Malaria in Al-Andalus: from written medical sources to a proposal for paleoparasitological study

El paludismo en al-Ándalus: de las fuentes escritas médicas a una propuesta de estudio paleoparasitológico

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Abstract

Malaria, also known as paludism, is a parasitic disease caused by protozoa of the genus *Plasmodium* and transmitted by the female *Anopheles* mosquito. It is notable for its high morbimortality and its importance throughout human history.

References to this parasitosis can be traced in contemporary sources, especially in ancient medical texts. In Al-Andalus, where medical knowledge became influenced by Greco-Latin and Oriental writings, descriptions of symptoms indicate the presence of malaria in populations of the Iberian Peninsula.

This study reviews possible evidence of malaria in medical texts from Al-Andalus and presents a novel proposal for paleoparasitological studies in areas especially susceptible to the presence of these parasites in this culture.

Keywords: malaria, paludism, written sources, Paleoparasitology, Al-Andalus.

Resumen

El paludismo o malaria es una parasitosis causada por protozoos del género *Plasmodium* que se transmite a partir de la picadura de la hembra del mosquito *Anopheles* sp. Destaca por su alta morbimortalidad y su importancia a lo largo de la historia de la humanidad.

Las referencias a esta parasitosis se pueden rastrear a partir de las fuentes antiguas, especialmente en los escritos médicos. En el caso de al-Ándalus, gracias al desarrollo de la medicina, influenciada por fuentes escritas grecolatinas y orientales, se puede inferir la presencia de paludismo a partir de la sintomatología en poblaciones de la península ibérica.

La presente contribución propone un recorrido a través de las posibles atribuciones de paludismo en textos médicos de al-Ándalus, así como una innovadora propuesta de estudio paleoparasitológico en zonas propensas al hallazgo de este parásito en dicho horizonte cultural.

Palabras clave: malaria, paludismo, fuentes escritas, paleoparasitología, al-Ándalus.

1. INTRODUCTION

The medicine developed in Al-Andalus (8th-15th c.) represented a major advance in medical knowledge in the Iberian Peninsula and throughout the known world. At its height, the Arab-Islamic empire extended from Iberia in the West to the Indus Valley in the East and from the

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Pyrenees to the Sahara and the Arabian Peninsula (PEÑA DÍAZ, 2012). Territorial conquests brought the acquisition of knowledge from both Eastern and Western cultures. Accordingly, Greek, Persian, and Hindu writings contributed to medieval Islamic medicine in a process of cultural appropriation common to all empires and civilizations (GUTIÉRREZ AROCA, 2018).

Written sources, especially medical texts, offer evidence on the state of knowledge on diseases in different societies (MITCHELL, 2017), although the lack of preserved manuscripts limits the information available in some settings. In the case of Al-Andalus medicine and its importance, influences from the East and later from the West are manifest in the translated works of some key Islamic physicians, including Avenzoar, Averroes, and Ibn al-Jaṭīb, among others (DE LA PUENTE, 2014).

However, research on medical knowledge in Al-Andalus has paid little attention to diseases caused by parasites, such as malaria. This disease caused by the protozoan genus *Plasmodium* sp. has been associated with a high mortality in the Iberian Peninsula until recent times (FERNÁNDEZ ASTASIO, 2018). The term malaria derives from its historic association with miasmas arising from swamps (in Italian, mal'aria = bad air). The same disease was also known as "paludism" in medieval times because it was associated with swampy areas (in Latin, palus = swamp). The term malaria is used consistently throughout this article.

The objectives of this study were: i) to seek evidence of the presence of malaria in contemporary medical texts, based on descriptions of its signs and symptoms of this parasitosis; ii) to develop a bidirectional methodology that uses the latest advances in the detection of genus *Plasmodium* sp. parasites in ancient materials and exploring their interrelationship with evidence of disease in bone remains, and iii) to propose investigation of the link between malaria in Al-Andalus and the introduction of novel crops such as rice and sugarcane.

2. GENERAL ASPECTS OF MALARIA

2.1. Parasite life cycle

There were estimated to be over 282 million cases of malaria worldwide in 2024, and this disease was considered responsible for around 610,000 deaths in a single year (WORLD HEALTH ORGANIZATION, 2025). Most of these deaths were recorded in Africa (95 %). Among affected populations, the most vulnerable groups were small children, attributable to their immature immune system (75 % of deaths were children aged <5 years in the African regions), and pregnant women, due to their reduced immunity function (WORLD HEALTH ORGANIZATION, 2025).

Malaria is caused by protozoan parasites of the genus *Plasmodium*. Six *Plasmodium* species affect humans: *P. falciparum*, *P. vivax*, *P. malariae*, *P. ovale* (*wallikeri* and *curtisi*) and *P. knowlesi*. The highest complication and mortality rates are associated with *P. falciparum* (BEESON *et alii*, 2002; DEL PRADO *et alii*, 2014). The life cycle of these parasites involves two hosts: humans (asexual replication phase) and mosquitoes of the genus *Anopheles* (sexual replication phase). In this way, humans are infected by the bite of a female mosquito of this genus, which inoculates sporozoites (the infectant form of *Plasmodium*) into the blood (ACHARYA *et alii*, 2017). The sporozoites pass from the dermis to the bloodstream and finally invade hepatic cells. The parasites then undergo a differentiation process in the liver until they reach maturity, when they destroy hepatic cells and return to the blood stream, entering the hemic phase of the infection (WIPASA *et alii*, 2002). These free forms adhere to and invade red blood cells, where the asexual replication phase is initiated and the parasite passes to the trophozoite stage and then to the schizont stage, when fully formed merozoites are ready for release. Next, the parasite ruptures the red blood cells of the host, releasing merozoites (COWMAN *et alii*, 2006) for the infection of new red blood cells and the initiation of a new cycle.

During the red blood cell invasion phase, some parasites differentiate into *Plasmodium* sexual reproduction forms. When an *Anopheles* mosquito bites an individual with malaria it ingests both blood and parasites (BAKER, 2010), initiating the *Plasmodium* sexual reproduction phase in the mosquito and leading to the development of sporozoans ready for inoculation in a new human host.

The red blood cell lysis is generally synchronic, taking place at 48-hour intervals in the case of *P. falciparum*, *P. vivax* and *P. ovale*, and at 72-hour intervals in the case of *P. malariae*. Clinical symptoms of the disease appear after the release of merozoites and are characterized by intermittent febrile episodes. The fever is classified as 'malignant tertian' (*P. falciparum*), 'benign tertian' (*P. vivax* and *P. ovale)*, or 'quartan' (*P. malariae*) according to the time interval between one febrile episode and the next (ROBERTS, JANOVY, 2008). Malaria-like fevers are frequently reported in historical written sources and are commonly used as indicators of the presence of this parasitosis in ancient population (MICHEL *et alii*, 2024; NEWFIELD, 2017; COX, 2002).

2.2. Malaria in human history

Malaria is an ancient disease that has been present in human populations for millennia (LOUFOUMA-MBOUAKA *et alii*, 2021). In common with many other infectious diseases, its impact increased with the development of agriculture and permanent settlements (CARTER, MENDIS, 2002; HEDRICK, 2012).

