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**Dermanyssus gallinae** attacks humans. Mind the gap!

Maria Assunta Cafiero, Alessandra Barlaam, Antonio Camarda, Miroslav Radeski, Monique Mule, Olivier Sparaganof and Annunziata Giangaspero

*Dermasyssus gallinae* is a haematophagous ectoparasite primarily known as a pest of domestic and wild birds. It occasionally feeds on a range of mammals, and, more importantly, is of growing concern in human medicine. This review highlights mite attacks on people working with poultry, and updates the increasing incidence of dermanyssosis in urban environments in Europe. Although several cases of dermanyssosis have been documented, there are a number of reasons why diagnosis of *D. gallinae* infestations in humans is likely to be underestimated. Firstly, medical specialists are not well aware of *D. gallinae* infestations in humans. There is also a lack of collaboration with specialists from other disciplines. The problem is compounded by misdiagnoses and by the lack of diagnostic tools. We review the literature on human dermanyssosis cases in Europe, and also provide information on the epidemiology, clinical, histo-pathological and immunological aspects of dermanyssosis. We stress the need for improved recognition of this challenging infestation in humans, and provide straightforward recommendations for health practitioners, starting with collection of the correct anamnestic information and including appropriate management methods for case recognition and resolution. Finally, we indicate the most urgent areas to be addressed by future research.

**RESEARCH HIGHLIGHTS**

- *Dermasyssus gallinae* is of growing concern in human medicine.
- Most physicians are not well aware of dermanyssosis in humans.
- Bio-epidemiological and clinical aspects of this ectoparasitosis are highlighted.
- Practical key actions for diagnosis and correct management of infestation in humans are provided.

**Introduction**

*Dermasyssus gallinae* (Arthropoda: Dermanyssidae) is a cosmopolitan haematophagous ectoparasite of birds. It is primarily a well-known pest of poultry farms worldwide, affecting over 80% of European poultry farms, with peaks above 90% in the Netherlands, Germany and Belgium (Mul *et al.*, 2017). The infestation burden on caged laying hens can be up to 500,000 mites per bird in severe cases (Kilpinen, 2005); this causes extreme stress, associated with feather-peeking, increased self-grooming and cannibalism (Kilpinen, 2005; Mul *et al.*, 2009), in addition to blood loss. As a consequence, the welfare, health and productivity of the birds are severely affected (Wójcik *et al.*, 2000; Cosoroaba, 2001; Kilpinen, 2005). In addition, *D. gallinae* serves as a vector for a number of viral and bacterial avian pathogens (Valiente Moro *et al.*, 2009; Circella *et al.*, 2011; Chu *et al.*, 2015; Sommer *et al.*, 2006).

It also poses a threat to other birds, such as broilers, turkeys and ducks, and also to canaries, budgerigars and synanthropic birds typically found in urban centres (e.g. pigeons, sparrows, starlings, doves).

*D. gallinae* mites are temporary nocturnal visitors; they remain hidden in close proximity to their hosts during daylight hours, and move onto their hosts at nightfall in order to feed. The life cycle consists of the following stages: egg, larva, two nymphal stages, adult male and female. All legged stages, except larvae, feed on blood. The complete life cycle typically takes two weeks, but under ideal conditions (35 °C and relative humidity over 70%), it may require only one week (Sparagano *et al.*, 2014).

Although *D. gallinae* is largely considered an avian-specific ectoparasite, when the natural host is absent...
hungry mites will occasionally feed on a range of mammals, i.e. cats (Grant, 1989; Di Palma et al., 2018), dogs (Declerq & Nachtgael, 1993), gerbils (Lucky et al., 2001), other rodents (Kowal et al., 2014), horses (Mignon & Losson, 2008), and humans. They may attack any person working in infested poultry farms or living in an urban environment where there are synanthropic birds.

