to Mediterranean-climate regions, to grow there. It was also too cold for *P. falciparum* and its principal vector in Italy, *A. labranchiae*. Pliny clearly observed the demographic consequences, an abundance of elderly people:

> Here there are many elderly people: you can see the grandfathers and great-grandfathers of young men and hear old stories and discussions about ancestors, and when you come here, you think that you have been born in another age.[5]

It has been frequently suggested by modern historians that only a small proportion of Romans would have had surviving fathers or grandfathers by the time they reached adulthood themselves; Tifernum, at least, was one Roman community where that theory is false. Undoubtedly there were numerous other communities like it, in the more mountainous parts of Italy along the Apennines. Pliny emphasized the healthiness of Tifernum, stating that he had

swarms with mosquitoes, and is not free from the suspicion of malaria'. [Aurelius Victor,] *Origo gentis Romanae* 12.4, ed. Richard (1983), mentioned the *duo stagna aquae salsae vicina inter se* (two swamps with salty water near each other) close to the spot where Aeneas is supposed to have landed in Italy, although the reference perhaps should be to the salt marshes of Ostia instead of Laurentum (commentary in Richard's Budé edn., pp. 149–50 n. 9), cf. Velleius Paterculus 2.19.1.

[2] Virgil, *Aeneid* 12.745, cf. 10.707–12. Quilici (1979: 65–6, 78, 81).

[3] The *rus vacuum* (empty countryside) predicted by Lucan, *de bello civili* 7.394–5.

[4] Defosse (1981) discussed the climate of Tifernum. Climate warming can be associated with an increase in the degree of climate variability, as is probably happening at the present time. Consequently the occasional occurrence of cold winters attested by Pliny does not necessarily contradict other evidence that the time of the Roman Empire as a whole was a warm period (see Ch. 4. 5 above).

[5] Pliny, *Ep.* 5.6.6, ed. Schuster (1958): *hinc senes multi, videas avos proavosque iam iuvenum, audias fabulas veteres sermonesque maiorum, cumque veneris illo, putes alio te saeculo natum.*

not lost any of the members of his household whom he had brought with him. There is an implicit contrast with two other places where he spent much of his time, Laurentum and Rome, where he was presumably not so fortunate:

> also my slaves have never lived in a healthier environment: so far I have not lost any of those whom I brought with me[6]

The contrast between Tifernum, on the one hand, and Laurentum and Rome on the other, in antiquity, is a typical example of the extreme regional variation in demographic patterns which is now known to have been the norm in early modern Europe. It exactly parallels the contrast made by del Panta between Treppio and Grosseto in the nineteenth century, for exactly the same fundamental reason, namely the absence or presence of malaria. In a review of a book on medieval demography Johannson made a devastating critique of a series of assumptions that are also frequently made by modern historians writing about the demography of the Roman Empire. She concluded that 'early modern Europe was characterized by extreme variability with respect to its mortality patterns', after noting that England in the seventeenth century AD contained places with life expectancy at birth as high as 50 and other localities with a life expectancy at birth as low as 20, as demonstrated by the parish studies.[7] These data destroy the view regularly expressed by Roman historians that the Roman population (it would be better to say Roman population*s*) could not have had a life expectancy at birth higher than 25 or 30. The inhabitants of Tifernum would have been astonished to learn of that hypothesis. Johannson then observed that 'long-run growth rates of 1% to 2% per year (on average) are not unusual for those villages which were free of malaria, sheltered from frequent epidemics, and spared major famines. In malarial parishes, in contrast, death rates persistently exceeded birth rates'.[8] This, again, destroys the widely held view among ancient historians that ancient populations could not possibly have grown at more than about 0.5% per annum. Since the attempt by Lo Cascio to overthrow the Roman demography of Beloch and Brunt depends on such assumptions about life

[6] Pliny, *Ep.* 5.6.46: *Mei quoque nusquam salubrius degunt; usque adhuc certe neminem ex iis, quos eduxeram mecum . . . ibi amisi.*

[7] Johannson (1994: 528).