The introduction of agriculture increased the population density of human settlements and, therefore, the incidence of contagions produced by mosquito bites. A more favorable habitat for mosquito reproduction also resulted from the ecological changes generated by agriculture through the development of water distribution, collection, and storage systems (IJUMBA *et alii*, 2002; ASENSO-OKYERE *et alii*, 2009; DEMISSEW *et alii*, 2020). A high density of *Anopheles* mosquitoes in irrigation systems and stagnant waters allowed malaria vector mosquitoes to be in constant year-round contact with populations.

From a biological perspective, human genes that confer resistance to malaria are a clear example of natural selection operated by pathogenic agents. Thus, there is evidence of a strong correspondence between areas that are or have been endemic of malaria and a high incidence of genetic diseases that affect human red blood cells, including ovalocytosis, thalassemia, falciform cell anemia, and G6PD deficiency (WEATHERALL, 2008; HEDRICK, 2011). Because red blood cells infected by the parasite of malaria by these diseases are not a suitable environment for replication, they provide a certain protection against paludism. The strong evolutionary pressure operated by malaria on populations is one reason why red blood cell diseases are the most frequent genetic diseases in humans (WEATHERALL, CLEGG, 2008).

The first written evidence of malaria in humans dates to 2,700 years ago in China (COX, 2002). There are also possible allusions to its presence in ancient Egypt in the Temple of Dendera (1500 BCE) (HOEPPLI, 1956) and Ebers Papyrus (1500 BCE) (BRYAN, SMITH, 1930). In ancient Greece, Hippocrates (5^{th}-4^{th} c. BCE) clearly described tertian and quartan fevers, while Herodotus (5^{th} c. BCE) reported that fishermen sleep under nets during the summer as a means of avoiding the disease (LÓPEZ ROMÁN, 1990). Malaria is also mentioned in writings from Roman, Asyrian, and Indian cultures (COX, 2002). Of the primary human species of *Plasmodium* that cause malaria only *P. falciparum*, *vivax* and *malariae* are thought to have a deep European history (MICHEL *et alii*, 2024; NEWFIELD, 2017).

The causes of malaria remained unknown until 1880, when the French military physician Alphonse Laverne used optical microscopy to detect the presence of *Plasmodium* in a blood sample from a soldier with typical

febrile symptoms (BOUALAM *et alii*, 2021). Ronald Ross was the first to identify the mosquito as vector of avian malaria in 1887, while Italian researchers reported a decade later that malaria is transmitted by mosquitoes of the genus *Anopheles* (COX, 2010). The discovery of these malaria vectors in Europe led to the implementation of preventive measures, including the draining of stagnant waters and the application of larvicides (ZHAO *et alii*, 2016). Malaria was finally eradicated in Europe in the mid-20th century thanks to national programs and the Global Malaria Eradication Program (194`1050), based on the massive use of DDT (dichloro-diphenyl-trichloroethane) against *Anopheles* mosquito larvae and the distribution of antimalarials to populations in the most affected areas (ZHAO *et alii*, 2016).

3. WRITTEN MEDICAL SOURCES IN AL-ANDALUS

3.1. The development of medicine in Al-Andalus

The development of medicine in Al-Andalus represented an important advance with respect to other contemporary cultures, and the combination of a clear religious vocation with Greco-Latin and Eastern knowledge (SAVAGE-SMITH, 2013) gave rise to a new approach to the study of the individual.

At the time of Muhammad, disease was considered as a series of demons in the Islamic world, imbued in the polytheist tradition that previously dominated the Arabian Peninsula (ÁLVAREZ DE MORALES, 1999, 2006). Rapid Islamic expansion, with territorial conquests in Asia Minor, Syria, and Alexandria, led to the incorporation of Greco-Latin texts and knowledge from Eastern and Hinduist worlds (ÁLVAREZ DE MORALES, MOLINA LÓPEZ, 1999) alongside the religious doctrine that dominated Islamic society (SAVAGE-SMITH, 2013). Translation work was crucial for the circulation of texts, and an especially important role was played by the *Bayt al-Ḥikma* (House of Wisdom) in Baghdad, founded in the 9th c. (CHANDIO, 2021). Greek ideas became increasingly influential, with the dissipation and evolution of disciplines towards a global and holistic understanding, bringing philosophical and theological issues into the formation of physicians (DE LA PUENTE, 2014).

The first Muslims who settled in the Iberian Peninsula during the 8th c. had a marked military character, accounting for the lack of medical writings at the beginning of Al-Andalus (CASTILLA BRAZALES, 1999), when there was a dependence on autochthonous Mozarab authors (DE LA PUENTE, 2014). Medical knowledge began to expand under Abd ar-Rahman II (Emir from 822 to 852) with the arrival in Cordoba of the prominent physician al-Ḥarrānī (CASTILLA BRAZALES, 1999). In the 10th c., the Caliphate of Córdoba became the epicenter of Al-Andalus science, and key authors such as Abulcalsis/al-Zahrawi, Sunprunt, and Ibn Ŷulŷul made important contributions to medical knowledge (DE LA PUENTE, 2014). Despite the subsequent fall of the Caliphate, these investigative efforts and the search for knowledge continued and was even intensified in the *Taifas* (small Muslim kingdoms/principalities) that remained (CASTILLA BRAZALES, 1999).

However, the greatest advances in medical knowledge were achieved in the 12th c., largely attributable to the Al-Andalus physicians of greatest renown at the time: Abu Marwan Abd al-Malik ibn Abil-Ala, known in the West as Avenzoar (1092-1162), and Abu l-Walid Muhammad Ibn Ahmad ibn Rushd, known as Averroes (1126-1198). Several of their writings are preserved, mainly due to their translation and circulation in the East and West, where they became the object of study from the Renaissance period onwards (DE LA PUENTE, 2014).

The 12th century was characterized by political tension and a change from Almoravid to Almohad dominance (DE LA PUENTE, 2014). Convulsions were also caused by battles against Christian populations to the North, with continual frontier changes. The publication of medical works declined in the 13th c., when there was an increase in the translation

of Latin texts (CASTILLA BRAZALES, 1999). The writings of Ibn al-Jaṭīb and Ibn Jātima stand out under the Nasrid dynasty (1232 to 1492), and these two authors from Almeria even developed the pathophysiological concept of multiple organ dysfunction syndrome (HERRERA CARRANZA, 2021).

3.2. Evidence of malaria in medical texts of Al-Andalus

Given the lack of contemporary knowledge on the parasites responsible for malaria, the study of Al-Andalus medical texts focuses on their descriptions of relevant signs and symptoms. The most indicative symptom is intermittent fever with a time cycle compatible with the different *Plasmodium* species responsible for malaria in humans.

There is a limited number of medical texts suggesting the presence of malaria in these populations. However, the works of only a few authors have survived or been translated, and greater evidence may emerge in the future with the translation of a larger number of authors and writings. Knowledge is restricted to a few authors whose great renown led to the assimilation of their writings within the Eastern and Western medical corpus.

