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Biological characteristics, socioeconomic impacts and medical importance of *Cimex* (Hemiptera: Cimicidae): A review

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Abstract
Bed bugs belonging to the genus *Cimex* (Hemiptera: Cimicidae) are recognized as significant household pests with notable socioeconomic and medical consequences. This review examines *Cimex lectularius* and *Cimex hemipterus*, *which* are of particular importance due to their close association with human environments. The review synthesizes current scientific literature regarding their biological characteristics, geographical distribution, life cycle, blood-feeding behavior, socioeconomic impacts, and medical relevance. Both species possess dorsoventrally flattened bodies and are obligate blood feeders. Morphological differentiation between C. *lectularius* and C. *hemipterus* is possible based on pronotal features. Environmental factors, blood meal availability, and mating behavior influence their development and reproductive success. Bed bug infestations impose financial burdens on households and accommodation providers, affecting pest control costs, consumer confidence, and willingness to pay for lodging. Medically, bed bug bites can lead to dermatological reactions, allergic responses, psychological distress, and sleep disturbances. While experimental research has shown that bed bugs can acquire and potentially transmit certain pathogens, their role in the natural transmission of human infectious diseases remains unverified. A comprehensive understanding of these biological and socioeconomic factors is critical for enhancing surveillance, preventing infestations, and implementing integrated bed bug management strategies.

Keywords: *Cimex lectularius*, *Cimex hemipterus*, socioeconomic, medical, bed bugs

Introduction
In recent decades, bed bugs of the genus *Cimex* (Hemiptera: Cimicidae) have re-emerged as significant urban pests, particularly *Cimex lectularius* and *Cimex hemipterus*. Their increasing occurrence in human-associated environments has been linked to international travel, the movement of infested materials, and the development of insecticide resistance (Doggett and Lee, 2023; Lee, 2025) [1,2]. The biological characteristics of *Cimex* contribute substantially to its ability to survive in human-associated habitats (Guerra *et al*., 2021) [3]. Bed bugs depend on blood meals for their nutritional requirements and undergo gradual development through egg, nymphal, and adult stages (Guerra *et al*., 2021; Flaven-Pouchon, Froschauer and Moussian, 2024) [3,4]. Their flattened bodies enable them to occupy concealed spaces, while their feeding behavior allows them to obtain blood from hosts with minimal disturbance (Mbuta *et al*., 2022) [5].
The consequences of bed bug infestations extend beyond the presence of insects in residential buildings. Repeated infestations may require substantial expenditure on inspection, treatment, and replacement of affected household items (Mbuta *et al*., 2022; Meisyara, Guswenrivo and Singham, 2023) [5,6]. In accommodation facilities, these problems may also influence operational costs and public perceptions of hygiene (Permatasari, Maghrifani and Wibowo, 2025). [7] From a medical perspective, exposure to bed bug bites may result in cutaneous irritation, allergic responses, disrupted sleep, and psychological discomfort (Egg *et al*., 2024; Porras-Villamil and DeVries, 2026) [8,9]. Although investigations have identified microorganisms associated with bed bugs, convincing evidence of their role in transmitting infectious diseases to humans remains insufficient (Lee, Wang and Su, 2023; Pietri and Laroche, 2025) [10,11]. Accordingly, this review synthesizes published findings on the biological characteristics, life cycle, socioeconomic consequences, and medical importance of *Cimex*, with emphasis on *C. lectularius* and *C. hemipterus*, *to clarify their relevance as urban pests and public health concerns.*

Results and Discussions
1. Classification
Cimex lectularius and *C. hemipterus* are particularly important because of their close association with humans and their significance as household ectoparasites.
Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Suborder: Heteroptera
Infraorder: Cimicomorpha
Family: Cimicidae
Subfamily: Cimicinae
Genus: *Cimex*
Species: *Cimex lectularius* Linnaeus, 1758
Species: *Cimex hemipterus* Fabricius, 1803 (Akhoundi *et al*., 2020) [12].

2. Morphological Description
Morphological identification is important for distinguishing species within the genus *Cimex*. Bed bugs generally possess oval, wingless, and dorsoventrally flattened bodies, with

distinctive structures such as segmented antennae, a piercing-sucking proboscis, and a well-developed pronotum (Mbuta *et al*., 2022) [5].