[8] Ibid., 531.

expectancy and growth rates, and more generally on defining too narrowly what Braudel called 'the limits of the possible', it must be regarded as unconvincing in detail. Nevertheless Lo Cascio was right to draw attention to the problems of interpreting the Roman census data, problems which will probably never be completely resolved without the discovery of new evidence.[9]

One of the conclusions of this book is that the figure of 25, commonly assumed by historians as an appropriate figure for the life expectancy at birth of the Roman population, is both too low and too high. Healthy areas could very easily have had substantially higher life expectancy at birth than that. It is worth quoting some of the exact words of Herlihy and Klapisch-Zuber about late medieval Florence to hammer home this point:

> About 1300 the average duration of a human life at Florence was approximately 40 years. But over the following 100 years, amid the fury of pestilence [sc. the Black Death], it collapsed to only one half that figure (an average of only some 20 years). In the fifteenth century the average duration of life grew more extended, especially after 1450, to regain the summit of 40 years . . . A perusal of the Florentine family memoirs leaves the impression that men lived to an old age in the thirteenth century.[10]

Florence was certainly not unique. In the course of a discussion in which he cited numerous examples of historical populations drawn from all over the world which had a life expectancy at birth significantly higher than 25, the Italian demographer Massimo Livi-Bacci drew attention to research showing that the nobility of Milan had a life expectancy at birth of about 40 in the seventeenth century AD.[11] However, the words of Herlihy and Klapisch-Zuber also illustrate the downside: in an unfavourable disease environment life expectancy at birth could easily be significantly less than 25. The city of Rome during the period of the Roman Empire did not have bubonic plague, but had *P. falciparum* malaria instead.

[9] Lo Cascio (1994).

[10] Herlihy and Klapisch-Zuber (1985: 83–4).

[11] Livi-Bacci (1983). Historical populations with a life expectancy at birth of more than 25 are now known from all over the world, e.g. Zhao (1997) suggested a life expectancy at birth of about 34 (Coale–Demeny Model East Level 8) for a Chinese clan in the period 1000–1750, relying on data for adult mortality; Farris (1985: 43) suggested life expectancies at birth ranging from 27.5 to 32.5, with growth rates of over 1% per annum, for some villages in Japan in the early eighth century AD. Barker and Rasmussen (1998: 102) observed that numerous very high ages are recorded on Etruscan funerary inscriptions, although these records are of course not necessarily reliable (Hopkins (1966)).

Once *P. falciparum* malaria has become endemic, its effects are nowhere near as spectacular as those of a sudden, major epidemic of plague (*Yersinia pestis*), such as the Black Death or the plague of Justinian. Nevertheless the depression of life expectancy at birth which it caused in the long run in historical European populations appears to match the magnitude of the effects of plague, since life expectancy at birth in Grosseto in the nineteenth century was apparently not dissimilar to that in Florence during the period of major plague epidemics. Shortly after the end of antiquity, the Rome of Pope Gregory the Great was unfortunate enough to have both bubonic plague and endemic malaria at the same time, the end of the sixth century AD.[12]

It is now well known, following the work of Roger Mols in the 1950s on European cities and the later classic studies of Wrigley and Finlay on London, that large pre-industrial urban populations were incapable of reproducing themselves. Large cities depended on constant immigration from less densely populated but more healthy rural areas both to maintain and to increase their population sizes. Early modern Rome certainly fitted the same pattern as London. As a nineteenth-century Italian writer put it:

> All the great cities . . . like Rome, consume more men than they produce, and are refurnished from the countryside.[13]

Research into the demography of early modern Rome by Schiavoni and Sonnino showed that the growth of the city of Rome depended on immigration for most of the period of study, from AD 1598 to 1824. There was a significant excess of deaths over births for most of this period (see Table 9). The exceptional period of low death rates from 1658 to the end of the seventeenth century followed a plague epidemic in 1657, accompanied by extensive migration away from the city to avoid the disease. Subsequently the city's population was recovering from a very low base. These data show that the Roman population was capable of increasing on its

[12] For bubonic plague (*lues inguinaria*) in Rome, accompanying a Tiber flood, at the beginning of the reign of Gregory see Paulus Diaconus, *Historia Langobardorum*, iii.24, ed. Waitz (1878) *Monumenta Germaniae Historica*, vol. xlviii (*Scriptores* 7) and Gregory of Tours, *History of the Franks*, x.1, cf. Paulus Diaconus, ii.4, iv.4, and vi.5 for other outbreaks of plague. It should be noted that the vocabulary used to describe plague was completely different from that used for malaria. Consequently there is no chance that the two diseases were confused.

