Man and insects – altruism and above

*Nivetha Ramanathan and Janarthanan Sundaram**

We are constantly amazed by various aesthetic and utilitarian services rendered by the members of class Insecta. Not just services, but they also enlighten us with fundamental philosophies of life. As an illustration, the metamorphosis of caterpillars to stunning butterflies whispers into our ears the significance of transformation and hope, ants moving in rows underpins the relevance of teamwork. They also form an integral component of the food web and act as scavengers. An attempt has been made to showcase the grandeurs of insects. Above all, the greatest challenge to us is conserving them as the very existence of insects is obligatory, for humankind will disappear without them!

Keywords: Insects, mankind, scavengers, value-added products.

INSECTS, the 'architects of biological foundation' in the terrestrial ecosystem, have evolved as the most successful group of animals dominating every conceivable habitat on earth. These most species-rich groups of organisms constantly astound us with the sempiternal and mystical services they bestow on nature's economy. As beneficial creatures, they are the food for many animals. As predators and parasitoids, they are the natural solution for controlling the pest population. As pollinators, they pollinate about 80% of flowering plants globally. As scavengers, they play a critical role in eliminating the dead and decayed matters from the environment. As healing agents, insects and their products cure several diseases. In addition, they render us countless value-added products that benefit humankind (Figure 1).

Apart from the aforementioned services, the magnificence of the insect world is transcendent. Picasso bug, graced with spectacular and vibrant patterns, exhibits its exquisite beauty by blowing its own trumpet on one side, and on the flip side are some bugs like *Umbonia crassicornis* that blend brilliantly with the environment. Another exemplary illustration of insect transcend that intrigues humankind is the altruistic behaviour of the hymenopteran insect force grounded in the fundamentals of eusociality. To add to these, the transformation of a monochromatic caterpillar into a vibrantly coloured butterfly that adorns the landscape symbolizes optimism and change. Characterized by exceptional fecundity potential, invincible abundance, confrontational behaviour and propensity to thrive on any food, these six-footed species continue to dominate this blue planet demonstrating themselves as the most species-rich and dominant group of organisms.

The tie-up Entomophily

With the land plants started to grow taller, insects evolved flight spreading their wings to take up the skies around 400–175 million years ago, establishing the foundation for the most celebrated mutualistic interaction, entomophily[1]. In the era of dinosaurs, by pollinating the first flowers, beetles started their invaluable service of pollination that underpins the fact that this ecosystem amenity is not a brand new business[2]. During evolutionary processes, plants have stockpiled adaptations that allure the protagonists of the entomophily anecdote, including the beetles, flies, bees, wasps and ants enchanting them with their floral scents and properly rewarding them with nectar and pollen. By moving from blossom to blossom carrying the pollen, this ecosystem service crucial for 80% of the crop plants is beyond the price and is contemplated to be a pivotal link in the ecosystem's operation. Adorned with audacious patterns and bright colours, the entomophilous flowers embrace their pollinators, who inadvertently cross-pollinate, resulting in genetic diversity that reinforces their capacity to evolve and adapt (Table 1). An enthralling illustration that can blow one's mind is the intimate relationship between the Yucca plant, *Yucca glauca* and its exclusive pollinator, the Yucca moth, *Tegeticulla yuccasella* where both cannot survive without each other.

According to the United States Department of Agriculture (USDA) (May, 2022), about 75% of flowering plants and 35% of world's food crops rely upon bees. A bee-pollinated product is thought to make up one in every three food items we consume. Crops like almonds that are rich in nutrients depend entirely on honey bee pollination. In India, the production of rapeseed and mustard depends mostly upon bee pollination. Without honey bees, there can be a catastrophic decline in the harvest of watermelons, berries and other fruits. Apart from bees, there are other non-bee insect pollinators like wasps, ants, mosquitoes and beetles.

