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Entomofauna of a buried body: Study of the exhumation of a human cadaver in Buenos Aires, Argentina

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ABSTRACT

This study focuses on insects and other arthropods sampled on the exhumation of an infant skeleton belonging to 'Prof. Dr. Rómulo Lambre' skeletal collection. The body was buried in soil inside a wooden coffin in a grave 40 cm deep, in autumn, and stored in the cemetery deposit after exhumation. Death records were obtained from the cemetery archive. Samples of faunal remains were recovered from wrappings, clothes, bones and soil samples, and were identified at different taxonomic levels depending on the stage of conservation. The dominant taxon was the muscid fly *Ophyra aenescens* (Wiedemann). The relationships among the identified taxa and the moving of the corpse, from the burial context to the cemetery deposit, are discussed and used to create a hypothetical colonization sequence after death. The application of entomological data to anthropological research can provide valuable information for the interpretation of taphonomic processes and burial contexts.

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1. Introduction

Forensic entomology studies carrion insects and other arthropods in relation to criminal investigations, and it has developed as a tool especially useful to determine the moment and circumstances of death [1]. Recently, its methods began to be used in anthropological and archaeological research and in the reconstruction of ancient environments [2]. Insect remains associated with human corpses may provide certain details of the cadaver history, funerary practices and other past events [2–4] and they also should be considered as post-depositional disturbance agents in taphonomic processes [5].

When an organism dies, there is a sequential colonization by sarcosaprophagous arthropods (mainly Diptera and Coleoptera), that originates a predictable ecological succession directly related to the various stages of decomposition. This succession has been corroborated in many studies on exposed animal carcasses [1,6,7] and some on human bodies [8,9]; it has also been established that alterations in this succession pattern may represent instances of environmental changes, inaccessibility due to the interposition of barriers, or cultural intervention related to funerary practices [10,11].

Until recently, there have been few studies focused on the faunal succession in buried human corpses. Some studies were carried out using carrion or bait buried at different depths [12–15], whereas others conducted exhumations of human corpses buried directly in soil or inside coffins or vaults [2,16,17]. In buried bodies there is a more limited faunal diversity than on the surface, and the rate of underground decomposition is considerably slower [13,18], given that only some species are able to colonize corpses that are buried even under a few centimetres of soil, and that the differences in temperature fluctuation between the soil and above ground have an impact on insect biology.

The purpose of this paper is to study the arthropod fauna sampled from the exhumed skeleton of a human infant [19] and contribute to a better knowledge of the fauna present in burials. The faunal colonization is discussed, relating the taxa found and the documentary information about this legally interred and exhumed body and previous forensic records.

2. Materials and methods

The skeleton studied belongs to the 'Prof. Dr. Rómulo Lambre' skeletal collection, which consists of 420 exhumed bodies that have remained buried for at least 3 years. After this period of time, exhumation took place only if there were no soft-tissue remains, and exhumed skeletons were stored at the cemetery deposit for relatives or the administration to decide upon their destination (*Ordenanza Municipal 7638/90*). After 6 years in deposit, those skeletons that went unclaimed were donated by the Municipal Cemetery of La Plata (*Cementerio Municipal de La Plata*) to the School of Medical Sciences (*Facultad de Ciencias Médicas, FCM*), National University at La Plata (*Universidad Nacional de La Plata*, UNLP) for research and

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teaching purposes (*Ordenanza Municipal 9471/02*). The skeletons arrived at FCM in numbered plastic bags including external wrappings and sediments. Death records included: age, sex, nationality, date and cause of death, location at the cemetery and date of exhumation were obtained from cemetery archives.

Among the skeletons of the collection, arthropod remains were found in more than 30 cases. In all cases but our subject skeleton, the sediments that accompanied the skeletons were scarce and no clothes remained, the faunal remains were few and did not contribute to the interpretation of the colonization sequence. The analyzed skeleton was a 5-month old male, whose cause of death was non-traumatic cardiorespiratory arrest. Human and arthropod remains were photographed during the unwrapping and after the preparation of the bone material (Fig. 1a and b).

2.1. Burial conditions

The burial location (city of La Plata, Buenos Aires province; 34°57′ S, 57°57′ W), presents the humid temperate climate characteristic of the Pampas, with a mean annual precipitation of 1146 mm, and marked seasonality. The soil is silty and at 50 cm depth has an annual average temperature of 17.2 °C (range: 11.0 °C in winter, 21.4 °C in summer) [20].

