Prospects and Pitfalls

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Abstract

Paleoanthropology is primarily rooted in the study of fossils and the analysis of sites. Dependence on these resources leads to challenges resulting from difficulty in gaining access to scarce, precious, and sometimes overprotected materials and from issues of control over field sites. The development of virtual paleoanthropology can sometimes be a way to partially solve the first problem. However, on some occasions, the access to and utilization of numerical data has also become an issue of dispute. In parallel, recent advances in studies focusing on microstructures, isotopic composition, and paleogenetics require direct sampling of the fossils. The trend in paleoanthropology is to integrate approaches from different scientific fields, and this is especially visible in developmental sciences, genetics, and environmental studies. In the meantime, dealing with

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human evolution remains a sensitive topic, subject to clear ideological and religious biases. The interest of the media and of the public in this science does not always contribute to an objective approach to the questions. Finally, among other issues, the expansion of paleoanthropological studies in developing countries must depend on a decline in its colonial image.

Introduction

In many respects, paleoanthropology is a paradoxical science. Although it addresses the oldest origins of humans, the discipline itself developed quite recently in the history of science. The first fossil hominid specimen on record, an immature Neanderthal skull, was discovered in 1830 in Engis (Belgium). However, it was not until the end of the nineteenth century that certain fossil specimens were truly accepted by the majority of the scientific community as evidence for the evolutionary process that gave birth to the human species. Although very significant discoveries occurred during the first half of the twentieth century and provided the basic framework for paleoanthropological studies, the last three decades of that century witnessed a spectacular increase in the available fossil record as well as in major advances in the knowledge of past environments and the chronological background of human evolution. Moreover, the birth of paleogenetics added a new dimension to the analysis of relationships among fossil hominid species. The current state of the discipline results not only from methodological progress but also from a major effort of field research. For the public, the media, and students, it is always a matter of amazement, and sometimes of criticism, to realize that the field of paleoanthropology is such a changing terrain. If prediction is always a difficult exercise, in science as in many other domains, it is even more challenging in this particular science, which is relatively newly born and still rapidly evolving.

Another distinctive aspect of paleoanthropology lies in the fact that the study of fossil specimens remains the core of the discipline. These are rare and precious objects. It is often emphasized that for the study of some extinct groups, the specimens are fewer than the specialists who analyze them, and sometimes the competition is harsh. After an undefined period during which they remain under the relatively rigid control of individuals or groups responsible for publishing descriptions of them, they are usually curated in museums or other institutions. While the specimens are in their possession, the curating institutions may also restrict access to the fossil specimens, emphasizing their conservation rather than their scientific study. On the one hand, there is therefore strong pressure to consult the fossil material, and on the other, growing restrictions that result from a multitude of reasons that range from the desire to maintain scientific monopoly to the legitimate policy of protecting fragile and valuable objects. In parallel, new techniques for the study of the specimens have been developed. However, while these new methods sometimes resolve issues, sometimes they generate new difficulties.

Virtual Paleoanthropology

Since the 1980s, new techniques in medical and industrial imaging have revolutionized the fields of human paleontology and physical anthropology (Wind 1984; Wind and Zonneveld 1985; Zonneveld and Wind 1985) allowing the development of what has become commonly called as "virtual paleoanthropology." The growing use of computed tomography as well as industrial imaging techniques (microtomography and laser scanners) has allowed the production of 3D images of fossil specimens. Combined with stereolithography and other techniques of 3D printing, these virtual representations have opened a number of new possibilities for the analysis of the specimens. Most notable among these are:

- Virtual extraction and reconstruction (including correction of plastic distortions) (Kalvin et al. 1992; Zollikofer et al. 1995; Ponce de León and Zollikofer 1999)
- Precise quantitative analysis of inaccessible internal structure (including tiny structures, such as middle and inner ears, bony tables, and vascular foramina) and their comparison with living references (Zonneveld et al. 1989; Hublin et al. 1996; Spoor et al. 1996)
- 3D morphometric analysis with the development of new mathematical tools (Harvati 2002)
- Modeling of ontogenetic processes, biomechanical properties, and of evolutionary changes themselves (Ponce de León and Zollikofer 2001; Mitteroecker et al. 2004; Gunz et al. 2010; Freidline et al. 2012)

