The paleopathological collection of the "G. D'Annunzio" University Museum (Chieti-Pescara, Italy)

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Abstract. Paleopathology is a multidisciplinary science which studies the origin and evolution of diseases. The main sources of information consist of biological remains (mainly bones and teeth), archaeological finds and historical documents. The study of diseases in prehistoric times is based solely on fossils showing pathological signs. The "G. d'Annunzio" University Museum of Chieti-Pescara (Italy) preserves a rich paleopathological collection consisting of 481 artifacts. The collection consists of plant, animal and human remains with pathological changes resulting from trauma, infectious diseases, joint diseases, tumors, metabolic diseases or nutritional deficiencies and congenital diseases. Each specimen has an inventory number and a technical data sheet, accompanied by photographic images from different viewpoints. The data sheet includes information regarding the taxonomic classification, the dating and origin of the specimen, the description of the lesion and offers a pathological diagnosis. It is a unique collection of its kind, which constitutes a precious source of information even on very ancient diseases, and an opportunity for researchers to study the interactions between ecosystems of the past and extinct animal and plant species through "paleopathological markers".

Key words: ancient diseases, fossils, anthropology

Introduction

"Paleopathology" is a multidisciplinary science, which studies human and animal diseases of the past and their evolution over time. The term was first used by Robert Wilson Shufeldt in 1893 to indicate the pathological signs on remains of extinct animals (1-3). In 1913 Sir Marc Armand Ruffer (1859-1917), considered the father of modern Paleopathology thanks to his pioneering and innovative studies on Egyptian mummies, used the term Paleopathology as it clearly explained the topic of his studies. He also specified that Paleopathology does not define extinct diseases but it is "the science of diseases which can be demonstrated in the human and animal remains of ancient times" (4, 5).

The materials studied in Paleopathology mainly consist of ancient biological remains, defined as "direct sources" to distinguish them from the so-called "indirect sources", that are represented by historical texts and remains of material culture and, therefore, strictly confined to the sphere of human paleopathology (e.g. 6). Direct sources can be both human (bones, teeth, mummified remains, calcified soft tissues) and non-human (fossil remains of animals and plants, coprolites, parasites and vectors of infectious diseases such as the ones preserved in amber; e.g. 7-15). The latter, as regards the study of diseases in prehistory, are the only remains from which it is possible to extrapolate information on the nature and epidemiology of ancient diseases (e.g. 16). The limits of direct sources are often linked to the fragmentation of skeletal remains, to the lack of specific pathological signs (pathognomonic) and to the taphonomic alterations of the bone elements (e.g. 17, 18). As for indirect sources, the major problem is an interpretative one, linked to the exegesis of ancient medical terminologies and to

the identification of any pathological signs on iconographic sources, which are in any case the product of an artist's vision (19).

Despite the limitations associated with the study of human remains from historical, archaeological and paleontological contexts, Paleopathology raises particular interest in both anthropological and medical fields. Diseases can be considered social and environmental markers of ancient human populations (e.g. 20, 21) and the interest of anthropologists for Paleopathology stems from the fact that it helps to reconstruct behavioral models, lifestyle, socio-economic and hygienic-sanitary conditions of the past (22-27). The study of the frequency and spreading of diseases in ancient human populations and their ways of migrating - correlated to living conditions, dietary and behavioral habits, lifestyle and environmental factors - enables the construction of epidemiological models, that could also be applicable to modern social, economic and health contexts for the purpose of preventing and/or limiting the diffusion of some pathologies (e.g. 16, 28-30).

Considering that the outbreak of a disease, in addition to the genetic characteristics of the host and the agent (in the case of infectious diseases), also depends on the characteristics of the ecosystem, in Paleontology, the reconstruction of the pathocenosis of fossil species could provide useful information to understand their paleobiology, adaptive capacities and their role in the ecosystem (31-33).

Despite the limitations of information sources, the diseases determined up to now in fossil and ancient remains are quite numerous and belong to all the main groups of affections. However, modern paleopathological investigation techniques (macroscopic, histological and molecular analyses, and comparative pathology) can narrow the range of differential diagnoses.