The inhumation took place in autumn (May 1994), with recorded air temperatures between 14 and 20 °C. In the days leading up to the burial and on the third day after the inhumation it rained ~30 mm (data provided by the National Weather Service, Argentina).

From cemetery archives, it could be known that the remains were buried shortly after death, and kept buried for 5.3 years. After exhumation remains were placed in the cemetery deposit for 6.5 years before being donated to the collection. The body was buried underground, clothed, placed in a soft wooden coffin (specially made for rapid decomposition) in a 40 cm-deep grave, and covered with loose soil. On arrival at the FCM, it still had a disposable diaper and woollen clothes, but it had the peculiarity of being completely wrapped in two woollen blankets, one over the other.

2.2. Arthropod remains

Faunal remains were sampled from the wrappings, clothing, disposable diaper, insides of bone cavities and sediments. They were collected with brushes, pins or fine-tipped tweezers, depending on the size and conditions, and the sediments were inspected through water flotation. The samples consisted in whole or fragmented insect adults, pupae and larvae, other arthropods and molluscan shells.

Morphological and systematic studies were undertaken at the Entomology Division (*División de Entomología*), School and Museum of Natural Sciences (*Facultad de Ciencias Naturales y Museo; FCNyM, UNLP*). The identification was possible at the species-, family- or order taxonomic level, depending on the state of preservation of the material. For that purpose, dry specimens were observed and photographed under a stereoscopic microscope (Leica EZ5, Canon EOS Rebel T3i). The identification was made on the basis of specialized literature and reference specimens hosted in the La Plata Museum (*Museo de La Plata*) collection (FCNyM).

3. Results and discussion

An anthropological study of the remains demonstrated that no soft tissues were present and that decomposition had reached the skeletal stage. The degradation may have been facilitated by the small size of the body, the faunal activity and the absorption of the early putrefactive fluids by the wrappings, diaper, clothing and soil.

The skeleton was nearly complete; only two long bones of the left leg and some of the flat bones of the cranial vault were lacking, these skeletal parts probably got lost during the exhumations and the later storage at the cemetery deposit. Its completeness made it possible to verify the age-at-death on the basis of dental development and long-bone growth. It did not show any evidence of traumatisms, allowing the conclusion that the death was probably caused by an acute event that did not leave any traces in bones. These results coincide with the cemetery death records.

The analysis of the arthropods remains revealed the presence of different species of thanatophilous entomofauna. Some of the specimens that were found are known to frequently colonize corpses buried in soil; the presence of others could be attributed to contamination or accidental arrivals, whereas some others are characteristic of the soil fauna of the burial substrate [16,22–24]. The inventory of the faunal remains is presented in Table 1.

The muscid fly *Ophyra aenescens* (Wiedemann) was the dominant taxon, represented by a considerable amount of empty puparia ($n > 200$) and some fragmented adults, heads, abdominal tergites and legs; these remains were found on wrappings, the diaper, clothes and in bone cavities such as in a tooth socket and one of the ear canals (Fig. 2a and d). Other fly remains consisted on one pupa of the Family Sarcophagidae, eight puparia of *Muscina stabulans* (Fallen) (Muscidae), five puparia of *Fannia canicularis* (L.) (Fanniidae), and ten puparia of *Megaselia scalaris* (Loew) (Phoridae). Notably, some puparia were observed within other puparia; specifically, some *O. aenescens* puparia were found within puparia of the same species, as some puparia of *M. stabulans* and *M. scalaris* were found inside puparia of *M. stabulans*. This finding suggests that flies bred on the corpse for several generations.

Other taxa found were two empty puparia of the lepidopteran moth *Tineola bisselliella* (Tineidae); beetle remains represented by one larva of Tenebrionidae, two larval exuviae of Dermestidae, three adults of Staphylinidae (one of them identified as *Atheta* sp.), and fragments of adults of *Carpophilus* sp. (Nitidulidae). Furthermore, the last portion of the abdomen of an earwig (Anisolabididae, Dermaptera) and one cockroach ootheca (Blattodea) were found.

