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The arthropods of corpses from above ground and from deep below*

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The Acari are one of the most ubiquitous arthropod inhabitants and associates of human and animal remains. Over 150 years ago, Jean Pierre Mégnin proposed that mites arrive at corpses at two particular stages of the decomposition process, that is within the first and the sixth waves of arthropod arrival or colonisation event (Mégnin, 1895). Now we know that mites actually arrive at each stage of the decomposition process of corpses, in a continuum (Rai *et al*., 2021). Interestingly, the mite fauna of cadavers is very diverse, and mite species composition varies as decomposition progresses and according to the environment where decomposition occurs (Baker, 2009; Braig & Perotti, 2009). In fact, specific stages of decomposition can be characterised by the associated mite species (Kamaruzaman *et al.*, 2018; Leclercq & Verstraeten, 1988; Mašán *et al*., 2013; Mégnin, 1895).

In terms of the environment where a corpse decomposes, if on a soil surface, outdoors, it will attract epigeal and hypogeal mites and a variety of carrion insects, which will bring their own phoretic mites (Fig. 1-A). Mites travelling on insects or small rodents are the most common and ubiquitous arthropods arriving on remains (Perotti & Braig, 2009; Perotti *et al*., 2010). Some carrion insects, like beetles, are able to transport several species and a great number of individuals, up to the hundreds or thousands. For example, silphid beetles are able to bring species of Parasitidae, Macrochelidae, Melicharidae, Uropodidae, Histiostomatidae, Acaridae at the same time—just to name some of the most common families of phoretic mites brought to a corpse (Perotti & Braig, 2009).

Opportunistic insects visiting or colonising, somehow taking advantage of the corpse (Byrd & Castner, 2009), for example, a queen bumblebee using part of it to build its nest, will bring too its diverse phoretic mites (Klimov *et al*., 2016). Ticks, although opportunistic, are also assiduous visitors of the decomposition environment (McNemee *et al*., 2003). They need to be nearby, ready to jump on the next host approaching the decomposed body, likely a scavenger or a forensic investigator. This is becoming so frequent that in Europe, the widespread species *Ixodes ricinus* utilises carrion and coprophagous beetles moving to and from carcasses to secure availability of hosts (Salona-Bordas *et al*., 2015).

All mites found in association with either an outdoor or indoor crime scene must be taken into consideration in the forensic analysis of evidence, regardless of the presence of the corpse or not, that could have been removed (Saloña-Bordas *et al*., 2010), and even if the crime did not involve a corpse at all (Hani *et al*., 2018). They all have a story to tell, explaining different circumstances or events associated with the crime. Indoors, analysing insect evidence can be a little more tricky (Pimsler *et al*., 2016). However, a forensic acarologist will find an established community of indoor, well studied house dust mites, a taxocoenoses that varies according to the room they inhabit (Frost *et al*., 2010; Solarz, 2009). If the indoor room is not sealed from access, like offering window openings, then the house dust mite community is generally complemented by mite species brought from outdoor visitors. For example, beetles or blumblebees are large insects that can only access through well open windows, then, mite identity can inform of the presence of openings, of the relative size and of the identity of these visitors (Kamaruzaman *et al*., 2018; Pimsler *et al*., 2016).

Corpses buried at various depths, hidden or concealed, represent perhaps the most widespread crime scenes involving death. A body buried deep in soil will likely support a large population of a single mite species that

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is introduced either with the corpse itself or by coffin flies (Fig. 1-B); while a wrapped or concealed corpse kept indoors will attract a handful of small species of house dust mites, particularly Astigmata (OConnor, 2009), one of which could dominate in abundance at the dry or mummified stages (Russell *et al*., 2004). Corpses found in a pit of soil mixed with animal excrement have been found to attract coprophagous flies with their specific phoretic mites (Rai *et al.*, 2020). The reliability of mites as markers of the environment should not be underestimated.

In corpses located in shallow graves, a combination of environmental conditions is observed. These corpses will be exposed to phoretic as well as to soil and epigean mites living in the upper layer of the substratum (Fig. 1-A)(Rai *et al*., 2021). Despite being buried superficially, the occurrence and abundance of mite species are mainly dictated by the composition and chemistry of the soil and by the surrounding soil pH (Rai *et al*., 2022).