To our best knowledge, the first medical author to describe malaria-related symptoms was Avenzoar (1092-1162). He was born in Seville into a renowned family of physicians (Banu Zuhr) and received first-level medical education from an early age, including the study of Greco-Latin texts, and his writings reveal the influence of the works of Galen (DE LA PUENTE, 2014). In accordance with the multidisciplinary approach that was dominant in Al-Andalus, he also underwent religious, legal, and literary education. His writings made an outstanding contribution to medicine, and two of his publications describe fevers that could be caused by malaria. Thus, he refers to a tertian fever in *Kitab al-Iqtisad* (the book of moderation) (THÉODORIDÈS, 1955), and he describes an intermittent tertian fever attributed to the putrefaction of yellow bile in *Kitab al-taysir fi l-mudawat wa-l tadbir* (book that simplifies medication and diet), which has not yet been translated (PEÑA MUÑOZ, GIRÓN IRUESTE, 2005, 2010). As noted above, intermittent tertian fevers are typical symptoms of malaria caused by *falciparum* and *vivax* species. In the 1950s, the Swiss German physician Hoeppli proposed that Avenzoar was familiar with the clinical aspects of malaria, but he did not cite a text to support this proposition (HOEPPLI, 1956).

References to malaria can also be traced in the writings of Averroes (1126-1198), who was born into a prominent family of jurists in Cordoba, where he received an education in grammar and poetry as well as medicine. He was considered one of the most important physicians in Al-Andalus, publishing philosophical and medical texts that were translated into other languages and became recognized in the Western world during the Renaissance (DE LA PUENTE, 2014). Averroes devoted a section of his work *Kitab al-Kulyat fi al-Tibb* (*Book of Generalities of Medicine*) to the healing of quartan fever (CORDERO DEL CAMPILLO, 1980), indicating the application of poultices to the area of the spleen as a possible remedy (VÁZQUEZ DE BENITO, ÁLVAREZ MORALES, 2003). Splenomegaly (spleen swelling) is a typical clinical characteristic of malaria, because the spleen is the organ most involved in the immune response against the parasite and in the elimination of parasitized and/or damaged red blood cells (ENGWERDA *et alii*, 2005; CHAVES *et alii*, 2011; DEL PORTILLO *et alii*, 2012). Quartan fever may also suggest an infection caused by *P. malariae*.

Possible allusions to malaria also appear in the work of physician Ibn al-Jatib (1313-1375), who was born into the Banu Wazirm family in Loja and engaged in various fields of knowledge. In his volume on medicine entitled *Mi'yār al-ijtiyār fī ḏikr al ma'āhid wa-l-diyār* (IBN AL-JATIB, 1977), he referred to fevers in areas of sugarcane cultivation in Salobreña (Granada) (MALPICA CUELLO,

2012). It can be assumed that these fevers are related to malaria because crops that require a high amount of water favors reproduction of the *Anopheles* mosquito (IJUMBA *et alii*, 2002; DILLON *et alii*, 2014). The *Plasmodium* species involved cannot be identified because, unlike the aforementioned authors Ibn al-Jatib did not describe the types of fevers encountered.

4. PALEOPARASITOLOGY IN THE STUDY OF MALARIA

4.1. Study of parasites in ancient material

Paleoparasitology involves the finding and interpretation of parasites in ancient material, either from archeological or paleontological sites (FERREIRA *et alii*, 2014). Combining these findings with the study of human populations can yield a wide spectrum of bioarcheological knowledge on hygienic/sanitary aspects, the presence of domestic and peridomestic animals, migratory routes, and different socioeconomic strategies (LE BAILLY *et alii*, 2021). However, this discipline remains underdeveloped in Spain, with a limited number of published studies, mainly in recent years (see MAICHER *et alii*, 2017; KNORR *et alii*, 2019; LÓPEZ-GIJÓN *et alii*, 2023a, 2024).

Development of this discipline worldwide and advances in rehydration techniques (DUFOUR, LE BAILLY, 2013; ROMERA BARBERA *et alii*, 2020) have revealed a wide range of materials in which parasitological evidence can be obtained. These include the contents of archeological structures such as latrines, cesspits, and pipework, which can be associated with human populations. A direct association of parasites with specific individuals can be detected by the study of parasites in mummified or skeletonized remains (LÓPEZ-GIJÓN *et alii*, 2023b; COPPOLA-BOVE *et alii*, 2024), allowing exploration of relationships between the presence of certain parasites and diseases or diet, among other anthropological issues (LÓPEZ-GIJÓN *et alii*, 2021).

The study of ancient parasites has been improved by technological developments, so that information can now be gathered on their morphology, associated antigens, and DNA. For morphological identification, the basic technique is still transmitted-light bright-field optical microscopy, while screening electron microscopy can also be used. Antigen detection is performed by indirect immunofluorescence using and enzyme-linked immunosorbent assay, while the DNA of parasites is studied by polymerase chain reaction amplification.

Studies of ancient parasites have revealed both endoparasites (within the host) and ectoparasites (on the host surface). Most research to date has been on intestinal helminths, focusing on the dispersion phases developed outside the host (known as geohelminths). This is because their highly resistant shells favor their preservation over long time periods (WHARTON, 1980). Less research interest has been shown in protozoa, despite the considerable information they can offer on ancient populations. Although their study is more challenging, some investigations have been conducted over the past few years on this type of parasite, including *Plasmodium* sp.

4.2. Finding of *Plasmodium* sp. in past populations

Unlike other parasites, *Plasmodium* sp. cannot be morphologically identified under optical microscopy because their structure is not preserved at cellular level. Consequently, one approach to study the presence of malaria has been to identify possible malaria-prone areas based on the presence of skeletal markers that can be related to anemia (GOWLAND, WESTERN, 2012), including *cribra orbitalia* (SMITH-GUZMÁN, 2015) and porotic hyperostosis (SETZER, 2014). However, it is difficult to establish their association with the presence of *Plasmodium* sp. because of the possible multifactorial etiology of these lesions (WALKER *et alii*, 2009; BRICKLEY, 2018; O'DONNELL *et alii*, 2020).

Hence, other methodologies are needed to evidence in a direct manner the presence of *Plasmodium* sp. in past societies. Technological advances achieved over the past few years include immunological techniques, which can be used to detect specific antigens of *Plasmodium* sp., and DNA testing, identifying the parasite from its genetic material (BIANUCCI *et alii*, 2015). Implementation of these technologies has yielded the first direct evidence of malaria in ancient mummified and skeletonized individuals (NERLICH, 2016). Molecular techniques can be used to detect *Plasmodium* spp. in different types of biological materials. They can be applied to samples of tissue (e.g., muscle) from mummified bodies (BIANUCCI *et alii*, 2015) and to different samples obtained from skeletal remains, including spongy bone, the pars petrosa of the temporal bone, and dehydrated matter from tooth pulp chambers (BIANUCCI *et alii*, 2015; MICHEL *et alii*, 2024).