Growing evidence suggests that, with increasing frequency, the anatomy of fossil hominins will be systematically studied not from the specimens themselves but from virtual representations. Principal among all the new possibilities opened by virtual paleoanthropology is the reduced need to manipulate real objects. Consequently, these techniques should be welcomed by many curators. However, they also raise new questions. One is related to the quality of the data. Until recently, the CT scanners that have been used to acquire the data were primarily those available in the medical environment. Although they evolve rapidly, machines of this type have their own limitations and are not specifically designed to explore fossilized specimens filled with dense sediments. The resolution of the 3D pictures produced in this way does not allow for the assessment of fine structures at an appropriate resolution. In recent years, large museums curating fossils, as well as research institutions, have been increasingly equipped with microCT scanners, initially designed for industrial uses, which provide high-resolution data in the order of magnitude of a micron or even under. Imagery techniques based on the use of synchrotrons such as the face contrast allow the study of microstructures otherwise inaccessible to the analysis in a nondestructive way (Tafforeau and Smith 2008).

Among the pitfalls related to the development of virtual paleoanthropology is a shift from a situation where access to the fossil specimens was difficult to a situation where access to the numerical data is even more challenging. Curators are sometimes reluctant to allow repeated acquisitions of these numerical data, while the techniques and equipment evolve rapidly. Often, the data are monopolized by those who acquired them initially, and they are hard to upgrade. In the long term, databases may develop in some institutions and on the Internet (Hublin 2013). To date, however, the development of such databases has faced insuperable difficulties. The commercialization of some of these data by the institutions concerned, or the simple trading of data between teams, will remain, for some time, the only alternative.

Another concern relates to the possibility that repeated irradiation of fossil material may alter biomolecules such as ancient DNA. Although this problem has been to date little investigated, it may in the future lead to necessary choices in priorities regarding the analysis of recent fossil material.

Into the Matter of Bone

In a somewhat opposite direction to virtual paleoanthropology, there are a number of other new approaches that have been developed in the fields of human paleontology, physical anthropology, and archaeology. Such techniques were initially based on rather invasive analyses of the specimens, inherited primarily from histology and geochemistry. However, with the rise of non- (or less) destructive methods, this field is rapidly expanding. In the future, study of the actual fossil remains will likely be reserved for the kinds of analyses that cannot be performed on virtual representations. At present, such analyses include, on the one hand, histological approaches mainly addressing bone and tooth microstructures and, on the other hand, chemical analyses addressing either geochronological or paleobiological questions.

Microstructural studies have developed mostly in the field of dental anthropology. The recognition of different types of incremental mineralized structures in the dentine and the enamel since the middle of the twentieth century has led to systematic analyses of their variation in extant and fossil primates (Dean 1987; Stringer et al. 1990; Lieberman 1993; Zhao et al. 2000; Dean et al. 2001; Martin et al. 2003; Schwartz et al. 2003; Smith et al. 2003). This development has been made possible by the improvement of technical equipment such as the scanning electron microscope, the confocal microscope, and computer-assisted microscopy for 3D visualization. The interest in these studies comes from the knowledge that microstructures could be the main, if not the only way, to assess life history in extinct species (Fitz Gerald 1998). This issue has been given increasing attention in an evolutionary perspective since the genetic bases of development have become better understood and their importance for evolutionary changes better appreciated. Future research in this direction will certainly include extensive work on modern variability and more experiments to assess the biological significance of accretional microstructures and their relevance for calibrating the growth patterns of extinct species. Although it is possible to work on externally visible features, such as perikymata (Ramirez Rozzi and Bermudez de Castro 2004), a drawback of these methods is the necessity of slicing precious fossil specimens to analyze fine internal microstructures. However, the technique of thin slicing has greatly improved, and it is possible today to “rebuild” a specimen after analysis following minimal destruction of tissue. In the future, new techniques of imaging may also partly resolve this problem. Although, to date, it remains a very expensive technique, the use of synchrotrons allows access to bone and tooth microstructures without destruction (Tafforeau et al. 2006).