The authors are in the Department of Zoology, University of Madras, Guindy Campus, Chennai 600 025, India.
*For correspondence. (e-mail: janas_09@yahoo.co.in)

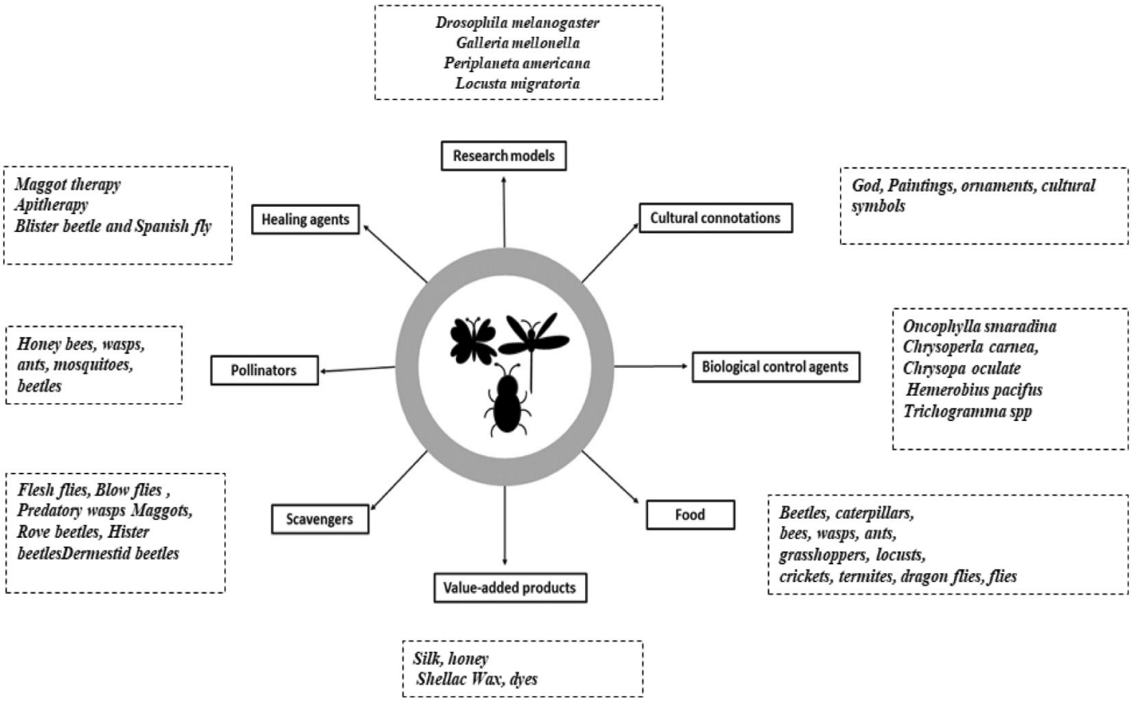

Figure 1. Schematic representation showing myriad services provided by insects.

Table 1. Most common pollinating mechanism (entomophily) exhibited by some specialized insect groups

Mechanism of insect pollination	Insect group	Pollination guides
Melittophily	Bees (Hymenoptera)	Flowers: showy, colourful – prefer yellow and blue, ultraviolet light, fragrant; nectar and pollen as guides
Cantharophily	Beetles (Coleoptera)	Sexual organs of flowers: fruity and foul odours
Psychophily	Butterflies (Lepidoptera)	Flowers: showy, colourful – prefer red and orange, fragrant usually with no nectar guides
Phalaenophily	Moths (Lepidoptera)	Flowers: large, night-blooming, white and pale colours, fragrant with no nectar guides
Sapromyiophily	Flies (Diptera)	Flowers: often maroon or brown, emit dung or rotten odour

The tiny chocolate midges are entitled as the 'only pollinator' that serves the cocoa plant.