Most studies have been conducted in regions in the Mediterranean basin using immunological (MILLER *et alii*, 1994; RABINO MASSA *et alii*, 2000; BIANUCCI *et alii*, 2008; FORNACIARI *et alii*, 2010a, 2010b; BIANUCCI *et alii*, 2014; AL-KHAFIF *et alii*, 2018; LOUFOUMA-MBOUAKA *et alii*, 2020, 2021) and DNA (TAYLOR *et alii*, 1997; SALLARES, GOMZI, 2001; ZINK *et alii*, 2001; NERLICH *et alii*, 2008; HAWASS *et alii*, 2010; LALREMRUATA *et alii*, 2013; GELABERT *et alii*, 2016; MARCINIAK *et alii*, 2016; LOUFOUMA-MBOUAKA *et alii*, 2021) techniques to identify parasites.

4.3. Proposal for the study of Al-Andalus populations

The study proposal outlined below is motivated by the evidence of malaria in Al-Andalus medical texts and the known presence of the genus *Plasmodium* in Spain, where malaria was endemic until recent times (FERNÁNDEZ ASTASIO, 2018; SAINZ-ELIPE *et alii*, 2010).

In an initial geographic approach, a study will be conducted to identify places that would have featured swamps or standing waters during the Al-Andalus period, allowing *Anopheles* sp. to lay their eggs. Temperatures will also be considered, given that the presence of mosquitoes is more likely in tropical or subtropical than colder regions (BECK-JOHNSON *et alii*, 2013). Economic factors must also be considered, given the relevance to human mosquito exposure of the ecological changes produced by the introduction of novel crops in Al-Andalus, especially rice and sugarcane in monoculture. These plants require flooded or canal irrigation and are responsible for the abundant availability of standing water for the mosquito eggs (IJUMBA *et alii*, 2002).

Rice has been cultivated in the Iberian Peninsula since the 10th c., although its consumption was initially limited to the elite (RIERA MELIS, 2016). Its cultivation in various areas was documented by various Al-Andalus authors, including Ibn Bassāl and al-ʻUḏrī (RIERA MELIS, 2016). For instance, climatic and geographic conditions favored the cultivation of rice in the Spanish Levante from the beginning (PERDIGUERO GIL, 2005; BUENO-MARÍ, JIMÉNEZ-PEYDRÓ, 2010; BUENO VERGARA, 2017). Indeed, this region was considered the principal focus of transmission for malaria outbreaks on the Iberian Peninsula during the 18th, 19th, and 20th centuries (ALBEROLA-ROMÁ, BERNABÉ GIL, 1999; MOLINA PRADOS, 2017).

Sugarcane also began to be cultivated in Al-Andalus in the 10th c., becoming part of the diet of the population (MURO, 2017; IBN AL-JATIB, 1977). One sign of its consumption is the increased prevalence of caries in infants (JIMÉNEZ-BROBEIL *et alii*, 2022). It was mainly cultivated in coastal areas of Al-Andalus, where it continues be grown to date (MACHADO SANTIAGO, JIMÉNEZ BAUTISTA, 1995). Unlike in the case of rice-growing areas, sugarcane fields were not regarded as main transmission locations, although evidence of an association between malaria and sugarcane has been observed until very recent dates (FERNÁNDEZ ASTASIO, 2018).

Although no bone markers can be exclusively attributed to malaria, the study of skeletal remains may contribute information on

its possible presence in ancient populations. It is included in this multidisciplinary proposal of study to gather the largest possible body of evidence. It may also allow the individualization of probable malarial infection by the detection of possible cases of anemia-related diseases (e.g., porotic hyperostosis and *cribra orbitalia*) and allow the exploration of their relationship with malaria. To enhance the probability of detecting malaria, skeletal samples will be selected from geographical regions in which historical medical sources describe malaria-like fever, or where past environmental conditions were favorable to the development and persistence of the parasite's vector. Due to the non-specific nature of the bone lesions observed in the macroscopic analysis of skeletal materials, the study will apply molecular techniques. In particular, the DNA analysis has, in recent years, proven to be the most suitable and reliable methodology for investigating malaria in past populations (COPPOLA-BOVE *et alii,* 2024*;* MICHEL *et alii*, 2024). For this reason, following Michel *et alii* (2024), samples of teeth and the petrous portion of the temporal bone will be collected during the macroscopic examination for subsequent DNA analysis. It is planned to study at least 50 individuals from each archaeological site, including individuals of both sexes and all age ranges, following previous work (MICHEL *et alii*, 2024).

5. CONCLUSIONS

The preserved writings of renowned physicians in Al-Andalus include descriptions of the typical symptoms of malaria inhuman. Given the amount of contemporary medical literature that would not have survived to the present day, it is not possible to rule out a greater knowledge of malaria in Al-Andalus.

The introduction of rice and sugarcane cultivation in Al-Andalus produced areas of standing water that favored the development of *Plasmodium* sp. in human populations. The proposed study will therefore focus on sites in Al-Andalus where these monocultures were practiced. In a multidisciplinary approach, anemia-related paleopathological evidence will also be gathered and compared with findings on the presence of malaria. In turn, this work will carry out molecular analyses to corroborate these findings.

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REFERENCES

ACHARYA, Pragyan; MANIKA GARG, Praveen K.; MUNJAL, Akshay; RAJA, Ravadev (2017): "Host–parasite interactions in human malaria: clinical implications of basic research", *Frontiers in Microbiology*, *8*, p. 889. https://doi.org/10.3389/fmicb.2017.00889

ALBEROLA-ROMÁ, Armando; BERNABÉ GIL, David (1999): "Tercianas y calenturas en tierras meridionales valencianas: una aproximación a la realidad médica y social del siglo XVIII", *Revista de Historia Moderna*, *17*, pp. 95-112. https://dx.doi.org/10.14198/RHM1998-1999.17.06

AL-KHAFIF, Ghada Darwish; ROKIA EL-BANNA, Nancy Khattab; TAMER GAD, Rashed; SALWA, Dahesh (2018): "The Immunodetection of Non-Falciparum Malaria in Ancient Egyptian Bones (Giza Necropolis)", *BioMed Research International*, 2018. https://doi.org/10.1155/2018/9058108

ÁLVAREZ DE MORALES, Camilo (1999): "El hombre ante la enfermedad", in C. Álvarez de Morales and E. Molina López (Eds.), *La Medicina en al-Andalus*, pp. 69-89. Granada: Junta de Andalucía y Fundación El legado andalusí.

ÁLVAREZ DE MORALES, Camilo (2006): "Elementos mágicos y religiosos en la medicina andalusí", *'ILU. Revista de Ciencias de las Religiones*. Anejos, *16*, pp. 23–46.

ÁLVAREZ DE MORALES, Camilo; MOLINA LÓPEZ, Emilio (1999): "El patrimonio científico de al-Ándalus. Su elaboración y transmisión", in C. Álvarez de Morales and E. Molina López (Eds.), *La Medicina en al-Andalus*, pp. 13-29. Granada: Junta de Andalucía y Fundación El legado andalusí.

ASENSO-OKYERE, Kwadwo; ASANTE, Félix A.; TAREKEGN, Jifar; ANDAM, Kwaw S. (Eds.) (2009): *The Linkages between Agriculture and Malaria: Issues for Policy, Research, and Capacity Strengthening*. Washington: International Food Policy Research Institute.

