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# Infectious Diseases in the Levant during Neolithic period

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***ABSTRACT**: This study deals with the possible infectious diseases that afflicted the population of the Levant during the Neolithic period, where social and environmental transformations took place that radically changed the lifestyle of the population, and this was reflected in the health and pathological state of the farming population. The study discusses infectious diseases by focusing on four factors: stability, population density, animal domestication, and environmental change associated with agricultural practices.*

***Keyword**: Paleopathology, infectious diseases, Neolithic, the Levant, Agriculture, domestication, stability.*

## INTRODUCTION

About 10.000 years ago, a major transformation occurred in the lifestyle of semi-stable human groups that live on hunting and gathering in the eastern Mediterranean, as these groups adopted a new economic pattern based on agriculture, domestication and stability. This transformation is called the "Neolithization" that characterizes the Neolithic period. These changes had significant effects on human social organization, demographics, diet and behavioral patterns, which promoted the development and spread of disease infections, as well as the accumulation of human excreta that created optimal conditions for the spread of parasites and disease vectors (Barrett, et al. 1998). There was a belief among researchers in human evolution that the agricultural revolution had a significant impact on human health and disease, with the increased likelihood of malnutrition in agricultural societies, and the increase in work requirements associated with the food production process (Armelagos and Harper 2005). As the dependence on a few domesticated crops would lead to health impairment and make many individuals predisposed to infection (Armelagos and Harper 2005), demographic growth has increased the susceptibility to spread of diseases, creating a favorable environment for infectious agents, especially those of animal origin (Barrett et al. 1998; Harper and Armelagos 2010). Domestic animals were the main cause of transmission of many infectious diseases such as tuberculosis, malaria, smallpox and influenza to humans by jumping bacterial species or viruses from the sick animal to humans in a process called "crossing the species barrier" (Georges and Matton and Courbot-Georges 2004). Infectious diseases of animal origin specialized in humans have emerged, and these bacteria are genetically modified from previous bacteria that had infected the domesticated animal (Diamond, 1997). Domesticated animals such as cows, goats, sheep, and pigs, were kept close by or inside the homes of early agricultural societies (Eshed, et al. 2010). In addition, the expansion of human settlement brought about by demographic pressures and the search for expanded food resources, and the encounter with new, previously uninhabited habitats and environments such as marshes, coastal areas and swamps that are attractive to disease-carrying insects such as mosquitoes, would create health risks with serious consequences for farming communities. The agricultural transformation has been linked to the emergence of a pattern of infectious diseases that still exist today; this was described as the "first epidemiological transition" (Barrett, et al. 1998). This study attempts to understand the potential infectious diseases that afflicted agricultural human groups in the Levant during the Neolithic period by focusing on four factors: stability, population density, animal domestication, and environmental change associated with agricultural practices.

## 1. Environmental and social factors that promote infectious diseases

The main 'environmental' event leading to the emergence of a new human infection is new physical contact between potential pathogens and humans. Infectious agents are often of animal origin, some of which originate from the soil (McMichael, 2004). There are four factors that cause infectious diseases, and they include viruses, bacteria, parasites, and fungi (Aufderheid and Rodriguez-Martin 1998). Transmission of microbial infection to humans requires that the microbial strain be mutated, so that it becomes more transmissible, viable, and reproducible in the human host, and this contact incident usually arises naturally (McMichael, 2004). Human culture, social, and behavioral developments have greatly contributed to the agenesis of these contacts between infectious agents and human.

The subsequent spread of an infectious diseases, after its onset, depends on several environmental and social factors such as:

1- Human demographic characteristics, such as increasing population density, intermarriage, and migration.
2- Changing the habitat and environment and settling new unfamiliar environments.
3- Changes related to food consumption, and this is related to the nature of dealing with domesticated animals, agricultural crops and food production means.
4- Living patterns and human behavior, such as managing housing, consumption, hygiene, and handling of waste.

The Neolithic transformation provided the basis for such factors, as stability was the first development, which was followed by an increase in population density. Another critical development is the techniques and behaviors associated with the practice of farming and domestication, which have given rise to great social complexity. This was accompanied by major environmental changes that imposed new survival challenges on the population, which showed an unprecedented response, by developing behaviors and a lifestyle based on agriculture and food production and helped its spread over a wider geographical extension. Although agriculture has played a decisive role in the development of human societies, its direct consequences for health and disease have been equally straightforward.