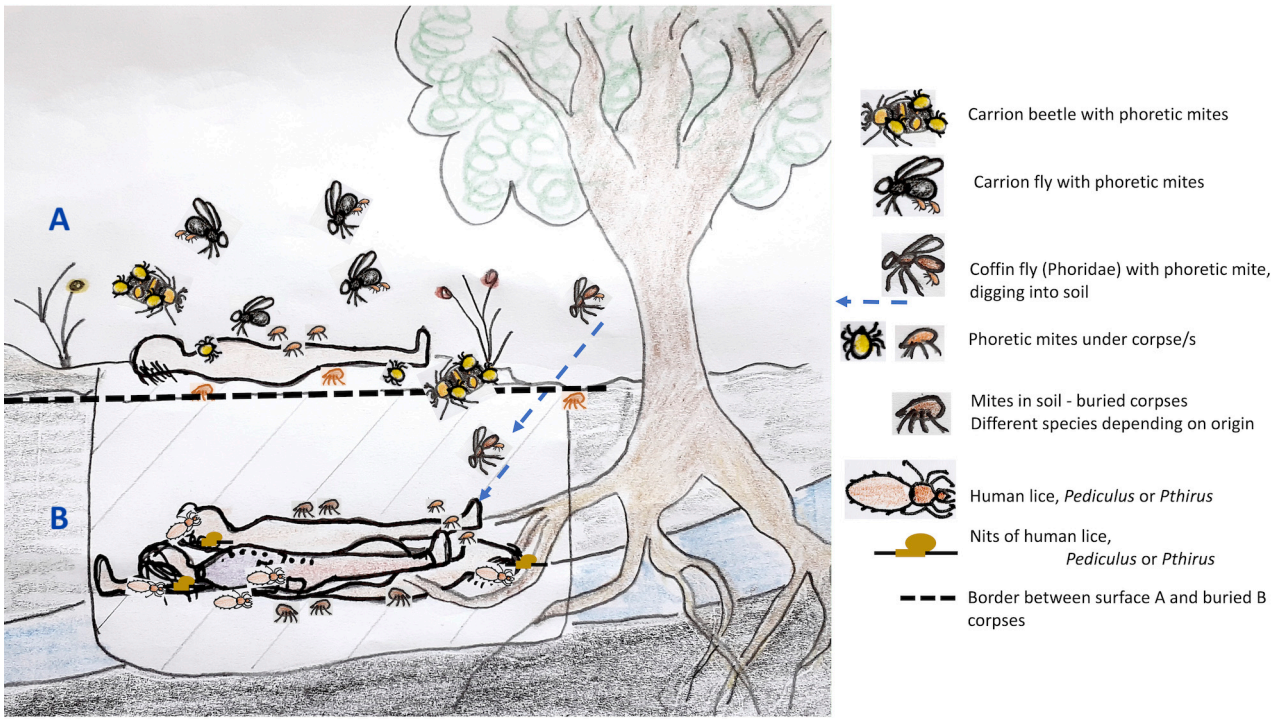

FIGURE 1. Sketch of fauna associated with: A) exposed/surface/shallow grave, and B) deep/mass grave.

Any arthropod species will inform about their part in the decomposition process; providing reliable evidence of what has happened to the victim just before and during death, about where death occurred, and, if there was a relocation of the corpse, explaining with their life cycles why and how a person died, linking environments, locations and people (Perotti & Braig, 2020). The whys and the hows could be explained in a particular case. A number of loose bones scattered on a small area of the forest soil were enclosed by partially burnt logs. The occurrence of hundreds of individuals of the 'mummy's mite', *Sancassania*, all in their hypopial stage suggested that i) the corpse reached the location where the bones were found in a mummified stage; ii) that it was concealed or wrapped and for a number of months, allowing the development of a large, super-mite colony, and, iii) that the mature *Sancassania* colony was suddenly exposed to fire, used by the perpetrators to eliminate evidence. During the fire, most adult mites located superficially in the 'corpse package' died, while a few remaining survivors being exposed to a new, unsuitable environment for survival, reproduced and their offspring developed into resistant hypopi. No adult mites or regular nymphs, just *Sancassania* hypopi were found (Szelecz *et al.*, 2018).

Mass graves (communal burials) constitute another habitat for cadaveric and human/animal associated arthropods (Fig. 1-B). The potential of these arthropods as markers or evidence is only now being considered. Mites plus other arthropods are transferred to a grave due to their association with human victims before death, e.g. dust mites, sarcoptic mange, lice and their nits, etc. (Arriaza *et al*., 2008). These arthropods are able to inform what might have happened in a temporal manner, offering insights about pre-mortem circumstances such as events of torture or abandonment and even describing post-mortem, the health status of the host before death (Lambiase & Perotti, 2019). In addition, cadaveric arthropods like mites can help estimate the timing of burial and provenance of the bodies. In mass burials where cadavers are deposited at different highs or levels (Cox *et al*., 2014), differences in

the composition or diversity of the cadaveric mite fauna, particularly phoretic mites attracted at specific times of the year, would help resolve origin and time of burial for particular layers/waves. Corpses at the bottom of the pit will have been colonised just after death by the carrion arthropods of the season and of the particular geographic location where death occurred; and these will differ from the fauna colonising the most recent and superficial corpses, and differ even more if they have a different geographic origin (Brown, 2006).

This work presents different scenarios and examines the role arthropods have in a variety of decomposition environments and processes, from indoor to large mass graves, highlighting the relevance of cadaveric and human arthropods, especially ectoparasites (mites and lice), as specific and reliable trace evidence markers in crime scene investigations.

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