There were also fragments or complete adults of mites (Oribatida and Gamasida, Acari), the terrestrial crustacean woodlice (Isopoda), Juliformia and Polydesmidea millipedes, and some molluscan valves of Pelecypoda and Gastropoda.

Finally, the presence of all arthropod taxa was interpreted in the context of the burial conditions, previous forensic records, and the biology of each taxa. This information allowed the reconstruction

Fig. 1. Unwrapping exhumed bundle; (a) the funerary bundle as it arrived at the collection; (b) initial conditioning of the material, showing entomofauna and skeletal remains.

Table 1
Faunal remains recovered from the exhumed bundle.

Class	Order	Family	Taxa	Life stage/remains
Insecta	Diptera	Sarcophagidae		Pupa
		Muscidae	*Ophyra aenescens* (Wiedemann)	Empty puparia; some puparia containing other puparia inside; adult fragments
			Muscina stabulans (Fallén)	Empty puparia; puparium containing another puparium inside of the same species and of *M. scalaris*
		Phoridae	*Megaselia scalaris* (Loew)	Empty puparia; puparium inside another of *M. stabulans*
		Fanniidae	*Fannia canicularis* (L.)	Empty puparia
	Coleoptera	Dermestidae		Larval exuviae
		Staphylinidae	*Atheta* sp.	Adult
				Adults
		Nitidulidae	*Carpophilus* sp.	Adult fragments (head, thorax, abdomen, elytron)
		Tenebrionidae		Larva
	Lepidoptera	Tineidae	*Tineola bisselliella* (L.)	Empty puparia
	Dermaptera	Anisolabididae		Adult fragments (forceps, last abdominal tergites)
	Blattodea			Ootheca
Myriapoda	Polydesmida			Adults
	Juliformia			Adults
Crustacea	Isopoda	Oniscidae		Adults
Chelicerata	Acari	Oribatida		Adults
		Gamasida (Uropodina)		Adults
Mollusca	Pelecypoda			Valves
	Gastropoda			Valves

of a hypothetical faunal colonization sequence, that is detailed below.

3.1. Colonization sequence of buried remains

In order to provide a complete interpretation of the arrival, establishment and development of sarcosaprophagous fauna (mostly Diptera and Coleoptera), it is essential to gather or review existing records on the inhumation context and the season in which the body was buried. In the present case, inhumation took place in autumn, and the colonization must have been favoured by the temperature, humidity and rainfall registered on previous and subsequent days. These conditions, as well as the presence of loose soil over the buried body, provided easy access for insects to the cadaver through soil cracks or pores, attracted by the odours from the decomposing corpse. A composite of photographs depicting the diversity of specimens found in association with the corpse is provided (Figs. 3 and 4).