Chemical analyses of fossil specimens have been aimed at reconstructing paleobiological features and are mostly concerned with the extraction of organic molecules. Nonorganic chemical properties of the fossil remains are primarily relevant to the determination of their geological age and are marginally useful in addressing paleobiological issues. To date, DNA and collagen have been the main targets of the research on ancient biomolecules. Techniques based on the use of restriction enzymes have allowed the duplication and subsequent sequencing of tiny and rare fragments of DNA chains. So far, this work has been based primarily on the analysis of mitochondrial DNA, which is smaller and much more abundant than nuclear DNA. The sequencing of a fragment of mitochondrial DNA of the Feldhofer 1 (Neanderthal) specimen in 1997 opened a new era of paleoanthropological studies (Krings et al. 1997). Future development of this research will involve the reconstruction of the entire sequence of the mitochondrial DNA in specimens such as Neanderthals. With the development of new techniques, future work will also address the issue of nuclear DNA in fossil hominids. However, the natural degradation of DNA under given physical conditions imposes a chronological barrier that today seems oddly unsurpassable. Another serious problem in paleogenetic studies comes from the potential for contamination. Paradoxically, the DNA of modern and relatively recent humans remains very difficult to identify as genuine fossil DNA and to distinguish from subsequent contamination (Serre et al. 2004). Studies on the taphonomic processes affecting the deterioration of DNA chains in archaeological or geological deposits may provide an answer to this problem.

Isotopic compositions of the mineral portions of hominid fossils have been used to assess biological issues. These studies face the difficult questions of the taphonomic transformation of the chemical composition of fossils in geological layers (Radosevich 1993; Fabig and Herrmann 2002). Most researchers have thus focused on the more stable component of bone, the protein collagen (Schoeninger 1985; Ambrose 1986; Bocherens et al. 1991, 1997; Richards et al. 2000, 2001). Collagen has been the primary source for the analysis of stable isotopes such as oxygen, nitrogen, and carbon. These isotopes are fixed in the living tissues antemortem, either at an early stage of individual development (e.g., in the teeth) or at some time before death. They are an essential source of information about the environment and the diet of individuals during their lifetimes. One constraint of these studies is that they are limited by the long-term preservation of collagen. For older hominins, carbon fixed in the mineral part of the dental tissues has also been used to investigate what type of plants (C3 or C4) herbivores and their predators extracted their food. One can expect that, as with the study of recent archaeological series, such analyses in the future will bring unexpected knowledge of issues such as migration, seasonality, or even mating strategies among relatively ancient hominids. New research into extracting other longer-surviving proteins, such as osteocalcin, has the potential to provide material for isotopic studies for much older material. An interesting development comes from the combination of microstructural studies and isotopic analyses to assess fine timescale changes in the diet or the environments of fossil individuals (Humphrey et al. 2004). The extension of isotopic analyses to new elements may also lead to interesting developments in this field. For example, sulfur isotopes in collagen, along with strontium and oxygen in minerals, can tell a lot about migration and movement patterns (Nehlich et al. 2010). Isotopic studies (especially of oxygen) will also likely contribute to a much greater knowledge of past environmental conditions and their rapid variation in continental environments, a topic that so far remains much less explored than in oceanic environments and the ice caps.

Understanding Evolutionary Processes

The reconstruction of the evolutionary history of hominoids, and more specifically of fossil humans, has for a long time focused primarily on taxonomic and phylogenetic questions. Important methodological progress has been made in this field during recent decades. In particular, the use of cladistic approaches has provided a better theoretical background. Although these approaches also have their own limitations (Trinkaus 1990), they have become indispensable for assessing the significance and the polarity of features. However, it should be underlined that the development of mathematical techniques to analyze size and shape, including 3D morphometrics, has at times led to the regression of some studies to a precladistic stage. The emphasis placed on the shape distances should not lead researchers to forget that morphological similarity is not a reliable way to analyze phylogenetic relationships when the polarity of the features is not taken into account.