Let's have a glance at the economics of pollination. It is roughly estimated that an adult bee visits about 50,000 Southeastern blueberry flowers accounting for over 6000 marketable blueberries[3]. Further, according to the assessment report on pollinators released by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Germany, in 2017, the annual market value of crop production was estimated as US$ 235–577 billion. It is projected that honey bees alone contribute about US$ 18 billion in revenue to crop production annually. The worth of pollination services is approximated as US$ 3 trillion globally (USDA, 2022). The pollinators work round-the-clock, and humans often overlook their irreplaceable service by indulging in pursuits that make the survival of one of the greatest contributors to the economy difficult. Loss of habitat, invasion of non-native species and use of insecticides are some activities that can diminish the delight we experience with each bite of an insect-pollinated product.

An appetizing platter – Entomophagy

With the population escalating at lightning speed, insects are in the spotlight to satisfy hunger and meet the community's nutritional requirements. They are not only at the helm of gracing our plates with berries and veggies, but also, they are perfect delicacies. About 1611 species of insects packed with rich proteins, omega-3 fatty acids, calcium, vitamins and minerals are eaten as delicacies globally in tropical and subtropical countries[4] (Figure 2). The steamed silkworms, deep-fried crickets, buttery wasps and peppered termites are finding their places on the menus as startling attractions of street food in Asian countries.

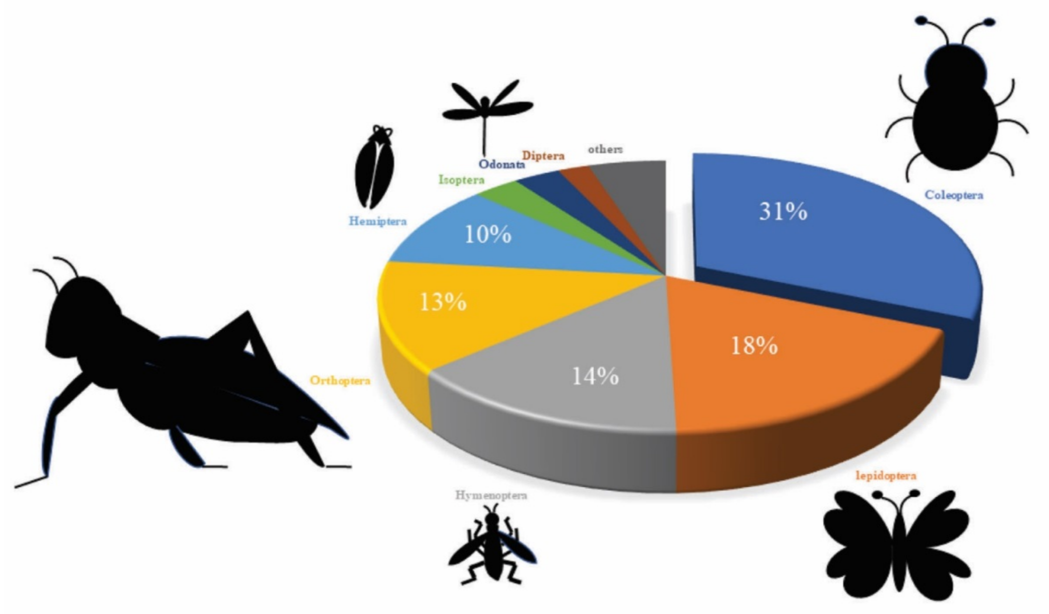

Figure 2. Distribution of edible insects in different orders.