[13] A. Gabelli, *Prefazione*, in *Monografia* (1881: lii): *Tutti le grandi città . . . al pari di Roma, consumano più uomini che non ne producano, e ne vengono rifornite dalle campagne.*

36. The angel of death striking a door during the plague of Rome in 1656. Engraving by Levasseur after J. Delaunay. The Wellcome Library, London.

Table 9. Baptisms and deaths (per 1000) in Rome from 1621 to 1824

Period	Baptisms	Deaths
1621–9	26.9	38.3
1630–9	30.4	29.0
1640–9	29.7	33.8
1650–5	27.9	31.8
1656–7	26.0	69.3
1658–9	30.8	28.1
1660-9	32.8	24.5
1670–9	30.1	25.6
1680–9	30.0	23.9
1690–9	30.9	24.0
1702–9	27.7	29.7
1710–19	26.0	39.3
1720–9	27.1	38.7
1730–9	28.3	41.1
1740–9	29.4	42.6
1750–9	32.3	39.9
1760–9	31.4	46.5
1770–9	32.6	38.3
1780–9	32.0	46.0
1790–9	33.1	44.9
1800–9	32.8	50.3
1810–19	30.8	37.6
1820–4	33.1	37.4

Source: Schiavoni and Sonnino (1982: 102, table II).

own when it was small. Such a capability of course helps to explain where the manpower for colonization came from in the early stages of Roman history in antiquity. At the same time the early modern data also make it clear that as the urban population grew, a deficit of births relative to deaths became inevitable, and inevitable at a population-size level far below the size of the population of the city of Rome during the time of the Roman Empire.

The availability of data from Rome itself in the early modern period means that there is in fact no need at all for historians to rely on the example of London; the data from Rome itself are much more pertinent. Delumeau studied the census of 1526–7 in Rome. Extrapolating from a sample of about 4,000 people for which evidence is available, he reached the conclusion that out of Rome's population of about 55,000 at that time, only 16% were actually of local origin. No less than 64% of the population of Rome in

1526 originated from other parts of Italy (principally Tuscany—encouraged by the presence in Rome at the time of popes born in Florence—and Milan), while as much as 20% of the population came from outside Italy (mainly from Spain, France, and Germany).[14]

There is no reason for thinking that ancient Rome was any healthier than early modern Rome. Celsus observed that *urbani*, the inhabitants of towns, were particularly liable to ill health.[15] Indeed the situation in ancient Rome was probably significantly worse than the situation in early modern Rome, since the population was larger and denser during the time of the Roman Empire, and Galen's information about the frequency of *P. falciparum* malaria in Rome in the second century AD must also be taken into account. The evidence of Herodian (commenting on the epidemic of AD 189, probably smallpox[16]) confirms that massive immigration to the city of Rome was occurring in Galen's own time.[17] Even as late as after the capture of Rome by Alaric in AD 410, it appears that the city was still attracting immigrants, according to Olympiodorus.[18] It was noted in Chapter 5. 4 above that visitors from northern Europe contracted malaria in Rome and took the parasites back home with them. However, it is also very important to observe that continuous immigration to Rome would by itself have intensified malaria in and around the city because undoubtedly some of the immigrants would have come from other areas of endemic malaria (e.g. in southern Italy), already be infected, and so bring new malarial parasites to the city in their bloodstreams. The city of Rome both exported and imported diseases, a role facilitated first in antiquity by increased human mobility following the unification of the Mediterranean countries and a large part of Europe under the Roman Empire, and secondly in subsequent historical periods by

[14] Delumeau (1957: i. 197–220); Black (1789: 17) recognized in the eighteenth century that the birth rate was lower than the death rate in Rome; Sori (1984: 554–9).

[15] Celsus, *de medicina* 1.2.1: *at imbecillis, quo in numero magna pars urbanorum*. Mudry (1997) discussed this text.

[16] Cassius Dio 73.14.3–4 also mentions this epidemic.