A major problem, discussed extensively in recent years, resides in the features used by paleoanthropologists for cladistic analyses. These discussions have focused on features' significance and relationships either to genetic determinism or to environmental conditions and behavior or to an interaction between the two. Beyond these discussions lie issues such as the independence of such features in their development and their homology when one passes from one species to another (Lieberman 1999; Wood 1999). These are critical questions for the analysis of the fossil evidence and the reconstruction of phylogenetic relationships from a parsimony perspective. However, one may be reasonably optimistic in this matter, as experimental data and a better understanding of the precise genetic and epigenetic mechanisms underlying the development of features will resolve these questions. These may also bring answers to related problems such as the discrepancy sometimes underlined between biomolecular evidence and phylogenetic reconstructions based on the analysis of morphological features of the phenotype (Collard and

Wood 2000; Strait and Grine 2004). They may also bring new light to the debate surrounding modular versus integrative models in the biological development of extinct organisms (Wagner 1996; Wagner and Altenberg 1996; Williams and Nagy 2001; Winther 2001).

As far as the recent stages of human evolution are concerned, it is reasonable to expect that taxonomic and phylogenetic issues will become of minor interest in the future as the main taxa are identified and their phylogenetic relationships understood. However, better understanding of variability, not only in extinct taxa but also in living forms, remains a crucial issue. Although some have predicted the decline of such anatomical studies, it is still striking to contemplate the lack of knowledge of the variability in living humans with respect to many features commonly used in paleoanthropological research. After several centuries of anatomical studies, longitudinal data on the growth and development of many anatomical features is still desperately needed. This lack of data is even more dramatic when one considers the populations of living apes, the closest relatives of humans in the animal world; most of them will likely become extinct in the wild before they have been properly studied.

Research may focus more on paleobiological issues. Changes in growth and development processes during life history, in terms of timing and pattern, are increasingly seen as powerful mechanisms to explain evolutionary changes. Studies of extinct species consider this dimension with increasing frequency, and developmental trajectories will hopefully be identified for different taxa as will the effects of epigenetic phenomena. This is, of course, dependent on an increase in the available paleontological material and also on a greater interaction between paleoanthropology and developmental genetics. 3D morphometrics and other mathematical tools have been identified recently as powerful tools for the reconstruction of those developmental trajectories that can sometimes be modeled (Ponce de León and Zollikofer 2001). Establishing reliable tools to assess the calendar ages of immature individuals in the fossil record is of crucial importance in this matter (Coqueugniot et al. 2004), and developing studies of skeletal microstructure seems an inevitable way to address this problem.

Other aspects of the biology of extinct species might also become accessible through progress in the extraction of biomolecules such as proteins. Osteocalcin has recently been extracted from Neanderthal remains and sequenced (Nielsen-Marsh et al. 2005). In the future, extraction of proteins or lipids from ancient material may even shed new light on the physiology of our ancestors and cousin species. It should also be noted that the extraction of ancient proteins and their sequencing may be extended much further back in time as some of these molecules seem to resist taphonomic degradation much better than DNA.

In recent years, paleodemographic questions have become more and more interesting to paleoanthropologists. Topics such as life history and longevity are critically important to understanding the biological and social adaptations of ancient groups, as well as to addressing questions of learning time during individual life and the transmission of knowledge from one individual to another. Other paleodemographic parameters that appear to be important are the questions of population densities in given areas in a geological time frame and their possible catastrophic variation in relation to environmental changes. Although paleodemographic parameters have long appeared unreachable (Bocquet-Appel and Masset 1982, 1996), different methods of evaluating size fluctuation in ancient populations have emerged from genetic or paleogenetic studies. In addition to providing new understanding of phylogenetic relationships, gene flow between groups, and differences in gene coding for some characters in ancient hominids, paleogenetics has also introduced a new way to assess group size through time in ancient humans (Meyer et al. 2012). Although paleogenetic studies on the Neanderthals did not revolutionize views of their phylogenetic relationships, they did bring a new way to assess genetic variability in ancient populations and, consequently, population size changes (Currat and Excoffier 2004; Serre et al. 2004). The animal models appear to be a tempting alternative for testing demographic fluctuations and their effects on genetic variability during the recent periods of the Pleistocene (Orlando et al. 2002). Such knowledge will allow a better understanding of the possible effects of demographic crashes and genetic bottlenecking on evolutionary processes themselves, as well as the relative roles of genetic drift and natural selection. Combining isotopic analysis and microstructural studies will also allow the garnering of information such as the weaning age of fossil individuals. A fine knowledge of climatic environmental changes, sometimes perceptible on the scale of one human life, also brings new light to the way human populations have adapted biologically and culturally. In this perspective, a better integration of biological and cultural evidence seems necessary for a more thorough understanding of human evolution.

