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Culture, Environment and Disease: Paleo-anthropological Findings for the Southern Levant

PATRICIA SMITH[1] and LIORA R. KOLSKA HORWITZ[2]

[1]The Laboratory of Physical Anthropology, [2]Department of Evolution, Systematics and Ecology, The Hebrew University of Jerusalem, Israel

Abstract

Most of our knowledge of the prehistory of disease in relation to culture and technology is based on the examination of skeletal remains dated to the last 20,000 years and so post-dates the emergence of *Homo sapiens sapiens*. There is little chance that we will ever recover sufficient material to directly assess disease incidence in the four million years of human evolution that preceded the development of modern humans. However, the archaeological record does provide some indication of habitats utilized, diet and methods of food preparation, as well as estimates of group size and interaction. In this presentation the extent

courtyards from the Upper Paleolithic to Chalcolithic Periods and are also present, in low frequencies, in Bronze Age and Iron Age sites alongside large necropoli. Even if the intramural graves were located in abandoned dwellings, they were still in close proximity to the living. Prior to the Late Bronze Age (14th century BCE), when public toilets may have existed in urban areas, there is no evidence of drainage channels or other sanitary arrangements. Toilet seats of pierced stone, placed on ceramic pots or draining into pits, have been identified from the Iron Age in urban settlements such as Jerusalem (Cahill et al. 1991). The earliest constructed water well dates to the terminal PPNB of Atlit Yam (Galili et al. 1993). Wells, together with cisterns in later periods, have traditionally provided water in most regions of Israel where there is only winter rainfall and few perennial rivers. In Israel, there is no evidence of large-scale irrigation projects such as those characteristic of Egypt and Mesopotamia (Adams 1966), but in the Chalcolithic and Byzantine periods, there is evidence to suggest water management using check dams and flood water irrigation (Levy 1995; Evenari et al. 1982).

Paleoclimate

Today Israel comprises three distinct phyto-geographic zones (Fig. 2). The northern Mediterranean zone is characterized by high annual rainfall (800–900 mm in the Carmel region) and lush vegetation cover; it contrasts with the arid, Saharo-Arabian zone in the south, with an annual rainfall of less than 250 mm. To the east, the Jordan Valley is characterized by Irano-Turanian steppe vegetation with semi-tropical enclaves (Orni and Efrat 1980). Until this century, marshy swamps predominated along the Mediterranean coastal plain and around the Hula Lake in the Jordan Valley. The boundaries between these zones have fluctuated markedly in the past, in response to global changes in climate (temperature and rainfall) and with variations in the sea level (Horowitz 1992).

In the Upper Paleolithic and Kebaran periods, the climate was cold and dry. In the Geometric Kebaran the climate became warmer and
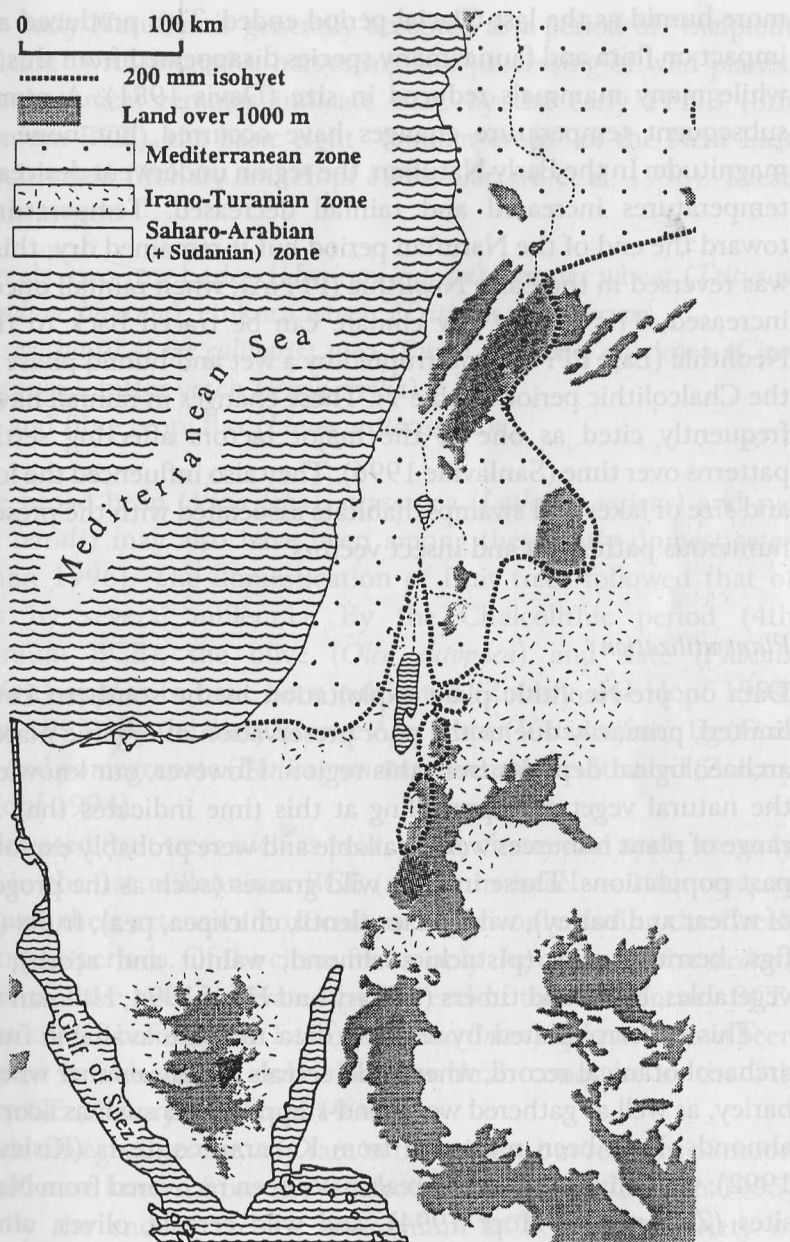
Fig. 2. Map of southern Levant showing phytogeographic zones.

more humid as the last Glacial period ended. This produced a major impact on flora and fauna; many species disappeared from this region, while many mammals reduced in size (Davis 1981). A number of subsequent temperature changes have occurred, but none of this magnitude. In the Early Natufian, the region underwent desiccation as temperatures increased and rainfall decreased. Temperatures fell toward the end of the Natufian period but it remained dry; this trend was reversed in the Early Neolithic (PPNA), when rainfall once again increased. The current dry climate can be traced back to the late Neolithic (Late PPNB), interrupted by a wet and humid phase during the Chalcolithic period (Table 1). These changes in rainfall have been frequently cited as one of the major factors affecting settlement patterns over time (Sanlaville 1996). They also influenced the location and size of lakes and swamps, habitats associated with the presence of numerous pathogens and insect vectors.

Plant utilization

Data on pre-Neolithic plant exploitation in the southern Levant is limited, primarily due to the poor preservation of organic material in archaeological deposits from this region. However, our knowledge of the natural vegetation prevailing at this time indicates that a wide range of plant resources were available and were probably exploited by past populations. These include wild grasses (such as the progenitors of wheat and barley), wild pulses (lentil, chickpea, pea), fruits (olives, figs, berries), nuts (pistachio, almond, walnut and acorn), herbs, vegetables, bulbs and tubers (Zohary and Hopf 1994; Hillman 1996).