The most important point related to human infestation is that physicians are usually unfamiliar with the dermatitis caused by several zoonotic ectoparasites, including D. gallinae (Haag-Wackernagel, 2005; Cafiero et al., 2008; Collgros et al., 2013). It is actually very difficult to diagnose a D. gallinae infestation from the cutaneous reactions it causes in humans; since the reactions are uncharacteristic (Kavallari et al., 2018), infestations are often misdiagnosed. The lack of guidelines and/or recommendations, and the insufficient awareness of physicians/dermatologists with this infestation and with the eco-biology of this ectoparasite, can prevent them from managing affected patients correctly. Furthermore, misdiagnosis of an infestation, and the inevitable relapses, negatively affect patients’ quality of life (Dogramaci, Culha, & Ozcelik, 2010). The problem of misdiagnosis is also worrying due to the possible role of D. gallinae as a vector/reservoir of several zoonotic pathogens (De Luna et al., 2008; Circella et al., 2011; Boseret et al., 2013).

According to the recent strategic document provided by the tripartite agreement of FAO, OIE and WHO (2017), the impact of D. gallinae on human health can be fully considered as a One Health issue.

This article is concerned with improvements in understanding dermanyssosis in humans. It aims to highlight salient aspects and key features of this ectoparasite, starting with its epidemiology by bringing order to the literature and updating, to the best of our knowledge, the case reports in Europe, and considering the clinical and diagnostic aspects involved. It provides physicians/dermatologists with practical information about the key actions needed for correct management of infestations in humans, and informs the scientific community about future research priorities to fill the gaps in the current knowledge of dermanyssosis.

**Epidemiology and public health significance of D. gallinae in Europe**

Given the high percentage of infected poultry farms (on average 83% of the European laying hen farms) (Mul et al., 2013) human dermanyssosis in this specific context can be regarded as “occupational cases” (Cafero et al., 2011), while those related to synanthropic birds can be regarded as “urban cases” (Figure 1). Table 1 summarizes the cases of dermanyssosis (occupational and urban) documented to date.

**Occupational cases**

Despite the high occurrence of dermanyssosis among poultry industry farmers, technicians and veterinarians working in infested farms (Camarda, personal communication, January 23, 2019), there are very few case-reports linked to poultry in the literature. Attacks on humans in poultry sheds occur when the infestation level in poultry farms is high, and when farmers, employees or visitors do not wear adequate protective clothing. D. gallinae bites can be considered a serious health hazard, and a source of discomfort and stress for all personnel working in poultry houses including amateurs. In these conditions, and given that the mite can bite in less than 1 s (Auger et al., 1979), there can be a major risk of attacks on humans handling birds and/or cages and collecting eggs (Rosen et al., 2002), or even visiting an infested farm. In some countries this has become a socio-economic problem for poultry workers, who demand three times the usual rate of pay before they are willing to work with D. gallinae-infested birds (Sahibi et al., 2008). Several occupational cases of human dermanyssosis have been registered worldwide (Sparagano et al., 2014).

In Europe, although it is very common in the field, and a well-known pest in veterinary handbooks, there are few published records of poultry workers being attacked by D. gallinae (Table 1). However, cases have been recorded since the 1950s in Poland (Litwinski, 1955), and later in the UK (Rossiter, 1997), Italy (Pampiglione et al., 2001; Cafiero et al., 2011) and Turkey (Dogramaci et al., 2010; Şengül et al., 2017).