BAKER, David A. (2010): "Malaria gametocytogenesis", *Molecular and Biochemical Parasitology*. *172*(2), pp. 57–65. https://doi.org/10.1016/j.molbiopara.2010.03.019

BECK-JOHNSON, Lindsay M.; NELSON, William A.; PAAIJMANS, Krij; READ, Andrew; THOMAS, Matthew B.; BJØRNSTAD, Ottar (2013): "The Effect of Temperature on Anopheles Mosquito Population Dynamics and the Potential for Malaria Transmission", *PLOS One*, *8*(11), e79276. https://doi.org/10.1371/journal.pone.0079276

BEESON, James G.; BROWN, Graham V. (2002): "Pathogenesis of *Plasmodium Falciparum* malaria: the roles of parasite adhesion and antigenic variation", *Cellular and Molecular Life Sciences CMLS*, *59*, pp. 258–271. https://doi.org/10.1007/s00018-002-8421-y

BIANUCCI, Raffaella; ADAUTO, Araujo; PUSCH, Carsten M.; NERLICH, Andreas G. (2015): "The Identification of Malaria in Paleopathology—An In-Depth Assessment of the Strategies to Detect Malaria in Ancient Remains", *Acta Tropica*, *152*, pp. 176–180. https://doi.org/10.1016/j.actatropica.2015.09.002

BIANUCCI, Raffaella; MATTUTINO, Grazia; LALLO, Rudy; CHARLIER, Philippe; JOUIN-SPRIET, Hélène; PELUSO, Alberto; HIGHAM, Thomas; TORRE, Carlo; RABINO MASSA, Emma (2008): "Immunological evidence of *Plasmodium falciparum* infection in an Egyptian child mummy from the Early Dynastic Period", *Journal of Archaeological Science*, *35*(7), pp. 1880-1885. https://doi.org/10.1016/J.JAS.2007.11.019

BIANUCCI, Raffaella; TOGNOTTI, Eugenia; GIUFFRA, Valentina; FORNACIARI, Gino; MONTELLA, Andrea; MILANESE, Marco; FLORIS, Roberta; BANDIERA, Pasquale (2014): "Origins of malaria and leishmaniasis in Sardinia: first results of paleoimmunological study", *Pathologica*, *106*, p. 90.

BOUALAM, Mahmoud A.; PRADINES, Bruno; DRANCOURT, Michel; BARBIERI, Rémi (2021): "Malaria in Europe: a historical perspective", *Frontiers in Medicine*, *8*, 691095. https://doi.org/10.3389/fmed.2021.691095

BRICKLEY, Megan B. (2018): "Cribra orbitalia and porotic hyperostosis: A biological approach to diagnosis", *American Journal of Physical Anthropology*, *167*(4), pp. 896-902. https://doi.org/10.1002/ajpa.23701

BRYAN, Cyril P.; SMITH, Elliot G. (1930): *Ancient Egyptian Medicine: The Papyrus Ebers*. Chicago: Ares Publishers Chicago.

BUENO MARÍ, Rubén; JIMÉNEZ PEYDRÓ, Ricardo (2010): "Crónicas de arroz, mosquitos y paludismo en España: el caso de la provincia de Valencia (ss. XVIII-XX)", *Hispania*, *70*(236), pp. 687–708. https://doi.org/10.3989/hispania.2010.v70.i236.329

BUENO VERGARA, Eduardo (2017): "Fiebres tercianas, sequías y lluvias torrenciales en el Alicante del Setecientos", *Revista de Historia Moderna*, *35*, pp. 377-409. https://dx.doi.org/10.14198/RHM2017.35.11

CARTER, Richard; MENDIS, Kamini N. (2002): "Evolutionary and historical aspects of the burden of malaria", *Clinical Microbiology Reviews*, *15*(4), pp. 564–594. https://doi.org/10.1128/CMR.15.4.564-594.2002

CASTILLA BRAZALES, Juan (1999): "Noticias médicas en fuentes árabes sobre al-Ándalus", in C. Álvarez de Morales and E. Molina López (Eds.), *La Medicina en al-Andalus*, pp. 29-69. Granada: Junta de Andalucía and Fundación El legado andalusí.

CHANDIO, Abdul R. (2021): "The House of Wisdom (Bait Al-Hikmah): A Sign of Glorious Period of Abbasids Caliphate and Development of Science", *International Journal of Engineering and Information Systems IJEAIS*, *5*(3), pp. 1-6.

CHAVES, Luis F.; TALEO, George; KALKOA, Morris; KANEKO, Akira (2011): "Spleen rates in children: an old and new surveillance tool for malaria elimination initiatives in island settings", *Transactions of the Royal Society of Tropical Medicine and Hygiene, 105*(4), pp. 226-231. https://doi.org/10.1016/j.trstmh.2011.01.001

COPPOLA-BOVE, Lorenza; KIRKPATRICK, Casey L.; VIGIL-ESCALERA, Alfonso; BOTELLA-LÓPEZ, Miguel C.; BOS, Kirsten I. (2024): "A morphological and molecular approach to investigating infectious disease in early medieval Iberia: The necropolis of La Olmeda (Palencia, Spain)", *American Journal of Biological Anthropology*, *185*, e24994. https://doi.org/10.1002/ajpa.24994

CORDERO DEL CAMPILLO, Miguel (1980): *Panorama de la Parasitología Española*. Madrid: Laboratorios Sobrino.

COWMAN, Alan F.; CRABB, Brendan S. (2006): "Invasion of red blood cells by malaria parasites", *Cell*, *124*(4), pp. 755–766. https://doi.org/10.1016/j.cell.2006.02.006

COX, Francis E. G. (2002): "History of human parasitology", *Clinical Microbiology Reviews*, *15*(4), pp. 595–612. https://doi.org/10.1128/CMR.15.4.595-612.2002

COX, Francis E. G. (2010): "History of the discovery of the malaria parasites and their vectors", *Parasites & Vectors*, *3*(1), pp. 1–9. https://doi.org/10.1186/1756-3305-3-5

DE LA PUENTE, Cristina (2014): *Médicos de al-Ándalus perfumes, ungüentos y jarabes*. Madrid: Nivola.

DEL PORTILLO, Hernando A.; FERRER, Mireia; BRUGAT, Thibaut; MARTIN-JAULAR, Lorena; LANGHORNE, Jean; LACERDA, Marcus V. (2012): "The role of the spleen in malaria", *Cellular Microbiology*, *14*(3), pp. 343-355. https://doi.org/10.1111/j.1462-5822.2011.01741.x

DEL PRADO, Gema; HERNÁN GARCÍA, Cristina; MORENO CEA, Lourdes; FERNÁNDEZ ESPINILLA, Virginia; MUÑOZ MORENO, María; DELGADO MÁRQUEZ, Antonio; POLO POLO, María; ANDRÉS GARCÍA, Irene (2014): "Malaria in developing countries", *The Journal of Infection in Developing Countries*, *8*(1), pp. 1–4. https://doi.org/10.3855/jidc.4610

DEMISSEW, Assalif; HAWARIA, Dawit; KIBRET, Solomon; ANIMUT, Adebe; TSEGAYE, Arega; LEE, Ming C.; YAN, Guiyun; YEWHALAW, Delenasaw (2020): "Impact of sugarcane irrigation on malaria vector Anopheles mosquito fauna, abundance and seasonality in Arjo-Didessa, Ethiopia", *Malaria Journal*, *19*(1), pp. 1-8. https://doi.org/10.1186/s12936-020-03416-0

DILLON, Andrew; FRIEDMAN, Jed; SERNEELS, Pieter M. (2014): "Health Information, Treatment, and Worker Productivity:

Experimental Evidence from Malaria Testing and Treatment among Nigerian Sugarcane Cutters", *World Bank Policy Research Working Paper, 7120*, pp. 1-46.

