PART I

DETERMINANTS OF ECONOMIC PERFORMANCE

https://doi.org/10.1017/CHOL9780521780537.003 Published online by Cambridge University Press

CHAPTER 2

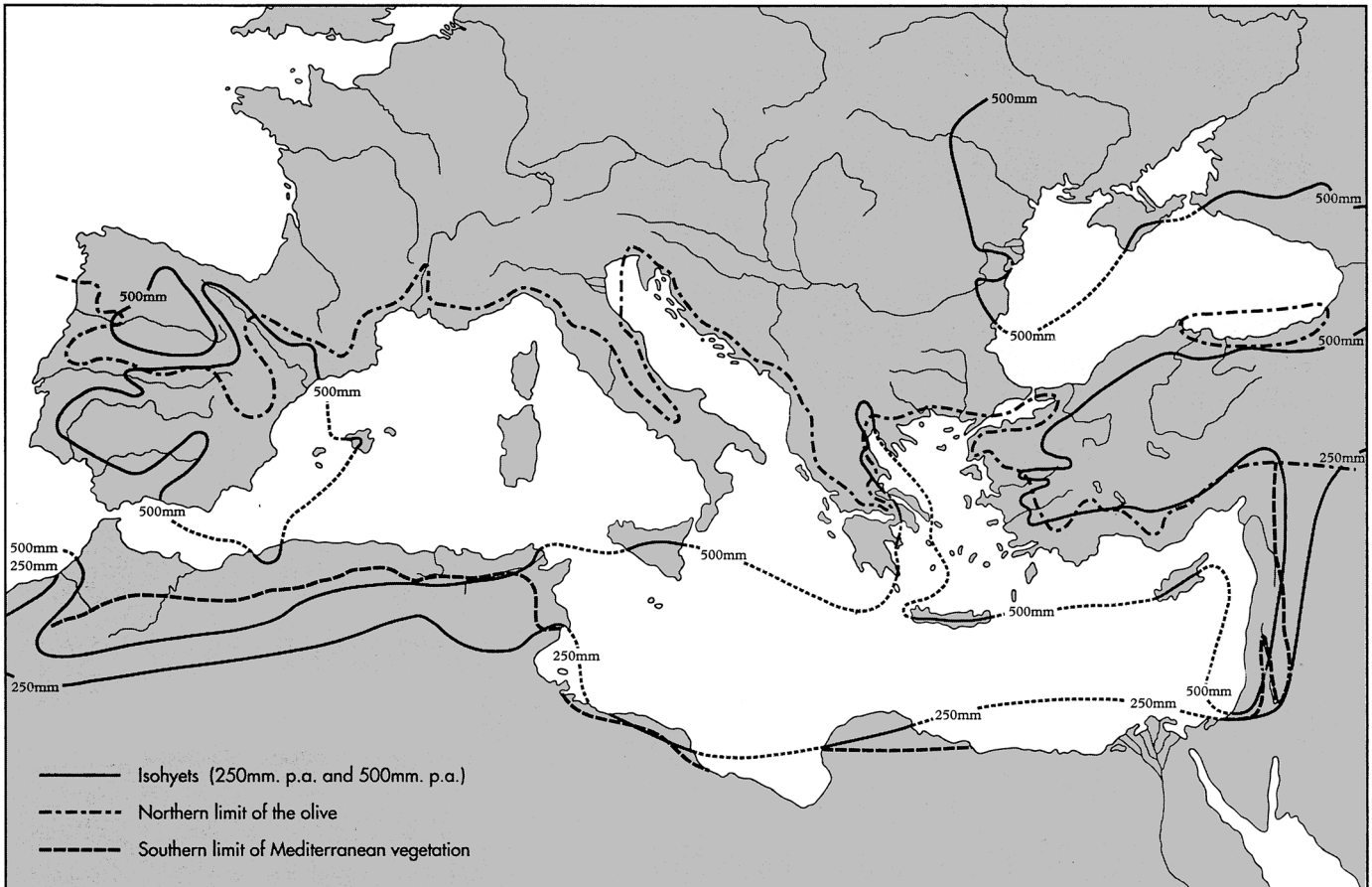
ECOLOGY

ROBERT SALLARES

I PHYSICAL GEOGRAPHY

The focus of the region of interest is the Mediterranean Sea, the world's largest inland sea, about 3800 kilometers long. The Mediterranean Sea requires a constant influx of water from the Atlantic Ocean to maintain its level, since evaporation is much greater than the inflow from rivers. It has a low productivity and most parts of the Mediterranean coast have a very narrow continental shelf. These factors reduce the size of offshore fishing grounds and lead to small fish populations. The Mediterranean is relatively poor in fish. However the sea has always been extremely important for interregional contact because of the proximity of mountain ranges to a large part of the Mediterranean coastline, and also for access to the numerous islands in the sea.

The lands surrounding the Mediterranean Sea are more often than not hilly or mountainous. This is the result of intense tectonic activity and uplift caused principally by the interaction of the Eurasian and African plates, which are moving towards each other at the rate of about two centimeters per year. Mediterranean geology is largely based on limestone, which is easily eroded by the catastrophic floods and rainstorms that are characteristic of the Mediterranean climate, creating extremely uneven topographies. Large flat plains are rare in Mediterranean countries. A large number of rivers and streams descend from the uplands to the sea; the Nile is the only major river whose water supply originates almost entirely outside the vicinity of the Mediterranean basin. The water courses are fed by winter rainfall. Many of them gradually dry up during the summer, as do many of the wetlands in coastal regions. The countries surrounding the Mediterranean are lands of great contrasts, frequently over very short distances. The degree of local ecological variation is so large that it is quite possible to have subtropical vegetation on the south side and temperate vegetation on the north side of the same mountain, with different processes at work (e.g. Monte Circeo south of Rome, cf. Monte Argentario north of Rome). However one generalization that is valid is that the lands around the Mediterranean are rich



Map 2.1 Physical definitions of the Mediterranean region
Reproduced with permission from Horden and Purcell 2000: 14

in biodiversity of flora and fauna, although population sizes of plant and animal species are frequently very small, a consequence of poor habitats.[1]

II THE MEDITERRANEAN CLIMATE

The character of the Mediterranean environment is largely determined by its weather, the well-known seasonal pattern of hot, dry summers and mild, wet winters. (In some areas there are two rainfall peaks in autumn and spring; spring rainfall is important, where it occurs, for cereal cultivation, as Theophrastus noted for Sicily.[2]) The summer drought favors annual at the expense of perennial vegetation and also results in fire (both natural and man-made) being an important agent of natural selection on both individual plant species and vegetation communities. Bioclimatic indicators such as the distribution of the olive or holm-oak trees are sometimes used to provide alternative definitions of Mediterranean-climate regions.[3] The distribution of the olive tree, which is killed by severe frost but requires temperatures to drop to a certain level to initiate flowering the following year, actually defines the Mediterranean winter rather than the Mediterranean summer. The total volume of predominantly winter rainfall in areas with a true Mediterranean climate is high enough to support evergreen sclerophyllous trees, but too low for deciduous trees.