This is corroborated by the few data that are available from the archaeobotanical record, where wild cereals such as emmer wheat and barley, as well as gathered woodland-steppe plants such as acorns and almonds, have been recovered from Kebaran contexts (Kislev et al. 1992); wild olives and wild cereals have been recovered from Natufian sites (Zohary and Hopf 1994), and wild cereals, olives, almonds, watermelon, and figs occur in Pre-Pottery Neolithic contexts (Zohary and Hopf 1994).

The early Natufian is generally accepted as a period of "incipient agriculture" with intensive harvesting and processing of wild plants. Archaeobotanical remains indicate that, by the early PPNB (8th millennium BCE), the basic eight "founder crops" of the Near East were cultivated (Zohary and Hopf 1994; Garrard et al. 1996). These crops included:

- Cereals: two-row barley (*Hordeum vulgare*), emmer wheat (*Triticum turgidum dicoccum*), einkorn wheat (*Triticum monococcum*)
- Pulses: lentil (*Lens culinaris*), pea (*Pisum sativum*), chickpea (*Cicer arietinum*), bitter vetch (*Vivia ervilia*)
- Oli and fibre crop: flax (*Linum usitatissimum*)

The broad bean (*Vicia faba*), grass pea (*Lathyrus sativus*) and rye (*Secale cereale*) may also have been among these early domesticates (Hillman 1996). The domestication of fruit trees followed that of cereals by several millennia. By the Chalcolithic period (4th millennium BCE), the olive (*Olea europaea*) and date (*Phoenix dactylifera*) appear to have been cultivated (Zohary and Hopf 1994; Grigson 1995). By the Early Bronze Age, grape (*Vitis vinifera*), fig (*Ficus carica*) and pomegranate (*Punica granatum*) were also cultivated (Zohary and Hopf 1994).

Cultivated fruit trees such as pear, plum, cherry and apple are only found in the 1st millennium BCE (apples in Israel — 10th century BCE) and their extensive horticulture occurs only during the Greek and Roman periods. Of the citrus fruits, only the citron (*Citrus medica*) appears to have been cultivated by the end of the 4th century BCE, but was known before then. Lemons (*Citrus limon*) appear to have been cultivated in this region only since the Arab conquest in the 7th century CE (Zohary and Hopf 1994).

Finds of vegetables are very rare in this region, but remains of onion and garlic are known from the Chalcolithic onwards (Grigson 1995) while by the end of the 1st millennium BCE, a wide variety of vegetables were grown, including cabbage, turnip, beet, carrot, chicory, celery, endive and globe artichoke (Zohary and Hopf 1994).

Methods of food preparation and storage also became more sophisticated in the periods preceding and accompanying domestication; open fires have probably been used for heating or cooking for hundreds of thousands of years, and earth ovens may date back more than 50,000 years. In this region, the use of pottery for boiling and stewing dates back some 7,500 years (Gopher 1995), and food so prepared can be easily stored, while soups and stews provide a perfect medium for the growth of pathogens. The changes observed in the prevalence and severity of dental disease over this same period demonstrate the increased importance of carbohydrates and reliance on boiled and stewed foods (Smith et al. 1984; Smith 1989).

In the southern Levant there is a 2,000-year gap between the first domesticates — dogs — in the Natufian (Tchernov and Valla 1997), and goats in the late PPNB (Garrard et al. 1996; Horwitz 1996). The full complement of animal and plant domesticates takes several more millennia to be established (Table 1). The advent of plant and animal domestication in Israel was then a prolonged and staggered process, revolutionizing social groupings and environmental balances, as well as exposing human communities to new diseases and sources of contamination.

The skeletal evidence for disease

The diagnostic procedures employed for the identification of disease in skeletal remains from the past draw on techniques used in clinical practice and forensic anthropology (Krogman 1962; Saunders and Katzenberg 1992; Smith 1995a, 1995b). Some are discussed elsewhere in this volume, such as the use of DNA analysis to identify genetic disorders and bacterial infections (Filon et al. 1995), the use of imaging techniques for diagnosis of various joint disorders and other skeletal lesions (Rothschild et al., this volume), or microscopic technics to identify pathogens (Hershkovitz, this volume). However, to date these methods are being applied to only very limited samples.

It must be borne in mind that the size of the skeletal samples available for analysis is small, usually incomplete and has suffered diagenesis, factors which limit the scope and reliability of analyses that can be carried out. Finally, many diseases leave no diagnostic signs on bones and teeth. This is especially true of acute infections causing rapid death. For this reason, most of our estimates of disease loads in early populations are based on the prevalence and severity of developmental defects such as growth arrest lines in the bones, hypoplastic defects of the teeth, or non-specific inflammatory conditions of bones such as sub-periosteal irregular bone formation. While dental caries and periodontal disease are associated with local rather than systemic infections, both are highly correlated with the physical and chemical composition of food. Their prevalence can therefore be used as a marker of the extent of dietary change. Dental lesions are highly correlated with age, since they are accumulative and undergo no repair. They also selectively affect premolars and molars rather than anterior teeth. Estimates of disease from total tooth counts, without correction for tooth type or age, are thus potentially misleading.

The prevalence and severity of many other chronic diseases, such as arthritis, are also highly correlated with age. Individuals younger than 24 years old can be aged with a reasonable degree of accuracy from skeletal and dental development. Age assessment in older adults, however, is much less accurate because of individual variation in the rate of onset of dental and skeletal indicators of senescence. Age assessments so derived may differ by as much as 10 years from chronological age, even when the entire skeleton is available for analysis (Krogman 1962). This imposes limitations on the analysis of age-related morbidity and longevity. Attempts have been made to assess birth rates from changes in the pubic bones of female skeletons, but once again individual variability in the extent of physiological change per birth makes this a far from accurate method (Saunders and Katzenberg 1992). Bocquet-Appel and Masset (1982) have pointed out that most skeletal series recovered from archaeological excavations include individuals from a number of different generations. Since

populations expanding or contracting over time will not experience the same ratio of births to deaths as a static population, longevity estimates derived from such samples will be biased. In Israel these problems are intensified by small sample sizes, poor preservation, and burial customs that in many periods represent selective burial of specific age categories (Smith 1993). For example, in many periods infants were buried apart from adults and older children. In addition, infants and the old may be missing because diagenetic changes are more pronounced in the thin, poorly mineralized bones of immature and old individuals.

Pre-Neolithic

Early humans may have inherited a number of diseases from their ape-like ancestors, such as pinworms and other intestinal parasites, various classes of bacteria and viruses, such as herpes, as well as insect-borne diseases (Cohen 1989; Capasso 1991). However, even early hominids seem to have regularly included meat in their diet, through hunting and/or scavenging, exposing them to a new spectrum of pathogens. Zoonoses transmitted by insects, or directly contracted from hunting, butchering and consuming animals, or working skins, bone and ivory probably formed the main source of infection during this period. Cohen (1989) lists toxoplasmosis, hemorrhagic fevers, leptospirosis, brucellosis, anthrax, salmonellosis, gangrene, botulism, tetanus and trichinosis as some of the diseases contracted from hunting and eating wild animals at the present time, while insects transmit a wide range of diseases including malaria, yellow fever, leishmania, sleeping sickness and 50 or so tick-borne diseases.