Here we present the paleopathological collection of the "G. d'Annunzio" University Museum in order to make the scientific community aware of the specimens and thus make them available for study and research.

Materials and Methods

The first exhibition of the paleopathological collection was inaugurated at the "G. d'Annunzio" University in 1994 in the city center of Chieti (Italy). In addition to paleopathological human, animal and plant remains, the collection included archaeological finds related to the History of Medicine (i. e. medical instruments and objects related to folk Medicine). In 2005 the University Museum moved to its current location in Palazzo Arnaldo Mussolini (Chieti) and during these 30 years it has collected over 20,000 specimens through agreements, loans, purchases and donations. The collection embraces different branches of knowledge: Paleopathology, Paleontology, History of Medicine, Anthropology, Natural Sciences and Art (33). The affiliation of the Museum to major national (the National Association of Scientific Museums) and international (the International Council of Museums, UNESCO) associations ensures the adequacy of its quality standards.

The paleopathological collection of the "G. d'Annunzio" University Museum consists of 481 specimens, of which 477 are original and 4 are scientific reproductions. These are plant, animal and human remains that come from various paleontological and archaeological sites around the world and cover a wide historical period that goes from the Paleozoic era to recent History (Table 1).

Many of these specimens are on public display, while the rest are kept in the museum's deposits, and all the finds are accessible to researchers for examination. Each specimen has an inventory number and a card containing the taxonomic classification and information on geographical origin, dating, diagnosis of the pathology, its location on display/deposit. In addition, each card is accompanied by high resolution photos with metric reference. The paleopathological collection consists of 31 plant species and 440 animal species. The animal specimens include n. 6 Phyla and n. 17 Classes (table 2); the most numerous is that of mammals with 202 specimens of which 86 belong to the genus *Homo*.

Table. 1. Geographical origin and dating of the paleontological records of the University Museum.

Geographic area	N. of records	Dating	N. of records
Eurasia	272	Paleozoic	9
Africa and Australia	90	Mesozoic	130
North and South America	119	Cenozoic	342

Table 2. Distribution of remains in taxonomic and paleopathological categories.

Kingdom*	Phylum	Subphylum	Class	Paleopathological categories**								
				1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***tot***
Plantae				37		2		2				41
Animalia	Brachipoda		Rhynchonellata					1				1
	Mollusca		Gastropoda			2						2
			Bivalvia			1	1					2
			Cephalopoda			21	7	19				47
	Annelida		Polychaeta								2	2
	Arthropoda	Trilobitomorpha	Trilobita			5						5
		Crustacea	Malacostraca			2		1				3
		Hexapoda	Insecta								41	41
	Echinodermata	Crinozoa	Crinoidea	1		1						2
		Eleutherozoa	Echinoidea	1		8	1	3				13
			Ophiuroidea			1						1
	Chordata	Vertebrata	Actinopterygii	1		1		3	10	1		16
			Elasmobranchii			3		64				67
			Placodermi			2						2
			Aves	2						1		3
			Reptilia	3	10	9	1	13	3	1		40
			Mammalia	61	38	41	18	25	10	9		202
			Total	106	48	99	28	131	23	12	43	**490**

* Storer et al., 1990 (34).

**1) infectious and inflammatory diseases; 2) joint diseases, including those of aging; 3) trauma; 4) metabolic diseases or nutritional deficiencies; 5) congenital diseases; 6) tumors (including malignancies).; 7) unidentified pathologies; 8) fossil remains of disease vectors.

For expository and informative purposes, the specimens have been grouped into paleopathological categories: 1) infectious and inflammatory diseases; 2) joint diseases, including those of aging; 3) trauma; 4) metabolic diseases or nutritional deficiencies; 5) congenital diseases; 6) tumors (including malignancies). Two other categories group fossils with pathological signs of uncertain diagnosis (7) and fossil remains of disease vectors (8) (Table 2). This is a convenient classification, because the boundaries among the proposed categories are blurred and, for example, some samples show alterations attributable to pathologies of a different nature, so they are counted several times in table 2.