Dendrochronological evidence from the Parthenon in Athens provides evidence for a pattern of climatic variability in the fifth century BC which resembles the modern pattern. The fragments of information available in ancient literary sources confirm that the climate of Greece was basically the same in the fifth and fourth centuries BC as it is today. The statement of Theophrastus, the founder of plant biogeography, that date palm trees could grow in Greece, if planted, but could not set fruit there, matches the situation today.[4] It indicates that mean temperatures in the summer months in the southern Aegean c. 300 BC were within a degree of the modern values. Precipitation also exhibits extreme interannual as well as seasonal variability, which often created shortfalls in agricultural production in the past. Runs of several successive good or bad years were not uncommon. Thus in Greece in the fourth century BC there were periods of food shortages probably caused by drought c. 360 and c. 330 BC, but Theophrastus recorded heavy rainfall in between which raised Lake Copais in Boeotia to an unusually high level

[1] Braudel 1966 created the concept of Mediterranean history, with reference to the sixteenth century AD. However it is only recently, despite isolated earlier efforts (Huntington 1917; Semple 1932; Cary 1949), that environmental history has begun to be fully incorporated into the mainstream of ancient history. The most important recent general works are Sallares 1991; Blondel and Aronson 1999; Horden and Purcell 2000; Grove and Rackham 2001; note also Fedeli 1990; Traina 1990; and Hughes 1994.

[2] Theophr. *Hist. pl.* 8.6.6. [3] Blondel and Aronson 1999: 13–18.

[4] Eginitis 1908 on Theophr. *Hist. pl.* 3.3.5.

https://doi.org/10.1017/CHOL9780521780537.003 Published online by Cambridge University Press

in the years preceding the Battle of Chaeronea in 338 BC.[5] In Italy in the late third century BC tree rings indicate a period of mild conditions at the time when Hannibal led his elephants across the Alps.[6] However, no detailed quantitative records of regular meteorological observations covering a long period of time were ever made in antiquity, yet another manifestation of the lack of interest in statistics in antiquity of which modern historians are painfully aware, and which is also a major problem for the economic history of the ancient world. Consequently, documentary sources do not provide us with the statistical data required to investigate possible long-term climatic trends.

Although the classical Greeks and Romans never experienced anything else, the pattern of hot dry summers and cool wet winters has only existed during the post-glacial period since about 3000 BC, although there were parallel changes in earlier interglacial periods. Palaeoanthracological and palynological evidence shows that Mediterranean rainfall was higher and more evenly distributed during the year in the Neolithic period, permitting deciduous oak and lime trees to flourish in areas which are dominated by drought-resistant evergreen vegetation today.[7] Consequently many important Mediterranean plants (e.g., the vine) have not had time to evolve adaptations to the Mediterranean climate; they grow in the hot, dry summer and are dormant in winter when it would be better to grow in winter, when more water is available, and be dormant in summer instead (like acacias in other parts of the world). As a result intensive irrigation is very important for agriculture in many parts of the Mediterranean today to overcome natural rainfall variability and increase yields. The degree to which controlled artificial irrigation was practiced in antiquity is an important question for economic history, e.g., was irrigation already being practiced in the *huertas* around Valencia in Spain during the Roman empire, or was this practice only introduced by the Arabs in the early mediaeval period? (Compare the dependence of ancient Egyptian agriculture on flood-basin agriculture watered by the highly variable natural ebb and flow of the Nile, or runoff farming in the wadis of North Africa.) It is significant that the Roman agronomists concentrated on wheat and barley cultivation as far as cereals are concerned and wrote virtually nothing about the cultivation of rice, a vastly more productive way of exploiting coastal Mediterranean plains.[8] Even the olive tree benefits from irrigation, yielding a substantial harvest every year instead of the biennial harvests characteristic of dry-farming conditions.

Superimposed on the normal alternation of wet winters and dry summers and the runs of good or bad years were periodic cycles lasting for centuries

[5] Sallares 1991: 390–5. [6] Neumann 1992.
[7] Vernet 1997 on southern France and Spain. [8] Sallares 1991: 22–4.

or longer, caused by variations in annual-mean radiation from the sun. It has been suggested that in the Levant, for example, warm and dry periods alternated with cold and humid periods. The Iron Age was cold and humid, the Assyrian and Persian periods were dry, the Hellenistic period was cold and humid, the Roman period was warm, while the Byzantine period was yet again cold and humid.[9] In semi-arid Mediterranean regions cold and humid conditions signified more rainfall. This is likely to have benefited cereal production and favoured population growth. Consequently a decline in solar activity leading to colder and more humid conditions c. 850 BC may well have been the critical factor underlying the simultaneous development of Iron Age cultures around the Mediterranean, which is otherwise difficult to explain.[10] It is important to note that global or hemispheric climate changes can produce different effects in different regions. The cold periods in Europe coincided with a weakening of the southwest Asian monsoon.[11]

Research on the periodic advances and retreats of the glaciers in the Alps, which have occurred throughout the Holocene, indicates that the bulk of the period of the Roman empire (c. AD 100–400) was warm, relative to the periods immediately before and afterwards.[12] Other types of evidence yield similar conclusions. For example the analysis of sediment grain-size data from the Iceland basin in the North Atlantic to reconstruct past changes in the speed of deep-water flow (believed by climatologists to be an important factor in the ocean current circulation pattern that determines climate in Europe) shows periodic tendencies that correspond with recent climatic developments such as the "Little Ice Age" of c. AD 1500–1800 and the Mediaeval Warm Period. Going back to antiquity, this record indicates a Roman Warm Period peaking at about AD 150.[13] Analysis of the atmospheric mercury deposition record (a process influenced by temperature) in a peat bog in Galicia in north western Spain also suggests that the Roman Warm Period at its peak might have been about 2 °C warmer than the present, and that the Roman Warm Period was more prolonged than the Mediaeval Warm Period.[14]

These conclusions are probably somewhat exaggerated. Nevertheless the reality of the Roman Warm Period can be corroborated by various types of proxy data, for instance the spread of viticulture into Roman Britain as demonstrated by recent archaeological finds at Wollaston in the Nene Valley in Northamptonshire.[15] In the vicinity of the Roman city of Sagalassos in south western Anatolia not only olive pollen (which can be blown considerable distances by the wind) but also olive presses and olive wood have been found in areas where it is too cold for the olive tree to survive there

[9] Issar 2003. [10] Speranza et al. 2002. [11] Gupta et al. 2003.
[12] Röthlisberger 1986. [13] Bianchi and McCave 1999.
[14] Martínez-Cortizas et al. 1999. [15] Brown et al. 2001.

today. It has been suggested that this indicates that average temperatures were 2–3°C higher than they are today.[16] The economic effects of climatic change were probably complex and varied from region to region and from crop to crop within the agricultural system. The warmer conditions during the period of the Roman empire, besides permitting the geographical extension of olive and vine cultivation, probably favored arable farming in northern Europe, but may have adversely affected it in some semi-arid areas, for example in the Near East.[17] The question of whether climatic changes favored increased agricultural production and so facilitated human population growth in the first two centuries AD, is obviously a very important question for economic history. More generally it is essential to consider the question of whether climatic trends can be correlated with and played a causal role in human population fluctuations.