DUFOUR, Benjamin; LE BAILLY, Matthieu (2013): "Testing new parasite egg extraction methods in paleoparasitology and an attempt at quantification", *International Journal of Paleopathology*, *3*(3), pp. 199–203. https://doi.org/10.1016/j.ijpp.2013.03.008

ENGWERDA, Christian R.; BEATTIE, Lynette; AMANTE, Fiona H. (2005): "The importance of the spleen in malaria", *Trends in Parasitology*, *21*(2), pp. 75-80. https://doi.org/10.1016/j.pt.2004.11.008

FERNÁNDEZ ASTASIO, Balbina (2018): *La Erradicación Del Paludismo En España: Aspectos Biológicos de La Lucha Antipalúdica*. Doctoral dissertation. Universidad Complutense de Madrid, Madrid.

FERREIRA, Luiz F.; REINHARD, Karl J.; ARAÚJO, A. (2014): *Foundations of Paleoparasitology*. Río de Janeiro: Editora Fiocruz. https://doi.org/10.7476/9788575415986

FORNACIARI, Gino; GIUFFRA, Valentina; FERROGLIO, Ezio; BIANUCCI, Raffaella (2010a): "Malaria was "the killer" of Francesco I de' Medici (1531-1587)", *The American Journal of Medicine*, *123*, pp. 568-569. https://doi.org/10.1016/J.AMJMED.2009.12.020

FORNACIARI, Gino; GIUFFRA, Valentina; FERROGLIO, Ezio; GINO, Sarah; BIANUCCI, Raffaella (2010b): "Plasmodium falciparum immunodetection in bone remains of members of the Renaissance Medici family (Florence, Italy, sixteenth century)", *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *104*(9), pp. 583-587. https://doi.org/10.1016/J.TRSTMH.2010.06.007

GELABERT, Pere; SANDOVAL-VELASCO, Marcela; OLALDE, Iñigo; FREGEL, Rosa; RIEUX, Adrien; ESCOSA, Raül; ARANDA, Carles; PAAIJMANS, Krijn; MUELLER, Ivo; GILBERT, Thomas; LALUEZA-FOX, Carles (2016): "Mitochondrial DNA from the eradicated European Plasmodium vivax and P. falciparum from 70-year-old slides from the Ebro Delta in Spain", *Proceedings of the National Academy of Sciences of the United States of America*, *113*(41), pp. 11495-11500. https://doi.org/10.1073/pnas.1611017113

GOWLAND, Rebecca L.; WESTERN, Gaynor A. (2012): "Morbidity in the marshes: Using spatial epidemiology to investigate skeletal evidence for malaria in Anglo-Saxon England (AD 410–1050)", *American Journal of Physical Anthropology, 147*(2), pp. 301-311. https://doi.org/10.1002/ajpa.21648

GUTIÉRREZ AROCA, Juan B. (2018): "Desarrollo de la ciencia y la medicina en Al-Andalus", *Arte, Arqueología e Historia*, *25*, pp. 133-148.

HAWASS, Zahi; GAD, Yehia Z.; SOMAIA, Ismail; KHAIRAT, Rabab; FATHALLA, Dina; HASAN, Naglaa; AHMED, Amal; ELLEITHY, Hisham; BALL, Markus; GABALLAH, Fawzi (2010): "Ancestry and Pathology in King Tutankhamun's Family", *Jama*, *303*(7), pp. 638-647. https://doi.org/10.1001/jama.2010.121

HEDRICK, Philip W. (2011): "Population genetics of malaria resistance in humans", *Heredity*, *107*(4), pp. 283–304. https://doi.org/10.1038/hdy.2011.16

HEDRICK, Philip W. (2012): "Resistance to malaria in humans: the impact of strong, recent selection", *Malaria Journal*, *11*(1), pp. 1–7. https://doi.org/10.1186/1475-2875-11-349

HERRERA CARRANZA, M. (2021): "A propósito de pandemias: Ibn Jatima de Almería anticipa el concepto fisiopatológico de fallo multiorgánico en el siglo XIV", *Medicina Intensiva*, *45*(6), pp. 362-370. https://doi.org/10.1016/j.medin.2020.05.010.

HOEPPLI, Reinhard (1956): "The knowledge of parasites and parasitic infections from ancient times to the 17th century", *Experimental Parasitology*, *5*(4), pp. 398–419. https://doi.org/10.1016/0014-4894(56)90024-8

IBN AL-JATIB, Muhammad (1977): *Mi'yar al-ijtiyâr fi dikr al ma'âhid wa-l-diyâr*. Marruecos: Instituto Universitario de Investigación Científica.

IJUMBA, Jasper N.; MOSHA, Franklin W.; LINDSAY, Steve W. (2002): "Malaria transmission risk variations derived from different agricultural practices in an irrigated area of northern Tanzania", *Medical and Veterinary Entomology*, *16*(1), pp. 28-38. https://doi.org/10.1046/j.0269-283x.2002.00337.x

JIMÉNEZ-BROBEIL, Sylvia A.; MAROTO, Rosa M.; MILELLA, Marco; LAFFRANCHI, Zita; REYES BOTELLA, Candela (2022): "Introduction of sugarcane in Al-Andalus (Medieval Spain) and its impact on children's dental health", *International Journal of Osteoarchaeology*, *32*(1), pp. 283-293. https://doi.org/10.1002/oa.3064

KNORR, Delaney A.; SMITH, William P. W.; LEDGER, Marissa L.; PEÑA-CHOCARRO, Leonor; PÉREZ-JORDÁ, Guillem; CLAPÉS, Rafael; PALMA, María; MITCHELL, Piers (2019): "Intestinal parasites in six Islamic medieval period latrines from 10th-11th century Córdoba (Spain) and 12th-13th century Mértola", *International Journal of Paleopathology*, *26*, pp. 75-83. https://doi.org/10.1016/j.ijpp.2019.06.004

LALREMRUATA, Albert; BALL, Markus; BIANUCCI, Raffaella; WELTE, Beatrix; NERLICH, Andreas; KUN, Jürgen; PUSCH, Carsten (2013): "Molecular Identification of Falciparum Malaria and Human Tuberculosis Co-Infections in Mummies from the Fayum Depression (Lower Egypt)", *PlOS One*, *8*(4), e60307. https://doi.org/10.1371/journal.pone.0060307

LE BAILLY, Matthieu; MAICHER, Céline; ROCHE, Kévin; DUFOUR, Benjamin (2021): "Accessing Ancient Population Lifeways through the Study of Gastrointestinal Parasites: Paleoparasitology", *Applied Sciences*, *11*(11), 4868. https://doi.org/10.3390/app11114868