Chronology

The determination of the geological age of fossil hominids is central to paleoanthropological work. Until recently, such determination has centered on the application of radiometric methods to the archaeological context of the discoveries. Although available methods require improvement in their precision and in their calibration, their direct application to hominid specimens also represents major progress, especially for specimens anciently discovered and/or for which the context is unknown or inaccessible. Once more, the development of such approaches has been limited initially by the destructive aspects of these investigations. However, the emergence of new techniques, such as laser ablation, makes the analysis of light or heavy isotopes on precious specimens almost completely nondestructive. In the future, these studies may be applied routinely and become the best way to establish a precise chronology.

As far as the radiometric methods based on C^{14} disintegration are concerned, the development of mass spectrometry has allowed the direct dating of fossil specimens by requiring only small amounts of matter for analysis. Since 2009 the calibration curve for C^{14} dates has been extended back to 50,000 BP, which makes the method more reliable in this time range that is of such crucial importance to the history of modern human dispersal (Reimer et al. 2009). In addition to calibration, contamination remains a major problem and the origin of the sampled carbon must be securely established; methods such as the ultrafiltration of the collagen may allow for the control of this factor. Another future development will be to work with organic carbon from biomolecules such as amino acids that can be identified as genuine fossil molecules belonging to the extinct organisms from which they were extracted. In practice, all this means that many C^{14} dates acquired during the last decades may become meaningless because of the limitations of the techniques used to establish them. Large databases that have been built to process these dates by the thousands and that provide a picture of biological and cultural evolution of humans, especially at the time of the replacement of Neanderthals by modern humans in Europe, can be improved by a critical assessment of the compiled dates. However, the screening process has provided very contrasting pictures and has not satisfactorily solved all questions. This probably results from some bias in the selection process of the data retained, partly depending on the views that different authors have on the evolutionary and peopling processes involved. Eventually, such databases may become obsolete and will need to be rebuilt with more reliable geochronological information.

Picture of an Ancestor

Every human society has built up physicotheological explanations to deal with the question of its origins. In the historical record, such explanations have been furnished by religions and mythologies, but from the middle of the nineteenth century, western societies substituted a scientifically based explicatory model for biblically based explanations. The question of human origins became the concern of scientists rather than priests. However, in 1863, T. H. Huxley, a major supporter of Darwin's views, wrote: "The question of questions for mankind, the problem which underlies all others, and is more deeply interesting than any other, is the ascertainment of the place which man occupies in nature, and of his relationship to the universe of things. Whence our race has come; what are the limits of our power over nature; to what goal are we tending are the problems which present themselves anew, and with undiminished interest, to every man born into the world" (see Huxley 1863, p. 71). Almost 150 years later, this issue is still not free of ideological, if not metaphysical, constraints. This may partly explain why the public has developed such an interest in this field of science. Aside from the inherent attraction of pictures of extinct worlds, any piece of evidence in paleoanthropological studies also becomes a matter of opinion and feeling, even for non-knowledgeable audiences. Prehistory is also consistently the topic of novels, films, and documentaries in which science always has to defend itself against fantasy (Sommer 2006, 2007; Stoczkowski 1994). Museums and educational centers have become incredibly successful with this subject, showing increasing sophistication in their ways of responding to the demands of the public for pictures or 3D reconstructions. Although some of these reconstructions are produced today (Fig. 1) using advanced techniques, they have their own limitations. It is certainly possible to provide reasonable