Case records concern both people living in rural areas, who rear free-range hens as a hobby (Pampiglione et al., 2001; Şengül et al., 2017), and poultry farmers (Rossiter, 1997; Dogramaci et al., 2010). Although there are several case reports, only one study has investigated the prevalence of cases involving
| Year of record | City, region, country | Type of infestation | Number of outbreaks | Location and number of people attacked | Source | References |
|---------------|-----------------------|---------------------|---------------------|----------------------------------------|--------|------------|
| 1930          | Zurich, Switzerland   | Urban               | 1                   | Unknown Poultry house, one farmer      | Synanthropic birds | Schrafl (1930) |
| 1953          | Poland                | Occupational        | 1                   | Poultry house, one farmer              | Infested poultry farm | Litwinski (1955) |
| 1961          | Rotterdam, the Netherlands | Urban           | 8                   | Twenty-three persons (one adult; three children; three times one child; two adults; four children; two adults; three children; two children; two adults; one child) | Pigeons, tiger finches, parakeets, canaries | Frenken (1965) |
| 1967          | Hamburg, Germany      | Urban               | 1                   | Hospital, Twelve patients              | Ventilation openings infested by mites from birds’ nest | Winkler (1967) |
| 1967 and 1968 | Cornwall, UK          | Urban               | 2                   | Private apartments Two children (1967), One girl (1968) | Starlings’ nest found in crevice where waste pipe exits the house (1967) | Reed et al. (1969) |
| 1967          | Danzig, Poland        | Urban               | 1                   | Hospital Unknown number of patients and hospital staff | Pigeons’ nest | Skierska (1968) |
| 1969          | London, UK            | Urban               | 1                   | Hospital Many patients (number unknown) | Abandoned pigeons’ nests | Freeman & Kataria (1969) |
| 1971          | Danzig, Poland        | Urban               | 1                   | Railway shipment Unreported number of office employers | Pigeons’ nests | Wegner (1973) |
| 1974          | Kielce, Poland        | Urban               | 1                   | Office One employee Immediately following removal of pigeons’ nest close to office | | Kowalska & Kupis (1976) |
| 1981          | Vienna, Austria       | Urban               | 1                   | Optical instruments factory Four employees Pigeons’ nest outside a factory window | | Bardach (1981) |
| 1985          | UK                    | Urban               | 1                   | Hospital Four elderly patients Infested pigeons nesting on window ledges of two hospital wards | | Neill et al. (1985) |
| 1988          | Basel, Switzerland    | Urban               | 1                   | University lab One man Laboratory infestation by D. gallinae, escaped from plastic bag containing pigeon faeces harbouring red mites | | Haag-Wackernagel (1988) |
| 1996          | Nijmegen region, the Netherlands | Urban | 2                   | Private apartments Two adults and one child Birds’ nests under the roof tiles | | Prins et al. (1996) |
| 1997          | Exeter, UK            | Occupational        | 1                   | Poultry house Two workers Chicks | | Rossiter (1997) |
| 2001          | Emilia Romagna, Italy | Occupational        | 1                   | An elderly woman Offices (Law Court/Town Hall) Small hen house adjacent to patient’s house | | Pampiglione et al. (2001) |
| 2001–2007     | Apulia, Basilicata, and Campania regions, Italy | Urban | 6                   | Ten employees (2003) Seven employees (2005) Abandoned feral pigeons’ nests near infested buildings (hole in the wall/ behind air-conditioning units) | | Caﬁero et al. (2007, 2008) |
|               |                       |                     |                     | Private apartments Six adults (2001, 2005, 2007) | (Continued) |
| Year of record | City, region, country | Type of infestation | Number of outbreaks | Location and number of people attacked | Source | References |
|----------------|----------------------|---------------------|---------------------|----------------------------------------|--------|------------|
| 2003–2008      | Amsterdam, the Netherlands | Urban | 96 | Apartments, several people | Synanthropic birds’ nests, mainly pigeons, in outer walls of apartments | Buijs (2009) |
| 2005           | Tilburg region, the Netherlands | Urban | 1 | Private apartment | Pigeons’ nest with dead pigeon adjacent to the bedroom window of the patient | Diederens et al. (2006) |
| 2005 and 2006  | Modena, Italy | Urban | 2 | Primary school Many pupils, number unknown (2005) – Private apartment One woman (2006) | Feral pigeons roosting and nesting on school roof – Colony of pigeons nesting on chimney-pot of attic | Gelati et al. (2007) |
| 2006–2008      | Valencia, Bétera-Camp de Turia, Spain | Urban | 4 | University offices/ army residence/ cottage Unknown number of adults and three children | Abandoned nest close to cottage/pigeons’ nest behind air-conditioning units | Fuentes et al., 2009 |
| 2007           | Modena, Italy | Urban | 3 | Site unknown Three subjects in total | Removal of pigeons’ nests from window ledge | Ferri (2007) |
| 2007           | Apulia region, Italy | Urban | 1 | Two private apartments in the same building Three adults and one child | Abandoned pigeons’ nest under gutter between balconies of two apartments | Cafiero et al. (2008, 2009) |
| 2007–2009      | Apulia region, Italy | Occupational | 11 | Poultry farms Eleven poultry workers | Caged laying hens | Cañiero et al. (2011) |
| 2007           | Czech Republic | Urban | 1 | Apartment Two adults and two children | Mites entered apartment via hole in the roof⁶ | Melter et al. (2012) |
| 2008           | Créteil, France | Urban | 1 | Hospital | Abandoned pigeons’ nest near a window | Bellanger et al. (2008) |
| 2008 e 2009    | Apulia and Basilicata regions, Italy | Urban | 4 | Private apartments Seven adults and one child (2008), One adult (2009) | Abandoned pigeons’ nests (2008); Sparrow nest (2009) | Cafiero et al. (2013) |
| 2009           | Kütahya, Turkey | Urban | 1 | Private apartment | Mites from pigeons through the air ventilation system | Akdemir et al. (2009) |
| 2009           | Basel, Switzerland | Urban | 1 | Renovated old apartment building Poultry house Elderly worker | Feral pigeons using balcony for roosting /breeding Poultry | Haag-Wackernagel & Bircher (2010) |
| 2010           | Hatay, Turkey | Occupational | 1 | Hospital | Feral pigeons using window ledge near the infested rooms for roosting/breeding | Galante et al. (2011) |
| 2010           | Puglia, Italy | Urban | 1 | Office, one employee | Abandoned pigeons nesting in air-conditioner unit surround | Giangaspero et al. (2016) |
| 2011           | Puglia, Italy | Urban | 1 | Private apartment Three adults | Following removal of an active pigeons’ nest close to the house | Mancini et al. (2012) |
| 2013           | Barcelona, Spain | Urban | 1 | Private apartment Two adults | Pigeons’ nests near balcony | Collgros et al. (2013) |
| 2008; 2011     | Pančevo, Serbia | Urban | 1 | Private apartment Five patients (couple and their three children) | Mites in nearby dove nest entering apartment through cracks in frame of balcony door | Gavrilović et al. (2015) |
| 2015           | Apulia, Italy | Urban | 1 | Office, one employee | Abandoned pigeons nesting in air-conditioner unit surround | Giangaspero et al. (2016) |
poultry industry workers; a questionnaire among workers in infested poultry farms in Southern Italy revealed that 18% (11 of the 58 people interviewed) had experienced irritating and itchy skin eruptions (Cafero et al., 2011).