Results

The collection includes some pathological findings of great scientific importance. Among them we recall some human and animal paleopathological cases of different eras and origin.

The skull from Catignano (Pescara, Central Italy; Inv. N. 370) is one of the oldest cases of cranial trepanation in the world (36). The remain dates back to the V millennium BCE and belonged to an adult female individual. The skull shows the signs of two cranial trepanations: the first on the cranial vault, at the interparietal suture, and the second in the center of the left parietal bone. According to Capasso and colleagues

(37), a surgical intervention may have been carried out for therapeutic purposes in order to remove bone fragments nearby the depressed fractures on the upper-left region of the neurocranium: the radiographs show the consequences of a healed fracture in the frontal bone and it is therefore likely that the individual suffered multiple fractures of the skull (Figure 1).

The "prehistoric" surgeon performed the surgery with a flint tool and was able to sedate the patient and control the risk of bleeding and infection. The edges of the lesions show evident signs of bone remodeling, which demonstrate that the woman survived the intervention for about a year.

The museum preserves a rare case of post-traumatic cervical arthrosis affecting a cervical vertebra of *Spinosaurus maroccanus* (Morocco, Middle Cretaceous; Inv. N. 830). Macroscopic and radiographic examination show a unilateral degeneration of the left inter-transverse joint facet resulting from a previous trauma (32). The habits and hunting style of *Spinosaurus maroccanus*, reconstructed through its anatomical analogies with current crocodiles, testify that this dinosaur species was exposed to possible traumas of the cervical spine as the large prey (fish and reptiles) were captured and violently rotated in the water. These energetic movements develop torsional forces that can cause trauma to the vertebral transverse processes and the inter-transversal joint structures, thus initiating local degenerative diseases (Figure 2).

Figure 1. Skull of an adult female with double cranial trepanation secondary to "scalping" with clear evidence of long survival. Catignano, Pescara (Italy), 5th millennium BC (Inv. N. 370).

The collection also includes histological sections of a pathological bone sample taken from a specimen of *Triceratops horridus* (Upper Cretaceous, Hell Creek Formation, South Dakota, USA; Inv. N. 23751). The sample come from the right squamosal bone showing a healed traumatic injury, that was probably inflicted by a conspecific (37). Morphological and chemical analysis of the remodeling bone suggest that the pathophysiology of the bone healing process in this dinosaur species could be similar to those described in humans and mammals and thus in need of further study.

The last example concerns a large traumatic lesion observable on a fossil armored fish from the Middle Devonian, *Dunkleosteus marsaisi* (Southern Morocco; Inv. N. 173) (Figure 3). The median dorsal plate of the specimen presents a broad trauma that occurred *intra-vitam*.

Figure 2. Fourth or fifth cervical vertebrae with post-traumatic interapophyseal arthrosis of *Spinosaurus maroccanus*. Taouz, Morocco, Lower-Middle Cretaceous (Inv. N. 830).

Figure 3. Skull cast of *Dunkleosteus sp*. with evident pathology on the median dorsal plate. Morocco, Devonian (Inv. N. 173).

The morphology and size of the injury strongly suggest that it was inflicted by another giant armored fish, and the attack may have been related to predation, or perhaps to intraspecific aggression. This paleopathological case thus sheds light on the behavior of the arthrodires, the most spectacular predators of the Devonian period (38).

The paleopathological collection also includes cases pertaining to plant species: two fossil plates consisting of leaves of *Pseudoplatanus* and other unclassified species with evident traces of phyllophagous insect bites (Inv. Ns. 421 and 422) such as lepidoptera and some orthoptera which, in the larval stage, feed on young leaves and shoots (39) (Figure 4); a cryptogamic herbarium on glass plates with portions of plants contaminated by fungal diseases (Inv. N. 11130; Figure 5); a series of glass jars containing other pathological dried vegetables, in formalin, probably made in school by students and teachers (this kind of material was widely used in the early decades of the 1900s for teaching botany and agriculture).

