SOME OBSERVATIONS ON MALARIA AND THE ECOLOGY OF CENTRAL MACEDONIA IN ANTIQUITY

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In the first volume of his history of Macedonia, Hammond describes the central (Emathian) plain of Macedonia in the time of Philip 11 thus:

One imagines that the central plain was at that time intensive cultivated by men and women who walked as far as 20 km from the cities to their fields in the plain and lived in the fields at the busiest seasons. The climate was healthy, and malaria was as yet unknown.(1)

How different this seems from the desolate and malaria-ridden country widely portrayed by nineteenth- and early twentieth-century visitors in the region, before the modern agricultural revolution changed the face of the landscape. At another time I hope to deal at length with the matter of cultivation in the Emathian plain in antiquity. At present, however, it may be useful to attempt to understand something of the physical condition of this plain, which was the heartland of the Macedonian kingdom. There are two immediate concerns: the incidence of malaria in the region in antiquity, and the topography of the plain itself.

I

The history of malaria in Macedonia is essentially the same as the history of the disease in Greece. There are three methods of determining the prevalence of malaria in antiquity. First, a considerable body of testimony about the affliction survives in the ancient writers. Second, modern techniques in paleo-pathology as a branch of the history of medicine enable us to trace the spread of this scourge. Finally, one may argue by analogy from the modern experience with malaria where it can be demonstrated that the ecological conditions which nurture the disease have not changed significantly from antiquity.

Malaria is an infection of the blood by a minute plasmodium parasite.(2) The parasites multiply rapidly and destroy red cells. Victims normally suffer severe fevers, general malaise, and sometimes death, depending upon the age and general health of the victim and the particular species of plasmodium parasites. Until recently the agent responsible for transmitting the disease was unknown. European colonial interest in the tropical malaria belts of Africa and Asia in the late nineteenth century led to considerable scientific investigation into the affliction. In July 1898, a British researcher working in India, Ronald Ross, described the results of his observations in a letter to a friend: "Malaria is conveyed from a diseased person or bird to a healthy one by the proper species of mosquito and is inoculated by its bite."(3) Ross' discovery led to his being awarded the Nobel Prize for medicine in 1902.(4) Italian scientists learned later that the mosquito genus *Anopheles* was the culprit, and recent research has shown that of the nearly 3000 known species of mosquito, about 375 are anopheline, of which more than 70 are vectors of four species of human malaria.(5)

Several anopheline species and subspecies are responsible for human malaria in Greece.(6) The *Anopheles'* habitat and breeding grounds are well known they are mainly (but not exclusively) marshy areas, regions of humidity and still or slow-moving water, where there are mean daily temperatures above 60 F--conditions necessary to incubate the mosquito. These conditions are conducive to endemic malaria in every habitable continent in the world.

Modern Macedonia, with its marshy areas in the Emathian and Strymonian plains and along the lower Axiosriver, is well-known as a malaria center.[(7)] In Macedonia malaria was especially severe because the two main vectors, *A. sacharovi* and *A. superpictus,* are complementary. *A. sacharovi* breeds in marshes, and in Greece has adapted to the brackish salt-water marshes in coastal areas, where it flourishes in early and mid-summer. It is a mosquito which bites man readily, and is the chief vector of malaria in regions where it exists. *A. superpictus* is a secondary vector, and is often found in the Mediterranean basin and Near East in conjunction with *A. sacharovi. A. superpictus* is a late-summer and autumn breeder in foot-hill streams which are reduced in volume and flow-force at that time of the year. These two malaria vectors, adapted as they are to different types of water surfaces where each may breed and thrive in conditions unfavorable to the other, combine to produce a transmission season which in Greece lasts from April to November. The transmission is thereby intensified through a long season over a range of ecological conditions; the result is that only those areas of Macedonia marked by high elevations and cool temperatures would be free from malaria.

Moreover, the winter pause in transmission and occasional drought amidst normally abundant rainfall interrupts the transmission process, which in the tropics enables the adult population to build limited immunities to the disease. Much of the Balkans, including Macedonia, has thus suffered through the deadly "endemic-epidemic" cycle which has proved so costly to human health and life (see notes 6 and 7).

A malaria crisis struck the area in the early twentieth century. In 1916-18 Macedonia became a major military front, and the susceptible personnel of the British, French and German armies were laid low. The situation was exacerbated by the fact that only a few years before, in the aftermath of the Balkan Wars, about 150,000 Greek refugees, many from malaria-free regions of the Balkans and Asia Minor, had settled in Macedonia and had become infected. The paralysis of three modern armies and a large civilian population before the ancient disease was a tragic lesson in human vulnerability. Malaria has disappeared from Greece only since the early 1950s.[(8)]

Ross' success in identifying the mosquito as the vehicle for transmitting the malaria parasite, and the rapid medical advances which followed his discovery, resulted in an especially high interest in the subject in the early twentieth century. Impressed with Ross' work, the Cambridge classicist W.H.S. Jones produced two volumes investigating the prevalence of malaria in classical antiquity.[(9)] Jones was correct in calling malaria a "neglected factor" in ancient history; ironically, his work has had much more influence on the students of epidemiology and the history of the disease than on the classical scholars for whom it was intended. The main criticism of Jones' work is that, having collected the ancient *testimonia* on malaria, he drew a number of inferences about social, moral and economic decline that appear naive to a modern public. Jones' views about the "degeneration" of the Greek character, the "loss of brilliance" after *ca.* 400 BC as the result of malarial infection, are based on outmoded racial and social premises.[(10)] Ross himself subscribed unreservedly to Jones' views, and argued that malaria was responsible for the "decline" of a vigorous Greek civilization. And no less an expert than the present leading scholar of the paleo-epidemiology of malaria restated Jones' thesis that after malaria became endemic *ca.* 500 BC it was probably responsible for the downfall of Greek civilization.[(11)]

Simplistic cultural notions like "degeneration" and "decline" aside, the value of Jones' work was his comprehensive collection of testimony from the ancient medical and non-medical writers. All subsequent accounts of the history of the disease in ancient Greece ultimately depend on Jones' *Malaria and Greek history.*

The weight of the ancient *testimonia* is impressive. It is collected and commented upon in Jones in detail, and there is no need to set it down here;[(12)]

a summary will suffice. The common ancient Greek word for fever was pyretos, and by the fifth century BC it is clear that, except in a few special cases, the use of the word normally refers to malaria.[(13)]

"Fever" was well known after the mid-fifth century, and that it was often malarial fever (as opposed to other types) is evident for two reasons. One is the ancients' association of the affliction with marshy areas and seasonal attacks, corresponding to modern experience with the disease. The other is the description of fever stages, degrees of severity (until recently the modern diagnostic terminology for malaria was based mainly on the phrases in the Hippocratic corpus), and the condition known as splenomegaly (enlargement of the spleen), which is one of the observable symptoms of the malady. It is obvious from the Hippocratic corpus and from the medical writers of the following four centuries that the ancients were so well acquainted with malaria as to describe symptoms in terms clear enough for modern medical scientists to recognize without doubt.[(14)]

II

Two challenges to Jones' view have emerged in recent years. One utilizes modern techniques in paleo-pathology; the other reveals underlying assumptions that the physical environment of the Emathian plain was not productive of malaria. Both argue that Greece was in fact virtually free from malaria in the classical period.