Beyond a shadow of a doubt, the gaining popularity of insects as food is due to their nutritional value. Based on dry weight, it is approximated that 40–75% make up the proportion of crude protein. The percentage of crude protein in different insect orders, including Blattodea, Coleoptera, Diptera, Hemiptera, Hymenoptera, Isoptera, Lepidoptera and Orthoptera is about 68.33, 41.75, 48.80, 48.83, 51.43, 33.00, 65.25 and 59.17 respectively. Nevertheless, it is also found that insects meet the World Health Organization's (WHO's) recommendation for amino acids with sufficient arginine, leucine, isoleucine, threonine, phenylalanine, valine and histidine[6]. The percentage of essential amino acids are found to be 5.18, 4.28, 4.16, 4.14, 4.42, 4.37, 4.50 and 3.95 in Blattodea, Coleoptera, Diptera, Hemiptera, Hymenoptera, Isoptera, Lepidoptera and Orthoptera respectively[5,6]. Saturated fatty acids (myristic acid, palmitic acid and stearic acid), monounsaturated fatty acids (palmitoleic acid and oleic acid) and polyunsaturated fatty acids (linoleic and α-linoleic acids) are also found to be prevalent in them[5,7]. Interestingly, these fatty acids are the greatest resources and possess the excellent potential to cure a wide spectrum of medical conditions[8,9]. Insects are also contemplated to be opulent sources of vitamins and minerals[10]. The Hymenopteran, *Apis mellifera* Linnaeus, possess about 1500 mg of potassium per 100 g (ref. 4). So next time, when you see a bug on your plate, do not panic; it is the richest delicacy with high nutritional values you could ever have!

According to the United Nations, the world population is increasing each year at an exponential rate. It is projected to reach 9.7 billion by 2050 (ref. 11). So, the search for an alternative food source to ensure food security is the need of the hour. The search ends with insects as an astounding protein source. Another important reason for the popularity of insects as food is that insect farming is green, i.e. sustainable and ecologically sound[12]. Other advantages of insect farming include no greenhouse emissions, high feed conversion efficiencies, use of insects as animal feed as well as aqua feed, and so on[12]. Consequently, insects are excellent, sustainable and resourceful candidates as both food and feed[12].

All the vegans and vegetarians out there, a word of caution, you may already be eating insects. Approximately 50–60 aphids, thrips or mites are present in frozen broccoli and frozen brussels sprouts. About 150 insect fragments are already found in wheat flour[13].

The slayer – biological control and beyond

Pest species are taking pains to munch and crunch the world's nutritional sources resulting in worse scenarios of reduced productivity and complete crop loss[14]. This marks the necessity to find an environmentally sound pest control method. One such strategy devised is biological pest control, which employs natural enemies to mitigate pests to save the world's nutritional resources. The history of biological control dates back to 200 AD. Nests of predaceous ants, *Oncophylla smaradina* Fabricius, were placed in trees by Chinese citrus growers where they fed on foliage-feeding insects in 304 AD (ref. 15). Apart from keeping the nests, bamboo bridges that could aid the predaceous ants to move from one tree to another were also built. The protagonists of the biological control strategy include the predators and the parasitoids. The former capture and eat other insects; on the other hand, the latter paralyse insects by developing within them and eventually killing them. For instance, ladybird beetles are known to attack mites, aphids, mealybugs,

Table 2. Nobel prizes for insects as magnificent research model organisms

Year of Award	Name of the scientist	Insect model and nature of work
1902	Ronald Ross	Anopheles mosquitoes: role of insects as vectors in the infectious cycle (malaria)
1933	Thomas Hunt Morgan	*Drosophila*: uncovered the role played by chromosomes in heredity
1946	Hermann Joseph Muller	*Drosophila*: X-ray irradiation to increase mutation rates in fruit flies
1948	Paul Hermann Müller	Colorado potato beetle, *Leptinotarsa decemlineata*: discovering the potent toxic effects of dichloro-diphenyl-trichloroethane (DDT)
1995	Edward B. Lewis, Christiane Nüsslein-Volhard and Eric F. Wieschaus	*Drosophila*: understanding genetic control of embryonic development
2004	Richard Axel	*Drosophila*: odour receptors and the organization of the olfactory system
2011	Jules A. Hoffmann	*Drosophila*: research on the activation of innate immunity
2017	Jeffrey C. Hall, Michael Rosbash and Michael W. Young	*Drosophila:* uncovering the molecular mechanisms that control circadian rhythms

whiteflies and other soft-bodied insects. Other examples of predators are species of lacewings, including *Chrysoperla carnea* Stephens, *Chrysopa oculata* Say and *Hemerobius pacifus* Banks[16]. Praying mantis also functions as a member of the biological pest control force by dining on mosquitos, crickets, grasshoppers and other insects in disguise.