III THE NATURAL ENVIRONMENT

In addition to being subject to regular climatic cycles, the Mediterranean environment is also a world of sudden, unpredictable catastrophes.[18] There were earthquakes, dust storms, swarms of locusts, devastating floods, and volcanic eruptions.[19] There was active volcanic activity in Latium in the area of the Alban Hills as recently as the Neolithic period. Further south in Campania, Mt. Vesuvius played a prominent role in the Roman period, destroying Pompeii and Herculaneum in AD 79. The eruptions in Sicily of Mt. Etna, an important source of both carbon dioxide and sulphur dioxide, in 44–42 BC probably had a significant short-term impact on the climate. However volcanoes did not have major long-term effects on the climate or the economy in classical antiquity.

Tectonic activity in the Mediterranean gave rise to many earthquakes in antiquity, too numerous to list comprehensively here; only the destructions of Helike on the Corinthian Gulf in 373 BC and Olympia in AD 426 in Greece and the earthquake at Pompeii in AD 62 will be mentioned here. Earthquakes presumably caused significant short-term damage to the local urban economy of affected towns; whether they also made a substantial impact on agriculture in the countryside is unclear. Besides earthquakes and volcanoes, there were numerous other catastrophes in the Mediterranean from time to time. Dust storms sometimes arrived in southern Europe from as far away as the Sahara; they may also have had local origins in soil erosion sometimes, as in the case of the dust storms which buried the Roman city of Stobi in Macedonia in late antiquity. Catastrophes sometimes

[16] Waelkens et al. 1999. [17] Issar 2003.
[18] Olshausen and Sonnabend 1996; Horden and Purcell 2000: 298–341.
[19] Stothers and Rampino 1983.

took a biological rather than a geological form. Swarms of locusts were one type of calamity which undoubtedly hit the countryside harder than the towns (unlike volcanoes and earthquakes). Livy records devastating locust onslaughts on North Africa in 125 BC and in Campania, the Pontine Marshes south of Rome, and Apulia in Italy; the last episode in 173 BC required intervention by the Roman army. Modern accounts of locust swarms in Lazio in the eighteenth century suggest that such events would have had severe short-term effects on the farming economy in antiquity.[20]

Floods were the type of catastrophe which arguably had the most substantial long-term impact by permanently altering the landscape. The river Tiber, for example, experienced a long series of severe floods in the past which frequently deposited sediments in the valleys between the hills of Rome. Strata in the Roman Forum dating to the time of the Roman empire are several meters above archaic levels and six–seven meters below the current ground level. The construction of the *Cloaca Maxima* shows that ancient Rome had drainage problems from the beginning of its history. Tacitus describes a debate in the Roman Senate in AD 15 which demonstrates how helpless the Romans were in the face of severe floods.[21] High rainfall in the mountains which fringe most of the Mediterranean frequently took the form of deluges, causing erosion in the uplands and interior. The eroded sediments were redeposited lower down river valleys, particularly in deltas such as those of the Po and Tiber in Italy, the Ebro in Spain, and the Achelous in Greece. Of course the silt brought down by the Nile is responsible for the fertility of Egypt. In the case of the Tiber the existing delta has only developed since about AD 1500, but in antiquity the large lagoons that existed on either side of the river near Ostia were being filled in.[22] On the one hand, this process created new economic opportunities in the shape of extremely fertile agricultural land. The most fertile land in Italy today is found in such areas, in the Po valley, or the Ombrone delta in Tuscany and the Pontine region south of Rome. However, it also had a negative impact on the human labor force required to exploit the land, since the expansion of easily flooded coastal plains which could readily turn into marshes paved the way for the spread of malaria around the coastal regions of Italy during the Roman period (see section V below).

The question of erosion and its possible causes leads us onto the problem of deforestation, the most controversial issue in Mediterranean environmental history. It is worth discussing here because the timber industry was undoubtedly extremely important in antiquity. Some at least of the hills of Rome were probably well wooded at the time of Rome's foundation c. 750 BC.[23] However by the late Republic the city of Rome had huge

[20] Sallares 2002: 183; Livy e.g., *Per.* 60.
[21] Sallares 2002: 109–10; Tac. *Ann.* I. 76, 79.
[22] Bellotti et al. 1995.
[23] Quilici 1979.

requirements for building construction work, heating baths and houses, cremations, industrial activities, cooking (an urban population of three quarters of a million people or more would have done a lot of cooking), and many other purposes, which could not be met locally.[24] These requirements were mainly met by floating timber down the rivers of Tuscany and the Tiber to Rome, according to Strabo. Pine, fir, and oak were most widely employed for building. Of course wood was also important for metal smelting, for example for silver ores in Attica and Spain, copper in Cyprus, iron from Elba at Populonia in Tuscany, and for shipbuilding. The Athenians took a strategic interest in the colony of Amphipolis in the northern Aegean during the Peloponnesian War precisely because it was a good source of shipbuilding timber for triremes, as well as silver.[25]

Many historians have believed, taking their lead from Plato's description of Attica, that extensive deforestation occurred in the Mediterranean in antiquity, leaving a denuded landscape. However this "ruined landscape theory" has also been criticized.[26] Looking at this debate as objectively as one can, it is necessary to observe that there is a great diversity of opinion. Even among professional scientists who are specialists in Mediterranean ecology, there are substantial differences of opinion.[27] Similarly among those historians who do believe in large-scale deforestation, there are differences of opinion regarding its chronology. One study concluded that there has been extensive deforestation in five mountain zones of the Mediterranean world (the Taurus in Turkey, the Pindus in Greece, the Lucanian Apennines in Italy, the Sierra Nevada and Alpujarra in Spain, and the Rif in north Africa). However the conclusion was reached that it occurred principally in the early modern period, not in classical antiquity.[28]

The view that little has changed is based on the observation that many regions of Mediterranean countries with low annual rainfall, a limestone-based geology that does not retain water, and a summer drought could never have supported significant forests. It is also argued that descriptions of ancient landscapes by classical authors were relative to the landscapes with which they were familiar. Consequently they included small shrubs and dwarf trees in the category of "forest," since they had never seen the tall trees in the forests of northern Europe. In other words, we should not necessarily assume that a "forest" necessarily included any very tall trees as far as an ancient Greek was concerned. However it is here that information about shipbuilding is very relevant, since trees of a certain size were required for that purpose, as in Theophrastus' description of the forests of Latium and Corsica c. 300 BC, rather than small shrubs.[29] The theory

[24] Meiggs 1982: 218–59; Rausing 1987. [25] Meiggs 1982: 126–30.
[26] Grove and Rackham 2001 *contra* Hughes 1994; Plato's *Critias* IIIc.
[27] Grove and Rackham 2001 *contra* Blondel and Aronson 1999: 201–6.
[28] McNeill 1992. [29] Theophr. *Hist. pl.* 5.8.2–3.

of no change maintains that savannah-style vegetation, with scattered trees in open country but no closed forest canopy (like the Spanish *dehesas*), is characteristic of many Mediterranean areas both now and in the past, and that little or nothing has changed over the last three thousand years; little deforestation has occurred and it is not responsible for soil erosion. Erosion is interpreted as predominantly gully erosion of underlying rock in badlands caused mainly by deluges, for example in Basilicata in southern Italy producing the alluvial deposits of Metapontum on the coast. Where soil erosion from cultivated land has occurred it is attributed principally to ploughing, not to deforestation.