First, J. Lawrence Angel has offered the materials of physical anthropology--skeletal remains in particular--to suggest that the evidence of patho-physiological adaptation in response to malaria is lacking for classical Greece.[(15)]

Angel's thesis is based on the connection he sees between malarial environment, bone enlargement and thalassemia. Thalassemia is a blood disorder resulting in severe anemia. It is a recessive genetic trait which can affect the individual's ability to resist malaria. Like a related disorder, sicklemia ("sickle-cell disease"), thalassemia provides the victim with a level of protection against the malaria parasite. It was observed long ago, for example, that Blacks in Africa and the American South seemed generally more resistant to fevers than Whites who worked in mosquito- infested areas. Many Blacks are traditionally affected by sicklemia, a debilitating and often lethal genetic blood disorder. Sicklemia harbors fewer malaria parasites by incidentally providing an unfavorable environment for the parasite.[(16)] Like sicklemia, thalassemia is often fatal, and would logically disappear through natural selection by the death of the host, but it curiously persists among populations which are also subject to malaria. By a mechanism not understood at the moment the presence of malaria infections activates certain resistant factors which provide a protection counteracting the defect of thalassemia and other genetic bloods disorders. A malarious population is sometimes characterized by a relatively high frequency of other blood disorders, especially those red-cell abnormalities that seem to exist in a symbiosis with malaria.[(17)] That is, the continuing existence of a population surviving such afflictions as thalassemia and sicklemia may indicate the presence of malaria as well, even while malaria may also exist in populations not suffering from other blood disorders.

A third important disorder often coincides with malaria, the glucose-6-phosphate-dehydrogenase (G6PD) deficiency. Known as "favism", this hereditary blood defect produces a severe temporary anemia when the affected individual ingests or inhales the pollen of a broad bean *(viciafava).* Exposure to the fava produces a deficiency in the vital G6PD enzyme which normally arrests the deterioration of red-cell membranes; the result of favism is a transient acute hemolytic anemia.[(18)] An advantageous effect of the malady is that, as in the cases of thalassemia and sicklemia, a hostile environment for the malaria parasite is also created; that is, an individual may continue to be affected by the genetic blood disorder, but will suffer less from malarial infections.

There is a considerable literature on the use of the fava among Greeks and other eastern Mediterranean peoples as the focal point of ritual, cult and kinship-systems.[(19)] There is also a notorious taboo on beans to be found in the philosophical writings, especially among the Pythagoreans.[(20)] It is problematic whether the existence of widespread beliefs and practices related to the bean suggests that a significant segment of the population of the eastern Mediterranean suffered from a G6PD deficiency often associated with endemic malaria.[(21)]

Within a population, individuals or groups may or may not be affected by these blood disorders, including thalassemia. In those who are thalassemic, however, an adaptive individual physiological response to their condition may occur: certain of the body's bones enlarge as the internal spongy matter producing red cells must of need increase to combat disease. The enlarged bone condition is known as porotic hyperostosis. On the basis of skeletal examinations Angel reports that there is a substantially higher incidence of porotic hyperostosis among farmers living in marshy areas--e.g., the sixth-millennium BC Macedonian settlement near Nea Nikomedeia in the southwestern part of the Emathian plain--than among those living on higher, drier ground. Angel claims a generally high incidence of porotic hyperostosis among persons who lived in the malarial belts of the Old World, although the statistical basis for this view is not made clear.

Angel also suggests (again on the basis of skeletal examinations) that there have existed fluctuating levels of malaria in the eastern Mediterranean, caused by two factors: one is the periodic draining of swampland; the other is the occasional variations in climate, which result in lower sea levels and drier land in normally marshy areas.[(22)]

During such "dry" periods the incidence of malaria would at least in theory decline.

Now, to the crux of Angel's argument. The incidence of poroffc hyperostosis appears to be variable from time to time. For example, the prehistoric Macedonian farmers at Nea Nikomedeia were presumably malaria-ridden, according to Angel, because their bones show evidence of porotic hyperostosis, an indication of the thalassemia which is sometimes symbiotic with malaria. Angel claims a 50% incidence of hyperostosis among the late Paleolithic bones he has studied, but the incidence drops gradually to only 8% for the Greek Bronze Age, 4% for the Archaic (early Iron) Age, and then to virtually "no malaria" for the classical period down to *ca.* 300 BC.[(23)]

There is a marked upward swing in the Hellenistic era (10%), and by Roman times malaria has again become endemic (24%) in the eastern Mediterranean.

Any attempt to establiish a necessary relationship between malaria and thalassemia is a complex problem, and there are some diffculties with Angel's thesis.[(24)]

First, the sample of bones studied is small, being limited to the availability of materials from a few archaeological investigations. The lack of a broadly-based statistical sample in both geographical and chronological terms makes one feel insecure in accepting a thesis describing fluctuations in a major, widespread disease over a long period of time.[(25)]

Next, Angel assumes "that much of this anemia [that which may have caused the bone enlargement] was thalassemia".[(26)] But thalassemia is not necessarily a function of climate or environment, and Angel appears to have overlooked the fact that thalassemia (which always produces bone enlargement as an adaptive response to infection) is also prevalent in some non-marshy areas where the bones may enlarge to combat some nonmalarial infections. Indeed, one modern diagnostic study in modern Greek villages has shown that the frequencies of thalassemia in malarious lowland villages and non-malarious mountain areas were approximately the same.(27) Further, even if the anemia causing bone enlargement were proven thalassemia--which it is not--there are other than malaria-related factors which can cause porotic hyperostosis.(28)

In sum, there is an apparent coincidence between porotic hyperostosis and marshy areas in parts of the Old World as evidenced in a few ancient sites (as Angel points out); these regions may or may not have been malarious. The existence of bone enlargement may or may not be evidence of thalassemia, and the existence of thalassemia, even in a marshy area not a proof of the existence of malaria (see note 27). That is, we cannot use the bones alone to show the existence of malaria.