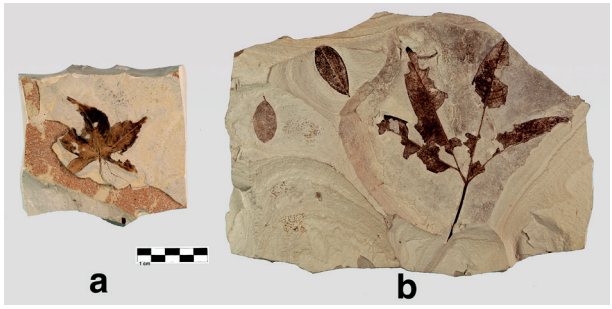

Figure 4. Leaves of *Paleoplatanus sp*. with traces of insect bites (a - Inv. N. 421). In 4 b there are fossil imprints of two other leaves of an unidentified specie. Utah (USA), Eocene (b - Inv. N. 422).

Figure 5. Glass plates containing dried specimens of 1 culm and 1 leaf of Poacea (primary host) and 3 leaves of *Berberis vulgaris* (secondary host) infested with Puccinia graminis (pathogen) which causes so-called wheat rust. Telia and uredia are visible on the leaf and on the stem of the wheat and clusters of aecia on the underside of the barberry leaf (39). Italy, early 1900s (Inv. N. 11130).

Discussion

Museums that dedicate exhibition rooms to Paleopathology are few and not always permanently open to the public. In Europe and Italy there are various museums of Pathological Anatomy (e.g. the Anatomy and Pathology Collections of the Royal Collage of the Surgeons of England, London; the Pathology Museum of the University College London; Morgagni Museum of Pathological Anatomy, Padua; The Museum of Pathological Anatomy, Pisa), which exhibit anatomopathological samples. The specimens are taken from autopsies or surgery and document the most diverse human diseases. Moreover, the pathological remains are mainly human and recent (mostly from the XVIII and XIX CE). The collections were created according to a medical and anatomopathological vision, aimed mainly at doctors, and they do not deal with the origin and evolution of diseases.

Although the Italian Museum of Anthropology and Ethnography of Turin (Italy), the Museum of Anthropology and Ethnology in Florence and the Anthropology Collection of the Alma Mater Studiorum (University of Bologna) do not have specific paleopathological exhibition sections, they preserve human remains with pathological signs (e.g. 41, 42).

Based on the research carried out on the main online databases and on the experience gained by the authors during their paleopathological studies, the only museum in Europe that carries the term "Paleopathology" in its name is the Museum of Medical and Forensic Anthropology, Paleopathology and Criminalistics of the Complutense University of Madrid. The Institute is open to the public by appointment and it exhibits historical pathological human remains with ritual alterations related to magical-religious and ethnic practices.

To the best of our knowledge, the "G. d'Annunzio" University Museum is the only European Institute

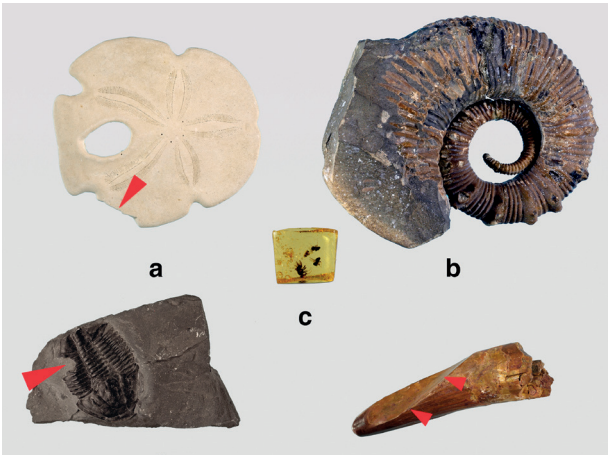

Figure 6. **A)** *Encope tamiamiensis*. Echinide with deformation of the shell as a result of bites (predation attempts) healings. Tamiami Formation, Charlotte County, Florida (USA), Pliocene (Inv. N. 111). **B)** *Australiceras jaekii*. Ammonite with abnormal and asymmetrical growth. Queensland (Australia), Cretaceous (Inv N. 334). **C)** *Glossina sp*. Tsetse fly with others three flies included in amber. Mombasa (Kenya), Miocene (Inv. N. 104). **D)** *Asaphiscus wheeleri*. Trilobite with traces of a bite probably inflicted by a euripterus. Wheeler Formation, Utah (USA), Middle Cambrian (Inv. N. 546). **E)** *Spinosaurus saharicus*. Dinosaur tooth with strong wear. Morocco, Cretaceous (Inv. N. 533).