The history of erosion is tied to the problem of the Older and Younger Fills.[30] The Older Fill does not concern our period. The Younger Fill now seems to be a heterogeneous mix of depositional episodes that occurred at different times in different areas; some are definitely classical in date, for example at Metapontum in southern Italy or on the coasts of western Anatolia; others date to late antiquity or the early mediaeval period (e.g., the burial of Olympia in Greece), while yet others occurred as recently as the time of the Little Ice Age.[31] Some of these episodes can be associated with human activity, while for others cyclical changes in the climate offer a more convincing explanation.

The most important point to emerge from the whole debate is that it is impossible to generalize about the Mediterranean as a whole. The human impact varied from locality to locality. Consequently the Mediterranean countries *as a whole* cannot be described either as a ruined or as an unchanged landscape. The theory that little has changed in the last few thousand years is reasonably convincing for some of the most arid parts of the Mediterranean, such as the Alpujarra in south eastern Spain, or south eastern Greece. However even in southern Attica there is archaeological evidence for farming in the fourth century BC on limestone ground which has virtually no soil cover today.[32] This shows that the question of environmental degradation cannot be considered independently of the question of human population pressure on the landscape. Some of the details of the theory of no change seem to be self-defeating. For example, the importance of anthropogenic erosion is minimized, but it is then acknowledged that soil erosion can be caused by ploughing arable land to grow rain-fed autumn-sown cereals, leading to criticism of the cultivation in southern Italy of durum wheat, the type of wheat best suited to the local environment. What are large human populations supposed to have eaten in the past if they had not been allowed to grow cereals, to avoid soil erosion?[33]

[30] Vita-Finzi 1969.
[31] Abbot and Valastro 1995; Kayan 1999; Huntington 1910; Grove and Rackham 2001: 291–4.
[32] Lohmann 1994. [33] Grove and Rackham 2001: 89, 265 and 270.

One general problem in making the debate relevant to ancient economic history is that the protagonists on both sides of the debate have tended to focus on certain areas, such as the badlands, which are undoubtedly of great interest from the perspective of environmental science, but are not exactly the heartlands of classical civilization. None of the five mountainous regions selected for study by McNeill, for example, ranks among the greatest centers of Greco-Roman civilization. Similarly by focusing on Mediterranean Europe, Grove and Rackham excluded north Africa from their consideration of the problem of "desertification," but it is surely in the vicinity of the Sahara (in an area where megafauna such as elephants and lions existed until Roman times) that this problem was and is most acute. Literary sources suggest that some parts of north Africa had plenty of trees, while others did not.[34] Computer modeling of the climate about two thousand years ago to study the effects of the presence of substantial vegetation in such areas on the climate suggests that there was considerably more rainfall in north Africa and Egypt than there is today, with increased rainfall levels in the Iberian peninsula and Armenia as well.[35] Such conclusions help to make sense of Ptolemy's weather diary, written in Alexandria during the second century AD, which describes a weather pattern with rain in every month except August and thunder throughout the summer (Table 2.1). These ideas help us to understand the agricultural prosperity of north Africa in antiquity, as well as the prosperity of the south of Spain during the Roman period. The rise and fall of the kingdom of the Garamantes in the Fezzan in north Africa has been linked to rainfall fluctuations.

Leaving aside marginal areas such as those bordering deserts, the greatest degree of human impact on the natural environment in antiquity is most likely to have occurred in the immediate vicinity of the largest human population centers, but such areas are actually rarely considered in detail in the debates between ecologists. For example it has been argued that the rate of soil erosion in Latium increased *ten times* in the second century BC.[36] It is hard to resist associating this trend with the increase in settlement numbers in south Etruria revealed by archaeological field surveys, presumably linked to intensive agriculture and market-gardening to feed the population of the city of Rome, which was increasing rapidly at the time.[37] Environmental degradation is then likely to have spread away from large settlements along communication lines such as river valleys and roads. It has been suggested that the major Mediterranean river valleys were once generally forested, since perennial rivers compensated for the shortage of summer rainfall, but are now largely deforested, with only a few exceptions such as the river Strymon in northern Greece.[38]

[34] Contrast Caes. *B Civ.* 2.37 with *B Afr.* 20.
[35] Reale and Dirmeyer 2000; Reale and Shukla 2000.
[36] Judson 1968.
[37] Potter 1979.
[38] Blondel and Aronson 1999: 122.

Table 2.1 *Distribution of rainfall in one year at Alexandria in the second century AD according to Ptolemy (cols. 2–3) and in 1889–1922 (col. 4). Source: Murray 1935, 19–20*

Month	Rainy days	Drizzle	Modern average
January	4	1	11
February	3	–	6
March	–	1	5
April	5	3	1
May	3	4	1
June	1	5	–
July	2	–	–
August	–	–	–
September	3	2	–
October	4	–	1
November	3	2	7
December	2	2	10
Totals	30	20	42

Livy described the Ciminian Forest north of Rome c. 300 BC as if it was the Amazon jungle. His account is sometimes regarded as exaggerated, but in the opinion of Italian specialists in environmental studies little of the ancient beech forest in the area of the Monti Cimini remains today.[39] A series of detailed local studies do support the idea of substantial human impact on the natural environment in many areas in classical antiquity. In the Biferno valley in the Molise region of eastern Italy (part of ancient Samnium) a field survey revealed a massive expansion (unparalleled until the early modern period) of rural settlements and intensification of land use from the fourth century BC to the first century AD accompanying a phase of extensive erosion and sediment deposition.[40] Similarly in the hinterland of Metapontum in southern Italy as much as ten meters of sediment was deposited during the period c. 600–c. 300 BC, when this Greek colony was flourishing. The affected areas quickly became marshy, a development which accelerated the spread of malaria in this region and subsequently led to the decline of the human population.

A balanced interpretation of the problem of environmental degradation in antiquity is that there were different outcomes in different areas; it is difficult to generalize. In many areas the vegetation cover was probably much the same as it is today. For example palynology yields this conclusion in the vicinity of the Lago di Pergusa in central Sicily.[41] In other areas there was a significant degree of deforestation in the past. For instance it has been

[39] Pratesi and Tassi 1977: 49 *contra* Grove and Rackham 2001: 172; Liv. 9.36.1–8.
[40] Barker and Hunt 1995. [41] Sadori and Narcisi 2001.

pointed out that the Roman boundary stones which enclose the famous cedar forest on Mt. Lebanon include considerable areas where there are hardly any trees today.[42] In the lower Rhône valley in France the scarcity of tree pollen and tree-dependent beetles indicates that this area was largely deforested in the classical period.[43] Of course there are still other areas where forests have spread, either naturally or through human planting, since antiquity. An example of a modern plantation is the pine forest on the shore of the Maremma national park in Tuscany in Italy, which was planted in the nineteenth century. The natural spread of a tree is illustrated by the increase, recorded in pollen cores, of Aleppo pine (*Pinus halepensis*), which is now common in Attica in Greece for example. It has increased in frequency since the Bronze Age because it is a good colonizer of cleared terrain, since its seeds germinate readily after forest fires.