Angel has suggested that there is a correspondence between the datable low incidence of porotic hyperostosis and minor climate fluctuations resulting in drier climate (hence fewer marshes and less malaria). At evidence he cites the work of Denton and Porter on climate variations.(29)

Denton and Porter discuss "neoglaciation", that is, the post-Ice-Age climate fluctuations evidenced by the occasional retreat and advance of glaciers. Glacial growth and shrinkage over the past five millennia reflect the slight reversible shifts from the warmer/ wetter range to the cooler/ drier range.(30)

Pollen records, Carbon-14 dating, botanical analyses, changes in the habitat of man and animals, agricultural data and, in the historical period, eyewitness accounts, are among the kinds of evidence used to document these climatological phenomena. Denton and Porter's data indicate that the first millennium BC was marked by a glacial advance which peaked about 500 BC. Thus the climate was cooler and drier than that of the Hellenistic period which followed. By *ca*. AD 500 the glaciers were in marked retreat beyond even present conditions. Angel sees a correlation between the incidence of porotic hyperostosis (malaria?) and glacial fluctuations (climate variations). He uses the climate data to suggest a reason for the lower incidence of bone enlargement: that is, a drier climate produces less marshland, hence less malaria.(31)

That there appears to be a correlation between Angel's data on porotic hyperostosis and minor climate changes is not in dispute. But Angel goes a step further in arguing that marshiness was further reduced because the Mediterranean sea level was 34 meters lower than present levels, as some Mycenaean and classical sites are now 1-2 meters below sea level. Whatever the value of sea-level arguments in archaeology (e.g. local land-subsidence can also produce underwater sites, for which see p. 111 below), the particular case Angel makes is dubious. For example, he uses the case of underwater "Mycenaean *and* Classical" (my italics) sites, even though the data published by Denton and Porter show that much of the second millennium BC was a period of relative glacial *retreat,* that is, *higher* sea levels according to Angel's argument (are we to suppose that the Mycenaeans deliberately constructed their sites underwater?), whereas classical glaciers were at the peak of *advance* (lower sea levels). One cannot have it both ways.(32) Angel's thesis is not supported by the evidence he cites.

Finally, Angel correlates the decline of malaria (presumably evidences by porotic hyperostosis) with the increase in population and more progressive methods of agriculture between the prehistoric and classics periods.(33) One must weigh this against the view that with an increase in population and consequent stripping of forest and cover-land for agricultural use, natural surface absorption and drainage are interfered with. The result is an expansion of the breeding grounds for anopheline mosquitoes.(34)

Such a transformation of the countryside for human use does not necessarily produce malaria, for the mosquito-vector must be infested with the deadly parasite; but one may suggest that, on ecological grounds alone the classical era offered more potential for the scourge than did the earlier periods.

III

We may now turn in detail to the matter of the sea level in antiquity, both for its general interest and for its connection with Macedonian marshland particularly in the Emathian plain. In his *History of Macedonia,* Hammond wrote (I 145):

In antiquity the level of the sea in the Mediterranean was some 5 feet lower than it is today, and this means that the high flood level in the central plain, e.g., in the vicinity of Alorus, was 5 feet lower and that the rivers had that much more fall.

The question of sea-level changes since antiquity is vexed and a matter of continuing concern to archaeologists and oceanographers alike. For his view that the level of the sea was lower in antiquity Hammond cites the evidence in his earlier article on the battle of Salamis and in his *Epirus.*[(35)] The evidence in the Salamis article consists of references to suggested North Sea level changes and opinions of local Greek seamen. Hammond admitted that the matter was problematic, and assumed (for the sake of his discussion of the topography of the Straits of Salamis) that the sea level has risen 5-6 feet since antiquity. In his account of the battle of Marathon published twelve years later,[(36)] Hammond made no reference to sea-level changes in an otherwise detailed discussion of topography. At Marathon five or six feet less depth of water would have significantly altered the coastline of that shallow bay and perhaps affected both fresh-water marshes and the sea-water lake. We cannot assume that Marathon Bay in 490 BC was as it is today, but that the level of the Aegean dropped five or six feet by the time of Salamis a decade later.

In *Epirus* Hammond cited six different points along the western coast of Greece, between the Gulf of Arta and the Gulf of Valona, where ancient remains can be seen beneath the surface of the sea. Hammond's argument is based entirely upon the existence today of these submarine remains, all consistently 5-6 feet below the present surface, and he concludes that the sea level was from three to five feet lower in antiquity. This view figures prominently in Hammond's reconstruction of the topography of the Emathian plain and the central Macedonian coastline. It even corresponds (although he does not mention this himself) with his view stated elsewhere (see note 1) that Macedonia was free from malaria in Philip II's time, on the assumption, of course, that a lower sea level would have produced more efficient alluvial drainage, hence less marshland in the Emathian plain.

There now exists a body of scientific research into the matter of sea-level changes. N.C. Flemming and others have devised a method using the resources of both archaeology and geology, which attempts to establish average sea-level measurements exclusive of wave and tidal fluctuations.

Analysis of the placement and type of coastal sites from antiquity, when joined with a study of attendant land forms with a known geologic history, has produced some conclusions about the ancient sea level relative to local coastlines. Flemming studied 69 Aegean sites; this survey, when taken together with his earlier research in the western Mediterranean, shows that the last great sea-level change occurred in the Mediterranean 10-11,000 years ago, and that since about 2000 BC the level of that sea has been within a few centimeters of present conditions.[(37)] The world-wide sea level has not increased more than about 30 cm (about one foot) in the last 3000 years. Any ostensible large change as evidenced by numerous sunken sites is more likely the result of local volcanic and tectonic subsidence, common in this geologically active part of the world. It is thus local earth movement which accounts for the apparent rise in the Mediterranean sea level; it may be understood that this subsidence of landforms is relative to a virtually stable sea level.(38)

One final note on climate. That minor periodic climate changes occur is beyond dispute; beyond this little else is certain about climate fluctuations. Since precise measurements of climatological conditions are lacking for ancient times, we are totally dependent upon the occasional observation of phenomena in our written sources, the dating of organic materials, botanical analyses, changes in human and animal habitat, agricultural data and mountain glacier variations. These data can indicate long-term trends or abnormal variances, but in the absence of detailed records they can provide only guidelines for describing the climatic history of a single region like Macedonia.(39)

The literature of antiquity, however, suggests that ancient Greece's climate was not significantly different from today's. Hesiod's growing seasons in Boeotia could provide a guide to a modern planter; Theophrastus' plants still grow in the same regions, though many are reduced in number owing to human mismanagement; some forms of wildlife are long extinct, but domestic animals continue to flourish in the same regions as in antiquity; the capes at Malea and Athos still blow fierce, and as recently as 1971 the author witnessed Athens "crowned in violet", as Pindar put it.(40) Aberrations aside, we can assume that the climate of the Greek peninsula in antiquity was about as it has been in modern times, when malaria was endemic in Greece.

Thus the views of Hammond and Angel on the physical conditions Conducive to malaria, and of Angel on the link between the bone evidence and the disease, seem unconvincing. It seems more prudent to accept the testimony of the ancient writers about the prevalence of malaria. It is unlikely that so much precise information could be transmitted about a disease that did not exist. Moreover, it will be shown below that the ecology of the Emathian plain in the classical period was about as it was in the early twentieth century (except for some coastline alterations resulting from alluvial processes), when the region was notorious as a malaria center.