LÓPEZ-GIJÓN, Ramón; CAMARÓS, Edgard; RUBIO-SALVADOR, Ángel; DURAS, Salvatore; BOTELLA-LÓPEZ, Miguel C.; ALEMÁN-AGUILERA, Inmaculada; RODRÍGUEZ-AGUILERA, Ángel; BUSTAMANTE-ÁLVAREZ, Macarena; SÁNCHEZ-BARBA, Lydia P.; DUFOUR, Benjamin; LE BAILLY, Matthieu (2023b): "Implications of the prevalence of *Ascaris* sp. in the funerary context of a Late Antique population (5th-7th c.) in Granada (Spain)", *International Journal of Paleopathology*,*43*,pp.45-50.https://doi.org/10.106/j.ijpp.2023.09.002

LÓPEZ-GIJÓN, Ramón; CARNICERO, Silvia; BOTELLA-LÓPEZ, Miguel; CAMARÓS, Edgard (2023a): "Zoonotic parasite infection from a funerary context: A Late Antique child case from Cantabrian Spain", *International Journal of Paleopathology*, *41*, pp. 55-58. https://doi.org/10.1016/j.ijpp.2023.03.003

LÓPEZ-GIJÓN, Ramón; DUFOUR, Benjamin; COPPOLA-BOVE, Lorenza; MARTÍN-ALONSO, José F.; BOTELLA LÓPEZ, Miguel C.; LE BAILLY, Matthieu (2021): "Los inicios de la Paleoparasitología como disciplina científica y su aportación a la Antropología Física", *Revista Española de Antropología Física*, *44*, pp. 41–46.

LÓPEZ-GIJÓN, Ramón; JIMÉNEZ-BROBEIL, Sylvia; MAROTO-BENAVIDES, Rosa; DURAS, Salvatore; SULIMAN, Amjad; FERNÁNDEZ-ROMERO, Pablo; BOTELLA-LÓPEZ, Miguel; SÁNCHEZ-MONTES, Francisco; MITCHELL, Piers D. (2024): "Parasite eggs in 16th-18th century cesspits from Granada (Spain)", *Journal of Archaeological Science: Reports*, *53*, 104342. https://doi.org/10.1016/j.jasrep.2023.104342

LÓPEZ ROMÁN, Ramón (1990): *Pasado y presente del paludismo*. La Laguna: Universidad de la Laguna.

LOUFOUMA-MBOUAKA, Alvie; BINDER, Michaela; NOEDL, Harald; GAMBLE, Michelle (2020): "Evaluation of rapid diagnostic tests and Enzyme Linked Immunoassay in the detection of malaria in ancient human remains", *Journal of Archaeological Science*, *116*, 105118. https://doi.org/10.1016/J.JAS.2020.105118

LOUFOUMA-MBOUAKA, Alvie; GAMBLE, Michelle; WURST, Christina; JÄGER, Heidi Y.; MAIXNER, Frank; ZINK, Albert; NOEDL, Harald; BINDER, Michaela (2021): "The elusive parasite: comparing macroscopic, immunological, and genomic approaches to identifying malaria in human skeletal remains from Sayala, Egypt (third to sixth centuries AD)", *Archaeological and Anthropological Sciences*, *13*(7), pp. 1–22. https://doi.org/10.1007/s12520-021-01350-z

MACHADO SANTIAGO, Rafael; JIMÉNEZ BAUTISTA, Francisco (1995): "Proceso de transformación del paisaje agrario del litoral granadino (vega de Motril-Salobreña): Implantación, desarrollo y crisis de la caña de azúcar: Conflictos y tendencias", *Cuadernos geográficos de la Universidad de Granada*, *24*, pp. 123–38.

MAICHER, Céline; HOFFMANN, Alizé; CÔTÉ, Nathalie; PALOMO PÉREZ, Antoni; SAÑA SEGUÍ, María; LE BAILLY, Matthieu (2017): "Paleoparasitological investigations on the Neolithic lakeside settlement of La Draga (Lake Banyoles, Spain)", *The Holocene*, *27*(11), pp. 1659-1668. https://doi.org/10.1177/0959683617702236

MALPICA CUELLO, Antonio (2012): "La caña de azúcar en los agroecosistemas irrigados andalusíes", in A. Viña Segura and D. Corbella Díaz (Eds.), *La ruta azucarera atlántica: Historia y documentación*, pp. 9-21. Portugal: Centro de Estudios de História do Atlántico.

MARCINIAK, Stephanie; PROWSE, Tracy L.; HERRING, Ann; KLUNK, Jennifer; KUCH, Melanie; DUGGAN, Ana T.; BONDIOLI, Luca; HOLMES, Edward C.; POINAR, Hendrik (2016): "*Plasmodium falciparum* malaria in 1st–2nd century CE southern Italy", *Current Biology*, *26*(23), pp. 1220-1222. https://doi.org/10.1016/j.cub.2016.10.016

MICHEL, Megan; SKOURTANIOTI, Eirini; PIERINI, Federica; GUEVARA, Evelyn K.; MÖTSCH, Angela; KOCHER, Arthur; BARQUERA, Rodrigo; BIANCO, Raffaela A.; CARLHOFF, Selina; COPPOLA BOVE, Lorenza; FREILICH, Suzzane; GIFFIN, Karen; HERMES, Taylor; HIß, Alina; KNOLLE, Florian; NELSON, Elizabeth A.; NEUMANN, Gunnar U.; PAPAC, Luka; PENSKE, Sandra *et alii.* (2024): "Ancient Plasmodium genomes shed light on the history of human malaria", *Nature*, *631*(8019), pp. 125–133. https://doi.org/10.1038/s41586-024-07546-2

MILLER, Ron L.; IKRAM, Salima; ARMELAGOS, George J.; WALKER, Ross; HARER, Benson; SHIFF, Charles; BAGGETT, D., CARRIGAN, M.; MARET, S.M. (1994): "Diagnosis of *Plasmodium falciparum* infections in mummies using the rapid manual Para Sight™-F Test", *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *88*(1), pp. 31-32. https://doi.org/10.1016/0035-9203(94)90484-7

MITCHELL, Piers D. (2017): "Improving the use of historical written sources in paleopathology", *International Journal of Paleopathology*, *19*, pp. 88-95. https://doi.org/10.1016/j.ijpp.2016.02.005

MOLINA-PRADOS, Laura (2017): *El Paludismo En España Desde Una Perspectiva Histórica*. Bachelor´s final project. Universidad Complutense de Madrid, Madrid.

MURO, María (2017): *El paisaje cultural del azúcar en la Vega del Guadalfeo en época preindustrial (siglos X-XVIII).* Doctoral dissertation. Universidad de Granada, Granada.