Although the human occupation of Israel dates back well over a million years, the total number of skeletal remains recovered that pre-date the last 12,500 years is less than 50, and these include infants as well as fragmentary skeletons represented only by teeth (Smith 1995b). Direct evidence of specific diseases as shown by skeletal pathology in early hominids is rare, with dental disease the most common. However, even this pathology is markedly less frequent than
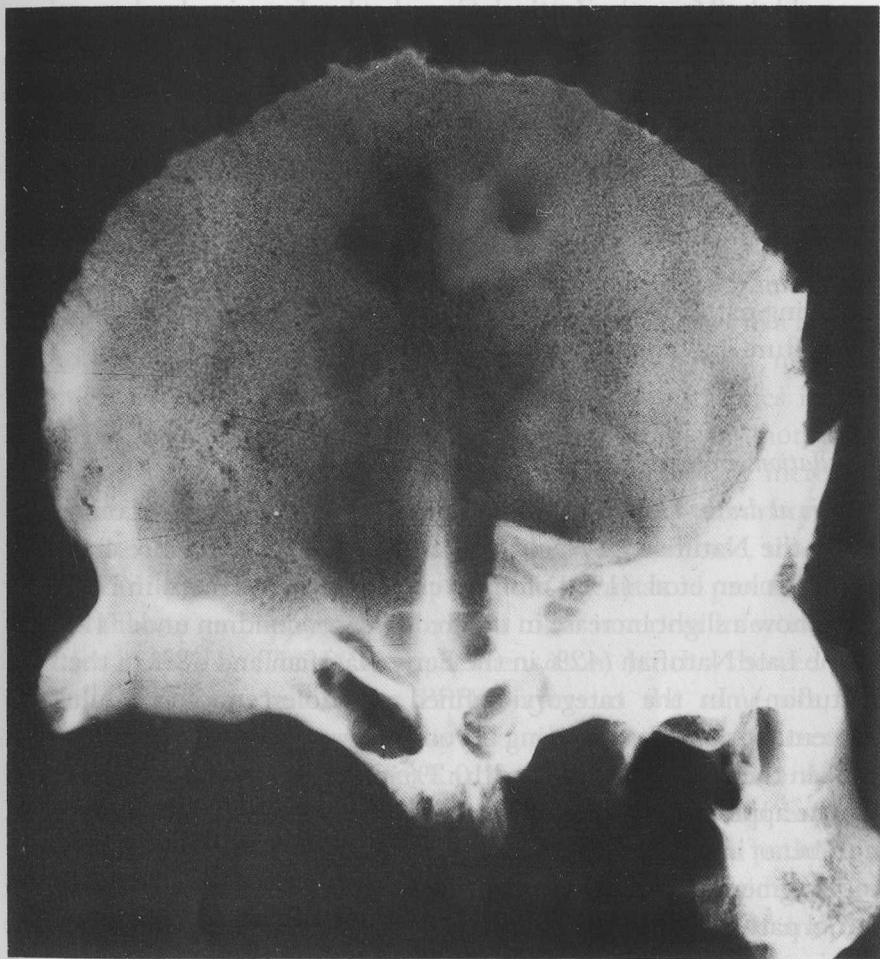
Fig. 3. Radiograph of the frontal bone of the Galilee skull (circa 250,000 BP), showing sclerotic bone formation around central area of resorption.

in later periods. This very small and possibly non-representative sample of prehistoric people from Israel shows little pathology and a low prevalence of dental hypoplasia (approximately one-third of individuals affected compared with over half in later periods: Smith 1991). The only lesion that may be infectious in origin is that seen in the 250,000-

year-old skull from the Zuttiyeh Cave that has four circular depressions on the frontal bone surrounded by sclerotic bone (Fig. 3). They may represent healed incomplete fractures of the outer cranial table, but radiographs show no evidence of bony spicules to support this explanation. A second possibility is that they result from chronic ulcers of the scalp, such as are occasionally found in yaws.

The human skeletal record for the past 12,500 years is far more detailed, and an increasingly explicit picture is accumulating on the changing patterns of human activities during and after the advent of agriculture and animal husbandry.

Populations in transition: the Natufian and Neolithic

Age at death: Few adults appear to have survived beyond the age of 45 in the Natufian or Neolithic Periods. The raw data presented by Belfer-Cohen et al. (1991) for age categories represented in Natufian sites show a slight increase in the frequency of children under 12 years in the Late Natufian (42% in the Early Natufian and 48% in the Late Natufian). In the category defined as adolescent and adult, the percentage of adults surviving beyond 45 years shows little difference: 12% in the Early Natufian and 10.3% in the Late Natufian. However, for the approximately 3,000 years representing the Natufian, the total number of individuals is less than 450, and over 100 of the adults were too fragmentary to be assigned to a specific age category. Moreover, burial patterns within and between sites change over time and indicate that not all individuals were buried in the same way (Perrot and Ladirey 1988). Sample sizes for the Neolithic period are even smaller, and in both periods secondary burials and disturbed burial contexts were commonly encountered, limiting the validity of the data for estimations of mortality patterns. However, few adults in either period show any age-related pathology, such as osteoporosis, arthritic changes or complete closure of the lambdoid and temporal sutures, and this indicates that few if any reached old age.

Disease experience: The sampling problems referred to above obviously influence attempts to define the appearance and prevalence of specific diseases, especially those that cause destruction of bone, such as tuberculosis, since this makes them more likely to be destroyed by diagenesis. Arensburg (1985) commented on the rarity of marked skeletal pathology in the Natufians. Only non-specific arthritic changes (erosions and lipping) have been reported. They are rare and seem to be age-related (Belfer-Cohen et al. 1991). Ante-mortem trauma was present in two individuals, one in a mandible and the other in a femur. In both cases, healing seems to have taken place with minimal infection (Belfer-Cohen et al. 1991). The situation changes in the Neolithic. While there is some inter-site variation in morbidity patterns, the prevalence and severity of skeletal pathology increases dramatically over time. Three of the seven adults recovered from the PPNA site of Hatoula had skeletal pathology. In one case, that of a young adult, abscess cavities were present in the mastoid process of the temporal bone and appear to be related to an inner ear infection (Le Mort et al. 1994). The PPNA specimens from Jericho showed less skeletal pathology, but in the PPNB layers at the same site, 28 individuals had cortical hypertrophy of long bones suggesting increased prevalence of disease at this time (Kurth and Rohrer-Ertl 1981). At the late PPNB site of Basta, Schultz (1987) and Schultz and Scherer (1991) found that 10 out of 35 individuals had endocranial pathology indicative of meningo-encaphalitis, while 64% of the individuals had hypoplastic teeth, reflecting ill health during infancy. At another terminal PPNB site, Atlit Yam, two individuals are alleged to have suffered from thalassemia, a mutation associated with endemic malaria (Hershkovitz et al. 1991). Finally, at Ain Ghazal, Jordan, three individuals showed pathological lesions of the vertebrae, typical of tuberculosis (El Najjar et al. 1997).

to which they may have affected the risk of exposure to different diseases in the past and their role in the evolution of modern population differences in disease susceptibility are discussed.

Introduction

For most literate societies, medical texts and treatises offer insights into the nature and extent of infectious diseases prevalent at the time. Some of the earliest examples of such texts are those from Mesopotamia and Egypt which date to circa 2000 BCE, and contain detailed instructions for the diagnosis and treatment of many of the infectious diseases present in the Near East today, including bilharzia, intestinal worm, skin infections and leishmania (Dawson 1953). Corroboration of the presence of these and other diseases, such as tuberculosis, has been obtained by the discovery of pathogens during the examination of skeletal remains, mummified tissues and feces dated to the same period (Ruffer 1921; Hoeppli 1956; Wilson and Kinner 1967; Sandison 1980). The presence of these diseases in people living some 4,000 years ago suggests that their origins must be looked for in earlier populations.