that preserves human and animal paleopathological remains, including paleontological ones (Figure 6). The collection is characterized, in particular, by numerous animal and plant fossils, which show a broader biological view of pathologies and their influence on the evolutionary history of the numerous organisms that lived from the Paleozoic to modern times. The collection offers an important opportunity to study the interactions between living forms in ancient ecosystems, which characterized the earth in past eras.

The display of ancient plant and animal remains of scientific interest is a common practice in all paleontological and natural history museums. Otherwise, human remains constitute "culturally sensitive materials", the display of which must take into account ethical and cultural issues.

In Italy the anthropological remains are part of the cultural heritage defined as "culturally sensitive materials" (art. 10 of the Code of Cultural Heritage and Landscape, Legislative Decree 22.01.2004, n. 42) as, once exposed, they could offend the sensitivity of visitors for ethical, religious or personal reasons. International museology is questioning the ethical issues related to the management and display of human remains (43), and some countries have drafted guidelines, which regulate the accessibility and display of human remains (44-46). In light of the ongoing debate, the decision to exhibit human remains in the Museum was thoughtful and conscious and was based on the consolidated experience of the Anthropology Section, on the scientific relevance of the remains and on the assessment of their communicative value towards visitors. In designing the museum section, the harmony was sought between the duty of correct and complete dissemination of scientific data and the obligation to respect human remains.

The paleopathology section was therefore designed in compliance with the indications of the Code of Ethics of the International Council of Museums (ICOM) on culturally sensitive materials (47, 48). Particular expository devices and didactic supports have been adopted to show the paleopathological human remains without in any way their ostentation, in order to guarantee a respectful visit by the public. In particular, as regards the mummified remains, they are hidden by a veiled curtain and placed on a 110 cm base, which prevents preschool children from viewing them. To observe them, a voluntary act of the visitor is therefore always necessary (49).

The exhibition of the paleopathological remains also took into consideration the technical, procedural and ethical indications proposed by the Italian Ministry of Culture useful for making the practices of their conservation, protection, enhancement and musealization homogeneous throughout the national territory (50).

The Museum has found a compromise between the duty of scientific communication, correct and complete, and the obligation to respect ancient human remains, reminding the visitor that the visit requires awareness and demeanor at the same time. The Museum welcomes about n. 15,000 visitors every year and the Paleopathology section, exhibited according to the criteria listed above, arouses great interest.

Conclusion

The paleopathological collection of the "G. d'Annunzio" University Museum is a great source of in-

formation and represents an excellent opportunity for researchers interested in the origin and evolution of diseases. The reconstruction of the living conditions of ancient and modern species must necessarily also consider pathologies. Diseases are often the result of the interaction between each organism and their conspecifics, interactions with other species, or their environment, and are able to shed light on the ethology and ecology of plants, animals and humans of the remote and recent past.

The paleopathological collection also includes human remains of great scientific interest. The conservation and display of anthropological remains deserves particular attention in the light of the museological, ethical, legal and scientific reflections that they stimulate. The future creation of new anthropological collections in museums must necessarily take into account the ethical aspects related to their nature. On the other hand, anthropological remains are evidence of ancient cultures and are essential sources of information for reconstructing the paleobiology, health status and behavioral patterns of ancient human populations. Compliance with conservation, study and ethical standards, as indicated by the MiC and ICOM, could constitute the regulatory framework within which the collaboration between anthropologists, who work in the field, study and conserve human remains, and the museum professions dedicated to their enhancement and dissemination of scientific data, could be stimulated.

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