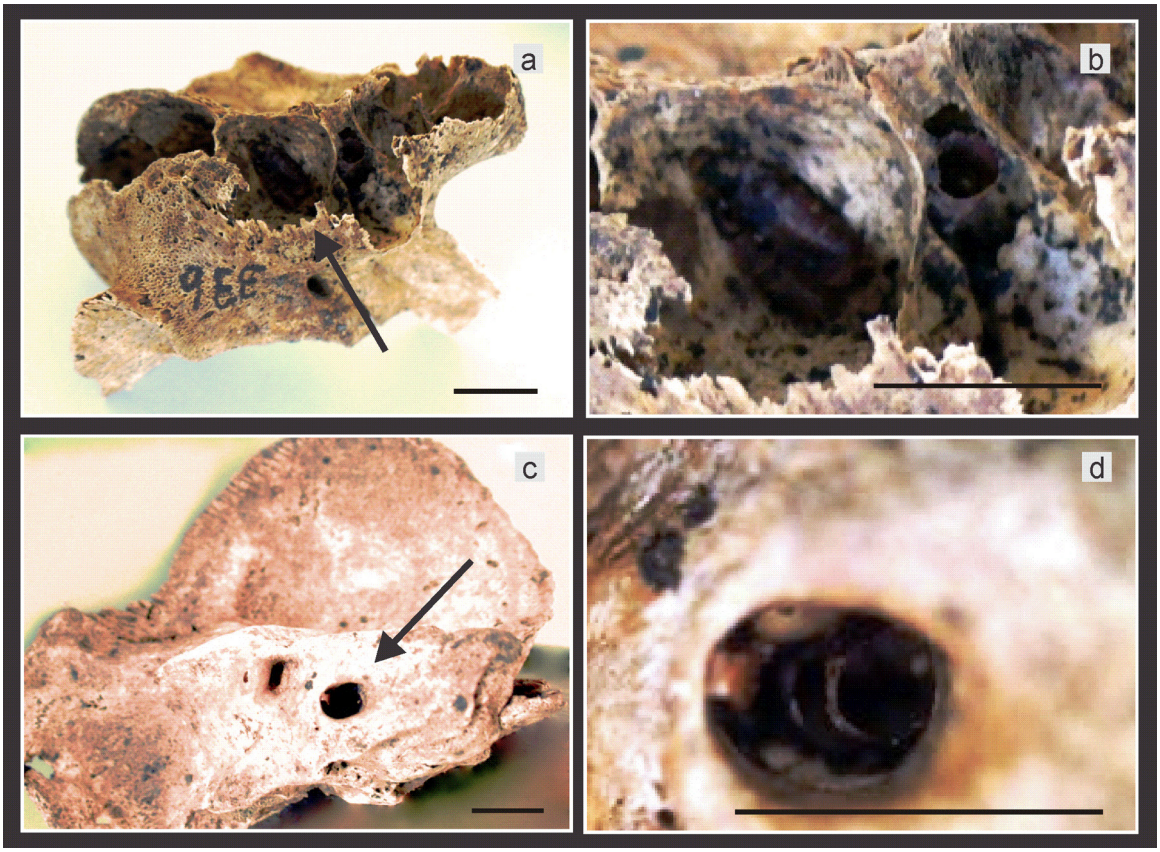

Fig. 2. (a) Right maxillary bone; (b) detail of a puparium in a tooth socket; (c) medial view of the temporal bone; (d) detail of a puparium in the internal acoustic meatus. Scale: 1 cm.