These two species can be distinguished by morphological characteristics, particularly the shape and proportions of the pronotum. *C. lectularius* is characterized by broad lateral pronotal lobes and a pronotal width-to-length ratio greater than two (Fig. 1), whereas *C. hemipterus* possesses narrower lateral lobes and a corresponding ratio below two (Fig. 2) (Akhoundi *et al*., 2020) [12].



Fig 1: Head and pronotum of *C. lectularius.*
Light microscopy, 4× magnification



Fig 2: Head and pronotum of *C. hemipterus.*
Light microscopy, 4× magnification

3. Sex and reproduction

The genus *Cimex* comprises distinct male and female individuals that exhibit sexual dimorphism, particularly in their abdominal morphology. In *C. lectularius*, adult males possess a more tapered abdominal tip, whereas females have a more rounded abdomen (Fig. 3). These morphological differences are associated with reproductive structures and can be used to distinguish the sexes (Kawasima *et al*., 2022) [13]. Similar sexual differentiation has been documented in *C. hemipterus*, with morphometric analyses identifying significant differences between males and females, primarily associated with the abdomen and the position of male genital structures on the terminal abdominal segment (Deku, Combey and Doggett, 2022) [14].

Reproduction in *Cimex* is characterized by a distinctive mating mechanism known as traumatic insemination, in which males penetrate the female abdominal wall using a specialized reproductive structure called the paramere. In *C. lectularius*, the paramere penetrates the external ectospermalege, allowing the ejaculate to enter the internal mesospermalege, a specialized organ involved in insemination and immune responses. Unlike conventional insemination through the genital tract, sperm initially accumulate in the mesospermalege before migrating toward the female reproductive tract. Sperm begin to reach the lower reproductive tract within the first few hours after mating, while the mesospermalege and the lower reproductive tract exhibit distinct patterns of postmating

gene expression. The mesospermalege is particularly associated with immune responses and initial interactions with the ejaculate, whereas the lower reproductive tract appears more specialized for subsequent reproductive processes, including sperm storage and oviposition (Martens *et al*., 2026) [15].

Beyond anatomical adaptations, mating behavior and frequency influence reproductive success in *C. lectularius*. Mating was more likely to occur within female harborages, with limited evidence of active female mate choice before copulation. Although insemination is necessary for reproduction, excessive mating may impose physiological costs on females (Gershman, Harrison and Jones, 2019)[16]. Females inseminated weekly survived longer and produced more offspring than those inseminated daily, indicating that mating frequency can influence both female longevity and reproductive output. Blood feeding also plays an important role in reproduction, although its effects differ between the sexes (Yan, Dobbin and Dukas, 2024) [17]. Unfed males were more likely to mate and initiated mating more rapidly than recently fed males, whereas blood-fed females produced more eggs and hatching offspring than unfed females. Together, these findings indicate that reproductive success in *Cimex* depends not only on specialized reproductive anatomy but also on mating frequency, feeding condition, and the physiological responses of females after insemination (Gershman, Harrison and Jones, 2019) [16].