[17] Herodian 1.12.1: *συνέβη δὲ καὶ κατ᾽ ἐκεῖνο καιροῦ λοιμώδη νόσον κατασχεῖν τὴν Ἰταλίαν· μάλιστα δὲ τὸ πάθος ἐν τῇ Ῥωμαίων πόλει ἤκμασεν ἅτε πολυανθρώπῳ τε οὔσῃ φύσει καὶ τοὺς πανταχόθεν ὑποδεχομένῃ, πολλή τέ τις φθορὰ ἐγένετο ὑποζυγίων ἅμα καὶ ἀνθρώπων*. (At that time an epidemic disease spread over Italy. Its effects were particularly bad in the city of Rome, which naturally had a large population and attracted immigrants from all quarters. There were many deaths of both animals and men.).

[18] Olympiodorus *ap.* Photius, *bibliotheca*, ed. Henry (1959), i. 175.

Rome's role as the centre of Christianity. Carcaterra noted that as recently as after the First World War immigration from southern Italy to the expanding city of Rome assisted the diffusion of malaria in the Agro Romano.[19] It was no different in antiquity. In a previous brief discussion of migration to Rome, Sallares described ancient Rome as a *population sink*, using a concept drawn from studies of animal populations, in which a rough maintenance of overall population size by migrations from areas of excess fertility to areas of excess mortality is a frequent observation. Recently Morley has also discussed this theme, in more detail.[20]

The presence of endemic malaria in at least some districts of the city of Rome in antiquity would have created extremely high mortality rates in an urban population of perhaps 750,000 to 1,000,000 people. Imperial Rome was a population sink of enormous dimensions. It soaked up the bulk of the natural increase of the rest of Italy (healthy places like Tifernum), as Morley argued.[21] It is impossible to define the vital rates of the population of the city of Rome in detail, given the scarcity of evidence, and of course it would be impossible to generalize even if suitable quantitative data were available; some parts of the city were undoubtedly healthier than others. It is probably not wise to take Ulpian's life-table as seriously as Frier did.[22] Nevertheless, just for the sake of argument, let us consider it for a minute. Duncan-Jones, reconsidering Frier's extremely complicated calculations, suggested that since Frier's

[19] Carcaterra (1998: 566).

[20] On Rome as a population sink see Sallares (1991: 88–9); Morley (1996: 33–54).

[21] Morley (1996: 49).

[22] Frier (1982) has made the most detailed study of Ulpian's life-table (*Digest* 35.2.68). However, his analysis suffers from unjustifiable a priori assumptions. At the very end of his article (p. 251 n. 84), he recorded that one of the Michigan demographers had pointed out to him that his Proposed Model is closer to Coale–Demeny Model South than to Model West, which he chose to use. Frier rejected this because the lower levels of Model South appeared to him to be 'rather unrealistic especially as to the relationship between child and adult mortality'. This problem requires empirical study commencing with knowledge about causes of death, not a priori assumption. It has been shown here that there is now available a considerable corpus of empirical evidence which supports the existence in populations affected by malaria of patterns of child–adult mortality even more divergent from Model West than Model South, which Frier rejected. Parkin (1992: 83–4) rightly criticized Frier for assuming a constant relationship between child and adult mortality. However, since Parkin too failed to pay any attention to the question of the causes of death, he did not make any significant progress beyond Frier's position. Research on the demography of female orphans in Rome in the seventeenth and eighteenth centuries yielded mortality rates approximating to 'low survival rates of the "southern" model', but the empirically attested rates fit different levels of the southern model at different ages (Sonnino (1994: 108)).

curve runs parallel to but well below the curve of Coale–Demeny Model South Level 1 (the lowest level), it indicates a life expectancy at birth well below 20. What sort of factors could possibly produce such extremely high mortality levels? Ulpian's life-table, if it has any value at all for demographic purposes, can only be a crude estimate of the mortality produced by malaria within the city of Rome. The comparative data from early modern European populations show that the adult mortality caused by malaria runs off the lower end of the scale provided by the model life-tables used by demographers. Duncan-Jones also suggested that the population of Ulpian's life-table was a servile population. If freedmen and their descendants were a significant component of the population of the city of Rome, as epigraphic evidence indicates, then saying that Ulpian's life-table represents the demography of a servile population and saying that it represents the demography of the population of the city of Rome itself (*not* the population of the entire Roman world) may amount to much the same thing.[23]