IV

When did malaria come into Greece? The original home of *Anopheles* may have been the

Ethiopian regions, and it may have preceded man's existence both there and in other temperate climates.(41) It undoubtedly took time for the relationship between the plasmodium parasite and the host *Anopheles* to develop; precise ecological and physical balance is necessary. The mosquito-borne infection is thought to have progressed from its East African genesis down the Nile valley and eventually into the Mediterranean and Near East.(42)

It is clear that the disease was endemic in the Greek world by the fifth century, since it was well known after midcentury by both the writers of the Hippocratic corpus and non-medical writers alike.(43)

To search for references to malaria in the pre-classical period is to confront the usual problem of historical research in that era: the paucity of literary evidence. Nonetheless and to risk an *argumentum e silentio*--it is curious that our best early source for practical matters, Hesiod, who complains about everything else, fails to mention the fever in his work. Perhaps his town of Ascra was high enough above the Boeotian plair (where malaria was rife in the early twentieth century) on the slopes of Mt. Helikon to have escaped the affliction, although modern *Anopheles* has spread its scourge in Greek villages up to 600 m elevation. It is also possible that malaria had not yet arrived in Greece. Whatever the case may be Hesiod is silent about the fevers when we would expect him to be otherwise. Also silent are a series of votive tablets at

Epidaurus dating from the early classical period. Sigerist summarized some seventy cases of afflictions noted on these tablets, and Bruce-Chwatt concluded that none referred to malaria.[(44)]

If it is correct to suggest that there is no evidence of malaria in at least two early sources where one would expect some indication of its existence, and that there is clear evidence of malaria in fifth-century Greece, we may postulate some post-Hesiodic and pre-Hippocratic circumstance that was favorable to the introduction and consequent spread of malaria in Greece. A single event may supply the answer: the entry into Greece in the early fifth century BC of a large number of Asians, many of whom came from areas of the Near East with endemic malaria.[(45)] Did Xerxes' armies or the military and administrative personnel who preceded them carry the scourge that would eventually attract so much attention from the Greek medical writers? Perhaps low incidences of malaria had already existed in parts of Greece. One assumes that malaria inevitably would have become endemic in Greece during the course of its inexorable spread. Yet one is tempted to suggest that the Persian army may have hastened the process, especially in those marshy areas where the hitherto uninfected Asian mosquitoes already flourished, which, now having an infected Asian population to prey upon, spread malaria to the local population.[(46)] The residents of northern Greece, especially the inhabitants of what in modern times was the malaria belt of Thrace and Macedonia, may have suffered more from the bite of the newly-infected mosquitoes than from the passage of a vast Asian army through their land.

There are other possible sources for the infection and for its spread. The gradual stripping of the land of its natural cover created mosquito breeding-grounds.[(47)] Increased commerce with malarious regions plus the occasional mingling of large groups of people from throughout Greece at panhellenic festivals may have contributed to the spread of the disease. There can be no certainty about these matters, but if we accept the notion that malaria was endemic in Greece at least by the fifth century--whatever its origin--and we believe that the Macedonian environment was as conducive to the affliction then as in modern times, we have little reason to doubt that it was a factor in Macedonian history.

What effect this scourge had on the Macedonians is diffficult to say. The disease takes its greatest toll among those who are newly exposed, as was the case with the highly susceptible recently-arrived populations in Macedonia in the early part of this century. Long-term inhabitants in heavily endemic areas develop some forms of resistance, but these are idiosyncratic and weak, as studies of modern Greek mortality rates and incapacitation among Macedonian villagers have shown. An infected population is unhealthy. The major effect of malaria on a population--after producing a high infant mortality rate is to reduce the residents' work efficiency. As modern experience throughout the world has shown, populations have lived and worked for centuries in malarious regions.[(48)]

One suspects that in antiquity the inhabitants of Macedonia kept to the highest, driest ground available, living and working on the terrace lands bordering the deadly marshes which were the center of ancient Emathia.[(49)]

V

Macedonia shares with the rest of Greece the fact that only a small part of the total land area is suited to agriculture. The combination of scant rainfall sharply eroded land forms which do not hold soil and water and a large proportion of mountainous terrain reduces the amount of tillable and grazing area. These factors are somewhat mitigated in Macedonia, however, by its large alluvial plains, relatively more abundant rainfall through-out the year, and cultivable terrace lands on mountain slopes. Moreover Macedonia's major rivers flow year-round, permitting both natural and artificial irrigation for crop and pasture land. As an agricultural area Macedonia is, compared with much of Greece, blessed by nature. The large mountain ranges also provide abundant well-watered summer pasture slopes and basins, a phenomenon which has sustained Macedonian agriculture for millennia. Until the agricultural revolution of the past half-century, Macedonia looked much as it had in antiquity. Two major natural factors particularly affecting river-plain cultivation in central Macedonia are climate and sea level. We have suggested that both in modern times are virtually what they were in antiquity.

As for human attempts to alter the landscape, Hammond claims that Philip II was responsible for a flood control project in the Emathian plain.[(50)] No direct evidence for this exists, although Theophrastus *(de Caus Plant.* 5.14.6) mentions that Philip drained and reclaimed the land around Phillippi. This area, the lower part of the plain which begins above Drama and runs down to the Kavalla coastal ridge, is hardly analogous to the central plain. The Philippi plain is an ill-drained alluvial basin, fed by the numerous streams falling from nearby mountains. The plain's drainage system narrows to a single stream where the Angitis river pierces the Pangaion-Menikion mountain barrier to flow into the lower Strymon plain. The drainage of the Philippi plain was accomplished with relative ease in modern times by the erection of a pumping station at the Angitis bottleneck.[(51)] If Philip was responsible for draining the Philippi plain shortly after he took it in 356 BC, he may have solved the drainage problem in some equally simple fashion.

The Emathian plain, however, is a different matter. It is huge and complex, fed by everflowing major rivers, and resists any single easy method for flood control and reclamation. In modern times it took the combined effort of the most advanced American and Greek hydraulic engineering skills and considerable amounts of money to alter river courses and drain swamps, a process occupying much of the two-decade period 1920-40 and continuing for several years after the end of World War II and the Greek Civil War. One doubts that ancient Macedonian technology and the royal purse were up to this formidable task, even on a more limited scale. That the region around Philippi was reclaimed may or may not be true. In either case, Philippi's drainage cannot serve as an analog for the great central plain. If the sea level were several feet lower in antiquity, it might be argued that drainage was naturally more efficent than it is today, and thus the Emathian plain was less swampy. But we have seen that the sea level in historical times has remained virtually unchanged; moreover, the silting process by which the plain was formed (for which see below) indicates that it was ill-drained in antiquity. It is thus best to assume that the area remained undrained, as it was until the modern program of reclamation.