Human infestation mostly occurs in daytime (when mites crawling off their preferential host, or hiding, are disturbed by human activities), and in spring-summer when climatic conditions are favourable to mites. However, given that temperatures in industrial farms are almost constant, infestations can occur in them throughout the year (Sparagano et al., 2014).

The importance of these mites in public health also stems from their role as reservoirs/vectors of zoonotic poultry pathogens, including *Salmonella enterica* (Pugliese et al., 2019), *Erysipelothrix rhusiopathiae* (Chirico et al., 2003; Valiente Moro et al., 2009; Huong et al., 2014), and the avian influenza A virus (Sommer et al., 2006). For these reasons, there has been whole-hearted support for official recognition of *D. gallinae* as a zoonotic agent in all occupational safety regulations, and for recognition of this mite dermatitis as an occupational hazard for poultry industry workers (Cafero et al., 2011).

**Urban cases**

Reports of dermanyssosis have become more frequent in recent years, particularly in residential contexts in association with common synanthropic birds, such as sparrows, starlings, doves, and mostly with feral pigeons (*Columba livia*). Feral pigeons are among the most successful avian settlers in our cities due to the abundance of available food and the absence of predators (Haag-Wackernagel, 2005). The ever-increasing pigeon populations build their nests close to homes (e.g., crevices and holes on the façades of buildings, behind external air-conditioner units, under eaves and in attics). When bird hosts are not available, mites search for alternative hosts and may migrate into nearby homes, where they bite humans. Most episodes of red mite dermatitis commonly occur in the late spring-early summer (Deoreo, 1958; Bellanger et al., 2008; Cafero et al., 2013; Giangaspero et al., 2016).

The seasonal occurrence of this infestation was extremely evident in an outbreak affecting five members of a family, who suffered recurrent pruritic skin lesions in April and May for four consecutive years before the parasites were observed and identified (Gavrilović et al., 2015). This seasonality reflects the red mite population peak; this is linked to the breeding season of birds, mostly pigeons, which peaks between April and June, when birds leave their nests once the chicks have fledged, and there are greater chances of human contact with mites. In fact, *D. gallinae* and *Argas reflexus* (sometimes in co-infestations) are the principal ectoparasites acquired by humans in urban
environments from feral pigeons (Haag-Wackernagel, 2005; Haag-Wackernagel & Bircher, 2010); the occurrence of feral pigeon ectoparasites increases as the density of their host (i.e. feral pigeons) increases (Haag-Wackernagel, 1991).