The effects of human pressure on the environment in classical antiquity took other forms besides deforestation. It is easy to think of pollution as a modern problem, but it has been demonstrated that there were sharp rises in the concentration of lead and copper in ice strata in the Greenland ice cap, in lake sediments in Sweden, and in peat bogs in Switzerland and Spain from about 600 BC onwards.[44] These metal deposits were undoubtedly by-products of the great increase in the scale of mining and metallurgy in classical antiquity. Modern historians frequently point out that the Laurium silver mines of Attica, which produced large quantities of lead as a by-product, paid for the Athenian navy, constructed by Themistocles, and so for the Athenian empire; they fail to point out that the Laurium mines were also the first major source of anthropogenic pollution in world history, a less savory distinction. Mining for other metals, such as mercury, also made a contribution to atmospheric pollution. Thus cinnabar mining started in the fifth century BC at Almadén in Spain and increased in Roman times; this is evident in the palaeoenvironmental record from a peat bog in Galicia in north western Spain.[45]

The Mediterranean Sea, since it is almost entirely landlocked and surrounded by large and (especially on its southern rim) increasing human populations, is one of the most heavily polluted seas on earth today. However, it would be a mistake to think that such problems are unique to the modern epoch. The pre-industrial environment was not clean either.[46] Seneca clearly described the high level of atmospheric pollution in the city of Rome, which is not surprising in view of the extensive burning of wood for fuel that was mentioned earlier. The Grotta Rossa mummy, the only surviving mummy from ancient Rome, displays severe anthracosis in the

[42] Mikesell 1969. [43] Andrieu-Ponel et al. 2000.
[44] Hong et al. 1994; Renberg et al. 1994; Hong et al. 1996; Shotyk et al. 1998.
[45] Martínez-Cortizas et al. 1999. [46] Nutton 2000.

lungs even though the individual in question died young.[47] This corroborates Seneca's evidence and indicates that the level of atmospheric pollution in the city of Rome was very high. Atmospheric pollution is important not only for environmental history and for human health; it is also a key indicator of the scale of "industrial" activity in antiquity. Although the metal deposition data do not tell us anything about productivity, they do demonstrate that the scale of mining activity in the period c. 500 BC – c. AD 500 was substantially greater than anything seen before, or indeed immediately afterwards (after the disintegration of the Roman empire). This supports the theory that substantial economic growth (at least in terms of total production levels) occurred during the time of the Roman empire.

IV AGRICULTURE

Agriculture was the foundation of the ancient economy. Mediterranean agriculture is a form of polyculture, based on the cultivation (and frequently intercropping) of cereals (principally wheat and barley), olives, and vines, as is well known, with legumes (broad beans, chickpeas, lentils, etc.) also playing a significant role by providing a balanced mix of proteins to the diet. This combination of crops had existed in the Near East since at least c. 3000 BC. However its spread to the western Mediterranean was an innovation of the first millennium BC. Columella and Pliny the Elder, scrutinizing earlier literature, both observed that the geographical range of olive and vine cultivation had expanded enormously by the first century AD. Pliny contrasted Fenestella's view that olive cultivation did not exist in north Africa, Spain or Italy during the reign of Tarquinius Priscus (sixth century BC) with the situation in his own time, when olive cultivation was not only practiced in these regions but had spread far inland in some areas.[48] The disappearance c. 600 BC of the SOS amphoras, which had been used to export olive oil from Attica to Etruria, and the simultaneous appearance of Etruscan ceramics holding locally manufactured perfumes incorporating olive oil, has been interpreted as evidence in support of Fenestella's opinion.[49] Pliny believed that wine production in Italy only became commercially important from the middle of the second century BC onwards.[50] Diodorus Siculus observed that the Greek colony of Acragas in Sicily acquired its wealth in the fifth century BC by exporting olive oil to Carthage, since arboriculture was not yet widespread in north Africa, although there is no doubt that that situation soon changed. Similarly, Justin noted that the Greek colonists at Marseilles introduced olive and vine cultivation to Gaul. One of the works in the Aristotelian corpus states

[47] Capasso 2000; Sen. *Ep.* 104.6. [48] Columella, *Rust.* l.1.4–5; Plin. *HN* 15.l.1.
[49] Gras 1985b: 212–15. [50] Pliny *HN* 14.13–14.87–91; Fregoni 1991.

that the Phoenicians exported olive oil to Tartessus in Spain (today by far the world's largest producer of olive oil) in exchange for silver.[51]

The evidence from literary sources yields a consistent picture of the dissemination of olive and vine cultivation into the western Mediterranean as a result of Greek and Phoenician trade, cultural influence, and colonization from c. 800 BC onwards. Archaeological or palaeobotanical evidence pertaining to this question is often ambiguous. Thus in the case of olive cultivation olive pollen in pollen cores could equally well have originated from wild or domesticated trees; olive wood could come from wild or domesticated trees; since oil from wild olive trees can be and was used for some purposes (e.g., perfume manufacture), evidence for the use of olive oil does not necessarily imply domestication; small-scale production of olive oil is possible without olive presses. Nevertheless it remains true that there is a lack of evidence for olive presses in the western Mediterranean before the commencement of Greek and Phoenician colonization. This lack of evidence for the technology of olive oil manufacture implies that there was at the very least no large-scale olive cultivation before the classical period in the western Mediterranean, and probably none at all.

Moreover it is sometimes difficult to date palaeobotanical evidence. For example the olive peak in pollen cores from the south of France used to be dated to the classical period, but it now appears that olive cultivation in southern France only reached its height in the mediaeval period.[52] Given the inherent ambiguities in the archaeological record, the evidence of the literary sources on this question should be accepted. Polyculture of cereals, olives, and vines was an innovation of the Early Iron Age in the western Mediterranean.[53] Its spread undoubtedly increased overall agricultural production, facilitated human population growth, and increased trade by extending opportunities for the exchange of staple agricultural products between areas of surplus and areas of deficit, given the high degree of interannual rainfall and so harvest variability in Mediterranean-climate regions.[54] Later in antiquity the existence of this market made possible further extensions of specialized olive cultivation in Tripolitania in north Africa and in northern Syria. There was also a considerable expansion of viticulture in Egypt during the Ptolemaic period.

The olive tree only gives a high yield every second year under dry-farming conditions. The labor input required by olive cultivation is very low, except at harvest time. Viticulture requires more labor than olive cultivation. Nevertheless viticulture was potentially more profitable than other types of agriculture, as was already argued by Cato the Elder in the second century BC. One analysis suggests that an average yield of good quality wine

[51] Diod. Sic. 13.81.4–5; Just. *Epit.* 43.4.1–2; (Arist.) *Pr.* 844a17–24.
[52] Leveau 1998. [53] Sallares 1991: 29–34. [54] Garnsey 1988.

on fertile land could give profit margins of about 7–10 percent, at least in central Italy to feed the huge market provided by the city of Rome.[55]

The spread of olive and vine cultivation in antiquity was only a fraction of the total east to west movement of useful plants, particularly fruit trees. No less than 42 percent of all the plants mentioned by Columella have Greek names in his Latin text. Moreover a comparison of Columella with the earlier agronomic treatise of Cato, written in the first half of the second century BC, indicates that the influence of Greek agronomy increased over time. Columella and Pliny both stated that many plants which were not native to Italy had been introduced by the Romans.[56] Pliny regarded the movement of useful plants as one of the benefits of the *Pax Romana*; for example Vitellius is said to have introduced the pistachio, and Lucullus the cherry tree, to Italy. He noted that the Latin names for fruit and nut trees were generally of Greek origin, suggesting that the Romans had obtained them (or at least techniques for their cultivation – see below) from the Greeks.[57] Pliny even says that from the time of Pompey onwards the Romans exhibited exotic trees (such as apricot) plundered from foreign countries in triumphal parades![58] A whole group of useful trees such as apple, sweet cherry, sour cherry, pear, pistachio, and plum all seem to have been domesticated and entered cultivation for the first time in the first millennium BC, even though it is clear from archaeological evidence that the fruits of related wild species had long been gathered by prehistoric peoples.[59]