NERLICH, Andreas (2016): "Paleopathology and Paleomicrobiology of Malaria", *Microbiology Spectrum*, *4*(6), 4.6.02. https://doi.org/10.1128/microbiolspec.PoH-0006-2015

NERLICH, Andreas; SCHRAUT, Bettina; DITTRICH, Sabine; JELINEK, Thomas; ZINK, Albert (2008): "*Plasmodium falciparum* in ancient Egypt", *Emerging Infectious Diseases*, *14*(8), pp. 1317-1319. https://doi.org/10.3201/eid1408.080235

NEWFIELD, Timothy (2017): "Malaria and malaria-like disease in the early Middle Ages", *Early Medieval Europe*, *25*(3), pp. 251-300. https://doi.org/10.1111/emed.12212

O'DONNELL, Lexi; HILL, Ethan C.; ANDERSON, Amy; EDGAR, Heather (2020): "*Cribra orbitalia* and porotic hyperostosis are associated with respiratory infections in a contemporary mortality sample from New Mexico", *American Journal of Physical Anthropology*, *173*(4), pp. 721-733. https://doi.org/10.1002/ajpa.24131

PEÑA DÍAZ, Manuel (2012): *Breve Historia de Andalucía*. Sevilla: Junta de Andalucía, Centro de Estudios Andaluces and Consejería de la Presidencia e Igualdad.

PEÑA MUÑOZ, Carmen; GIRÓN IRUESTE, Fernando (2005): "The Identification of Medieval Fevers According to Al-Isra'ili, Avenzoar and Bernard Gordon", *Cronos*, *8*, pp. 95-120.

PEÑA MUÑOZ, Carmen; GIRÓN IRUESTE, Fernando (2010): "El "capítulo sobre la conservación de la salud" del Kitáb al-taysir fí l-mudawat wa-l-tadbir de Avenzoar (c. 1095-1162)", *Dynamis*, *30*, pp. 281–308. https://doi.org/10.4321/S0211-95362010000100012

PERDIGUERO GIL, Enrique (2005): "Huerta, Arroz y Mosquitos: La Lucha Contra El Paludismo En La Provincia de Alicante", *Cuadernos de Historia de España*, *79*, pp. 203–235.

RABINO MASSA, Emma; CERUTTI, Nicoletta; SAVOIA, A.; Marin, D. (2000): "Malaria in ancient Egypt: paleoimmunological investigations in predynastic mummified remains", *Chungará*, *32*(1), pp. 7-9. https://dx.doi.org/10.4067/S0717-73562000000100003

RIERA MELIS, Antoni (2016): "De la cuenca Del Yangtsé a las marismas del Guadalquivir: la introducción del cultivo y del Consumo del Arroz asiático (*Oryza Sativa*) en Al-Andalus durante la Edad Media", *Estudis d'història agrària*, *28*, pp. 149–67. https://doi.org/10.1344/eha.2016.28.149-167

ROBERTS, Larry; JANOVY, John (2008): "Phylum Apicomplexa: Malaria Organisms and Piroplasms", in L. Roberts and J. Janovy (Eds.), *Foundations of Parasitology*, pp. 147-174. New York: McGraw-Hill.

ROMERA BARBERA, Aida; HERTZEL, Darwin; REINHARD, Karl J. (2020): "Attempting to simplify methods in parasitology of archaeological sediments: an examination of taphonomic aspects", *Journal of Archaeological Science: Reports*, *33*, 102522. https://doi.org/10.1016/j.jasrep.2020.102522

SAINZ-ELIPE, Sandra; LATORRE, José M.; ESCOSA, Raul; MASIÀ, Montserrat; FUENTES, Marius V.; MAS-COMA, Santiago; BARGUES, María D. (2010): "Malaria resurgence risk in southern Europe: climate assessment in an historically endemic area of rice fields at the Mediterranean shore of Spain", *Malaria Journal*, *9*(1), pp. 1–16. https://doi.org/10.1186/1475-2875-9-221

SALLARES, Robert; GOMZI, Susan (2001): "Biomolecular archaeology of malaria", *Ancient Biomolecules*, *3*(3), pp. 195-213.

SAVAGE-SMITH, Emilie (2013): "Medicine in Medieval Islam", in D. Lindberg (Ed.), *The Cambridge History of Science*, pp. 139-167. Cambridge: Cambridge University Press.

SETZER, Teddi J. (2014): "Malaria detection in the field of paleopathology: A Meta-Analysis of the state of the art", *Acta Tropica*, *140*, pp. 97–104. https://doi.org/10.1016/j.actatropica.2014.08.010

SMITH-GUZMÁN, Nicole E. (2015): "*Cribra orbitalia* in the ancient Nile Valley and its connection to malaria", *International Journal of Paleopathology*, *10*, pp. 1–12. https://doi.org/10.1016/j.ijpp.2015.03.001

TAYLOR, Michael; RUTLAND, Paul; MOLLESON, Theya (1997): "A sensitive polymerase chain reaction method for the detection of Plasmodium species DNA in ancient human remains", *Ancient Biomolecules*, *1*(3), pp. 193-203.

THÉODORIDÈS, Jean (1955): "La Parasitologie et la Zoologie dans l'œuvre d'Avenzoar", *Revue d'histoire des sciences et de leurs applications*, *8*(2), pp. 137-145.

VÁZQUEZ DE BENITO, María C.; ÁLVAREZ MORALES, Camilo (Eds.) (2003): *El Libro de Las Generalidades de La Medicina*. Madrid: Trotta.

WALKER, Phillip L.; BATHURST, Rhonda R.; RICHMAN, Rebecca; GJERDRUM, Thor; ANDRUSHKO, Valerie A. (2009): "The causes of porotic hyperostosis and *cribra orbitalia*: a reappraisal of the iron-deficiency-anemia hypothesis", *American Journal of Physical Anthropology*, *139*(2), pp. 109–125. https://doi.org/10.1002/AJPA.21031

WEATHERALL, David J. (2008): "Genetic variation and susceptibility to infection: the red cell and malaria", *British Journal of Haematology*, *141*(3), pp. 276–86. https://doi.org/10.1111/j.1365-2141.2008.07085.x

WEATHERALL, David J.; CLEGG, John B. (2008): *The Thalassaemia Syndromes*. New Jersey: John Wiley & Sons.

WHARTON, David (1980): "Nematode Egg-Shells", *Parasitology*, *81*(2), pp. 447–463. https://doi.org/10.1017/S003118200005616X

WIPASA, Jiraprapa.; ELLIOTT, Salenna.; XU, Huji; GOOD, Michael F. (2002): "Immunity to asexual blood stage malaria and vaccine approaches", *Immunology and Cell Biology*, *80*(5), pp. 401–414. https://doi.org/10.1046/j.1440-1711.2002.01107.x

WORLD HEALTH ORGANIZATION (2025): "World malaria report 2025: addressing the threat of antimalarial drug resistance", *World Health Organization*.

ZHAO, Xia; SMITH, David L.; TATEM, Andrew J. (2016): "Exploring the spatiotemporal drivers of malaria elimination in Europe", *Malaria Journal*, *15*(1), pp. 1–13. https://doi.org/10.1186/s12936-016-1175-z

ZINK, Albert; HAAS, Cristopher; HERBERTH, K.; NERLICH, Andreas (2001): "PCR amplification of Plasmodium DNA in ancient human remains", *Ancient Biomolecules*, *3*, p. 293.