In Europe, published/ascertained urban *D. gallinae* infestations have been recorded in 12 countries; these were more frequent in private homes/apartments (with more than 150 outbreaks recorded), but also in hospitals (six records) and offices/public buildings (12 records) (Table 1).

The urban cases of *D. gallinae* infestation have all been caused by mites migrating from synanthropic bird nests of pigeons, starlings or sparrows, except for a few cases: one caused by an accidental laboratory infestation in Switzerland (Haag-Wackernagel, 1988), and other cases caused by caged canaries in Netherlands (Frenken, 1965) and Italy (Cafero et al., 2017) (Table 1).

The attacks can occur during daytime (mostly in workplaces) or at night (mostly in private homes).

The implications of these infestations in urban environments may well cause concern, since *Chlamydia psittaci* (Circella et al., 2011), and both *Borrelia burgdorferi* s.l. and *Coxiella burnetii* DNA, the agents of Lyme disease and Q Fever, respectively, have recently been detected in *D. gallinae* during three outbreaks of human dermatitis related to sparrow and pigeon nests (Raele et al., 2018). More importantly, *Bartonella quintana* DNA has been detected in *Dermatophagoides* mites collected in an apartment during an outbreak of urban trench fever caused by *B. quintana*, which affected a family with high socio-economic status (Melter et al., 2012).

**Clinical signs**

People attacked by *D. gallinae* mites present erythematous eruptions consisting of 1–3 mm papules (Figure 2) (Bardach, 1981; Collgros et al., 2013), sometimes with a visible central puncture mark or vesicles (Deoreo, 1958; Kowalska & Kupis, 1976; Haag-Wackernagel & Bircher, 2010; Cafero et al., 2018); urticarioid manifestations have also been described (Rockwell, 1953; Deoreo, 1958; Sexton & Barton, 1975; Auger et al., 1979; Ahmed et al., 2018). Bites can be painful (Berndt, 1952) and skin lesions may occur in any area of the body, except in the interdigital spaces, genitals or skin folds; itching is commonly intense, with reported cutaneous excoriations due to scratching (Gavrilović et al., 2015).

In the Italian survey of poultry farm workers, two of the 11 parasitized workers (18.18%) reported skin eruptions on their arms and hands, seven (63.63%) reported symptoms on their chests, and two (18.18%) on their legs. None of these workers usually wore personal protective equipment during their work, including egg collection, so that their skin was exposed, particularly on their hands and arms (Cafero et al., 2011), as was also reported for poultry farmers in Israel (Rosen et al., 2002).

In addition, there are reports of intriguing cases of persistent infestation in unexpected sites, such as the ears (auditory meatus) in the UK (Rossiter, 1997), and on the scalp, as in the case of an Italian woman living in the countryside (Pampiglione et al., 2001) and of two Turkish farmers (Dogramaci et al., 2010; Şengül et al., 2017). Surprisingly, all these cases involved elderly subjects (aged 60+). In all of the above-mentioned cases, symptoms occurred for as long as 9 months.

Urban cases document more severe clinical pictures, involving people attacked at night while sleeping at home, or else bedridden patients attacked in hospitals during the day. In these cases, skin lesions are particularly abundant on body areas covered by pyjamas, e.g. the trunk and limbs (Freeman & Kataria, 1969; Cafero et al., 2018), or on the patient’s entire body; in an outbreak in a Hamburg hospital, one of the 12 parasitized patients suffered over 500 bites (Winkler, 1967). In these cases, cutaneous lesions are often described as grouped and more intense where clothes constrict the body, for example in relation to a belt (Cafero et al., 2017) or under the breasts (Bellanger & Paba, 2008). When mites attack sleeping subjects, red spots (crushed mites or mite droppings) can be found on bedclothes and pillows (Regan et al., 1987; Cafero et al., 2009).

By contrast, attacks in workplaces and public buildings occur during daylight hours. Patients also present intense itching, but their skin reactions are less severe and less numerous, almost always involving exposed body areas, mainly the arms and legs. Victims usually see mites crawling on their clothes or skin and/or on office furniture and usually refer to experiencing a biting/stinging sensation while they work (Fuentes et al., 2009; Giangaspero et al., 2016; Cafero et al., 2017; Pezzi et al., 2017; Şengül et al., 2017).