There is no doubt whatsoever that people in antiquity were in fact fully aware, in an elementary fashion, of the existence of the enormous regional variations in mortality rates that are discussed above. Otherwise, why should Pliny the Younger have pointed out to his correspondent Domitius Apollinaris that Tifernum was much healthier than the coast of Tuscany? What was Varro talking about when he mentioned the reckoning with death, *ratio cum orco*, in pestilential localities? These passages from ancient authors directly parallel similar but more detailed texts from later periods, for example Doni's writings in the seventeenth century. Doni singled out Faesulae in Tuscany and Stabiae in Campania, as well as Spoleto in Umbria, mentioned earlier (Ch. 4. 2 above), as examples of towns where the average duration of life was very long. Conversely, he mentioned Ferrara and the Po delta, the Pontine region, and Ostia as places where life was short on average. However, for Doni the worst place of all was Aquileia, where everyone died young. There is a very striking contrast here with the situation in antiquity, when Aquileia was regarded by Vitruvius as exceptionally healthy for a town situated in a marshy area, but the prin-

[23] Duncan-Jones (1990: 96–101). He also (p. 104) noted the possibility of a 'range of variation'. In the discussion appended to Etienne (1973), J. Dupâquier was one notable professional demographer who expressed the view that it is likely that there were different demographic patterns in different parts of the Roman Empire.

ciple was the same. Short average life span was very highly correlated with the presence of endemic malaria in the seventeenth century just as it was in antiquity.[24]

Mary Dobson noted that in early modern England the parishes that were perceived by contemporary observers as very unhealthy corresponded very closely to the parishes with excess mortality caused by *P. vivax* malaria, as revealed by her demographic research.[25] North noted that the inhabitants of the Roman Campagna in the nineteenth century had a very fine perception of degrees of (un)healthiness within their environments:

> If we were to start from almost any of the gates of Rome, and follow the main road for a few miles, carefully examining the character of the land on either side, and inquiring of such inhabitants as we might find, their opinion of the healthiness or otherwise of their immediate neighbourhood, we should be greatly struck by the apparent precision with which they would indicate varying degrees of infection, within exceedingly limited areas.[26]

Long and bitter experience enabled the inhabitants of regions where malaria was endemic to build up a considerable stock of knowledge regarding its distribution, even though its aetiology was not understood. A passage of Xenophon, advising generals to choose healthy locations for army camps, shows clearly that this was already happening by the fourth century BC in Greece. Similar advice appears in later authors.[27]

This stock of knowledge allowed people to engage in a variety of forms of avoidance behaviour to minimize the risk of infection. The greater security of living above ground-floor level is one example, which has already been mentioned (Ch. 4. 3 above). Another method was to completely avoid perilous areas during the dangerous time of the year, in summer and autumn, as much of the population of the city of Rome did in the twelfth century AD, according

[24] Doni (1667: 129–30).

[25] Dobson (1997: 123–5).

[26] North (1896: 108).

[27] Xenophon, *cyropaedia* 1.6.16, ed. Gemoll: *καὶ γὰρ λέγοντες οὐδὲν παύονται οἱ ἄνθρωποι περί τε τῶν νοσηρῶν χωρίων καὶ περὶ τῶν ὑγιεινῶν· μάρτυρες δὲ σαφεῖς ἑκατέροις αὐτῶν παρίστανται τά τε σώματα καὶ τὰ χρώματα* (For men do not stop speaking about pestilential and healthy places, since their bodies and their complexions are clear witnesses of both.); Vegetius, *epitoma rei militaris* 3.2.2, ed. Önnerfors: *locis, ne in pestilenti regione iuxta morbosas paludes . . . milites commorentur* (soldiers should not camp in a pestilential region near unhealthy marshes).

to Otto of Freising (Ch. 8 above). In Grosseto in 1840 no less than 43% of the people who were registered as permanently resident in the town left their homes during the summer to stay and work in Scansano, a town which was only twenty-nine kilometres south-east of Grosseto, but, significantly, situated at an altitude of 500 metres above sea level. The annual *estatatura* (exodus) from Grosseto had been instituted by 1333 by the government of Siena, which ruled Grosseto at the time and decreed that government officials should leave Grosseto in July and August each year to avoid malaria. It was only abolished as recently as 1897, by which time the increasing use of quinine and widespread bonifications were having a significant impact on malaria in the region.[28] It is very striking that mortality in Grosseto was so high even with such a large proportion of the permanent population practising avoidance behaviour. Malaria was also endemic in Grosseto among migrant workers who only spent the summer there.