The historical geography of the central plain's metamorphosis over the centuries is too complex to deal with here.[(52)] As late as the classical period an inlet of the Thermaic Gulf extended quite far west into what became the central plain, much as the sea stretches eastward today to form the Gulf of Salonica (see Map). No evidence of prehistoric settlement has been found in the area,[(53)] and all the known sites of the historical period--including Aigai (Vergina), Beroia, Mieza, Edessa and Pella--lie on the adjacent terrace-land.[(54)] The alluvial activity of the four rivers which flow into the region--the Haliakmon from the southwest, the Moglenitsas (Loudias) draining Almopia, the Axios and the Gallikos (anc. Echedoros) from the north--plus innumerable small streams draining the slopes of Mt. Bermion, gradually began to silt up the inlet. In the fifth and fourth centuries BC Emathia was still largely a sea inlet and marshes, with the main route from Tempe and the Pierian coastal plain hugging the adjacent piedmont. It was not until Roman times that lower Emathia was able to support a road directly across the deltas from Pieria to Salonica,[(55)] and that the plain assumed roughly the form it has retained until the twentieth century: a large marsh with a nuclear lake of varying dimension (Lake Loudias in antiquity; mod. Yiannitsa) connected to the sea by a river.[(56)]

We may thus envisage the central Macedonian homeland as the fertile terraces above the swampy Emathian plain. Farmers tilled the slopes, or drained patches at the marsh's edge,[(57)] probably avoiding the central swamp wherever possible. Pasturists utilized the mountain meadows above, and game and timber was widely available from the nearby slopes. It was, by Greek standards, a prosperous region, but awkwardly arranged in its central portions. As local populations increased and the foreign demand for Macedonian metals and timber grew, the need both for cultivable land and for security against Greek encroachments gave rise to an expansion of Macedonian interests in all directions.[(58)]

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Notes

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2. The literature on malaria is extensive, most of it, as one might expect, on technical matters relating to treatment of the disease and to mosquito-eradication programs. Useful general accounts include: Gordon Harrison. *Mosquitoe malaria and man: A history of the hostilities since 1880* (London 1978). with frightening fnal chapter showing that because of political instability and the breakdown of public health services, malaria is again becoming endemic in parts of Asia and Africa; L.W. Hackett, *Malaria in Europe. An ecological study* (London 1937); and Paul F. Russell, *Man's mastery oi malaria (London* 1955). On the origins and early spread of the affliction see LJ. Bruce-Chwatt, "Paleogenesis and paleo~epidemiology of primate malaria," *Bull. World Health Org.* 32 (1965) 363-87 this is a comprehensive account of what is known about the transmission of malaria in antiquity written by the (then) Chief of Research and Technical Intelligence for the World Health Organization. For a valuable description of the disease see Brian Maegraith in Adams and Maegraith, *Clinical tropical diseases (Oxford* 1976) chap. 16.

3. Letter reprinted in full in Russell; see esp. p. 60.

4. Ross' own account of these matters can be read in Sir Ronald Ross, *Memoirs* (London 1923).

5. Bruce-Chwatt 36S; and see next note.

6. The taxonomic classification of anopheline mosquitoes is a continuing problem. As an indication of the increasingly subtle distinctions brought to this study by taxonomists, the number of known separate species of mosquitoes has risen from about fourteen hundred in 1932 to nearly three thousand in 1973, see the statistics cited in Kenneth L. Knight and Alan Stone, *A catalog of the mosquitoes of the world* (College Park, Maryland 1977) 1. Part of the difficulty in determining the vectors for malaria in Macedonia rests in the changing classification of anopheline mosquitoes, and, in particular, the precise type and location of the species A. *maculipennis* and its various subspecies, once thought to be vectors in Greece. see Marston Bates, "Anophelines of the palearctic regions 420, 422 and 426; M.F. Boyd, "Epidemiology of malaria. Factors related to the definitive host", table 104; and L.W. Hackett, "Conspectus of malaria incidence in northern Europe. the Mediterranean region and the Near East" 788, all in M.F. Boyd (ed.), *Malariology* (Philadelphia and London 1949), 2 vols.

The most recent comprehensive classification (Knight and Stone, *Catalog;* see indices) makes *A. maculipennis'* status uncertain, but clearly identifies *Anopheles anopheles sacharovi* and *Anopheles cellia superpictus* as the main vectors in Macedonia. See especially Hackett (pp. 79S-97 and 1422 in Boyd, *Malariology)* for a description of the ecological relationship between the two species.

7. Great Britain, Admiralty, Naval Staff, *A handbook of Macedonia and surrounding territories* (London 1920) 65: "Malaria is notoriously the disease which is the scourge of these lands." As late as 1936 malaria

was (excluding deaths ascribed to senility) the fourth leading cause of death in Greece, behind pneumonia. tuberculosis and intestinal diseases. The malaria death-rate (7580 per 100,000 population) was twenty times that of any other European country of the time. An observer noted that on any one day in eastern Macedonia up to 5.6% of the village population was incapacitated during the malaria season. In the summer of 1936, 69% of the infants in those Macedonian villages under observation were infected. It was estimated that about two million of Greece's seven million inhabitants were malarious. See Great Britain, Admiralty Handbook, Naval Staff, *Greece* I (London 1944) 170-75 and 270-80, and the studies cited by Hackett, in Boyd, *Malariology* 796. For a basic demographic survey of the incidence of malaria in modern Greece, see M.C. Balfour, "Malaria Studies in Greece. Measurements of Malaria, 1930-33", *American Journal of Tropical Medicine* 15 (1935) 301-30.

8. Malaria was also endemic in the eastern sections of Yugoslavia in the 1930s and spread quickly as the result of the govemment's policy of shifting soldiers from one province to another. See H.E. Sigerist, *The Sociology of Medicine,* ed. M.l. Roemer (New York 1960) 97.

9. *Malaria, a neglected factor in the history of Greece and Rome* (London 1907). and *Malaria and Greek history* (Manchester 1909).

10. *E.g.., Malaria and Greek history* 101-108.

11. Bruce-Chwatt 377.

12. *Malaria and Greek history, passim.* A useful epitome of Jones' *testimonia,* conclusions and historical theories can be found under his name as "The prevalence *of* malaria in ancient Greece," in *Diseases in Antiquity,* ed. Don Brothwell and A.T. Sandison (Springfield, I11 . 1967) 170-76.

13. In modern Greek "malaria" is either *elodis pyretos* or *elonosia.*

14. E.g., Bruce-Chwatt 377; Harrison 1; Russell 80-82; Sigerist 301-302; Adam Patrick, "Disease in antiquity: Ancient Greece

and Rome", in *Diseases in antiquity* 238-46; Douglas Guthrie, *A history of medicine* (London 1945) 57; Arturo Castiglioni, *A*

history of medicine, trans. E.B. Krumbhaar (New York 1940) 163 and 170; and Henry E. Sigerist, *History of Medicine* 11 (New

York 1961) 328-30.

15. J.L. Angel, "Porotic hyperostosis, anemias, malarial and marshes in the prehistoric eastern Mediterranean", *Science* 153 (1966) 760-63 [henceforth *Science],* "Porotic hyperostosis and osteoporosis symmetrical", in *Diseases in antiquity* 378-89; and "Ecology and population in the eastern Mediterranean", *World Archaeology* 4 (1972) 88-105 [henceforth *World Archaeology*]. It must be emphasized here that agreement among anthropologists and biologists on many of these technical medical matters is

lacking. Malaria itself is a complex disease; its mechanisms and pathological effects are not completely understood. In the following pages I cannot claim to have avoided controversy, as any serious review of the medical literature will confirm. I hope, however, to have provided for my fellow ancient historians a fair summary of the main trends, and to have shown that there is little to suggest that malaria was absent from Greece classical times.