![Figure 2. *Dermatophagoides gallinae*-dermatitis caused by mites migrating from a sparrows’ nest (original, M.A. Cafero).](image-url)
Histopathological aspects

There are few studies of histological changes to the skin of animals and humans affected by *D. gallinae*-dermatitis.

In a study of poultry, hyperkeratosis, skin thickness and a focal loss of epidermis were observed in 90% of the birds examined, together with extremely numerous small focal lymphocytic infiltrations in all hens (Sokol & Rotkiewicz, 2010). Another study involving poultry reported severe subcutaneous oedema, congestion of the hypoderma, lymphocytic infiltration, necrosis of feather follicles at 24 h post-infestation (p.i.), and hyperkeratosis, parakeratosis, acanthosis and local epidermal hyperplasia at 72 h p.i. (Hobbenaghi et al., 2012).

A study of infested cats described a perivascular and interstitial inflammatory infiltrate (Di Palma et al., 2018).

In humans, histological examination of skin lesions caused by *D. gallinae* revealed a perivascular inflammatory skin reaction, and sometimes a superficial perivascular eosinophilic infiltration (Hidano & Asanuma, 1976; Kowalska & Kupis, 1976). Moreover, a modest spongiosis and focal parakeratosis were also found in a case of severe *D. gallinae*-related dermatitis (Cañiero, personal communication, February 10, 2019).

Immunological response

Unlike mammalian immunological responses to ectoparasitic arthropods, the humoral and cellular immune response of birds to *D. gallinae* (as for other Gamasida) are still poorly understood, and there is a complete lack of knowledge about human responses.

Arkle et al. (2006) found significantly higher ($P < 0.05$) yolk IgY levels in hens’ eggs. However, no significant relationship was found between yolk IgY levels and *D. gallinae* population levels, or between serum and yolk IgY levels, although egg and serum samples were not collected from the same bird. Arkle (2007) reported that the level of cytokine expression did not appear to be significantly correlated with *D. gallinae* levels in naturally infested commercial poultry, while numerical and significant associations between IgY and cytokine levels lacked consistency (although there was some suggestion of a relationship between IgY levels and IL-5 and IL-12α expression). These data would suggest that *D. gallinae* blood feeding stimulates a significant IgY immune response by the host; such immune response following natural infestation would allow older birds to better tolerate mite attacks in the presence of high IgY levels and lower side effects from these attacks compared to young chicks. Reports of host inflammation or skin damage following *D. gallinae* infestation of hosts (birds or humans) do not appear in the literature, possibly highlighting counter-immune reactions developed by the mites. Further hypotheses regarding the apparent lack of development of host immunity to *D. gallinae* include the following: (a) *D. gallinae* has a mechanism which modifies host immunity, making it less effective; (b) mite populations adapt to host immunity between the first attack and the later attacks (however it is unclear how mites could communicate within colonies and if the mite population diversity stays the same during the flock life) (Arkle et al., 2006).

Diagnosis

Medical texts and parasitology manuals rarely mention Mesostigmata mites in relation to human infestation. This means that most physicians are unfamiliar with the diagnosis of several less common mite-related forms of dermatitis, including the dermatitis caused by *D. gallinae* (Cañiero et al., 2008; Haag-Wackernagel & Bircher, 2010; Collgros et al., 2013).

This is extremely important, not only because misdiagnosis may lead to failure in the treatment of patients, but also because, as underlined above, *D. gallinae* may be a vector/reservoir of ascertained zoonotic agents (Chirico et al., 2003; Valiente Moro et al., 2009; Brännström et al., 2010; Circella et al., 2011; Melter et al., 2012; Raele et al., 2018).

Clinical recognition of dermatitis due to *D. gallinae* bites (described in the section above) is a challenging task. *D. gallinae* bites may be confused with urticarial atopic dermatitis, or with the dramatically common/widespread delusional ectoparasitosis caused by fragile psychological conditions (Lucky et al., 2001; Bellanger et al., 2008; Akdemir et al., 2009; Cañiero et al., 2013). They may also be confused with lesions caused by

Figure 3. A pigeons’ nest in close proximity to an apartment, identified during an inspection to investigate a *D. gallinae* outbreak (original, M.A. Cañiero).
zoonotic mange (Sarcoptidae mite), baker’s itch (Acaridae mite), Cheyletiella, Trombicula and Cimex lectularius, if not arranged in linear arrays. Additionally, D. gallinae bites may be mistaken for those of avian mites in the Ornithonyssus genus (Acari: Macronyssidae); this mite group of zoonotic interest is similar to D. gallinae, but less common in Europe, and has a different relationship with the host (Cafiero et al., 2018).