It was also possible to take avoidance measures at certain times of the day and night. In the nineteenth century Romans frequently made excursions to Fiumicino (now the site of Rome's airport, near Ostia), whose small resident population was 100% infected with malaria, during the day to have a seaside meal, but they returned to Rome before nightfall and did not sleep there. Sambon noted that at Ostia in 1900 'in July and August the *Anopheles* used to appear very punctually a few minutes after sunset and disappear again a few minutes after sunrise'.[29] De Tournon, without any understanding of the aetiology of malaria, advised visitors to Rome itself to avoid in dangerous parts of the city the evening strolls which are such a prominent feature of everyday life in so many Mediterranean towns (with the effect of avoiding mosquitoes).[30] Tommasi-Crudeli noted that in Rome in the nineteenth century:

> in some parts of the city the inhabitants, during the hot weather, remain indoors after sunset, because experience has taught them that during the first hour of the evening there is a risk of infection, but later on they emerge from their houses[31]

[28] Del Panta (1989: 29–31); Celuzza (1993: 151); Santi (1996: 150); Bueti and Corti (1998).

[29] Blewitt (1843: 528); Sambon (1901*a*: 199).

[30] De Tournon (1831: i. 216): [sc. during the dangerous season] *sur toutes choses, il faut éviter, pendant la soirée, les promenades, soit dans la campagne, soit dans les parties désertes de la ville.*

[31] Tommasi-Crudeli (1892: 80); Wrigley (2000: 219) quoted Berlioz' observation that Romans disappeared from their promenade on the Pincio 'like a cloud of gnats' (a doubly appropriate metaphor) at seven o'clock in the evening, cf. Blewitt (1843: 165).

37. The site of the Circus Maximus at Rome, where chariot races were held. It is situated in a low-lying area between the Aventine and Palatine hills where there was a risk of malaria infection in the past.

Knight had earlier also noted this advice which was given by Roman doctors, adding the comment that 'it would not be prudent to sleep with an open window'.[32] Female *Anopheles* mosquitoes generally bite at night, commonly in the period leading up to midnight. As recently as 1893, Filippo Pacelli noted the custom of shutting windows in the district on the left bank of the Tiber, near Isola Tiberina, to avoid malarial fevers.[33] Conversely, Lapi noted that in some areas of the city people kept the windows open all the time and remained healthy, but this is merely stating the obvious, namely that malaria did not occur everywhere.[34] Lancisi had also recommended keeping windows and doors closed. Evidently not everyone took all the precautions. In the fourth century AD Ammianus Marcellinus wrote that poor Romans set off at dawn for the Circus Maximus to watch the chariot races, but neglect of essential precautions helps to explain why malaria was common in imperial Rome.[35] Nevertheless in antiquity as well the accumulation of

[32] Knight (1805: 3).

[33] Carcaterra (1998: 560): *per schivare le febbri malariche, si è costretti a chiudere le finestre un'ora prima dell'Ave-Maria.*

[34] Lapi (1749: 81).

[35] Ammianus Marcellinus 28.4.31.

empirical knowledge would have permitted the practice of avoidance behaviour, to try to minimize the known risks, as Herodotus shows when he describes sleeping in towers in Egypt to avoid mosquitoes (Ch. 4. 3 above). Apparently a hieroglyphic text from a temple at Denderah in Egypt advised people not to go outside their houses after the sunset in the weeks following the Nile flood.[36] This ancient Egyptian text recalls the statement of Athenaios that people in the Greek colony of Sybaris who wanted to avoid dying young must not see either the setting or the rising sun.[37] Tommasi-Crudeli, followed by W. H. S. Jones, interpreted this text as a reference to malaria in southern Italy.[38] This remains a possibility, since Lancisi recommended staying indoors until sunrise to avoid malaria, although the text of Athenaios could equally well simply be a reference to the legendary life of luxury enjoyed by the citizens of Sybaris.