Many of these trees require the technique of grafting for successful cultivation. The fact that all the trees that require grafting became domesticated at roughly the same time, long after their wild ancestors were well known to farmers, suggests that the technique of grafting only became known in the Mediterranean in the first millennium BC.[60] Grafting may have originated with citrus fruit cultivation in the Far East. The spread of arboriculture using grafting was a very important development in Mediterranean agriculture in the first millennium BC, which increased both agricultural production and productivity and facilitated the development of specific varieties. Grafting is also the most rapid way of propagating the domesticated olive tree, although it can be propagated in many different ways.

Movements of crop plants within the Mediterranean climatic zone were relatively easy and successful. In some cases progress in agriculture north of the limits of the Mediterranean required on the spot improvement of

[55] Duncan-Jones 1982: 33–59. Cf. Carandini 1983a; Tchernia 1986: 209–18.
[56] Columella, *Rust.* 3.8.4–5; Plin. *HN* 27.1.2–3.
[57] Plin. *HN* 12.7.14, e.g., peach – *malum Persicum*; almond – *amygdalis*; chestnut – *castanea*; walnut – *nux iuglans*.
[58] Plin. *HN* 12.54.111. [59] Zohary and Hopf 1988: 128–66.
[60] Zohary and Hopf 1988: 129–30.

local indigenous varieties of plants. For example the author of a speech attributed to Demosthenes suggested to an Athenian jury in the fourth century BC that the idea that wine could be produced in the Black Sea region was preposterous, but palaeobotanical evidence shows that viticulture commenced in the Crimea in the Hellenistic period.[61] In this region outside the Mediterranean its development required the domestication of local vine varieties, although Greek traders and colonists naturally brought the idea of viticulture with them from Greece.

This process of the amelioration of locally occurring varieties of wild vine was also important in France, for example, as viticulture spread northwards beyond the boundary of the Mediterranean-climate zone in the south of that country. According to Braudel the development of new vine varieties (one ancestral to the *cabernet* of Bordeaux, the other ancestral to the *pinot* of Burgundy), probably from the local wild vine (*lambrusca*) of French forests, was required for viticulture to spread into the wetter and colder regions of central and northern France.[62] Ancient sources show how the spread of a new crop stimulated, firstly, trade with areas lying beyond its cultivation limits – Diodorus Siculus states that the Gauls were willing to trade a slave for an amphora of wine – secondly, a desire to extend its cultivation limits, and thirdly, a desire in some quarters to prevent overproduction. The Roman authorities seem to have had some misgivings about the extension of viticulture at the expense of arable farming, since Domitian in the first century AD is said to have ordered half the vineyards in the provinces to be uprooted after a bad grain harvest, although he did not take any action to enforce his edict. His main concern was to safeguard the grain supply of the city of Rome.[63] In practice the inevitable could not be prevented. As we have already seen, viticulture reached Britain during the Roman Warm Period. The emperor Probus in AD 276 is said to have permitted all the inhabitants of France, Spain, and Britain to have vineyards.[64] It was only during the late Roman empire that viticulture expanded to its natural limits in France.

Palaeobotanical evidence shows that the Romans also tried to take other Mediterranean plants such as lentil and peach northwards with them, as their empire expanded, as far as Britain, but such introductions were less successful. However many species of insects exploited the increase in interregional contact to move around without being noticed by anyone in antiquity (an important theme to which we shall return below to consider the movements of the mosquitoes which transmit malaria). For example the Mediterranean timber beetle *Hesperophanes fasciculatus*, which is common

[61] Dem. 35.35; Janushevitch et al. 1985; Neumann 1991 discussed the climate of the Black Sea region.
[62] Braudel 1990: 318–21. [63] Suet. *Dom.* 7; Tchernia 1986: 221–33.
[64] Aur. Vict. *Caes.* 37.3; SHA *Prob.* 18.8.

in Greece today, and the furniture beetle *Anobium punctatum* were brought to Britain in timber or furniture imported in Roman times.[65]

Cereal cultivation in antiquity did not change in quite such a dramatic way as the advent of olive and vine cultivation in the western Mediterranean. However there were some notable developments during our period. Barley (*Hordeum vulgare*) and emmer were the most important cereals at the beginning of our period.[66] Barley requires less water than wheat. Consequently barley cultivation predominated (probably for human as well as animal consumption) in arid areas such as Attica and parts of north Africa.[67] Xenophon advocated a safety first policy of spreading the sowing in Attica over a considerable period of time, an adaptation to extremely irregular rainfall. Theophrastus described Attica as the best land for barley cultivation, an indication of Attica's poverty, since barley was regarded as food for the poor and slaves; the rich always preferred to eat wheat.[68] Josephus noted that the poor ate barley while the rich ate wheat in Palestine in the first century AD.[69] Similarly in Sparta most Spartiates contributed barley to the common messes, but the rich sometimes made contributions of wheat.[70] Cultural preferences favored one cereal, while climatic constraints favored the other. In Greece barley was used for porridge, while the Egyptians liked it for beer. Barley requires a lower labor input for cultivation than wheat and was consequently cheaper than wheat in antiquity. Autumn-sown dense-eared varieties of six-row hulled barley were usually grown in Greece.

Emmer (*Triticum dicoccum*, a hulled tetraploid wheat) played an important role in wetter areas such as central Italy. It has been found in the archaic strata of the Roman Forum in Rome, and emmer rations are mentioned in the *Twelve Tables*.[71] Pliny's statement that it was still important in Campania (and North Africa) in the first century AD has been confirmed by palaeobotanical finds at Pompeii.[72] It was used to manufacture groats. Emmer was the principal cereal cultivated in Egypt until the Hellenistic period. Herodotus described Egyptian consumption of it in such a way as to suggest that it was contrary to Greek habits. According to Pliny the Egyptian varieties of emmer were easier to thresh than the Greek varieties.[73] Emmer was the hulled wheat best suited to Mediterranean climatic conditions. Palaeobotanical evidence shows that its place was taken in northern Europe, e.g., Britain in the Iron Age, by spelt wheat (*T. spelta*), a hexaploid hulled wheat which is better adapted to cold conditions. However spelt wheat is rarely mentioned in literary sources, which concentrated on the lands around the Mediterranean. Einkorn (*T. monococcum*), a hulled

[65] Osborne 1971. [66] Sallares 1991: ch. 3. [67] *IG* II² 1672; [Caes.] *B Af.* 67.
[68] Xen. *Oec.* 17.1–6; Theophr. *Hist. pl.* 5.8.2. [69] Joseph. *BJ* 5.427.
[70] Xen. *Lac.* 5.3. [71] *Twelve Tables* 3.4. [72] Pliny *HN* 18.29.109–16.
[73] Hdt. 2.36.2; Plin. *HN* 18.20.92.

diploid wheat, was important in northern Greece in the prehistoric period and in the countryside of Pergamum in Asia Minor in the second century AD according to Galen. However it never became important in the western Mediterranean.[74] The hulled wheats needed the same labor input for cultivation as the naked wheats and were less vulnerable to some pests.[75] However, converting the grain into bread is a much more laborious process in the case of the hulled wheats; one reason why they were eventually abandoned in favor of the naked wheats.

