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# Scientific and Technological Advances in Anthropological and Archaeological Research

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## Abstract

Anthropological and archaeological sciences have played an essential role in reconstructing how humanity has developed throughout time. They have also provided insight into our biological, cultural, and technological evolution as members of the human species. Both anthropology and archaeology have experienced a scientific transformation in recent years, primarily through the use of scientific technologies, such as radiometric dating, isotope analysis, remote sensing, and ancient DNA analysis. These technologies give scientists the ability to reconstruct ancient ecosystems, follow the migration of ancient peoples, analyze ancient diets, and confirm the relationships among ancient populations through genetics. This article summarizes current scientific techniques in both anthropology and archaeology, focusing on the contributions of archaeometry, paleo-genetics, and computational methodologies to the interpretation of archaeological data. These new techniques and technologies are changing how we understand our evolution as humans and how we interacted with our environment and each other in prehistoric times. Anthropology and archaeology also provide a powerful means of trying biological data, cultural records, and technological advances to reconstruct the distant past of humanity and to better understand our current diversity and adaptability to the world today.

**Keywords:** anthropology, archaeology, archaeometry, ancient DNA, bioarcheology, human evolution

## Introduction

Anthropology and archaeology are two related sciences that study the origins, evolution, and cultural differences among human beings. Anthropology provides a wide variety of information on human biological evolution, culture, and the way people as a society organize their lives [1]. Archaeology, on the other hand, studies the physical remains of past societies (i.e., the artifacts they produced and how those artifacts relate to the global climate). Together, anthropology and archaeology together provide anthropologists and archaeologists with their scientific basis (i.e., their scientific study of the past), using techniques from both the social and natural sciences.

The introduction of new ways to study archaeology has greatly increased the quantity and quality of archaeological research [2]. Basic techniques, such as excavating and analyzing artifacts, have been complemented by new ways to analyze archaeological materials. Specifically, new methods from chemistry, physics, genetics, and modeling have greatly improved the accuracy of dating (i.e., the estimation of how old an archaeological artifact is), the analysis of genetic material (i.e., the evaluation of biological materials such as bones), and the reconstruction of ecosystems based on data from a past climate. As such, the scientific study of anthropology and archaeology is now critical for understanding how humans evolved; how human culture has changed over time; and how humans have adapted to environmental changes over time [3].

## Scientific Foundations of Archaeological Research

The use of science in archaeology developed into what is now known as archaeometry in the 20th century. The concept of archaeometry refers to the application of scientific techniques to materi-

als found at archaeological sites. Methods included in archaeometry include the use of radiometric dating; materials analysis; and geophysical surveys, which allow archaeologists to study the contexts in which archaeological findings were found. The most widely used method of scientific archaeological dating is radiocarbon dating. With radiocarbon dating, archaeologists can measure the decay of carbon-14 isotopes found in organic remains (bone, charcoal and plant material) that are up to 50,000 years old, thereby enabling them to develop a chronological framework for prehistoric cultures [4].

In addition to radiocarbon dating, archaeologists can use other dating techniques including potassium-argon dating and thermoluminescence dating to chronologically date materials at prehistoric hominin sites or to study ancient geological contexts [5]. These various dating techniques illustrate how the archaeological interpretation of a site depends on scientific measurement, as well as laboratory analysis, and not on excavation alone.

## Advances in Bioarcheology and Ancient DNA Research

Paleogenetic, the science of investigating the DNA of past living organisms that have been unearthed in an archaeological excavation, is one of the biggest advancements within the field of anthropological sciences. With paleogenetic, effects of the migrations that shaped our modern human population, as well as migrations between different hominin species, have now been analyzed through genome sequencing. In addition, almost every modern human population has background genetic contributions to their genome derived from ancient human populations and migrations [6].

Currently, some of the most recent scientific advances have made it possible to isolate DNA from archaeological and other forms of sediment. Using this method, researchers can identify the presence of an extinct group of humans (due to the lack of skeletal remains) via sediment and also learn about past ecosystems and prehistoric interactions between diverse groups through analysis of sediment DNA. Despite the scientific advances in ancient DNA technologies, several inherent problems arise from studying ancient DNA including contamination of ancient DNA with environmental DNA, degradation of DNA over time/age of the sample, which require diligent laboratory and computational techniques and protocols to effectively analyze and interpret the ancient DNA [7,8].