For pre-historic and proto-historic populations, the presence of these diseases may be assessed in two ways: either directly through the examination of the human skeletal record (Smith 1995a), or indirectly based on inference from the archaeological and paleoenvironmental record. This is founded on the premise that the same factors that are responsible for the emergence and maintenance of diseases today would have contributed to their development and transmission in the past. Thus information on past population size and density (paleodemography) may be obtained directly through the examination of mortality profiles of skeletal remains as well as indirectly from the study of the size and permanence of human settlements. Additional information on the anthropogenic environment may be obtained from examination of housing types, sanitation and water supplies, natural habitats exploited (which support populations of wild animals and

Table 2. Changing patterns of dental disease in the Natufian sites of Hayonim and Eynan (Mallaha) (after Smith 1991)

Site	Condition	Early Natufian, %	Late Natufian, %
Eynan	Caries	15	20
Hayonim		10	12.5
Eynan	A.M. tooth loss	30	40
Hayonim		0*	37.5

*Small sample.
Note: Data presented here are based on the number of adult individuals examined. In Figs. 4 and 5 data are based on the number of teeth examined.

Dental pathology: Fig. 4 shows the frequency of caries and ante-mortem loss in Natufian and Neolithic populations. It increases from the Early to Late Natufian periods (Table 2), and increases further in Neolithic and later periods, attesting to increased utilization of cooked carbohydrates (Smith 1989, 1991). The frequency of enamel hypoplasia also increases over time (Figs. 4, 5). The condition has been attributed to lowered serum calcium levels during the period of enamel apposition (Nikiforuk and Fraser 1981). It results in defects on the enamel of the teeth in the form of pits or grooves. Their location denotes the age of the individual when affected (Fig. 6). Since teeth develop sequentially, those permanent teeth forming at periods of greatest susceptibility — teething of milk teeth, weaning — are more likely to show hypoplastic defects than others. Estimates for the prevalence of hypoplastic defects may then be biased when skeletal remains are compared, unless teeth in the same developmental age category and susceptibility are compared. As can be seen from Figs. 4 and 5, the prevalence of hypoplastic teeth increases in severity from the Early to Late Natufian and increases again during the Neolithic.
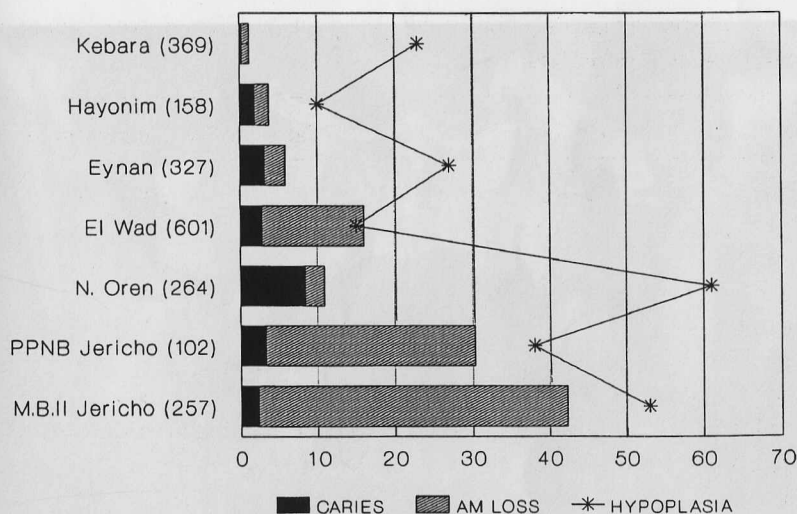
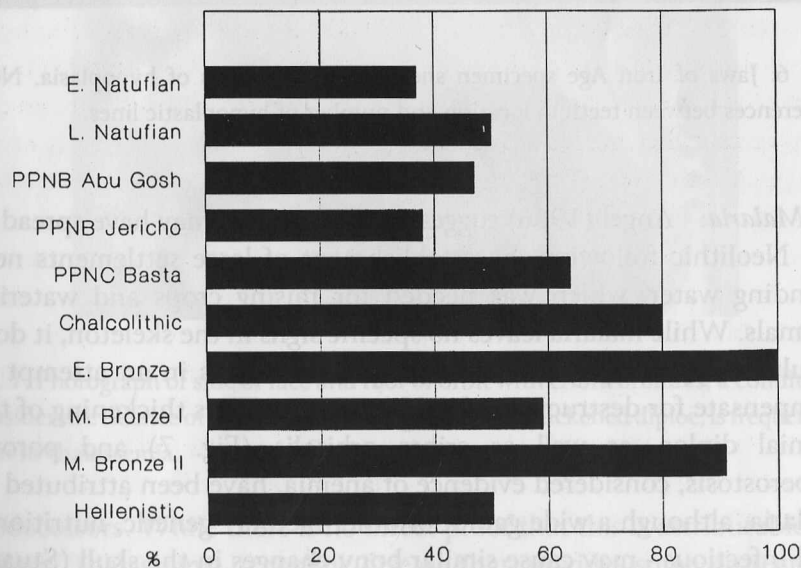Fig. 4. Dental pathology in different periods.

Fig. 5. Frequency of hypoplasia in different periods.

Fig. 6. Jaws of Iron Age specimen showing annular lines of hypoplasia. Note differences between teeth in location and number of hypoplastic lines.

Malaria: Angel (1966) suggested that malaria may have spread in the Neolithic following the establishment of large settlements near standing water, which was needed for raising crops and watering animals. While malaria leaves no specific signs in the skeleton, it does result in hypertrophy of the haemopoietic tissues in an attempt to compensate for destruction of red blood cells. Thus thickening of the cranial diploe, as well as cribra orbitalia (Fig. 7) and porotic hyperostosis, considered evidence of anemia, have been attributed to malaria, although a wide gamut of other factors - genetic, nutritional and infectious - may cause similar bony changes in the skull (Stuart-Macadam and Kent 1992). Skeletal evidence of anemia is significantly more common in Neolithic and subsequent populations than in their
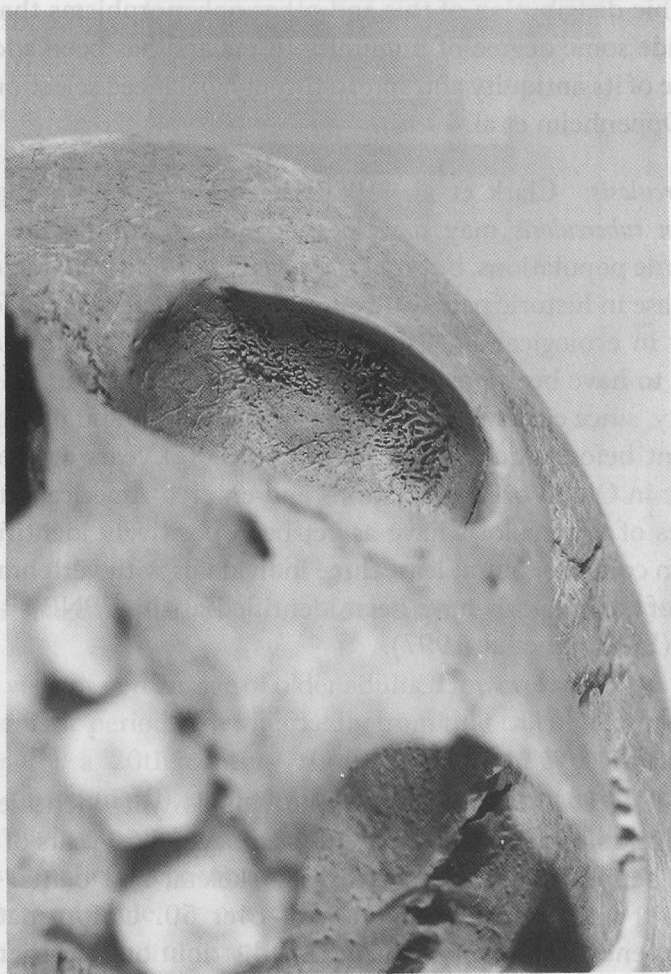
Fig. 7. Photograph of side of face and roof of orbit with cribra orbitalis, a condition considered evidence of anaemia which, together with thickened diploe, is frequently seen in thalassemia.