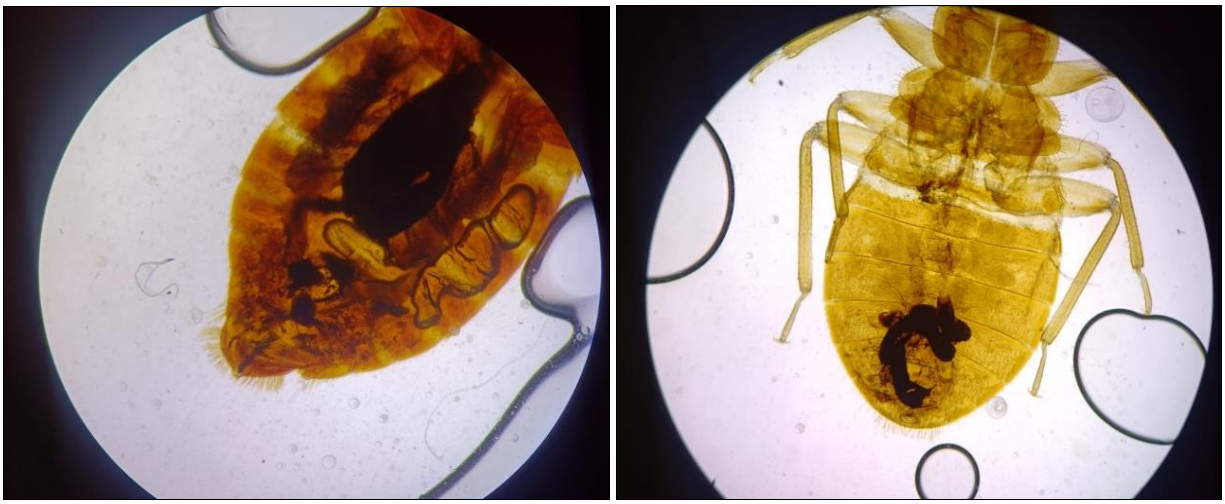


Fig 3: Sex of bed bugs: male (left) and female (right).
Light microscopy, 4× magnification

4. Geographical Distribution

Bed bugs of the genus *Cimex*, particularly *C. lectularius* and *C. hemipterus*, have a widespread geographical distribution and are closely associated with human habitation. *C. lectularius*, commonly known as the common bed bug, has predominantly been reported from temperate and subtropical regions, whereas *C. hemipterus*, the tropical bed bug, is primarily associated with tropical and warmer subtropical environments, including Southeast Asia (Akhoundi *et al*., 2020; Doggett and Lee, 2023) [2,12]. Although *C. hemipterus* has traditionally been associated with tropical and subtropical regions, its occurrence has also been documented in temperate European regions, including France, the Czech Republic, Slovakia, and Switzerland (Balvín *et al*., 2021; Chebbah *et al*., 2021) [18,19]. More recent studies have also reported this species in Russia and South Korea, providing further evidence of its occurrence outside traditionally tropical environments (Lewis *et al*., 2020; Cho *et al*., 2023; Han *et al*., 2024) [20–22]. The geographical distribution of *C. hemipterus* is not strictly limited to warmer climatic regions (Balvín *et al*., 2021) [18]. These findings indicate that regional climate alone does not explain the geographical distribution of *Cimex* species, and they underscore the need to further investigate the long-term establishment and spread of *C. hemipterus* in temperate environments.

5. Life cycle

Bed bugs of the genus *Cimex* undergo incomplete metamorphosis (hemimetaboly), consisting of three main developmental phases: egg, nymph, and adult. The nymphal phase comprises five successive instars, each separated by molting, before individuals reach sexual maturity. In *C. hemipterus*, females generally begin laying their first batch of eggs approximately 2–3 days after feeding and mating, with oviposition continuing for 2–7 days within a reproductive cycle. Under laboratory conditions of 26 ± 2 °C and 70 ± 5% relative humidity, the eggs typically required 5–7 days of incubation before hatching into first-instar nymphs (How and Lee, 2010) [23]. In *C. lectularius*, egg hatching was highest at 25 °C and 90% relative humidity, reaching approximately 98.23%, whereas the fastest hatching occurred at 30 °C and 90% relative humidity, with hatching beginning after approximately 5.19 days (Banerjee *et al*., 2024) [24]. Following hatching, the nymphs undergo five molts, with each developmental stage generally requiring a blood meal to support growth and successful molting into the next instar. The duration of this developmental process varies between species and is influenced by environmental conditions, particularly temperature, relative humidity, and blood meal availability. These factors jointly regulate the life cycle of *Cimex* and determine its developmental rates and population growth potential.

6. Blood-Feeding Behavior

Bed bugs of the genus *Cimex* are obligate hematophagous ectoparasites that require blood meals for survival, development, and reproduction. Both nymphs and adults feed exclusively on blood. Host-seeking activity typically occurs during periods of darkness, when bed bugs leave their harborages to locate a suitable host. In *C. lectularius*, host detection is mediated by responses to body heat, carbon dioxide, and human skin odors (Wang *et al*., 2017; Gaire *et al*., 2020) [25,26]. Antennal structures facilitate heat detection, while exposure to carbon dioxide stimulates movement and exploratory behavior, especially in individuals subjected to prolonged starvation (Gaire *et al*., 2020) [25].