D. gallinae-related dermatitis can be diagnosed by using dermoscopy and reflectance confocal microscopy. However, this tool is helpful only when the mites are present on the patient’s skin, although this must be considered a rather rare circumstance (Navarrete-Dechent & Uribe, 2018). Dermoscopy evaluation of D. gallinae-induced dermatitis also reveals dilated vessels on an erythematous background in correspondence to the macules and papules, and reflectance confocal microscopy demonstrates the presence of intraepidermal vesicles (Cinotti et al., 2015).

Currently, D. gallinae-related attacks on humans can be addressed only via different perspectives/approaches, which require:

- greatly improved awareness of the problem among medical doctors;
- enhanced knowledge of D. gallinae taxonomy and eco-biological aspects;
- closer collaboration of doctors with entomologists/acarologists/veterinarians.

Given these starting points, there are some important actions doctors should take when faced with suspected pruritic dermatitis caused by D. gallinae.

A series of straightforward recommendations/instructions is listed below, beginning with the collection of the correct anamnestic information and including appropriate/accurate management methods to enable case resolution.

**Practical recommendations to physicians**

*Dermanyssus gallinae* should always be suspected when unexplained, recurrent dermatitis occurs in humans.

**Detailed personal and environmental anamnnesis**

In addition to collecting the usual anamnestic data, physicians should ask patients about where they live (i.e. in the countryside, city, etc.), their occupation and their lifestyle. They should also ask patients for details about the onset of pruritus: the place, season and time of day it appeared; the recurrence of the symptoms; whether other family members (including their pets) have/had the same symptoms; whether they live close to a poultry farm; and whether there are pet birds and/or bird nests near their home/workplace.

**Site inspection**

For poultry farm workers, it may be relatively simple to predict and identify the cause of their dermatitis, given the prevalence of *D. gallinae* in rearing systems, but in an urban context, it is crucial to have a good knowledge of *D. gallinae* biology/ecology in order to search for the mites. It is strongly recommended that inspections (or requests for inspections) be made for adult stages (which are visible to the naked eye) in the environment where an infestation is suspected. It is important to know that mites are attracted by warm hiding places simulating the body temperature of birds. In apartments, offices and public buildings, the places to inspect are under bed covers, electrical devices. In stand-by mode (e.g. laptop computers, television and radio clocks), and all other sites generating heat. Balconies, attics, eaves, windows and holes near the building must be also inspected for the presence of active or, more probably, abandoned birds’ nests (Figure 3).

**Environmental sample collection**

Having obtained the consent of the house/building owner/s, dust samples must be taken near/under windows, beds, furniture and desks, where people usually rest or work. The dust must be brushed into a
transparent bag, then sealed and labelled with the collection site, date and time. If noticed in a room, arthropod specimens can be collected using scotch tape (Figure 4). Samples have to be examined under a microscope and we strongly recommend that the specimens be correctly identified, since correct identification is the first requirement before applying control methods.

**Identification**

*D. gallinae* is relatively small at the adult stage (0.5–1 mm long), with long legs and a greyish-white body that becomes reddish-brown when engorged (Figure 4). However, since cases of dermatitis caused by the avian mites *Ornithonyssus bursa* (Castelli et al., 2015; Mentz et al., 2015; Bassini-Silva et al., 2019) and *Ornithonyssus sylviarum* (Orton et al., 2000; Cañiero et al., 2018), or by the rodent mite *Ornithonyssus bacoti* (Beck & Fölster-Holst, 2009; Cañiero et al., 2016) have been recorded in humans even recently, there may be some confusion over identification of the mite responsible.

Firstly, fresh (or, less efficiently, frozen) specimens must be macerated in lactophenol for one week at 45 °C on a hot plate, and then mounted on slides with Hoyer’s medium for light microscopy (LM) observations (Di Palma et al., 2012).