predecessors. While there is no direct proof that this is attributable to malaria, thalassemia, a genetic disease that provides some protection against malaria in the heterogeneous form, has been identified in two Neolithic individuals from Atlit Yam (Hershkovitz et al. 1991). The

geographic distribution of this and other polymorphisms that appear to provide some degree of immunity to malaria has been adduced as evidence of its antiquity and spread through balanced selection (Weiss 1993; Oppenheim et al. 1996).

Tuberculosis: Clark et al. (1987) have hypothesized that *Mycobacterium tuberculosis* may have been common world wide in early prehistoric populations, but that the severe morbidity characteristic of the disease in historic periods results from altered resistance following changes in ecological and environmental factors. Unlike malaria, it appears to have been present in pre-contact America, attesting to its antiquity, since either the organism was ubiquitous and present in the continent before humans arrived some 30,000 years ago, or it was endemic in Old World populations and entered America with them. No cases of tuberculosis have as yet been positively identified from Natufian contexts, but at least three individuals with vertebral lesions typical of tuberculosis have been identified at the PPNB site of Ain Ghazal (El-Najjar et al. 1997).

Chalcolithic and later periods

Age at death: None of the individuals yet identified from Chalcolithic sites appear to have survived beyond 50 years of age, but in later periods some adults do show skeletal and dental changes consistent with an age estimation of over 50. Unfortunately, the problems encountered in analyzing age distribution in earlier periods still apply. Few sample sizes from any site exceed 200 and most are smaller. At some sites infants under 3 years old are totally absent; at other sites the age distribution is heavily skewed, indicating selective burial, preservation or recovery of different age groups (Smith 1993). In order to minimize the effects of under-representation of children, we have followed Arensburg (1973) and examined the age distribution within the adult category alone. As seen in Fig. 8, most adults from all the archaeological sites appear to die before 50 years of age. The Iron Age seems to be the lowest and the Hellenistic the highest, from the

CHALCOLITHIC
M.BRONZE I
M. BRONZE II
IRON AGE
HELLENISTIC
ROMAN
BYZANTINE
OTTOMAN
EGYPT - RURAL
EGYPT- TOTAL
ENGLAND

0   20   40   60   80   100   120

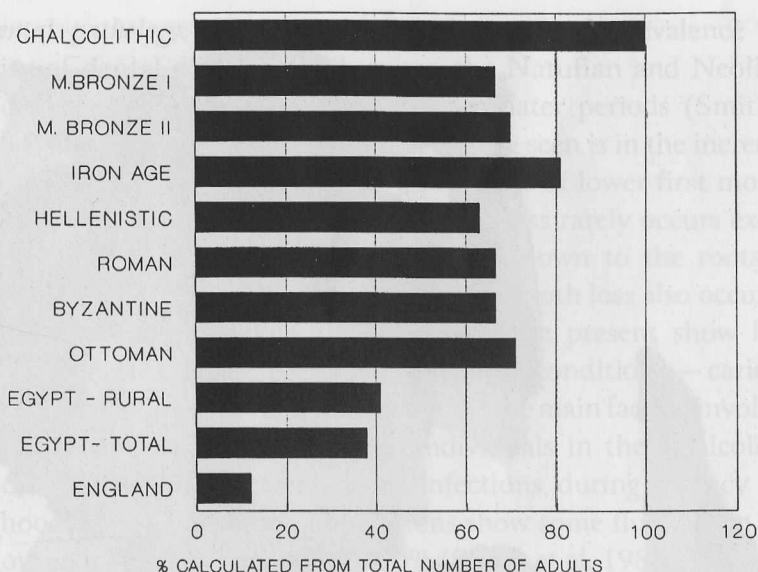% CALCULATED FROM TOTAL NUMBER OF ADULTS

Fig. 8. Percentage of adults dying before 50 years of age (after Smith 1993).

point of view of percentage of older adults. However, even the data for the Hellenistic period differ markedly from that calculated from death registries for a 20th century rural district in Egypt (nearly 60% surviving beyond 50), while WHO statistics for England report over 85% surviving beyond 50 years of age. Either conditions in the Hellenistic period were incomparably worse than those of rural Egypt at the present time, or our data are too incomplete to provide an accurate assessment of longevity.

Disease experience: The trend toward increased severity and frequency of skeletal and dental pathology noted in the Neolithic, continues in the Chalcolithic and Early Bronze ages. Ortner (1979) reports that two individuals from Early Bronze Bab edh–Dhra in Jordan had skeletal lesions typical of tuberculosis, and one adolescent from Gilat, a Chalcolithic site in the Negev, has irregular new bone formation on the endocranial surface of the frontal bone which may be attributable to meningo-encephalitis (Fig. 9). This is accompanied by
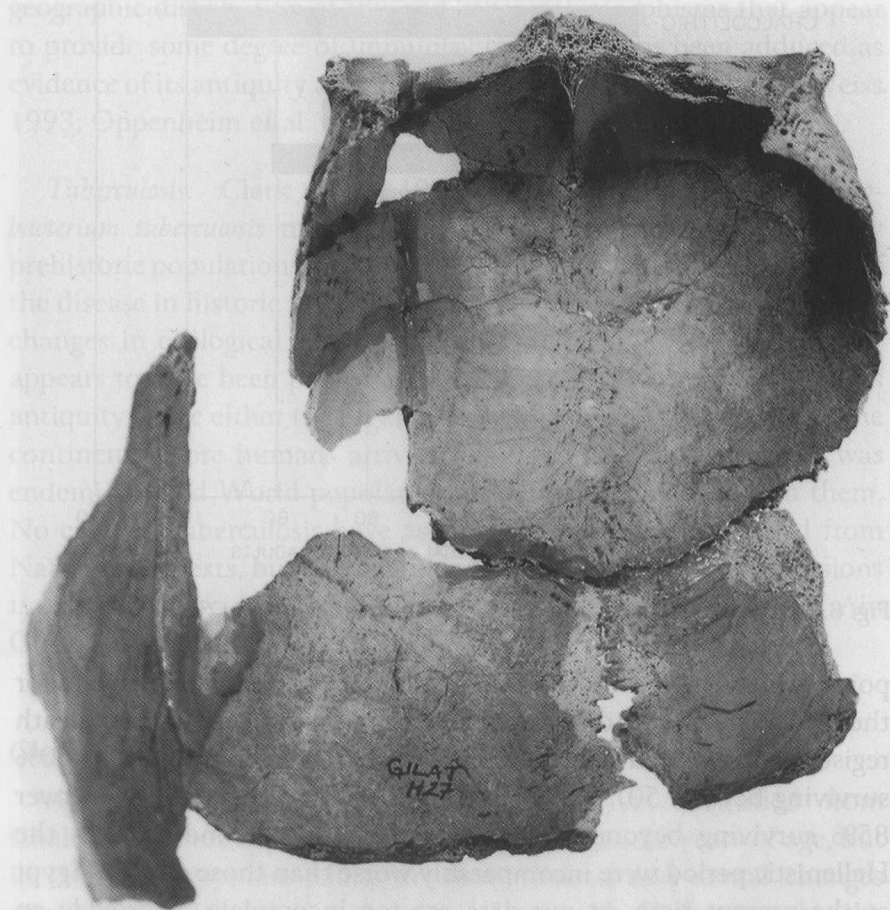
Fig. 9. Endocranial surface of frontal bone from the Chalcolithic site of Gilat, showing irregular new bone formation attributed to inflammation of the meninges.

arthritic lesions of the knee and elbow joints. While the pathology seen in this individual is exceptionally severe, most samples from the Chalcolithic have a high incidence of dental hypoplasia, while periostitis, cribra orbitalia and arthritic changes in the joints of even young individuals are common (Smith et al., in press).