About 70,000 species of parasitoids, mainly wasps and flies, attack all the stages of arthropods. With more or less 650 species, *Trichogramma* spp. is paramount in managing the population of many lepidopteran pests[17,18]. Other examples of parasitoids include *Cotesia flavipes*, *Anagyrus kamali*, *Encarsia perplexa*, *Tamarixia radiata*, *Acerophagus papaya* and *Galeopsomyia fausta*[19].

Researchers' stroke of luck – insects as models

Insects are idiosyncratic and magnificent models at a researcher's desk. *Drosophila* is one of the illustrious success stories and a proven model in a wide array of disciplines with more than a hundred-year history in genetics research. About 60% genome is homologous to humans, and 75% of the genes that are the root cause of human diseases have counterparts. Easy rearing, short-life cycle, high fecundity and availability of genome information are other reasons to include in the list. About six Nobel prizes in Physiology and Medicine have been awarded to scientists for their ground-breaking research based on *Drosophila* (Table 2).

Some other insects are also gaining traction as excellent model organisms in biological research, viz. *Galleria mellonella*, *Periplaneta americana*, *Locusta migratoria* and *Bombyx mori*[20–23]. Coleopterans are extrapolated as outstanding biomedical research models that include studies that untangle the mechanism of life processes comprising feeding, control and coordination and various other disease conditions[24]. In addition, they are used in environmental studies to unravel the toxicity associated with various pesticides and insecticides, and also investigated in behavioural studies, especially to decipher insights on parental care[24]. Different constituents of silkworms also find purpose in research like haemolymph (in the maintenance of cell cultures, as a defence against microbial infection and also in anti-apoptosis), sericin (cosmetic and pharmaceutical industries), chlorophyll derivative from excreta (photodynamic therapy of tumours as photosensitizer)[23]. *P. americana* is considered a utilitarian model in neurobiological and electrophysiological studies[20]. Another insect that has grown as a promising model is *G. mellonella*, finding applications in pathogen assays owing to their short life cycle, rapid growth and high fecundity[21]. Insects propound several advantages over mammalian models, including lack of ethical issues, ease of handling, being economical and so on.

Army of death eaters – the scavengers

Death eaters in the insect community are groups associated with cadavers predominantly belonging to the orders Coleoptera and Diptera. The former order includes carrion beetles, dermestids and scarab beetles; the latter includes blow flies, flesh flies, house flies and cheese skippers. Endowed with a secondary consumer position in the food web, they are crucial elements that are obligatory to eliminate the dead and decayed organic matters from the environment and hold a crucial position in securely fastening the links in the food web. These insects get rid of dead and decayed materials and mitigate the spread of several diseases. Moreover, researchers are integrating termite-based bioreactors with lignocellulose biorefineries to make them zero waste. Do these insects have any pivotal role in human decomposition? There are four stages of human decomposition: fresh, bloated, decay and post-decay. In all the above stages, insects are engaged as members of the natural cleansing system. The insects, viz. flesh flies, blow flies and predatory wasps, are pioneers who act in the fresh stage. The other insects involved in different stages of decomposition are ants, several species of flies, maggots, predatory beetles like rove beetles, hister beetles and dermestid beetles.

Blow flies and flesh flies, so-called crime scene insects, are explored in forensics to determine the time of death due to their close association with the cadavers. The first recorded incidence of crime investigation with the aid of insects dates back to 13th century China as illustrated in the book

The Washing Away of Wrongs by Sung Tzu, where a murderer of a farmer was identified by asking the sickles of suspects to be placed in the ground[25]. The sickle that belonged to the suspect, which attracted blowflies to the blood which was invisible to the naked eye, was identified as the murderer[26]. Let's not call them filthy anymore. The role of the death eaters proceeds as long as life exists on earth!