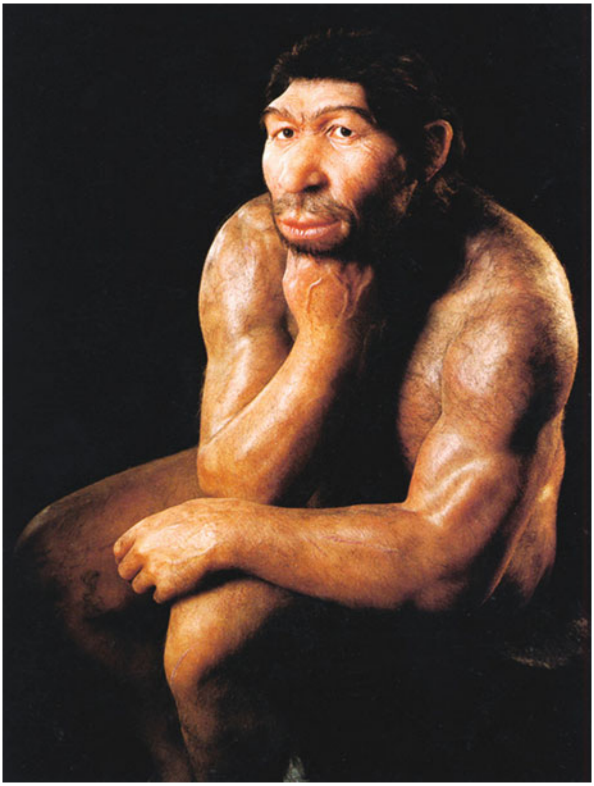

Fig. 1 A reconstruction of a pre-Neanderthal at the Landesmuseum für Vorgeschichte (Halle, Germany). Accurate methods have been developed to reconstruct soft tissues in fossil hominids. However today, like in the past, the picture of ancient humans primarily remains a projection of human fantasies

reconstructions of the general anatomy of well-known fossil species. However, to date, many fine anatomical details, such as skin, hair, and eyes, remain beyond the range of scientific assessment. Unfortunately, they are also of crucial importance to the way other species of humans appear from a modern perspective. The "scientifically based" reconstructions of fossil hominids filling the museums in Europe and America may say much more about the way human diversity is perceived than about the actual aspects of these hominins. In this respect, the progress of the reconstructions since the beginning of the twentieth century may be more limited than is often assumed. Underlying notions of humans as belonging to different species, and possibly contemporaneous in the past, are difficult to integrate, not only for the public but also for scientists from sister disciplines. The humanist framework within which the human and social sciences developed in universities may explain the difficulty that cultural anthropologists and archaeologists, attached to the notion of "uniqueness" of the human being, face in dealing with notions such as ape cultures or the multispecific nature of hominins. More generally, in the post-Second World War era, new conceptions understandably developed around human diversity that provided an ideological framework to which paleoanthropological evolutionary models had to adapt. The questions of Neanderthal nature and abilities and their relationship to extant humans, in other words the last well-documented divergence in the human phylogenetic tree, is one arena in which science and ideological preconceptions have clashed in a complex way.

In this interaction between scientists and the public, the media play an important role. There are many reasons why scientists need to communicate with the public. One is that the interest of the public partly justifies society's investment in this field of pure research. Another may result from more personal reasons. For a department, for a team, for an individual, the visibility of the scientific results obtained becomes increasingly important as it impacts on possible personal promotion and political decisions to support this field of research in general, or a project in particular. Thus, the scientist and the reporter face each other in a dialogue where each needs the other. The reporter needs material for exciting articles; the scientist needs a reporter for publicity (Henke 2010). In the past few decades, this interaction has become increasingly important and has sometimes led to undesirable effects. One obvious pitfall is that the public and reporters are more interested in some issues than in others. Those problems most debated in the media may be of limited interest to the scientific community, and vice versa. Sex between Neanderthals and modern humans is an example of a question universally addressed to paleoanthropologists, and one danger is that, in the need to be well represented in the media, scientists might be led to pander to such questions or even to develop research interests geared to public attention. It is amazing to see how well-developed press services have become, not just in institutions dedicated to public education and communication but also within research structures as well.