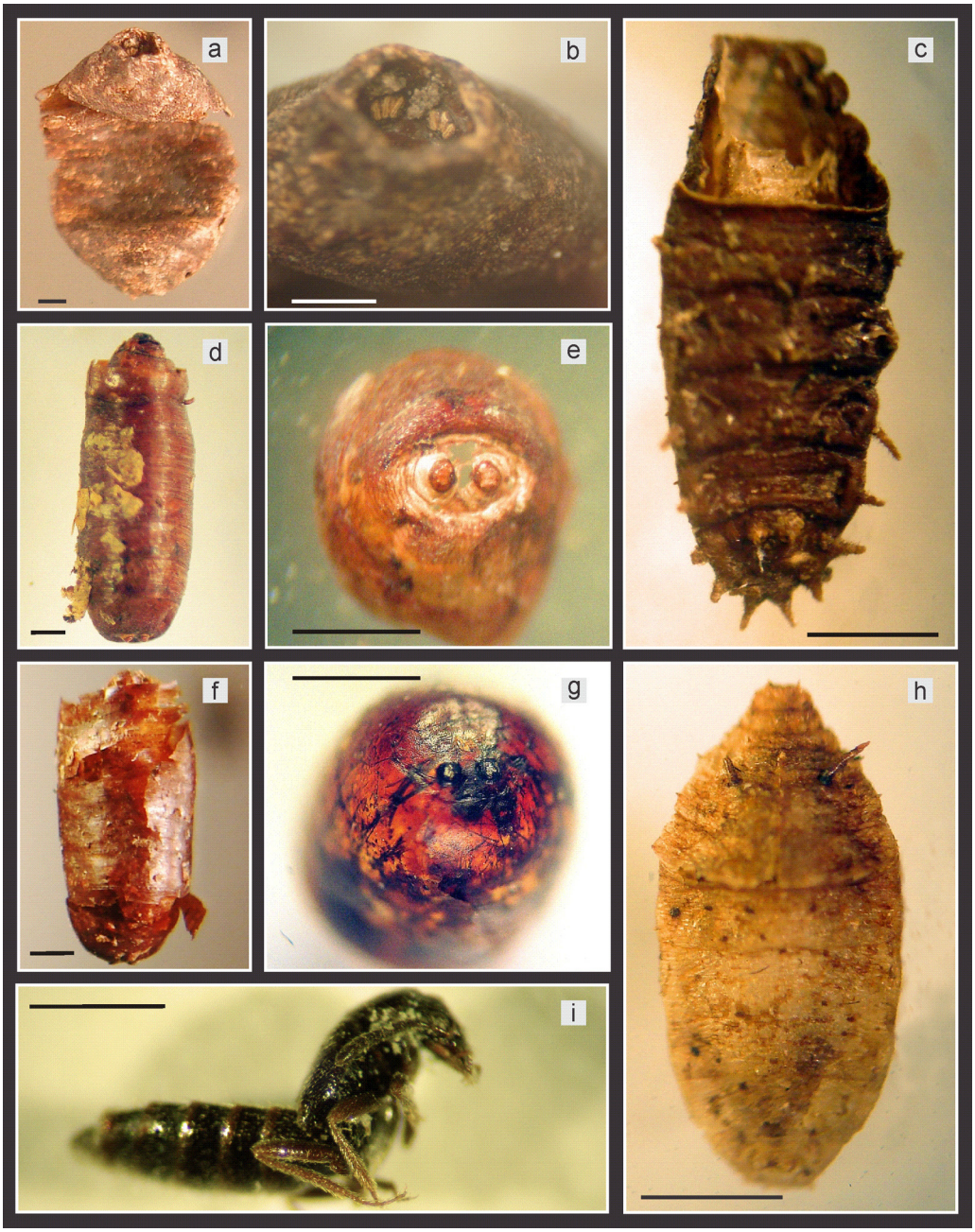

Fig. 3. (a) Sarcophagidae, pupa; (b) Sarcophagidae, detail of the posterior spiracles; (c) *Fannia canicularis*, empty puparium; (d) *Ophyra aenescens*, puparium containing another puparium inside; (e) *Ophyra aenescens*, detail of the posterior spiracles; (f) *Muscina stabulans*, puparium containing another puparium inside; (g) *Muscina stabulans*, detail of the posterior spiracles; (h) *Megaselia scalaris*, empty puparium; (i) *Atheta* sp., adult. Scale: 1 mm.

3.1.1. Diptera

The Diptera recovered from this context correspond to the taxa to be expected in accordance with seasonality and geographical distribution records for Buenos Aires province, from both field experiences [21–24] and forensic examinations of human remains [17,25].

3.1.1.1. Sarcophagidae. One Sarcophagidae pupa was found (Fig. 3a and b); this family has distinctive larviparous females whose larvae are capable of reaching corpses through small openings inaccessible to adults and other insects [1,21,26]. The larva that yielded the pupa may have arrived before the inhumation or immediately afterwards; such specimens are frequent on any decomposing tissues on surface, especially those located in an indoor environment, but they have also been recorded on human bodies buried at a depth of 30 cm [16].

The literature dealing with field experiments using buried carcasses reports the finding of adult sarcophagids in topsoil during the primary bloated stage [13] and some species of this family, as *Eumacronychia persolla* Reinhard and *Phylloteles pictipennis* Loew, have been registered at a depth of 66 cm, and then they were proposed as forensic indicators in buried bodies in dry habitats [15]. Sarcophagid fly remains recovered from archaeological contexts appeared as informative taxa in the understanding of Pre-Columbian mortuary practices [3].

3.1.1.2. Fanniidae. Bourel et al. [27] mention that representatives of the Fanniidae are rarely found in association with human bodies,