Dental pathology: The trend toward increased prevalence and severity of dental disease seen between the Natufian and Neolithic periods, continues in the Chalcolithic and later periods (Smith et al.1984; Smith 1989, 1991). The main change seen is in the increased frequency of ante-mortem tooth loss, primarily of lower first molars. In pre-Neolithic periods ante-mortem tooth loss rarely occurs except in individuals in whom the teeth are worn down to the roots. In Neolithic and later populations, ante-mortem tooth loss also occurs in young individuals in whom the teeth that are present show little attrition (Fig. 10). This suggests that infectious conditions — caries or peridontal infections — and not attrition are the main factors involved. Enamel hypoplasia affects nearly all individuals in the Chalcolithic period, attesting to recurrent acute infections during infancy and childhood. Post-Chalcolithic populations show some fluctuation, but all show an incidence of more than 50% (Smith et al. 1984; Smith and Peretz 1986).
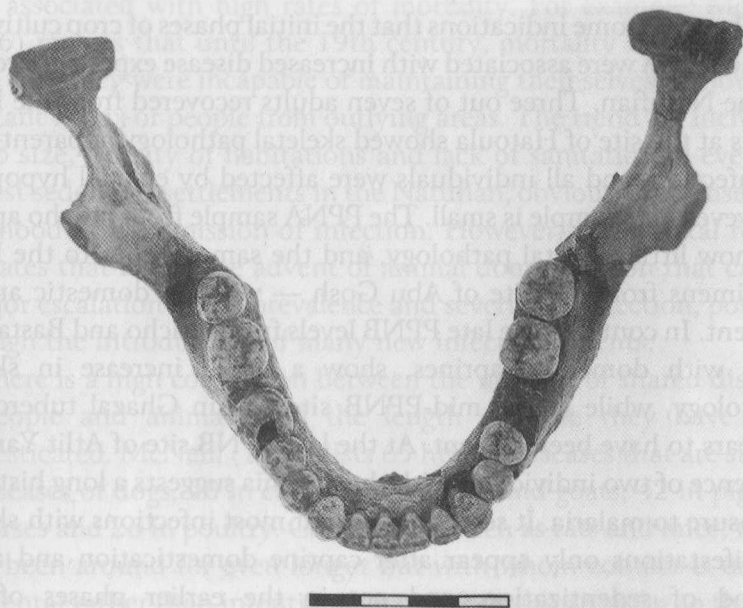

Fig. 10. Mandible of young individual from the late PPNB showing ante-mortem tooth loss of first molars, probably from caries.

Discussion

As the preceding paragraphs have shown, the transition from hunting and gathering to urbanization can be subdivided into a number of chronologically distinct phases. This offers the possibility of good resolution in identifying the timing of specific adaptations and their association with changing disease patterns. The establishment in the Early Natufian of large sedentary communities of hunter-gatherers, focusing on the exploitation of wild cereals, does not seem to have produced any immediate response in disease patterns or increased mortality through large-scale epidemics. On the contrary, it appears that population size increased during this period (Bar-Yosef 1995). By the terminal Natufian, about 2,000 years later, some reduction had occurred in tooth and jaw size, accompanied by an increased frequency of dental disease and enamel hypoplasia. But in the absence of skeletal pathology, it is unclear whether changing diet or emerging pathogens were responsible for the apparent deterioration in health.

There are some indications that the initial phases of crop cultivation in the PPNA were associated with increased disease experience relative to the Natufian. Three out of seven adults recovered from the PPNA levels at the site of Hatoula showed skeletal pathology apparently due to infection, and all individuals were affected by enamel hypoplasia. However, this sample is small. The PPNA sample from Jericho appears to show little skeletal pathology, and the same applies to the PPNB specimens from the site of Abu Gosh — with no domestic animals present. In contrast, the late PPNB levels from Jericho and Basta, both sites with domestic caprines, show a major increase in skeletal pathology, while at the mid-PPNB site of Ain Ghazal tuberculosis appears to have been present. At the late PPNB site of Atlit Yam, the presence of two individuals with thalassemia suggests a long history of exposure to malaria. It seems, then, that most infections with skeletal manifestations only appear after caprine domestication and a long period of sedentization, and not in the earlier phases of crop domestication and initial sedentization.

Disease levels may have risen further in the Pottery Neolithic, with domestication of cattle, pigs and donkeys, but there are few human skeletal remains dating to this period. By the early Chalcolithic, some 6,500 years ago, the burden of chronic disease manifested in dental hypoplasia, cribra orbitalia, and porotic hyperostosis was extremely high (Smith 1989). At this time secondary product utilization of wool, milk and milk products assumed greater importance and was associated with more intensive handling of animals. This may have increased the potential for infection still further.

The establishment of urban societies in the Early Bronze Age created a new set of environmental conditions which further contributed to the establishment of disease. There is no skeletal evidence from the southern Levant to suggest that the health of urban populations differed in any major respect from that of contemporaneous rural villagers. However, historical studies indicate that crowding, poor sanitation and problems of food distribution in towns were associated with high rates of mortality. For example, McNeill (1976) reports that until the 19th century, mortality was so high in cities that they were incapable of maintaining themselves without the constant influx of people from outlying areas. The trend for increased group size, density of habitations and lack of sanitation in even the earliest sedentary settlements in the Natufian, obviously increased the likelihood of transmission of infection. However, the skeletal record indicates that it was the advent of animal domestication that caused a major escalation in the prevalence and severity of infection, possibly through the introduction of many new infectious agents.

There is a high correlation between the number of shared diseases in people and animals and the length of time they have been domesticated. McNeill (1975) lists 65 human diseases that are similar to diseases of dogs, 50 in cattle, 46 in sheep and goats, 42 in pigs, 35 in horses and 26 in poultry. Commensals such as rats and mice, which have been around for even longer but with whom contact is usually accidental rather than intentional, have 32 diseases similar to those of humans. Obviously, prehistoric people may have been exposed to some

insects that serve as reservoirs and vectors of disease), as well as the type and location of stabling for animals and storage facilities, as the latter are known to attract commensals which serve as reservoirs for numerous diseases. The prevailing paleoenvironmental conditions can be reconstructed from archaeozoological and paleobotanical remains. Paleodietary information and inferences on past health status may be directly acquired through the examination of human skeletal remains as well as those of plants and animals recovered from archaeological contexts. The study of non-human organic remains may offer insights into the type of contact with, and/or consumption of, plants and animals (the latter may cause direct infection through zoonotic diseases), as well as information concerning methods of food preparation and selection that may limit or contribute to the multiplication of infectious organisms. Hence the resulting data set may elucidate the origin and development of many of the diseases prevalent in human communities today.