The major features of the history of cereals in classical antiquity were, firstly, the decline of barley in many areas with a concomitant increased preference for wheat, and secondly, a tendency for hulled wheats of all ploidy levels to be replaced by free-threshing wheats. Emmer declined in favor of durum wheat (*T. durum*) and poulard wheat (*T. turgidum*), both tetraploids, in Mediterranean-climate regions, while spelt wheat tended to give way to modern bread wheat (*T. aestivum*), another hexaploid, in northern Europe. The changeover was most dramatic in Egypt, where the native emmer was almost entirely displaced during the Ptolemaic period by the durum wheat preferred by the Greeks.

Wheat came to be preferred to barley and other cereals because it contains gluten, which raises loaves of bread during baking. Within the free-threshing types of wheat, the soft-grained bread wheat is excellent for making fine flour for bread, while the hard grains of durum wheat can be broken down easily into semolina, but cannot be pulverized any further towards the fine flour state with primitive milling technology. Poulard wheat gave a high yield, but the flour produced from its grains is much weaker than the flour from bread wheat. Moreover its grains are softer than those of durum wheat, making it less suitable for food products based on semolina. The best bread was made from bread wheat (Latin *siligo*), which was cultivated mainly in northern Italy, Gaul and Britain in the Roman period and imported to warmer regions. The upper class in Rome ate *panis siligneus* made from bread wheat, while the lower classes ate *panis plebeius* made from other types of wheat or other cereals.[76]

Bread wheat was also cultivated in the Crimea. Consequently the Black Sea grain trade was important to classical Athens not only for supplying its grain requirements in purely quantitative terms, but also for cultural reasons. The high Roman evaluation of bread wheat was related to the spread of the practice of making leavened bread, for which bread wheat is most suitable. The introduction of the rotary grain mill and finer sieves permitted finer "white" flour to be produced, although the very best bread available in antiquity contained much more grit than modern bread. However bread wheat was still difficult to cultivate in antiquity because its ears did not ripen

[74] Gal. VI, p. 518 ed. Kühn. [75] Columella, *Rust.* 2.12.1–2. [76] Sen. *Ep.* 119.

evenly and shattered rapidly once ripe, according to Pliny. These technical problems led to the invention in Gaul of the *vallus*, a reaping machine.[77] Varieties of all types of wheat in antiquity generally contained a higher proportion of proteins and a lower proportion of carbohydrates (giving smaller seeds) than their modern counterparts. Consequently ancient wheats were more nutritious per unit weight, although modern varieties of course give a much higher yield per unit area.

A variety of other cereals was also cultivated in antiquity, often in areas outside those upon which our literary sources focus, but none were very significant in Mediterranean-climate regions. Oats cultivation is mentioned in Mysia in Asia Minor by Galen; it is also recorded for Thrace. Galen also notes rye cultivation in Thrace and Macedonia. Rye was also a significant crop in northern Italy and in central and northern Europe. Millets gave a low yield, but as the only summer cereals available in classical antiquity they had an agroecological niche of their own. Rice, the most productive cereal in modern Mediterranean agriculture, was cultivated in some parts of the Near East in Roman times; its spread westwards in antiquity was hindered by the lack of suitable artificial irrigation works to keep paddy fields permanently submerged.[78] Maize, which is also very important in modern Mediterranean agriculture, only arrived from the western hemisphere after Columbus.

Agricultural systems based on the more productive maize and rice can support larger human populations than systems based on wheat and barley cultivation. This conclusion has implications for the human population sizes that could have been supported by ancient agricultural systems. In general the yields of ancient arable farming were probably fairly low. Columella reckoned that a 4:1 yield: seed ratio was not unusual in most parts of Italy, amounting to a net wheat yield of about 400 kg./ha.[79] Higher yields would have been possible in particularly fertile areas, for example regions with rich volcanic soils such as the vicinity of Mt. Etna in Sicily.[80] The highest yields would have been obtained in areas of irrigation agriculture such as Egypt and Mesopotamia. However, even in such areas there were many uncertainties. The fragmentary records of astronomical diaries from Hellenistic Babylonia mention several years in which harvest failures accompanied droughts and disease, while a low Nile flood was always a possibility in Egypt.

Cereal yields also depended on the extent to which arable farming was integrated with animal husbandry to provide animal manure for the crops. In general it appears that transhumance was a characteristic feature of pastoralism in the past in semi-arid Mediterranean dry-farming regions. To find fresh pastures flocks and herds of animals were regularly led up into

[77] Plin. *HN* 18.20.91; Palladius 7.2.1–4. [78] Sallares 1991: 22–4.
[79] Columella, *Rust* 3.3.4; Duncan-Jones 1982: 370–1. [80] Cic. *Verr.* 2.3.109–13.

greener mountainous areas in the summer from the desiccated lowlands. This practice reduced the availability of animal manure to arable crops. Animal products, especially dairy produce and wool from sheep and goats and meat from pigs, did make a considerable contribution to the economy (both the food sector and the textile industry), but animal husbandry was not closely integrated with arable farming in antiquity.

V HEALTH AND DISEASE

In order to explain the glories of Greco-Roman civilization it would be easy to assume that ancient populations must have been extremely healthy. However such an assumption would be false. There is a considerable volume of evidence that many ancient populations suffered from a substantial disease burden, consisting of both endemic and epidemic diseases. It is safe to assume that diarrhoeal and intestinal diseases were a major cause of high infant mortality and consequently of low life expectancy at birth in ancient populations. Celsus recorded that dysentery mainly affected infants and children up to the age of ten.[81] Waterborne diseases would have been particularly important in Egypt, but were certainly not confined to that country.[82] Older age groups also suffered from a heavy disease burden. Nearly a fifth of the skeletons of the people who were killed trying to flee Herculaneum during the eruption of Mt. Vesuvius in AD 79 display morphological changes consistent with brucellosis, a disease generally contracted by consumption of infected animal products, particularly milk from goats.[83] This at once tells us that much of the food and drink consumed by the Romans was not sterile. It also indicates the scale of the problem; nearly 20 percent of the population of one of the most well-known Roman towns was afflicted by just one out of the numerous infectious diseases that are known to have been active in antiquity.

Herculaneum was certainly not unique. Similar findings have emerged from research on the human biology of the skeletal remains from the Greek colony of Metapontum in southern Italy.[84] A number of skeletons display probable traces of thalassaemia, a human genetic disease which confers some resistance to malaria. As the physical environment of the territory of Metapontum became steadily more marshy, providing more breeding sites for the mosquito vectors of malaria, it is likely that malaria played a major role in the decline of the population of Metapontum during the Hellenistic period. However malaria was by no means the only problem faced by the inhabitants of Metapontum. There is also osteological evidence for the presence of an endemic treponematosis related to venereal syphilis.