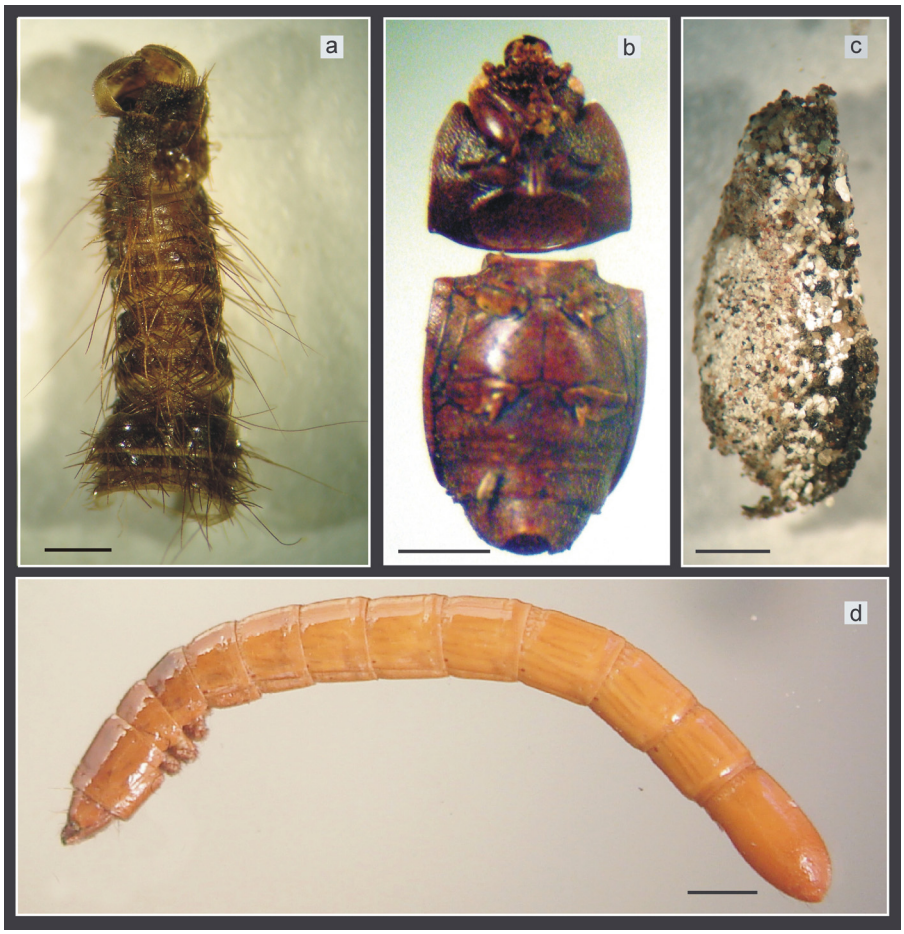

Fig. 4. (a) Dermestidae, exuviae of larva; (b) *Carpophilus* sp., adult fragment; (c) *Tineola bisselliella*, empty puparium; (d) Tenebrionidae, larva. Scale: 1 mm.

even though, they discovered specimens of *F. scalaris* (Fabricius) and *F. manicata* (Meigen) in a few human exhumations. Generally, these species are prone to be indoors and the larvae prefer a semi-liquid habitat, arriving at the caseic fermentation stage in surface decomposition [1,21,25]. Due to their preference for moist habitats, as observed in buried pig carcasses [13], it is reasonable to assume that the *Fannia canicularis* specimens collected in this case study (Fig. 3c) could have played an early role in the faunal succession.

3.1.1.3. Muscidae. Muscidae are the most common family associated with burial contexts [1,6]. Some species are not deterred from oviposition when a corpse is covered by a layer of soil and it is known that the females lay their eggs on the surface, whereas the young larvae reach the corpses by burrowing through the substrate [1,14,28].

In this case, *Ophyra aenescens* (Fig. 3d and e) massively colonized the body, which is in concordance with the findings from other exhumed corpses, buried in wooden coffins in Buenos Aires [17]. It is noteworthy that certain species of *Ophyra* sp. are indicated in the literature as the most abundant in bodies buried in coffins [27]. They have also been recorded in the secondary bloated stage in buried carrion [13], and mummified bodies [29].

Moreover, *Ophyra aenescens* is frequently found on human corpses located indoors, arriving during the active or advanced stages of decay. This species is associated with urban environments, being more abundant during warm months [21,23,26]. It has also been found in archaeological graves and used to interpret burial practices [3].

Muscina stabulans (Fig. 3f and g) is frequent in urban and suburban environments and scarce in winter [23]. It specializes on detecting and exploiting buried remains; it has been registered in exhumations of corpses buried in soil in the city of Buenos Aires along with *Megaselia scalaris* [17,21], and in carrion buried up to 40 cm deep [14]. Larvae of *Muscina* sp. have been pointed as dominant among the fauna of buried carcasses in the top layers of soil [1,12].

3.1.1.4. Phoridae. Megaselia scalaris (Fig. 3h) may have colonized the body after the above-mentioned species. This small fly tolerates darkness, is common indoors and may be the primary or the only insect in buried bodies with restricted access to larger flies. Larval instars are able to burrow vertically through the substrate more than 50 cm to reach a buried body and they are usually registered on exhumed cadavers [21,30–32]. In the city of Buenos Aires, *M. scalaris* is frequently found in exhumations from crypts and soil, and specifically for Argentina, this species replaces *Conicera tibialis* Schmitz in buried corpses [17,21].