**2- Sedentary lifestyle**

The loss of mobility contributed to the creation of favorable conditions for the spread of many types of parasites. For example, it is not possible for mosquitoes to develop the ability to feed on human blood without the human being permanently stable. Which contributed to the emergence of malaria and its transmission to the human host. The settlement of agricultural human groups in one area, and the accumulation of their excreta near residential places, provided favorable conditions for the spread of worms that cause serious infectious diseases such as hookworms and roundworms (Ascaris) (Cockburn, 1971). The human and animal waste and waste accumulated next to the population is considered a source of attraction for many insects such as flies, ticks and mosquitoes that transmit dangerous diseases to humans.

**3- Population density**

Stability and food production have increased population density, which is a prerequisite for the spread of infectious diseases. The hunter-gatherer groups tended to control a constant birth rate, apparently through behavioral expressions that would inhibit fertility for a time, such as delaying the weaning (Tattersall, 2008), Or adherence to deliberate controls at the group level that ensure that the population size does not exceed the environmental carrying capacity, and the practice of infanticide is mentioned as one of these controls (Hayden, 1972; Vila-Mitjà and García-Piquer and Carracedo 2016), But this latter mechanism is a matter of debate among researchers (Page and French 2020). This social pattern based on a limited number of human groups has continued since the emergence of Homo sapiens, as the oldest sample dates back to about 300 kya, until the adoption of a lifestyle based on agriculture and food production. The agricultural societies showed rapid population growth, which was a condition for the occurrence of the "first epidemiological transition".

Many infectious diseases require a minimum host population size, so if the population numbers are below critical levels, the infection dies. Among the diseases to which these factors apply are measles, cholera, mumps and smallpox, which are human-specific and do not have an animal host; It also spreads quickly (Cockburn, 1971). As for diseases such as tuberculosis, malaria and schistosomiasis, they make the host infectious for long time, and they have an external vector or an intermediate host (animals) that represents an additional reservoir of infection. Such diseases can spread in relatively sparse populations of humans. However, no anthropological evidence was found to support the spread of these diseases before the Neolithic period, with the exception of a single case of tuberculosis that affected a 17,000-year-old bison (Rothschild, et al. 2001), and the case of a part of the cranium of Homo Erectus found at the site of Kocabaş in Turkey (Kappelman, et al. 2008), But this diagnosis was refuted in another study (Roberts and Pfister and Mays 2009). It is possible that infectious diseases existed before the Neolithic period (Cardona and Catala and Parts 2020). it seems that the large population increase, the increase in the number of susceptible individuals, and the increase in infectious pathogens that accompanied the agricultural transformation, have raised the incidence rate in neolithic societies significantly compared to the sparsely populated Paleolithic groups. Some statistical estimates indicate that many Neolithic villages in the Near East contained a large population. Larsen et al. (2019) estimated the population of Çatalhüyük at about 3500-8000 people during the middle stage of the settlement of the site; This is a relatively large population, but it is reasonable given the site's area of more than 12 hectares (Düring, 2007). While Moore et al. (2000) estimated the population of the Abu Hureyra site, which may have reached a size of 16 hectares, between 3600-10080 people.

Finally, the population increase creates pressures on food resources, prompting the population to search for alternatives by expanding into new, previously uninhabited environments such as marshes, coastal areas and swamps, which are attractive to disease-carrying insects, and create a suitable environment for parasites, causing outbreaks of diseases such as malaria and schistosomiasis.