After locating a host, bed bugs pierce the skin using specialized piercing-sucking mouthparts and obtain blood through a feeding mechanism involving the cibarial pump. Female bed bugs ingest larger blood meals than males but require longer contact with the host to complete feeding (Araujo *et al*., 2009) [27]. Salivary nitrophorin, a nitric oxide (NO)-carrying hemeprotein produced by the salivary glands of *C. lectularius*, facilitates the delivery of NO to host tissues during blood feeding, promoting local vasodilation and supporting blood acquisition (Leverkus *et al*., 2006) [28]. *C. lectularius* demonstrates greater blood-feeding efficiency than *C. hemipterus* when feeding on experimental hosts, such as mice and pigeons. Elevated salivary anticoagulant activity and hemeprotein content in *C. lectularius* indicate that differences in salivary composition may contribute to interspecific variation in blood-feeding performance (Araujo *et al*., 2009) [27].

Host-seeking behavior in *C. lectularius* is regulated by the interaction between mating status and nutritional condition, rather than solely by the presence of host-associated chemical cues. Mated females are more responsive to human skin odors than unmated females. These behavioral differences likely reflect variation in nutritional requirements associated with egg maturation and oviposition, as mated females require repeated blood meals to sustain reproductive activity (Saveer *et al*., 2021) [29].

After successful feeding, bed bugs typically return to sheltered locations. In contrast, individuals unable to obtain a blood meal continue searching for a host (Reis and Miller, 2011) [30].

7. Socioeconomic Impacts

Bed bug infestations impose substantial socioeconomic burdens on households, commercial establishments, and the hospitality industry. The prevalence of bed bugs is significantly associated with neighborhood-level median household income, residential overcrowding, and eviction rates. Among these factors, household income is the strongest predictor, with infestations occurring more frequently in lower-income neighborhoods (Sutherland, Greenlee and Schneider, 2020) [31]. Limited financial resources restrict access to effective pest control, while residential displacement facilitates the introduction of bed bugs into previously uninfested dwellings through the movement of infested belongings. Therefore, bed bug infestations constitute not only a household pest management problem but also a socioeconomic and public health concern, with disadvantaged communities experiencing a disproportionate burden of infestation, associated control costs, and broader impacts (Sutherland, Greenlee and Schneider, 2020) [31].

Sixty percent of leisure travelers and 51% of business travelers reported being very unlikely to select a hotel after encountering a single recent online report of bed bugs. Additionally, approximately 60% of respondents indicated they would leave the hotel and request a refund if they discovered signs of bed bugs in their room. Forty-seven percent of travelers would report and share their experience on social media after finding a live bed bug, indicating that infestation-related complaints can extend beyond the affected property through online communication (Potter, Penn and Hu, 2017) [32].

Reports of bed bug infestations negatively influence hotel selection and reduce consumers' willingness to pay for accommodation. The magnitude of this effect depends on the explicitness of bed bug mentions in hotel reviews and the level of concern expressed by travelers, demonstrating that infestation reports can affect the perceived value of hotel services (Penn and Hu, 2020) [33]. A substantial proportion of surveyed travelers express a willingness to pay for proactive bed bug prevention, with the greatest value placed on protective mattress encasements and professional pest inspections (Penn and Hu, 2021) [34].

8. Medical Importance

8.1 Dermatological and Allergic Reactions

During blood feeding, the salivary nitrophorin of *C. lectularius* facilitates the delivery of NO to host tissues, thereby promoting local vasodilation. It may also contribute to IgE-mediated allergic hypersensitivity and severe cutaneous reactions following bed bug bites. However, this mechanism was demonstrated in an individual clinical case and should not be generalized to all bite-associated skin reactions (Leverkus *et al*., 2006) [28].

In addition to allergen-specific responses, bed bug saliva may stimulate inflammatory pathways that contribute to cutaneous lesions. In an experimental macrophage model, bed bug salivary gland extracts induced several chemokines and cytokines, including interleukin-8 (IL-8), which is associated with neutrophil recruitment; eotaxin, which promotes eosinophil recruitment; and granulocyte colony-stimulating factor (G-CSF), which contributes to neutrophil production and survival. The study also identified IL-7, IL-10, and IL-12 responses, indicating that salivary components may influence multiple aspects of immune regulation (Goddard *et al*., 2013) [35].