16. For a detailed review of the processes of acquired and innate immunities to malaria, see Carol Laderman, "Malaria and progress: some historical and ecological considerations", *Social Science and*

Medicine 9 (1975) 587-94, with comprehensive bibliography.

17. *Ibid.* 589 and 592.

18. *Ibid* 488-89, with bibliography for the mechanics of the process.

19. Summarized in A.C. Andrews, "The bean and Indo-European totemisms, *Amer. Anthropologist* 15 (1949) 274-92.

20. Walter Burkert, *Lore and science in ancient Pythagoreanism,* trans. E.L. Miner, Jr. (Cambridge, Mass. l 972), passim, esp. l83-5. The fava-Pythagorean link is, however, no aid in attempting to date the introduction of malaria into classical Greece. Pythagoras was a sixth-century figure, but the earliest firm date for the writings of the Pythagorean school in which the bean is mentioned is the fourth century. See Burkert, 97- 120, and Holgor Thesleff, *An introduction to the Pythagorean writings of the Hellenistic period,* Acta Academiae Aboeosis, Humaniora XXIV.3 (Abo 1961) 30-45.

21. Paul B. Burke, Jr., of Clark University, has recently argued in his detailed study of favism and the Pythagorean taboo that loog-term exposure to malaria led the peoples of antiquity to develop a substantial lore about the bean. l am grateful to Dr. Burke for permitting me to see and use a draft version of his paper, "Malaria in the ancient world: Prolegomenon to an ecological and environmental study" presented at the 1978 meetings of the American Philological Association and now being prepared for publication.

22. *World Archaeology* 98.

23. *Ibid* 94-95 and 100 (". . . malaria may have actually disappeared."); also *Diseases in antiquity* 384, and *Science* 760-63.

24. Angel was aware of some of the problems inherent in the attempt to connect hyperostosis with thalassemia and thus malaria; see *Diseases in Antiquity* 381-84.

25. The statistical bases for Angel's conclusions raise some questions about method. The table in *Science,* which serves as the foundation for the hyperostosis-malaria link, gives the following data for Greece (my summary):

Site Date No. skeletal remains

Nea Nikomedeia 6000 BC 45

Kephala, Kea 3000 BC 37

Corinth 2400 BC 21

Lerna 1800 BC 149

Classic Greece [*sic*] 450 BC 115

The frequencies of hyperostosis vary among these remains; what can be concluded from such variations? The data are drawn from one site in Macedonia, two in the Peloponnesus, one on Kea island, and one general category. They represent a chronology ranging from the early Neolithic to the classical periods, but at widelyseparated sites. Further, there is no topographical evidence to provide a common frame of reference for anopheline ecology beyond a proximity to marshes. With respect to the aforementioned we have already seen that at least one malaria vector *(A. superpictus)* is a stream, not a marsh, breeder. An examination of the statistical tables in Angelo 1967 *(Diseases in Antiquity)* and 1972 *(World Archaeology)* articles reveals that the data are based on the same few sites (plus some new excavation material), and arranged virtually in the same manner. The method seems questionable on the grounds that a constant geographical or chronological reference is lacking. If, for example, one were to take a single site (or region) and examine skeletal remains representing a long period of time--say, several centuries--it might be possible to produce a history of the health of the inhabitants of that locale. Moreover, if several such area-analyses existed, we would be in a position to speculate about a large region such as Greece. But to utilize materials from a handful of sites scattered throughout the Aegean world over a 5500-year period--a sample lacking any constant factor--does not, on methodological grounds alone, seem convincing.

Further, the statistical sample is small, and percentage figures can be misleading. In one case (Angel's report on Neolithic human remains in "Excavations in the Franchthi Cave, 1969-71. Part II", *Hesperia* 42 (1973) 277-82) it is stated that 31 % of

the Neolithic skeletons at the Franchthi cave showed evidence of hyperostosis, and were probably rnalarious. This is an impressive figure until one realizes that the evidence is drawn from the remains of four persons out of a total of thirteen discovered. Similarly, we may note conclusions derived from four persons at early Bronze Age Corinth, and two skeletons from the late Bronze Age level at Episkopi, Cyprus. The percentages drawn from the observable hyperostosis in these human remains serve to plot curves upon which Angel bases his theories about the incidence of malaria in the entire eastern Mediterranean.

One of the oddest examples of this method occurs when Angel describes adult porotic hyperostosis at the 4% level ("trace to slight degree", *World Archaeology* 101) in the modern period, even though there is abundant first-hand evidence that much of the Balkans (especially Greece) was malarious in the extreme in recent times (see note 7 above). And it will be recalled that this same 4% level for hyperostosis was given for the Greek archaic period when malaria, according to Angel, was declining to virtual nonexistence in the classical period (see note 23 above).

26. *World Archaeology* 97.

27. G.L. Fraser *at al,* "Thalassemias, abnormal hemoglobins and Glucose-6-Phosphate Dehydrogenase deficiency in the Arta

area of Greece: Diagnostic and genetic aspects of complete village studies", *Annals of the New York Academy of Science 119*

(1964) 415-35. The studies accepted by Angel, *Diseases in antiquity* 385, offer a contrary view.

28. See Laderman 589-90, who points out that to explain porotic hyperostosis in the New World, Angel posits causes other than malaria: iron deficiency and prolonged lactation, restricted childhood diet, dysentery and response to other parasitic infections. Laderman comments: "With so many choices before us, why should we attribute porotic hyperostosis in two groups of early farmers to thalassemia alone? With a change from hunting and gathering to sedentary farming [precisely the stage of development of the Nea Nikomedeia farmers] there are many opportunities for anemia to develop, including parasitism and infection of all sorts, as well as dietary deficiencies."

29. *World Archaeology* 89 and 100. George H. Denton and Stephen C. Porter, "Neoglaciation," *Scientif c American* 222.6 (June 1970) 100-110.

30. See Denton and Porter's diagram (p. 107) of estimated average fluctuations of mountain glaciers.

31. *World Archaeology* 89 ff. We have already noted that the presence or absence of marshland *per se* is not a contributing factor to the incidence of thalassemia, and also that bone enlargement can result from other than thalassemic conditions.

32. Roughly speaking, there is a constant amount of free water on this planet. It exists in the atmosphere, in seas, lakes, rivers, etc., and in the form of ice and snow. The balance between the amount of water in ice sheets and glaciers and in the sea will shift depending upon the temperature of the general climate.

I accept the view that the change in the level of the Mediterranean in historical times has been no more than 30-S0 cm; see W. Gordon East, "The destruction of cities in the Mediterranean lands," *The sixth J.L. Mares memorial lecture* (Oxford 1971) 4-5, following the archaeological-geological surveys of N.C. Flemming, for which see below.

33. As far as Angel's argonauts on the efficacy of man-made marsh drainage are concerned, the only evidence we possess is Theophrastus' statement *(de Caus Plant.* 5.14.6) that Philip II reclaimed the water-logged plain of Philippi. There is no evidence for drainage in Emathia, and the Lake Kopais region of Boeotia (heavily malarious in modern times) remained marshy following the breakdown of the Mycenaean drainage system. Pollen analysis in the Kopais region shows that the forests had been decimated since at least Bronze Age times; see J.R.A. Grieg and J. Turner, "Some pollen diagrams from Greece and their archaeological significance", *Journ. Archaeol. Science* 1 (1974) 177-94. Malaria may be the "fever" mentioned as having struck the region not long afler the battle of Chaeroneia (338 BC); see Theophr. *Hist. Plant* 4.11.3.