Regardless of the correct interpretation of this text, it was indeed well known in antiquity that the average duration of life was much lower in marshy areas where malaria was endemic than in mountainous areas (like Tifernum) where it did not occur at all. The following question in the pseudo-Aristotelian *Problems* proves it beyond doubt:

> Why do men grow old slowly in places with fresh and pure air, while those in hollow and marshy places grow old rapidly?[39]

As a comparison, the early modern tradition about Ninfa, which was abandoned because of malaria in the seventeenth century, should be recalled:

> The modern legend that an evil spirit waits in ambush for passing young adults, to make them at once grow old miserably, is a personification of the wickedness of the air, which makes the youthfulness of those who breath its exhalations decay.[40]

[36] Capasso (1985: 304) quoted this Italian translation of the Egyptian text: *non uscire di casa dopo il tramonto del sole nelle settimane che seguono l'ingrossamento del Nilo.*

[37] Athenaios 12.520a: τὸν βουλόμενον ἐν Συβάρει μὴ πρὸ μοίρας ἀποθανεῖν οὔτε δυόμενον οὔτε ἀνίσχοντα τὸν ἥλιον ὁρᾶν δεῖ.

[38] Dunbabin (1948: 80, 216–17) emphasized the scarcity of documentary evidence with regard to the possibility of malaria in Sybaris in the archaic period.

[39] [Aristotle,] *Problems* 14.7.909^{b}: Διὰ τί οἱ μὲν ἐν τοῖς εὐπνόοις τόποις βραδέως γηράσκουσιν, οἱ δὲ ἐν τοῖς κοίλοις καὶ ἑλώδεσι ταχέως.

[40] Tomassetti (1910: ii. 394): *la leggenda odierna che una fata malignamente sta in agguato dei giovani che passano per farli subito miseramente invecchiare è una personificazione della malignità dell'aria, che fa intristire la giovinezza di chi ne contrae l'effluvio.* See also Hadermann-Misguich (1986: 23–46, esp.

The prevailing view among ancient historians is to assume a fairly low life expectancy at birth across the whole of Roman Italy. Lo Cascio, following Hopkins, is a typical example of the traditional view:

> Life-expectancy at birth cannot have been higher than, say, 25 for males . . . life-expectancy at birth for females must not have been higher than 25 and is likely to have been a bit lower . . . [this is] the assumption that we are entitled to make.[41]

The reality of Roman Italy was more subtle, more complicated, and more interesting than this bland uniformity. There were some extremely unhealthy localities, with a life expectancy at birth hovering around 20, in some cases no more than a few kilometres away from other localities, where life expectancy at birth may have been as high as 40 or 50.[42] As was noted at the beginning of this book, the Italian demographers del Panta and Rettaroli found that the population of Grosseto, ravaged by malaria in the nineteenth century, did not have an age-structure corresponding to any of the main types described in the standard sets of model life-tables and based on data from modern European populations. The closest parallels instead come from *African populations*. African population structures in central Italy as recently as the middle of the nineteenth century AD? African population structures in central Italy in antiquity? This will come as a tremendous shock to those historians who are accustomed to rely upon sets of model life-tables derived from modern European populations in their research on classical antiquity. A major flaw of the bulk of research carried out into the demography of the Roman Empire over the last thirty years has been the failure to realize that the standard sets of model life-tables do not encompass the entire universe of possibilities. In fact, they

43–5 on malaria). She noted that the eighteenth-century historian Pietro Pantanelli stated that no one in the region survived past the age of forty.

[41] Lo Cascio (1994: 36).