Background

In the course of human evolution, two main adaptations can be identified. The earliest one, still extant in a few localities, is that of hunting and foraging, which has persisted throughout the entire four million years or so of human evolution. The second adaptation, which has revolutionized the intensity of contacts amongst people and between them and animals, stems from animal and plant domestication; it dates back only some 10,000 years. The shift to agriculture and animal husbandry occurred independently in many parts of the world (Smith 1995; Zohary and Hopf 1994). Although the specifics — in terms of founder crops and animal domesticates — vary, in all cases studied this transition seems to have been uniformly associated with an increased disease load (Cohen and Armelagos 1984; Cohen 1989). This is not surprising given the gamut of changes taking place in features such as population size, density and movement, degree of sedentism, settlement size, activity patterns, dietary staples

of these diseases in the periods preceding domestication, but daily handling and stabling of domesticates would have increased the possibilities for infection, whether indirectly from insect vectors, or directly from infected meat, blood or milk (Brothwell 1991). Surgical procedures, such as castration or the removal of horns in cattle, which have been carried out for at least 4,000 years, may have provided an additional avenue for transmission of pathogens. Descriptions of treatment for diseases of animals as well as humans are found in the earliest written records and demonstrate that veterinary medicine was already established as a specialty some 4,000 years ago [the Kahun Papyrus, quoted by Baker and Brothwell (1980:4)].

McNeill (1976) suggests that seven-eight generations of continued exposure are needed for equilibrium to be established between a pathogen and its host population. Neither the sample sizes at our disposal, nor the accuracy of dating techniques currently in use, permit examination of inter-generation trends in disease patterns. It is nevertheless clear that disease load increased after the advent of animal domestication and peaked in the Chalcolithic and Early Bronze ages, when intensive animal husbandry was practiced together with the exploitation of wool, milk and milk products. Horses and camels, both later domesticates, have been implicated as the source of many respiratory diseases, but since these leave no pathognomic signs on the skeleton, there is no direct evidence for this.

The possible role of epidemics on past population size or the abandonment of settlements has yet to be elucidated. There are no mass graves or other evidence in the southern Levant to support the hypothesis that cataclysmic epidemics, similar to those caused by plagues in Europe in the 13th and 17th centuries, were responsible for cyclical reduction of population size in prehistoric periods. However, the Bible and earlier Egyptian texts (Dawson 1953) indicate that such phenomena were not unknown. The cyclical population crashes of societies in the southern Levant have traditionally been associated with droughts and political upheavals rather than epidemics. However, in Europe, infectious disease has been shown to have played a major role in limiting population size (McNeill 1976). The findings presented

here for disease patterns are obviously still incomplete. They do nonetheless illustrate that the prevalence of infectious diseases increased considerably in the wake of animal domestication and have posed a serious health threat in this region ever since.

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Discussion

Henri Atlan: In the previous talk [Ubelaker], the abstract of an article on the osteological paradox has been projected, saying, contrary to your conclusion, that there is as much evidence for an increase in health following the beginning of agriculture and animal domestication as evidence for an increase in diseases. Can you comment about that?

Douglas Ubelaker: There are two ways to look at disease: if you find no evidence for disease in early ones, they may have died before the disease really developed. Alternatively, if you find a disease you can at least say they survived! One of the problems with this area is that rarely do you have enough samples to really look at demography, which requires a minimum of a few hundred skeletons. Even if we look at mortality, how do we distinguish the elements? In nomadic populations the subadults-to-adults ratio is relatively low (few subadults); however, few adults survive to over 40 — is that paradoxical? In sedentary populations the percentage of subadults is high and some adults survive to be much older. Thus changes in social behavior affect the data, i.e., people try and keep you alive in sedentary populations.

and food preparation, trade systems, warfare and population movements.

The archaeological record of the Near East indicates that this region served as the earliest locale for the domestication of plants and animals (Smith 1995; Zohary and Hopf 1994), after which they spread into Europe, Africa and Southeast Asia. Consequently, Israel, with a rich and almost unbroken archaeological record extending back some 1.4 million years, offers a unique sequence for studying the impact of the "Neolithic Revolution" on human health status. This paper draws upon the available evidence from the human skeletal and archaeological record of Israel as regards the evidence for the origin and evolution of some of the infectious diseases prevalent in this region today.

The archaeological record

Paleodemography and settlement patterns

Archaeological estimates of past population densities are based on a variety of features, including the nature of the subsistence base, potential of available resources (carrying capacity), settlement number, settlement size, size of structures and/or number of rooms, while written sources are often used for historical periods (Hassan 1978; Broshi 1980; Broshi and Finkelstein 1992; Falconer 1994; Shiloh 1980).

Early hunters and gatherers occupied a wide variety of environments, as reflected in their diverse technologies and choice of food staples. However, it is assumed that all prehistoric hunter-gatherers shared certain characteristics that served to limit disease. Both archaeological reconstructions of site size and density of occupation, and ethno-historical accounts of sub-recent and recent hunter–gatherers indicate that group size in such societies ranges from 50–200 individuals, with larger groups meeting only temporarily. This is assumed to have limited the establishment of acute infectious diseases, which spread through inter-person contacts. Conditions favorable for the establishment of such diseases are assumed to have

arisen only after the establishment of large permanent communities (McNeill 1976, Cohen 1989). This occurred relatively recently in the history of humankind and, as can be seen in Table 1, it was associated with far-reaching changes in every aspect of life.

In the Israeli record, population size in the Upper Paleolithic (32,000–20,000 BP) appears to have been low. These hunter–gatherer sites are of relatively small size and ephemeral in nature, indicating low population density, a high degree of mobility and, probably, seasonal site usage (Gilead 1995). In contrast, from the Kebaran onwards (circa 20,000 BP) population growth is indicated, as evidenced by an increase in the number of sites associated with longer periods of site occupation (Kaufman 1992; Gilead 1995). By the Early Natufian (circa 12,500 BP) there may have been year-round occupation of some sites in the core region of the Natufian, specifically in the Galilee (Belfer-Cohen 1991; Bar-Yosef and Belfer-Cohen 1992; Valla 1995). The transition to sedentism at this time is assumed to have been rapid and is associated with a further increase in site size, as well as density and duration of settlement (Table 1 and Belfer-Cohen 1991). It was also probably accompanied by a higher degree of social organization and complexity than that characteristic of earlier societies (Bar-Yosef and Belfer-Cohen 1992).

There was, however, no unidirectional trend toward increased site size. During the Natufian — as in all subsequent periods — there is a recurrent pattern characterized by a transient increase in site size and density of settlement, followed by retraction and/or abandonment in sites. This pattern continues until the recent past, as the balance swings between low population density with a greater emphasis on pastoralism, and greater population density with more emphasis on agriculture and large urban sites (Fig. 1). This scenario differs from that seen in the regions to the north and south of the southern Levant, such as Syria and Egypt, where the trend toward increased growth is both more substantial and more unidirectional, and is fairly rapidly followed by the development of urban societies and large states (Adam 1966).