34. Laderman 587-88 and 592-93, and L. W. Hackett, "Distribution of malaria", in Boyd, *Malariology* 722-35. esp. p. 730.

35. "The battle of Salamis," *JHS* 76 (19S6) 32-54, esp.35-36, and *Epirus* (Oxford 1967), see index under "Sea level, changes of."

36. "The campaign and battle of Marathon" *JHS* 88 (1968) 13-57. Revised versions of both the Salamis and Marathon papers appear in Hammond's *Studies in Greek history* (Oxford 1973), but nothing there affects the present discussion.

37. N.C. Flemming, N.M.G. Czartoryslca and P.M. Hunter, "Archaeological evidence for eustatic and tectonic components of relative sea level changes in the South Aegean., *Marine Archaeology,* ed. D.J. Blackman, Colston Papers, Vol. 23, Proceedings of the 23rd Symposium of the Colston Research Society (Bristol 1971) 1-63. Also see Flemming, *Cities in the*

sea (New York 1971), App. II, and "Changes of land and sea level in the Aegean area since the Bronze Ages", 155

57. The view the the sea reached close to its present level about 5000 years ago is found in H.E. Wright, Jr., "Glacial

fluctuations, sea-level changes and catastrophic floods," in *Atlantis: fact or f iction?* ed. Edwin S. Ramage (Bloomington, Ind. and

London 1978) 161-74.

The matter, however, is being debated. Opposed to Flemming's view, and arguing that the Mediterranean

sea level has been rising at the rate of about one meter per millennium since about 6000 BC, is John Bintliff, *Natural*

environment and human settlement in prehistoric Greece, British Archeological Reports, Suppl. Ser. 28i (Oxford 1977) 13-26, although in his preface (p. 1) he suggests that he feels less confident about his argument than when he first wrote it. Bintliffs

thesis is summarized in his "New approaches to human geography. Prehistoric Greece: A case study., in F.W. Carter (ed.), *An*

historical geography of the Balkans (London, New York and San Francisco 1977), chap. 3.

38. E.g., thc block of the Peloponnesus is now tilted relative to its position in antiquity, and apparently southeastern England is sinking, with London some 12 feet lower today than it was in Roman times. In Greece the effect of land subsidence caused by seismic disturbances was clearly recognized by the excavators of the (now) underwater harbor site at Kenchresi on the east side of the Corinthian isthmus. See Robert Scranton and Joseph Shaw, "Changes in relative sea levels, App. E in Robert Scranton, Joseph W. Shaw and Leila Ibrahim, *Kenchreoi, eastern port of Corinth I. Topography and architecture* (Leiden 1978). The authors have compiled a useful list (with sources) of earthquakes attested in the region and have added an outline of the effect of these seismic disturbances, which have resulted in a subsidence of more than two meters since Roman times. In some cases, however, earth movements have caused a relative rise in land forms, as in the example of the isthmus of the Athos peninsula, which is nearly 14 meters higher today than when Xerxes cut a canal through it. An important methodological point emerges from these studies: the evidence of a few scattered submarine remains from antiquity cannot, without corroborating geological data, be used alone to prove that there has been a general rise in the sea level of the Mediterranean.

39. For example, a comparison of Denton and Porter's data (op. cit., n. 29) showing estimated average fluctuations of mountain glaciers (an indicator of shifts between warmer/wetter and cooler/drier climate patterns) with pollen records from the plain of Philippi shows *no* correlation between climate change and the two brief periods *(ca.* 1900-1300 BC and *ca.* 1050-500 BC) during which a few olives grew in the region. See Denton and Porter 107,and Grieg and Turner (cit. n. 33)*, passim.* For a review of additional studies supporting the notion that the climate of Greece today is much as it was in Classical antiquity, see Bintliff, *Natural environment* 51.

40. Although the famous honey-bees have fled Attica's Mt. Hymettos for relief from the quarrying operations, the small purple Hymettan flowers that occasionally suffuse Athens' atmosphere with a reflected pale violet light in the late afternoon sun still exist. For Hesiod's comments on the seasons see *Erga* 383ff., 415ff., 448ff., 479ff., and 564ff. While we cannot pinpoint Hesiod's home-town of Ascra, the region of Mt. Helikon where it was located is still "bad in winter, difficult in summer, good at no time" *(Erga* 639-40). On the abundance of pine, oak and beech--major Macedonian woods today--in antiquity, see, e.g., Theophrastus, *Hist. Plant.* 3.8.7; 3.9.2,6; 3.10.2; 4.5.5; 5.2.1. For a useful survey of Macedonian timber resources see E.C. Semple, *The geography of the Mediterranean region. Its relation to ancient history* (London 1932) 276-77. The olive tree, which characterizes the "Mediterranean" climate *par excellence,* is not a regular feature of the Macedonian scene. Mention of its existence in Macedonia is lacking in our ancient sources (except for a fragment of Theopompus in Athen. 3.77E, which is too complex to deal with here beyond pointing out that it is mainly nonsense, speaking as it does of double-bearing fruit trees and fig trees, vines and olive trees producing fruit in the middle of Spring). Except for the southern slope and the peninsulas of the Chalcidice, the olive is rarely seen in Macedonia. the climate being too harsh and unmitigated by Mediterranean sea-breezes. The northern limit of olive trees I have observed lies along the northwestern Chalcidic coast about 20 miles south of Salonica (This, of course, excludes the single tree which the Director of the New York and San Francisco 1977), chap. 3. Archaeological Museum in Salonica claims to have planted and nurtured in the Museum courtyard!) For a general survey of plant life in Macedonia see W.B Terrill, *The Plant-liJe of the Balkan peninsula A phytogeographical study* (oxford 1929).

As for fauna, many of the wild and domesticated animals of antiquity--goats sheep, cattle, boar, pigs--are common enough today in the mountains and plains of the region. Finally, both Xerxes and Odysseus would appreciate the warnings on wind force at Athos and Malea mentioned by any Mediterranean pilot's guide, and confirmed by the Greek Meteorological Service; some of this information appears in a table which accompanied my "Alexander's Communications", *Archaia Makedonia* II (Thessaloniki 1977); see p. 303 for Kythira, lying opposite Malea. Where these matters can be checked, it appears that the general climate of Greece in modern times is similar to what it was in classical antiquity.