**4- Animal domestication**

Most infectious diseases that have affected humans are of animal origin, and they are transmitted from animals to humans through direct contact, the environment, food or water (McArthur, 2019). Tuberculosis was transmitted to Neolithic farmers from cattle, a disease caused by Mycobacterium tuberculosis, a non-motile and rapidly acidifying aerobic bacillus (Kumar, 2012), Although it infects the respiratory system through the alveoli in the lungs, it can spread to almost any part of the body (Pai, et al. 2016). Tuberculosis is caused by a group of closely related bacterial species. M. bovis has a wider range of hosts. It is the main cause of tuberculosis in other animal species. Humans are usually infected with M. bovis through milk, dairy products, or meat from an infected animal (O'Reilly and Daborn, 1995). Tuberculosis can cause characteristic skeletal changes, such as degeneration of the vertebrae, reactive periosteal lesions, and osteomyelitis (Ortner and Putschar 1981). The authors have long considered that tuberculosis was transmitted to humans in the Neolithic period. Three cases of tuberculosis were diagnosed in the Ain Ghazal site in Jordan (Al-Sarie and Al-Shiyab and El-Najjar 1996), and two cases of a woman and a child in Atlit-Yam, Israel, using polymerase chain reaction analysis and bone anatomical diagnosis (Hershkovitz, et al. 2008). It is assumed that the woman was the mother of the infant and may have transmitted the disease to him, and they were buried together after their death of the disease. The Atlit-Yam site is one of the rare Neolithic sites where bovine bones were found in abundance, which indicates that cows formed an important food source for the inhabitants of the site, and may be related to the transmission of the disease (Galili, et al. 2002). Recently, the study showed large samples (170 individuals) from two sites dating back to the pre-Pottery Neolithic period, namely Dja'de el-Mughara on the middle Euphrates (11300-10290 years ago) and Tell Aswad (10200-9500 years ago) south of Syria, the presence of ten cases of tuberculosis in skeletons excavated from the cave, and one case of tuberculosis from the site of Tell Aswad, based on several anatomical, molecular and biological bases (Baker, et al. 2017). All of these samples date to the pre-pottery Neolithic era of PPNB. All cases of tuberculosis were related to the period of domestication, with the exception of three samples dating back to the early settlement stage in Dja'de el-Mughara, in which no evidence of animal domestication was found. However, it is not excluded that the inhabitants of the site dealt with animals during that period, given that contemporary sites near Dja'de el-Mughara, such as Navali Cori, which is about 100 km away, witnessed the domestication of goats, sheep and pigs (Peters, et al. 1999).

As well as the emergence of Brucellosis as a result of contact with domestic animals. Brucella melitensis is the main agent responsible for human brucellosis, one of the most common zoonotic diseases in the world (Pappas, et al. 2006). Humans become infected as a result of eating unpasteurized dairy products and contact with infected animals, especially sheep and goats, which are the animals that are the main reservoir of the disease (Moreno, 2014). Goats, cattle and pigs were domesticated in multiple centers of the Fertile Crescent region of western Asia in the Neolithic period (Arbuckle, 2014). A mathematical model simulating the transmission of Brucella melitensis between localized local goat populations in Neolithic sites such as Jarmo and Ali Kush in Iraq showed an increase in the possibility of transmission of infection between the population of those sites, by promoting appropriate conditions that allow domesticated goats to be a reservoir of infectious bacteria, as Male goats were selectively culled in order to improve the efficiency of food production while maintaining the continuity of reproduction in the domestic herd (Fournié and Pfeiffer and Bendrey 2017). This contributed to the high density of domesticated livestock, which would promote zoonotic pathogens, and maintain their level of spread, and thus their transmission to humans.

Raising domesticated animals inside or near residential houses in some sites (Eshed, et al. 2010; Hillson, et al. 2013), created favorable environmental conditions for the spread of infection and its transmission to the human host, which helped the spread of parasitic worms, fleas and germs among the population living with those animals.

The emergence of diseases of animal origin was not limited to domesticated animals, as man's anchorage in his fields made contact with non-domesticated animals that could transmit disease inevitable, such as rats, mice, ticks and flies. Rats roaming in the fields can infect humans with rat-bite fever through the bacteria transmitted by the bite (Gaastra, et al. 2009). Ticks that spread in grassy areas, shrubs and around rubbish can also transmit many dangerous infectious diseases, such as types of infections that affect the blood and the brain and types of hemorrhagic fevers. They are carriers of bacteria and viruses and transmit them through their bites (McFee, 2018). Also, dogs and warm-blooded animals transmit rabies by being bitten by an infected animal (Drew, 2004).

**5- Behavioral patterns and environmental changes associated with farming practice**

At the beginning of the Neolithic period, environmental changes caused by climate change occurred at the end of the last Ice Age, as rising temperatures, melting snow and rising sea levels (Clark, et al. 2009), led to the formation of marshes and swamps, which are a suitable environment for the settlement of epidemics such as schistosomiasis and malaria, and the emergence of related serious diseases, Such as thalassemia and anemia.

The oldest evidence of schistosomiasis was discovered at site of Tell Zeidan, Syria (7800-6000 years ago) in the Euphrates basin in northern Syria, using light microscopy (Anastasiou, et al. 2014).