## Isotopic and Molecular Analysis in Archaeological Science

Isotopic and molecular techniques, as well as DNA analysis, are valuable methods for gathering data regarding ancient diets, migrations, and environmental conditions. Stable isotopes consist of chemically unique chemical identifiers, or 'signatures', that are preserved in human and animal tissue; therefore, they can be used to recreate ancient dietary patterns and other ecological interactions. For example, isotopic analysis of bone collagen will indicate whether or not an ancient population relied predominantly on a plant-based diet or on terrestrial animals or marine resources. These techniques are now essential to bioarchaeological research and have expanded our knowledge of ancient subsistence patterns.

One emerging technique is Zooarchaeology by Mass Spectrometry (ZooMS), which allows for the identification of species through the identification of individual components, called "collagen peptides," found in animal tissues. ZooMS is especially useful for the analysis of fragmented bone remains that cannot typically be identified using traditional morphological analyses. Thus, by determining the species of origin of various bone artifacts, ZooMS provides researchers with critical data regarding past environments, animal domestication, and populations' use of various resources [9].

## Digital Technologies and Computational Archaeology

Archaeological fieldwork and analysis of archaeological data have greatly advanced due to technological innovations. Archaeological investigators can discover and document buried structures or modification of landscapes in situ through various remote sensing technologies, such as ground-penetrating radar (GPR), magnetometry, and LiDAR, without excavation. These methods have uncovered new archaeological sites and architectural elements in areas such as the Maya lowlands.

Researchers are able to analyze artifacts, and human remains in three dimensions due to digitized imaging methods (including micro-CT scans) and high-resolution scanning technologies. Three-dimensional (3D) digital models facilitate analysis of fragile archaeological artefacts, which otherwise would be destroyed during analysis. New research demonstrates that utilizing automated computational workflows permits analysis and scanning of large collections of archaeological artefacts, thereby allowing greater efficiency in research and data analyses and expanding the scope of research [10]. Machine Learning and Statistical Modelling are becoming more prevalent in archaeological research. Predictive models identify archaeological sites and analyze spatial distributions of settlement patterns. Modern computational techniques assist archaeologists in managing large datasets and refining their interpretation of how humans behaved in the past.

## Interdisciplinary Perspectives on Human Evolution

Increasingly, anthropological and archaeological sciences depend more heavily on the collaborative efforts of archaeologists, geneticists, chemists, geologists and computer scientists. Through these types of collaborations, researchers are able to combine a large number of types of evidence, such as artefacts, biological remains, environmental data and genetic information, into a more complete reconstruction of human history. One example of this collaborative approach is when research looking at archaeological data and genetic analysis have identified complicated relationships between anatomically modern humans and archaic hominins like Neanderthals. The findings from these studies suggest that the evolution of humans does not represent a simple line from one form to another, but rather an ever-changing record of humans moving from one population to another and adapting to new environments

while exchanging genetic information with the people who lived near them.

Furthermore, new fields like paleo proteomics (the study of ancient proteins) are allowing scientists the opportunity to study evolutionary relationships in many cases when the DNA has not been preserved well [7,8]. Since proteins decay at a slower rate than DNA, they can provide biological data from fossils millions of years ago and create possibilities to study the artefacts that belong to the earliest human ancestors [11,12].

## Conclusion

Anthropology and archaeology are becoming more interdisciplinary and utilizing technology, natural sciences, and cultural interpretation. They are also using new analytical techniques: they now employ radiometric dating techniques such as isotopic analysis, paleogenetic, and digital imaging, and they are transforming the methods used to study past human populations' and human societies' histories. Currently, the continued introduction of new technological advancements into archaeology will increase the data available for the archaeological study of past human societies. Anthropological and archaeological studies will be primarily collaborative and utilize a combination of biological evidence, environmental data, and cultural artifacts for their research in understanding human history and how it has contributed to today's world.

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