41. See Bruce-Chwatt 36S-77.

42. Evidence of malaria may exist in some first-millennium BC mummies, and splenomegaly is mentioned in Egyptian medical texts *(ibid.),* although the symptoms may reflect other diseases as well. It would appear that malaria was more prevalent in upper Egypt than in the region of the Nile Delta; see the studies cited by Bruce-Chwatt 373 and 376. One also recalls that Herodotus commented on the excellent health of the Egyptians (2.77), even while describing (2.95) the annoying biting flying insects--probably mosquitoes. Much of the above is confirmed by modern experience. It is curious that lower Egypt--in particular the vast Delta, which on ecological grounds alone would appear likely to be malarious--is only mildly infected, even though the country is surrounded by regions of intense malaria in the eastern Mediterranean and tropical Africa. None of the deadly anopheline vectors of East Africa, the Near East or the northern Mediterranean littoral inhabit the Nile Delta The short life of the ubiquitous Delta mosquito, *A. pharoensis,* living under conditions of extreme heat and low humidity, plus the inability of the fearsome *A. gambiae* to penetrate into Egypt from the south because of the geographical configuration of the upper Nile valley, has made transmission of the disease into the region difficult. Only in the oases of the Western Desert, where some hardy anophelines have adapted to the harsh existence, and in the pools of the upper Nile is malaria a serious health hazard; see Hackett, in Boyd, *Malariology* 794-9S, and George Macdonald, *The epidemiology and control of malaria* (London 1957) 51 and 75-77.

43. Evidence for antiquity cited in Jones, *Malaria and Greek history* 23-59 (nonmedical writers) and 61-73 (medical writers). Also, see a selection of passages describing malaria drawn from the Hippocratic corpus, Aristophanes, Varro. Celsus, Pliny the Elder and Martial, in R. H. Major, *Classic descriptions of diseased* (Springfield, Ill. and Baltimore 1939) 105-111.

44. Henry E. Sigerist, *History biomedicine II (cit*. n. 14) 66; Bruce-Chwatt 377, whose citation of Sigerist is incorrect.

45. See Bruce-Chwatt 376, for the incidence of malaria in Mesopotamia as early as *ca.* 2000 BC. Sigerist, *The Soc. of Med.* (cit. n. 8) 338, suggested that Greece was saved because of the outbreak of an epidemic of malaria that decimated the Persian armies. Sigerist, however, offered no evidence for this, and the reader is left wondering whether the Persians suffered from an affliction brought with them or from one contracted in Greece.

46. Laderman (p. 592) is among others who have suggested a Persian source for the disease. For another example of an infected army spreading malaria, see note 8 above. An extraordinary example of malaria being transmitted into a region by an infected person occurred in 1952-53, when a single outbreak of 35 cases was reported in California All the victims were females (mainly teenagers) who had spent 12 days at a Camp Fire Council summer camp at Lake Vera, California, in the foothills of the Sierra Nevada near the Nevada border. Anopheline mosquitoes inhabit the area, but malaria was virtually unknown in the region. Intensive investigation of the outbreak revealed that the source of the infection was probably a single American serviceman, recently discharged after duty in Korea, who himself had suffered a malaria attack, and who was known to have spent a holiday weekend at Lake Vera. The presence of the infected man in the area in early July, and the appearance of symptoms among the girls not long afterwards, coincide with the acceptable timing for infection and transmission by the mosquito vector. See Rosemary Brunetti, RF. Fritz and A.C. Hollister, Jr., "An Outbreak of Malaria in California, 19S2-S3", *Amer. Journ. of Trop. Med. and Hygiene* 3 (19S4) 779-88. The development of international travel on a mass scale at a time when malaria is increasing in the tropical and subtropical regions (see note 2 above) raises the spectre that the disease may again become a serious world health problem. Indeed, during the final days of revision of the

present paper, the travel section of the Sunday edition of the *New York Times* (May 11, 1980) carried a bleak and ominously-entitled article, "Travelers Are Warned of Increasing Danger of Malaria."

47. See note 34 above.

48. In Greece the Lake Kopais region was also highly malarious in modern times, yet continued to support a large, though diseased, population. For the possibility that the area was malarious in antiquity, see note 33 above.

49. I have not attempted yet to read through the accounts of death and disease among the ancient Macedonians as preserved in authors from antiquity, but attention should be called to the article of Donald Engels, "A note on Alexander's deaths, *CP 73* (1978) 224-28, who argues that Alexander died of malaria first contracted in Cilicia. Perhaps the king was reinfected at Babylon, the original source of the disease having been Macedonia itself.

One might also wonder whether, when in the course of a campaign against the Olynthians in 380 BC the Spartan king Agesipolis came down with fever and died at Aphytis on the Cassandrean peninsula, the "fever" might not have been malaria. See Xen. *Hen.* 5.3.10; Diod. 15.22.2, 23.2; Paus. 3.5.9; Tod, *GHI* 2.120. My thanks to Professor Fordyce Mitchel for calling this incident to my attention.

50. *History of Macedonia* I (cited n. 1 above) 149 and 160.

51. Admiralty Handbook, *Greece* 111 (cited note 7 above) 140 and plate 57.

52. The most comprehensive recent studies are by Hammond, *History of Macedonia* I 145-47, C.F. Edson, "Strepsa

(Thucydides 1.61.4)", *CP* 50(195S) 176, and J. Bintliff, "The plain of Macedon and the neolithic site of Nea Nikomedian", *PPS* 42 (1976) 241-62. and *Hisr. Geog. Balkans* (cited n. 37 above), chap. 3 Whose reconstruction of the geological history of the Emathian plain I follow. Apparently the observable chages in the plain's topography are the result of a fairly well understood alluvial process, not of any tectonic or volcanic shift.

53. See the distribution of prehistoric sites in D.H. French, Index *of prehistoric sites in central Macedonia (Athens* 1967),

now reproduced as an end paper in R.A. Crossland and Ann Birchall, *Bronze Age migrations in the Aegean. Archaeological and*

linguistic problems in Greek prehistory (London 1973).

54. Modern maps and travellers' accounts agree that medieval and modern settlement also was confined to the nearby higher ground. The eshablishment of villages in the plain itself had to await the twentieth-century program of reclamation.

55. This is, roughly speaking, the route of the new National Road, from which can be seen, near the village of Kleidi, the sole remnant of the Roman road, an impressive bridge arch. For background, see Hammond, *History of Macedonia I* 162, and Edson 180.

56. In Colonel Leake's time (1806) the lake of Yiannitsa was deep and fresh enough to provide large pike to the residents of Naoussa. See William Martin Leake, *Travels in northern Greece* 111 (London 1835) 287.

57. We must assume that Macedonian farmers, like those of Egypt and Mesopotamia in an earlier age,

were capable of irrigating and draining land on a small scale. But the evidence is lacking for any large-scale reclamation in the Emathian plain, which was not receptive to flood-control and irrigation works as used in thc Nile and Tigris-Euphrates valleys. Even at Babylon, flooding continued to be a problem, and we hardly need a reminder that it was in those very Babylonian marshes that Alexander's final ailment struck; see note 49 above.

58. I am indebted to Don Brothwdl, Department of Environmental Studies of the University of London, to Alexander C. Tokarewicz, M.D., and to the library staff of the London School of Hygiene and Tropical Medicine for their assistance with some of the technical medical aspects of this paper. The Editor of and readers for this Journal have offered additional valuable criticism, which I acknowledge with gratitude. None of the above is to be held responsible for my views.