3.1.2. Coleoptera

3.1.2.1. Staphylinidae. The Staphylinidae are a widespread polyphagous family of soil fauna, most of which are predatory on eggs and larvae of other insects. These beetles are the commonest predators found on surface corpses, both as larvae and adults, they arrive during the bloated stage and they are present as long as there is insect activity on the corpses [1,6]. They are often encountered in buried corpses because the females can pass through loose soil and

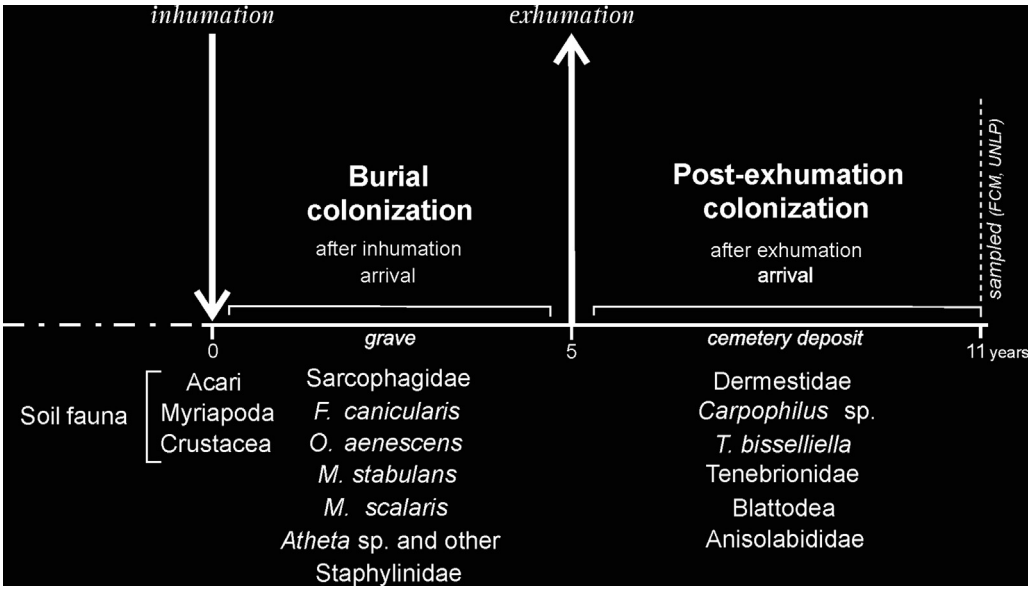

Fig. 5. Hypothetical colonization sequence based on the remains of entomofauna recovered from the exhumed bundle.

lay eggs on corpses where abundant dipteran maggots develop, and when these migrate to pupate they even chase them into the soil [13,27,28].

Several staphylinids were recovered from the exhumed bundle; among them a specimen of *Atheta* sp. was identified (Fig. 3i). The beetles belonging to this genus are known as predator of both dipteran eggs and larvae in buried corpses at deeper layers (~25–50 cm) [12,13].

3.2. Post-exhumation colonization

Once the body was exhumed in the skeletal stage, it was stored in poorly sealed plastic bags at the cemetery deposit. The insects likely to have colonized the body, the wrappings and the remains of pioneer insects, in this post-exhumation stage are discussed below.

Most of these species described below typically attack dry stored products and were described as belonging to the community of the cadaver succession. They typically settle when the tissues are completely dry in exposed corpses, and some of them have exhibited osteophagous behaviour [5]. Others are omnivorous and opportunistic, using a wide variety of resources for food, oviposition and/or nursery [1,12,26,33].

3.2.1. Coleoptera

3.2.1.1. Dermestidae. The post-exhumation period was characterized primarily by the presence of Dermestidae (Fig. 4a), a storage pest which feeds upon dry organic material. They typically colonize exposed corpses and may arrive by any path at the butyric fermentation stage or later, at the dry stage, attracted by dry tissue, hair, bones or by the remains of dead insects and the presence of fibres or textiles. Dermestids are also relevant in the interpretation of taphonomic processes in forensic [21,25] and archaeological contexts, and in the reconstruction of past environments [3,34,35]. Their presence is especially informative in mummification as they may also leave macroscopic damage in bones [5,36–38].