Table 1. Chronology of prehistoric and protohistoric cultures in the southern Levant

Age BP	Period	Main adaptations	Climate
32,000	Early Upper Paleolithic	Hunting and gathering; small bands; highly mobile; ephemeral settlement	Humid
22,000	Late Upper Paleolithic	Hunting and gathering; small bands; highly mobile; ephemeral settlement	Dry, cold
18,000	Kebaran	Hunting and gathering; increased no. of larger sites	Dry, cold
14,500	Geometric Kebaran	Hunting and gathering; increased no. of larger, more permanent sites	Wet, humid
12,500	Early Natufian	Further increase in site size, number and permanency; intensive gathering of wild cereals and pulses for storage-"incipient agriculture"; small game hunting increases in importance	Moist
11,250	Late Natufian	Large, permanent/semi-permanent settlements; "incipient agriculture"; hunting of alrge variety of small game; domestication of the dog	Dry, warm
10,200	Pre-pottery Neolithic A (PPNA)	Sedentary villages; cultivation of domestic cereals; hunting of large variety of small game and birds	Wet, humid
9,400	Early Pre-pottery B (PPNB)	Sedentary villages; agriculture; hunting of medium/small-sized game	Wet, humid
9,200	Middle PPNB	Permanent villages based on agriculture; "incipient domestication" of goats; little hunting	Increased warming and aridification
8,500	Late PPNB	Domestic goats and sheep	Dry, warm
8,100	Pre-Pottery Neolithic C	Village economies based on domestic crops and animals; decreased hunting	Dry, warm

Table 1, continued

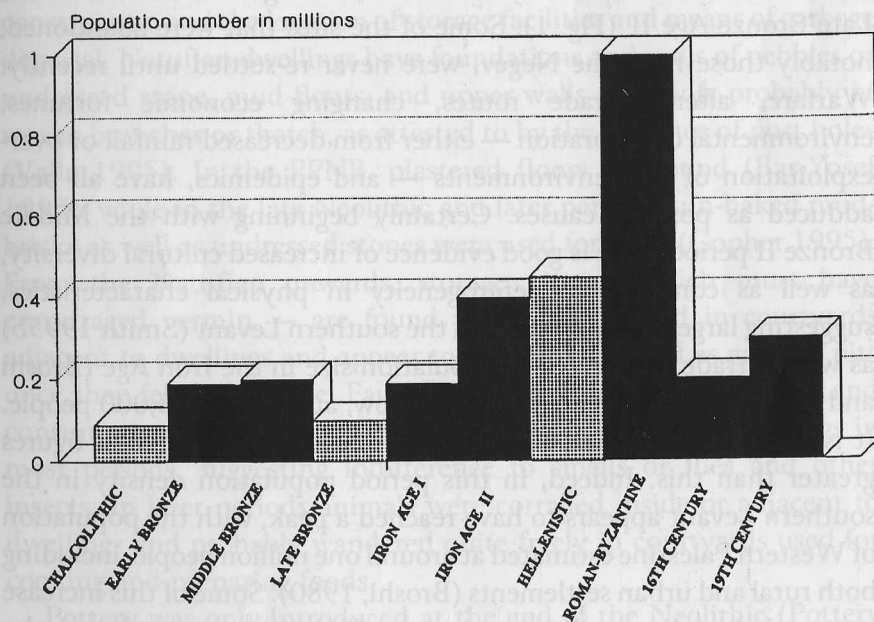| Age BP	Period	Main adaptations	Climate
7,500	Pottery Neolithic	Domestic cattle, pigs and donkey; ceramic vessels for cooking and storage; earliest cemeteries	Dry, warm
6,500	Chalcolithic	Proto-urban villages	Moist
5,500	Early Bronze Age	Urban societies	Dry, warm

Fig. 1. Histogram showing population density over time. Bars in black based on data given in Broshi and Finkelstein (1992). Stippled bars show trends rather than absolute values based on Gophna and Portugali (1988) for the Chalcolithic; Falconer (1994) for the Late Bronze Age; and Smith (1990), Levant 22:123–130, for the Hellenistic period.

In the southern Levant, there are far fewer sites in the Pottery Neolithic (PN) (7,600 BP) than in the earlier Pre-Pottery Neolithic B (PPNB), when many villages ranged from 2,000–12,000 hectares (Bar-Yosef 1995). Population size increases again in the Chalcolithic (6,500 BP). Many settlements are abandoned at the end of this period, especially in the southern desertic region. In contrast, in the first urban period, the Early Bronze II, Gophna and Portugali (1988) and Gophna (1995) estimated that urban populations were of the order of 2,000 and hence smaller than those of the unwalled villages of the preceding Early Bronze Age I, as well as fewer in number.

During the Bronze Age, the cyclical pattern of population expansion and retraction continues, with urban economies crashing at least twice: once at the end of the Early Bronze III, and again at the end of the Late Bronze Age II (Fig. 1). Some of the sites that were abandoned, notably those from the Negev, were never re-settled until recently. Warfare, altered trade routes, changing economic fortunes, environmental deterioration — either from decreased rainfall or over-exploitation of arid environments — and epidemics, have all been adduced as possible causes. Certainly beginning with the Middle Bronze II period there is good evidence of increased cultural diversity, as well as considerable heterogeneity in physical characteristics, suggesting large-scale gene flow in the southern Levant (Smith 1995b) as well as trade. Estimates of population size in the Iron Age (Broshi and Finkelstein 1992) are once again low, at around 403,000 people. It is only in the Roman–Byzantine period that we approach figures greater than this. Indeed, in this period population density in the southern Levant appears to have reached a peak, with the population of Western Palestine estimated at around one million people, including both rural and urban settlements (Broshi, 1980). Some of this increase was probably due to immigration, as Christianity spread and the concomitant importance of the Holy Land grew.

However, while individual settlements may have been small in prehistoric periods, they were not isolated. Presumably from even the earliest periods, there was contact between different hunter–gatherer groups, sometimes accidental where territories overlapped, or organized

for ceremonial purposes and/or exchange. A population of some 200 individuals is probably the minimum number necessary for a group to maintain its reproductive efficiency over time, but phenotypic similarities throughout the southern Levant suggest that gene flow occurred over a wide region (Smith 1995b). Additional evidence of contacts over wide areas is provided by the presence of trade items, such as red seashells in Upper Paleolithic sites from the Jordan Valley (Gilead 1995) or obsidian from Anatolia in the PPNB of the Negev, while during this same period arrow heads were apparently traded from the Taurus mountains to southern Sinai (Bar-Yosef 1995).

From the viewpoint of hygiene and sanitation, both prehistoric and proto-urban settlements left much to be desired in terms of the construction and the location of storage facilities and means of garbage disposal. Natufian dwellings have foundations and walls of pebbles or undressed stone, mud floors, and upper walls and roofs probably of woven branches or thatch, as attested to by the presence of post holes (Valla 1995). In the PPNB, plastered floors are found (Bar-Yosef 1995), while in the late Neolithic and later periods, sun-baked mud-bricks as well as undressed stones were used for walls (Gopher 1995). From the Natufian onwards, storage pits — which must have encouraged vermin — are found within rooms and in courtyards adjacent to dwellings and appear to have often served as garbage pits once they fell into disuse. Faunal remains, comprising butchery and consumption discards, are also common in and around dwellings in most periods, suggesting indifference to smells or flies and other insects. In later periods animals were corralled inside or adjacent to dwellings and probably wandered quite freely in courtyards used for cooking and preparing foods.

Pottery was only introduced at the end of the Neolithic (Pottery Neolithic), by which time permanent village economies were based on agriculture and animal husbandry (Gopher 1995). It is only at this time that intra-mural burial begins to be replaced by cemeteries such as found at Neve Yam and Eilat (Avner et al. 1994). Prior to this period, people were buried in and around dwellings. Graves are found beneath living floors, in disused storage pits and in simple graves in