Recently these interactions between scientists and the media have entered a new dimension, as personal issues or rivalries between individuals have become of themselves a matter of interest for the press. High-profile international scientific journals have developed "people sections" that deal almost exclusively with these subjects. Reporters have therefore become part of the scientific debate and actors in rivalries, by promoting opinions and sometimes by fueling controversies and conflicts in a way designed to make their articles more exciting.

The Unbalanced Ecology of Paleoanthropology

Paleoanthropology is based on the study of specimens to which access may be difficult. It is also based on sites and fieldwork. The result is that it can be a highly territorial activity, to an extent unequaled in other fields of science. Indeed, aside from scientific problems, the paleoanthropologist must also face a series of political and ethical issues. Although specimens discovered and published a long time ago should be fully accessible to the scientific community, this is not always the case. The situation is even more complex regarding specimens soon after their discovery and/or after a partial description. So far, the scientific community has not established a consensus on resolving such questions. The discoverer of a new specimen has a scientific and moral right to it and is granted priority in providing a scientific analysis of this material, alone or in collaboration with other specialists. However, this well-accepted notion is often blurred by complications. One such complication can result from the multiplicity of the discoverers involved and from lack of agreement at the time of the discovery, or later. And many discoveries occur during the course of archaeological excavations conducted by teams that were not anticipating the possibility of hominin discoveries. Another problem can result from an abusive extension of the time spent between a discovery and the publication of a reasonably comprehensive description of it. The competition that is natural in science is sometimes displayed in a negative form, such as preventing challengers from accessing material, which may be used as a more efficient way to surpass them than producing better scientific results.

Similar situations have developed with respect to site and field access. Most commonly, research teams obtain the monopoly of the study of one site or a geographical area for a certain length of time in order to conduct a defined scientific program. However, apart from this formal arrangement, there are a number of situations where informally and based on political influence, tradition, or nationalistic issues, institutions manage to secure a geographical domain of influence. This is often the case when excavations or field operations are conducted by scientists from western countries in less developed areas. Often, this is facilitated by the fact that the studied areas are located in countries lacking indigenous research in the field of paleoanthropology and/or scientists trained in this discipline. In such cases the work is conducted under the authorization of local administrations that are primarily preoccupied by the conservation of their national patrimony. Here again, different institutions or scientific communities may develop some level of competition in guaranteeing their access to the field. Different countries have developed different regulations restricting the exploitation of archaeological and paleontological material. Situations in which fossil specimens can simply be transferred from the country of their discovery to scientific institutions or museums in Europe or America have almost completely disappeared today.

Many scientists have felt compelled to develop balanced collaborations with the host countries in which they conduct their research, in particular, by helping with the conservation of the material and with the training of local scientists. Furthermore, many countries outside of the western world have managed to develop their own programs and scholars, and the trend is more and more to develop joint projects, although a very unequal equilibrium in terms of financial contribution and/or scientific expertise can lead to bitter conflicts. Although the time of scientific colonialism is over, and in an ideal world, fossils and sites should be accessible to “everyone,” this ideal situation is still far from being reality. Archaeological and paleontological materials are considered as part of the national patrimony in most counties, yet the future of the field lies in fair and fruitful international collaborations.

Conclusion

In summary, although the development of virtual paleoanthropology has opened new venues to access the fossil evidence and to study it, paleoanthropology remains a science primarily centered on objects and sites to which access for researchers is far from being guaranteed. In the last two decades, the field has witnessed spectacular methodological progress providing new insights into the processes of human evolution. However, the question of the origin and nature of humankind remains a sensitive issue. In addressing these questions, science is challenged by many preconceptions.

Cross-References

▶ Chronometric Methods in Paleoanthropology
▶ Evolutionary Theory in Philosophical Focus
▶ Historical Overview of Paleoanthropological Research
▶ Hominin Paleodiets: The Contribution of Stable Isotopes
▶ Virtual Anthropology and Biomechanics

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