Bed bug bites may produce a wide range of cutaneous manifestations, including erythematous papules, pruritic wheals, urticaria, and, in more severe cases, vesicular or bullous eruptions. However, clinical responses vary considerably among individuals. These differences are associated with individual sensitivity to salivary components introduced during feeding, while delayed hypersensitivity responses may contribute to skin lesions appearing several days after exposure (Goddard and DeShazo, 2009; Doggett *et al*., 2012) [36,37].

Persistent pruritus and repeated scratching may further damage the skin and increase susceptibility to secondary bacterial infections. Although systemic allergic reactions have also been reported, they appear to be considerably less common than localized cutaneous manifestations. Consequently, the dermatological importance of bed bugs extends beyond transient irritation to inflammatory skin reactions, potential secondary complications, and difficulties in clinical diagnosis, particularly because bite-associated

lesions are not specific to *Cimex* infestations (Goddard and DeShazo, 2009; Doggett *et al*., 2012) [36,37].

8.2 Psychological and Sleep-Related Impacts

Individuals living in infested environments may experience anxiety, persistent worry, sleep disruption, and a reduced sense of security within the home, linked to heightened vigilance arising from the possibility of repeated nocturnal bites (Doggett *et al*., 2012; Ashcroft *et al*., 2015) [37,38].

8.3 Potential Role in Pathogen Transmission

Although bed bugs are obligate hematophagous ectoparasites, their role in the transmission of human infectious diseases remains uncertain (Goddard and DeShazo, 2009; Doggett *et al*., 2012) [36,37]. Experimental evidence has nevertheless raised questions regarding their potential vector competence. *C. lectularius* can act as a vector of *Trypanosoma cruzi*, the causative agent of Chagas disease, after feeding on infected mice under controlled laboratory conditions. However, experimental transmission does not establish the occurrence or epidemiological significance of natural transmission to humans. Thus, the potential involvement of bed bugs in pathogen transmission warrants further investigation (Doggett *et al*., 2012; Salazar *et al*., 2015) [37,39].

Previous experimental studies have suggested that *C. lectularius* may be capable of acquiring and potentially transferring certain bacterial pathogens, although its epidemiological significance as a natural disease vector remains *unconfirmed. C. lectularius can act as a vector for Bartonella quintana, the causative agent of trench fever*. The bacterium was detected in both adult and nymphal bed bugs, with bacterial DNA remaining detectable in their feces. However, transmission to susceptible hosts under natural conditions was not confirmed, and the role of bed bugs in the natural epidemiology of *B. quintana* remains uncertain (Leulmi *et al*., 2015) [40].

More recently, acquired methicillin-resistant *Staphylococcus aureus* (MRSA) was found both externally on the cuticle and internally after feeding through experimentally contaminated membranes. Viable MRSA persisted for up to 7 days in some bed bugs, with evidence of bacterial proliferation. Furthermore, MRSA was transferred to previously uncontaminated feeding membranes in two of three experimental trials, suggesting a potential role in mechanical bacterial transmission, although natural transmission to humans remains unconfirmed (Herrera, Chaussee and Pietri, 2024) [41].

Conclusion

Bed bugs of the genus *Cimex*, particularly *C. lectularius* and *C. hemipterus*, are significant household ectoparasites due to their biological adaptations and close association with humans. Their widespread distribution, distinct morphological features, reproductive strategies, reliance on blood meals, and adaptive responses to environmental conditions facilitate their persistence in human environments. Bed bug infestations result in substantial socioeconomic impacts, including increased control expenditures, decreased accommodation desirability, and reduced consumer confidence. Medically, bed bugs are primarily associated with dermatological and allergic reactions, psychological distress, and sleep disturbances. Although experimental studies have demonstrated bed bugs' capacity to acquire and transmit pathogens, there is insufficient evidence to support the natural transmission of infectious diseases to humans. Consequently, effective management of bed bugs requires an integrated strategy that includes precise species identification, systematic surveillance, prompt detection of infestations, and appropriate control measures. Ongoing research is essential to elucidate their epidemiological role and to develop sustainable management approaches that better support long-term prevention and control.

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