[42] Herlihy and Klapisch-Zuber (1985: 199–201) noted the existence of populations with an older age structure in highland areas in the territory of Renaissance Florence. They explained this in terms of emigration of the young from the uplands. Although this did undoubtedly happen, numerous other studies leave no doubt that in general uplands were healthier than lowlands (see Ch. 4. 2 above). In antiquity it was believed that fertility levels were high in mountain populations in central Italy, according to [Aristotle,] *peri thaumasion akousmaton* 80.836a. This is highly plausible even though the author of this work had no statistical evidence whatsoever for his assertion.

do not cover populations heavily ravaged by malaria, or tuberculosis, or smallpox, for example.[43] Thus the results of a general assessment of the applicability of these model life-tables to ancient populations, as called for by Hopkins in 1966, are intrinsically likely to be negative for many ancient populations, especially in southern and central Italy. It is worth recalling that Herlihy and Klapisch-Zuber refrained from calculating a life-table for the population of Florence as reconstructed from the *Catasto* of AD 1427 for the following reason:

> Our age pyramids emphasize the instability of the Tuscan population described in the *Catasto*. At the same time, they reveal the obstacles involved in utilizing for historical purposes model life tables which are based on stable or stationary populations . . . the age pyramid of 1427 does not fit any of the theoretical distributions closely.[44]

Of course it can be argued that the situation in Florence in 1427 was exceptional because of the effects of massive plague epidemics. Nevertheless the fact remains that the first major source of quantifiable demographic information in Italian history provides no support whatsoever for the hypothesis that model life-tables based on data from normal modern populations are likely to be useful for ancient populations afflicted by diseases which are no longer endemic in modern Europe. Moreover the situation in antiquity was itself not static, since disease evolution and history is a never-ending process. The spread of malaria in Italy in the first millennium BC created new demographic patterns in both time and space. The demographic patterns of much of Latium and Etruria in the first century AD were probably completely different from what they had been in the seventh century BC.

There is yet another methodological issue of fundamental importance at stake here. Hopkins entitled his well-known article '*On the probable age-structure of the Roman population*'. This begs the question of whether the Roman population had an age-structure. Or, to put the question more precisely, making explicit a crucial assumption implicitly made by Hopkins, did the Roman population *as a whole* have *a single age-structure*? The answer to that question

[43] Coale and Demeny (1983: 33) stated that 'any extraordinary incidence of a cause of death that is highly age-and-sex specific produces a mortality schedule that naturally does not conform to the model tables'. Populations affected by malaria evidently fall into this category.

[44] Herlihy and Klapisch-Zuber (1985: 195).

must be no, taking account of the prevalence in historical populations of the type of regional variation which has been discussed here. The inference is clear. The age-structure of the Roman population is an illegitimate concept. The homogeneity of modern populations is a consequence of the process of modernization. Only an anachronistic, modernizing approach to ancient history can imagine such homogeneity in ancient populations.

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GLOSSARY

erythrocyte Human red blood cell.

gametocyte Male and female sexual cells of malaria parasites, formed by some merozoites inside erythrocytes, generally after several cycles of merozoite multiplication in the case of *P. falciparum*.

hypnozoite A stage of the parasite's life cycle formed from some sporozoites inside the human liver. Hypnozoites remain dormant for a predetermined period of time after which they give rise to relapses. Only found in *P. vivax*, not in *P. falciparum* or *P. malariae*.

merozoite Asexual stage of malaria parasite which invades erythrocytes.

polymerase chain reaction (PCR) An enzymatic method for amplifying very small quantities of DNA.

recrudescence An exacerbation of low-level erythrocytic infections of *P. falciparum* or *P. malariae*.

relapse Production of clinical symptoms of *P. vivax* malaria by the activation of dormant hypnozoites in the liver.

schizogonic periodicity The species-specific length of the erythrocytic cycle (multiplication of merozoites).

schizogony The asexual phase of multiplication of malaria parasites in the human (or other vertebrate) host.

sporogony The sexual phase of malaria reproduction in the mosquito.

sporozoite A parasite stage which migrates from the stomach to the salivary glands of the mosquito, from where it can infect a person bitten by the mosquito. Once inside the human blood stream, sporozoites enter liver cells, where they either differentiate into pre-erythrocytic schizonts and then into merozoites ready to invade erythrocytes (always in *P. malariae* and *P. falciparum*), or sometimes into hypnozoites (in *P. vivax*).

zygote The product of fusion of male and female gametocytes. It gives rise to oökinetes, oocysts, and then to sporozoites. All this occurs inside the stomach of the mosquito.

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