Literary texts can reveal the presence of diseases which do not or only rarely leave identifiable lesions on human bones. Most of the acute

[81] Celsus, *Med.* 2.8.30. [82] Scheidel 2001a.
[83] Capasso 1999. [84] Henneberg et al. 1992.

infectious diseases fall into this category. The books of *Epidemics* in the Hippocratic Corpus show that numerous infectious diseases of varying degrees of severity were present in the small city states of northern Greece during the fifth and fourth centuries BC; for example it is possible to recognize an epidemic of mumps on Thasos, while there are many references to more deadly diseases.[85] Among the respiratory diseases tuberculosis was particularly feared. It appears to have had a high mortality rate. The various types of human malaria were well known in northern Greece. The Hippocratic texts describe other dangerous infectious diseases that are less well known today, such as relapsing fever. In addition, it may be surmised that other deadly tropical diseases which have not been recognized so far in ancient texts or archaeological materials were nevertheless present. An example is leishmaniasis, which still occurs in animal reservoirs in parts of Italy and other Mediterranean countries today, despite modern eradication campaigns, and causes sporadic human infections. It was surely present in the Mediterranean world in antiquity, despite the lack of attention paid to it. As far as health and disease were concerned, the lands around the Mediterranean were part of the tropical world in antiquity.

Malaria did not occur everywhere for two reasons. Firstly, it is a temperature dependent disease. Consequently the most dangerous species of human malaria, *Plasmodium falciparum*, was confined to Mediterranean-climate regions and was only active even there during the summer and autumn, although other less virulent types of malaria also occurred in central and northern Europe in antiquity. Secondly, it requires the presence of certain types of mosquito as a vector; not all species of mosquito can transmit malaria to humans, and mosquito breeding sites do not occur everywhere. Nevertheless, malaria was common in some areas in antiquity, such as western central Italy around Rome, as well as large parts of southern Italy, Sicily, Sardinia, north Africa, and the eastern Mediterranean lands. A malaria epidemic in late antiquity has been identified at an archaeological site in Umbria in central Italy.[86] Where malaria occurred in antiquity, in the long run it was the single most important component of the pathocoenosis, or ecological community of pathogens, not only because of its own direct effects on mortality and morbidity but also because of its synergistic interactions with other diseases, in particular infectious respiratory and intestinal diseases. This combination drastically reduced both life expectancy at birth and adult life expectancy in areas where malaria was endemic. Its effects were so severe that malaria had a direct influence on human settlement patterns, encouraging people to live in hilltop settlements, since mosquitoes as weak fliers are generally confined to low-lying areas. The seven hills of Rome are the best example of this phenomenon.[87]

[85] Grmek 1989. [86] Soren and Soren 1999; Sallares 2002: 66–8. [87] Sallares 2002.

Besides its purely demographic effects, malaria has and had considerable effects on the agricultural economy where it occurs, because repeated chronic infections have a debilitating effect on farmworkers, particularly at harvest time in late summer or early autumn. Thus economists have found a significant negative correlation between malaria incidence and per capita growth rates in developing countries today. The same correlation probably occurred in antiquity. Consequently the frequency of *P. falciparum* in southern Italy in the past is likely to be one of the reasons why in the long run northern Italy became more prosperous than the south. The economic divide observed in recent times between highly developed northern Italy and underdeveloped southern Italy commenced in antiquity with the spread of falciparum malaria from north Africa to southern Italy. Malaria can also influence the nature of agricultural systems; it makes difficult the cultivation of any crop that requires a lot of attention during the late summer and early autumn.[88] As has already been stated, malaria requires the presence of certain types of mosquitoes. Consequently it is likely that the spread of malaria northwards in the western Mediterranean in the first millennium BC required the prior spread of these mosquitoes, presumably on board ships; an unintended side-effect of the increase in trade by sea in classical times indicated by increases in the number of shipwrecks. Malaria was probably already common in Greece, especially northern Greece, and the Near East before its spread to central Italy.

Galen regarded *P. falciparum* malaria as particularly common in the city of Rome in his own time in the second century AD, but he was also well aware that different diseases were common in different cities.[89] There is no doubt that his perception of the situation was correct; we have already seen the examples of malaria in Rome, brucellosis in Herculaneum, treponemal disease in Metapontum, tuberculosis in the cities of northern Greece; leprosy in Alexandria is another example. Leprosy is the best example of the appearance of a new disease in classical times, according to the perceptions of classical authors. The Hippocratic authors show hardly any awareness of leprosy. It had become well known in Egypt and the Near East by the end of the Roman empire, but it did not spread widely in western, central and northern Europe until the mediaeval period. Galen's perception implies that there was a diversity of urban mortality patterns in the ancient world. In general cities were less healthy than the countryside in the past, as Celsus was aware, although malaria can produce extremely high mortality rates in small rural communities.[90]

In addition to the endemic diseases mentioned so far, which can frequently assume chronic forms of long duration, there were acute infectious epidemic diseases, which were often density dependent. These diseases were

[88] Sallares 2002: 242–4. [89] Sallares 2002: 222. [90] Mudry 1997.

favored by increasing urbanization in the classical world. The texts in the Hippocratic corpus provide evidence for the presence of numerous diseases in classical Greece, but really major epidemics seem to have been rare in Greece in the fifth and fourth centuries BC. Only the so-called "plague of Athens" in 430–426 BC described by Thucydides, in which about a third of the whole population of Athens perished, stands out. The pathogen responsible for that calamity was certainly not bubonic plague; numerous identifications have been proposed, of which smallpox and typhus are the most plausible. However Livy, following the annalistic tradition, does record a series of epidemics in the city of Rome as it grew during the Republic. In general not enough detail is given to be able to even attempt a retrospective diagnosis, but it is clear that epidemics became more frequent in Rome as it eclipsed the cities of Greece with respect to size.

Nevertheless it is not until the time of the Roman empire that we first hear of epidemics that appeared to affect virtually the whole of the then known world. The appearance of pandemics was a side-effect of the general increase in inter-regional trade and movements of people in classical times. The first pandemic was the so-called "Antonine Plague," which raged for about twenty years in the second half of the second century AD.[91] The causative agent responsible for the "Antonine Plague" was again definitely not bubonic plague; it is widely agreed to have been smallpox. Owing to the fragmentary nature of the sources it is difficult to trace its effects in detail, but later parallels make it plausible that the "Antonine Plague" might have killed about a third of the population, at least in some areas. In the middle of the third century AD there was another pandemic, the "plague of Cyprian." Unfortunately the evidence available for this pandemic is even worse than that for the "Antonine Plague"; it cannot be identified.

True plague (*Yersinia pestis*) did not become an important human disease until the time of the plague of Justinian in the sixth century AD. However, the foundations for the early mediaeval explosion of true plague were laid during the time of the Roman empire by the silent spread of its rodent host, the black rat (*Rattus rattus*), which is now gradually being revealed by archaeology. The spread of the black rat was yet another consequence of increased inter-regional contact in classical antiquity. Economists have suggested that the occurrence of pandemics in the past could have had sudden stochastic effects on the balance between population and resources so massive as to affect the whole course of long-term economic history in Europe, with respect to the timing of the Industrial Revolution.[92]

[91] Duncan-Jones 1996. [92] Sallares 2007.