*D. gallinae* can be identified according to the following principal morphological characters (Di Palma et al., 2012; Giangaspero et al., 2016):

- the dorsal surface has a shield with prominent lateral margins tapering towards the rear, but these do not reach the distal end of the body and are truncated at the end.
- the ventral side has a sternal plate much wider than it is long and bears two pairs of bristles, with a third pair situated posteriorly and apart from the first two pairs.
- the posteriorly rounded genitoventral shield bears one pair of setae.
- the rounded or D-shaped anal plate bears three characteristic setae.
- hair-like chelicerae (when extended).
- chelicerae bases look like wine glasses upside down in the middle of the body when chelicerae are retracted.

*Ornithonyssus* spp. has different features (see Di Palma et al., 2012 and Giangaspero et al., 2016 for morphological details on this genus).

**Molecular identification**

It has been demonstrated that *D. gallinae* is a complex of species, which includes *D. gallinae* L1 (a cryptic species related to synanthropic birds) and *D. gallinae sensu stricto* (associated with poultry farms and chickens). Since these are morphologically indistinguishable (Roy & Buronfosse, 2011), it would be helpful to analyze the DNA of specimens from the environment to understand the source of attacks on humans.

**Treatment of patients and the environment**

Diagnosis of *D. gallinae* dermatitis is challenging, and misdiagnosis can lead to use of antihistamines and steroids to relieve symptoms, sometimes in combination with anti-parasite shampoos, antibiotics and tranquilizers. However, if symptoms are caused by *D. gallinae* infestation, the clinical signs usually return when treatments end.

If physicians suspect and/or confirm dermanyssosis in urban outbreaks, the following measures will achieve complete regression of the symptoms, and no evidence of mites or dermatitis will appear in the follow-up period: (i) patient showering extensively and washing their clothes at 60 °C; (ii) removal of the mite source (abandoned birds’ nest); (iii) intensive vacuum cleaning, removal of the vacuum bag which needs to be packed in a sealed plastic bag and thrown away outside in a contained bin; (iv) disinfection of the infested areas using pyrethroids; (v) steam cleaning or washing of textiles (curtains, carpets, cushions) at 60 °C and then preferably dried with an automated laundry drier. Textiles which cannot be washed at 60 °C should be placed in a plastic bag for a day together with anti-moth balls releasing an acaricide product.

In the case of occupational dermanyssosis, the problem of farm infestation requires intervention using an integrated pest management (Sparagano et al., 2014; Mul, 2017). Moreover, physicians should remind their patients that all poultry workers must be protected by suitable protective clothing, before entering poultry houses.

**Conclusions and future research perspectives**

Dermatitis due to *Dermanyssus* mites is an increasing but neglected problem. It features as an occupational hazard for poultry workers due to the great prevalence of infested poultry farms, and also appears in urban contexts due to the worrying spread of synanthropic birds to megacities worldwide (George et al., 2015; Kavallari et al., 2018).

Medical specialists should always include *D. gallinae* in their differential diagnosis of patients presenting pruritic dermatitis of unknown aetiology. The widespread circulation of *D. gallinae* in humans indicates the need for targeted actions at different levels to provide better understanding of this mite, allowing researchers to fill the gaps in current scientific
knowledge and enabling the development of strategies for recognition/diagnosis and control.

Therefore, we suggest that health service practitioners (physicians, medical doctors, dermatologists and occupational doctors) receive the above-mentioned recommendations. This could help to raise their awareness of the role of these ectoparasites in human health, allowing them to suspect and recognize *D. gallinae* infestations in humans, thus increasing the number of case reports.

In addition, there is a need for research with the following aims:

- to carefully describe the symptoms and skin reactions of red mite dermatitis, although they may overlap other diseases;
- to investigate the development of the lesions and haematological parameters (if any) over time;
- to investigate the effects of *D. gallinae* on the human immune and dermal systems;
- to uncover possible immunological host markers for setting up diagnostic tools.

All these efforts are crucial for the future development of a reliable diagnostic protocol that will make it possible to avoid using the wrong treatment products, which can cause side effects and damage patients’ health.

Finally, it is of paramount importance for treatment of this disease, as for other zoonotic infestations, that clinicians, parasitologists, microbiologists, veterinarians, epidemiologists and environmental scientists work together according to the “One Health” approach, which is often mentioned but too rarely put into practice.

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M. A. Cafiero et al.

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