3.2.1.2. Nitidulidae. The genus *Carpophilus* sp. is included in a family of omnivorous nitidulids (Fig. 4b), most species of which are associated with stored products, but they can be necrophagous on carrion carcasses [25,39]. *Carpophilus hemipterus* (L.) in particular, has been reported in the marrow cavities of exposed human remains associated with *Piophila* sp. (Piophilidae) [40]. To our knowledge, the only finding of this genus in a buried body was made by Gaudry in an illegal cadaver in a shallow grave at 20 cm depth in France [41].

3.2.1.3. Tenebrionidae. The larva of Tenebrionidae from this case (Fig. 4d), belongs to a family of omnivorous insects that frequent dark, enclosed environments and often infest stored grain and other related products. They correspond to the last colonization stages on completely dried corpses [1,33]. Larvae and adults of this family were found in the silt-clay soil layer beneath bodies, attracted by the nutrients released during decomposition inside a subterranean cistern [9].

3.2.2. Lepidoptera

3.2.2.1. Tineidae. Larvae of the moth *Tineola bisselliella* (sampled at the pupa stage in this study; Fig. 4c) live among hairs or fibres, and feed on wool, leather and dried skin. They are usually found indoors in forensic cases [21,40]; they have also been registered together with Tenebrionidae in a case involving mummified bodies in an enclosed underground environment [9] and in archaeological contexts [34].

3.2.3. Other insects

The omnivorous and household pest cockroaches Blattodea and the earwigs Anisolabididae (Dermaptera) feed on decaying organic matter and upon every stage of decay of corpses, and could also predate on necrophagous insects. They are considered as opportunistic feeders in forensic entomology and in the context of our study, they probably used the body remains as a food source and as an oviposition and nursery site [1,26,42].

3.3. Soil fauna

Some soil fauna like Acari, Isopoda, Juliformia and Polydesmidea were collected from the sediments and wrappings. In surface decompositions they are often in the protected area underneath

the remains, where the body comes in contact with the soil. They are considered as opportunistic feeders, using corpses as an extension of their habitat, most of them are detritivorous, while others become necrophilous. The Acari (*i.e.*, Oribatida and Uropodina) typically arrive at the final stages of decomposition. They usually reach corpses on their own, whereas the Uropodina also disperse by phoresy on fly and beetle carriers [1,43]. Some small valves of Pelecypoda and Gastropoda that make up the soil were also found.

4. Conclusions

The insects remains recovered from the exhumed bundle revealed the presence of species of recognizable forensic importance, most of which are necrophagous and contributed to the reduction of the necromass. A hypothetical colonization sequence was constructed on the basis of three sources of information: the ecology of each taxa, burial records from the cemetery archives, and supplementary information about the colonization of buried remains from specific references (Fig. 5).

The dipterans *Fannia canicularis*, *Muscina stabulans*, *Ophyra aenescens* and *Megaselia scalaris* were among the first taxa to colonize burial remains; they are capable of laying eggs on the remains surface and the neonated larvae reach corpses by boring through the substrate. The large number of empty puparia, and the presence of some puparia within other puparia suggest that the flies bred on the corpse for several generations. The presence of sarcophagid pupae can be explained by the arrival of the larva either before the inhumation and burial of the corpse, or later, by digging down into the soil. Specimens of Staphylinidae might had arrived searching for dipteran eggs and larvae as prey.

A second instance of colonization, dominated by omnivorous and storage pests, occurred in the context of post-exhumation at the cemetery deposit. The presence of the beetles Dermestidae, Nitidulidae, Tenebrionidae, Tineidae moths, the omnivorous cockroach Blattaria and Anisolabididae earwigs, provide evidence of contamination during storage in the cemetery deposit after exhumation, provided that none of these insects are able to burrow as adults or larvae to buried remains.

This work provides valuable first-hand data on the role of insects in the taphonomic processes involving necromass reduction. In that sense, the importance of the recovery of pre- and post mortem information for the better interpretation of the insect activity is highlighted. Future multidisciplinary research involving anthropology, entomology and other forensic sciences will likely increase the knowledge in this area.

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