In the pre-Pottery Neolithic site of Atlit-Yam on the Israeli coast, a skeleton of a young man aged 16-17 years was found, showing skeletal indicators associated with thalassemia and hemolytic anemia. Only small portions of the skull have been restored, precluding the confirmation of porotic hyperostosis in this individual (Hershkovitz, et al. 1991), the diagnostic criteria for thalassemia on old skeletons.

anemia and thalassemia are found in malaria-endemic areas (Kuesap, et al. 2015). The evidence of thalassemia or anemia is an indication of the endemicity of malaria. The parasite that transmits malaria cannot infect carriers of thalassemia or anemia with its severe symptoms, so they have partial immunity and protective effects against malaria for a reason that is not yet clear, as they have an increased frequency of antibodies, especially to Plasmodium vivax (O'Donnell, et al. 2009). The parasitic plasmodium falciparum that is transmitted to humans through the bite of a carrier mosquito is less likely to remain active in the cells of those carrying genetic modifications in hemoglobin, particularly sickle cell hemoglobin (HbSC), which results from a single amino acid substitution in b-globin (Kilian, et al. 2015). Thus, the forces of natural selection propagate hemoglobin mutations in areas of malaria endemicity that are considered more dangerous.

Lawrence Angel believes that the skulls of early farmers from the site of Çatalhüyük in western Anatolia, which date back to 6500 BC, suffered from porotic hyperostosis suggestive of thalassemia associated with malaria (Angel, 1966). It should be noted that the natural environment of the settlement of Çatalhüyük is surrounded by the plains of Konya Province, ridges, a number of swamps and shallow lakes (Rosen and Roberts 2006).

Also, agricultural practices can help spread many dangerous diseases. We mention, for example, that using infected animal feces as soil fertilizer is considered dangerous for transfer of pathogens to crops that are used as food for farming communities. Many epidemics may have spread in this way, such as typhoid. Parasitic worms, bacteria, hookworms, ascaris and amoebic dysentery are also spread in this way (Cockburn, 1971). The use of polluted water, pond water, and stagnant water to irrigate crops may transmit schistosomiasis and malaria. Water channels and small ponds attract insects such as mosquitoes that transmit malaria, lymphatic filariasis (the cause of elephantiasis), dengue fever, yellow fever, and encephalitis (Rozendaal, 1997).

## DISCUSSION AND CONCLUSIONS

The agricultural revolution had the greatest impact on population biology since the existence of Homo sapiens. The agricultural economy has radically restructured human societies. These societies have adopted a non-mobility lifestyle due to their connection to the land and their stability. Animals have been domesticated and dealt with directly. The process of food production has led to an increase in population density and made separate and distant human groups more accessible to each other. Selective and population pressures have also pushed the population to face new environments. These changes have had profound consequences, increasing the potential for disease and infection.

Several conclusions were reached in this study, which confirm many of the previous hypothesis:

1- Environmental and cultural changes had decisive effects on the health status of the population, in terms of the emergence of patterns of infectious diseases, and their susceptibility to spread. A lifestyle based on agriculture and animal domestication has led to the emergence of new diseases and an increased risk of pre-existing diseases.

2- Stability, increase in population density, domestication of animals, environmental and behavioral change associated with the agricultural revolution and what is related to it, were the most influential factors in the emergence and spread of epidemics and infectious diseases in the Neolithic age. Referring to the complex relationship between infectious diseases and human societies, these diseases are the result of the expression of natural, demographic, cultural and nutritional selective pressures, as well as the genetic characteristics of the population.

3- Natural selection increases the resistance of a population to pathogens. When a population is exposed to pathogens, natural selection increases the spread of alleles that are beneficial to new ecosystems of both the host and the pathogen (Karlsson and Kwiatkowski and Sabeti 2014), an important example being thalassemia. It appears that thalassemia emerged as a positive immune response against the deadly malaria epidemic, which was reinforced by the high frequency of mutated globin genes in malaria endemic areas.

4- The study of skeletons discovered in the Neolithic sites of the Levant shows the world's oldest evidence of infectious diseases such as malaria, schistosomiasis and tuberculosis. It provides insight into how prehistoric societies dealt with the diseases that afflicted them, and how they coped with them. These evidence also give the Levant region crucial importance for understanding the evolutionary history of these diseases that still exist today.

5- In the Neolithic age, the environmental and social factors and conditions that promoted the emergence and spread of many infectious diseases were available, but not all infectious diseases leave an impact on the bones, a material studied by anthropologists and paleopathologist, which makes it difficult to diagnose some disease cases. Therefore, it is necessary to develop diagnostic methods based on biomarkers, ancient DNA, faecal residue analysis, and statistical models to infer the presence of diseases, in order to gain a greater understanding of the patterns of infectious diseases that were prevalent among Neolithic communities. These techniques were used, albeit in part, in the identification of many diseases that were present, such as tuberculosis, malaria, schistosomiasis and fever.

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