The art of healing – entomotherapy

Good health and effective medical care are required to maintain society's robustness. The legacy of using insects for medical applications is perhaps long and relatively well documented. They have long been an integral component of folklore medicine across many parts of the world. For instance, there are multiple mentions of therapeutics made from insects in the Ebers papyrus, an Egyptian medical book from the sixteenth-century BC (ref. 27). The use of honey to cure several dermatological disorders, the use of cantharidin from blister beetle bodies to treat warts, the use of cockroach and earwigs to cure aches are some of the several mystical services that these six-footed species furnish that make us spellbound[28]. Digging deep into the discussion is maggot therapy, the potential remedial treatment for the care of necrotic wounds in the world to come[29]. Technically known as maggot debridement therapy (MDT), it is contemplated to heal wounds and speed up healing. From the historical point of view, the therapy gained popularity when an American doctor noticed that soldiers with maggot infestation in their wounds recovered better than those without them after World War I. With more than 300 centres in the US and 1000 centres in UK and Europe, maggot therapy is capturing the attention of millions across the globe[30].

A mystical product from the members of the order Hymenoptera is honey. As depicted by the stone age paintings, ancient Egyptians, Chinese, Romans, Greeks and Assyrians have used honey for almost 8000 years to cure various ailments. From the perspective of the Indian scenario, honey is considered a boon to man with unprecedented applications in the Indian medical system of Ayurveda. Various studies have demonstrated its anti-microbial, wound healing, anti-viral and anti-inflammatory properties. Besides these, it is used in wound dressing and gastrointestinal, cardiovascular, inflammatory and neoplastic states[31]. Endowed with more than 200 substances, honey is the sweetest medicine we could ever have. The second product is the royal jelly. These secretions from the bee's hypopharyngeal glands can increase vigour, appetite, physical strength, rejuvenate the aged and strengthen memory.

In India, ants, especially the soldier ants, were used to close wounds about 3000 years ago[31]. Other examples of insects used to cure ailments include blister beetle, whose blistering agent cantharidin is used in treating infections including urogenital and kidney. Under the generic name *Pulvis tarakanae*, powdered cockroaches are sold in Europe that can work in opposition to pleurisy and pericarditis[32]. Another example of the use of insect products is venom, first experimentally licensed by the U.S. Food and Drug Administration (FDA) in 1976, which is a perfectly engineered chemical from the bees that can be used to treat arthritis, bursitis and rheumatism. Additionally, biomolecules from insect sources that could induce mitotic activities in human peripheral blood lymphocytes (T and B cells) are also uncovered recently. Apart from their purposes in the assessment of immunocompetence, they also find applications in immunostimulant and immunosuppressive treatments[33]. We need to probe deeper regarding entomotherapy, for our future of healing lies in this class of arthropods.

From the production houses of class Insecta – Value-added products

You cannot resist admiring an Indian bride adorned with rich and vivid hues of six yards of pure elegance, beauty and a smile. We are talking about 'silk', the queen of fabrics gifted by an altruistic lepidopteran that sacrifices itself for the aesthetic beauty of humankind and is a symbol of panache. With about 10 nanometres in diameter, silk is the strongest fibre known for its durable and resilient qualities. About 4000–6000 cocoons can produce 1 kg of raw silk. The tensile strength is comparable to steel and is used to construct tyres and parachutes. Another important product from the insect factories includes the shellac, produced by the lac insect, *Laccifer lacca* Kerr. This resinous exudate finds uses in many industries, including inks, floor polish, wood coatings, electrical insulators, leather dressings, etc. The dyes from cochineal bugs are used in the food industry as food colouring agents and to dye cosmetics, textiles and drugs.

Honey, the elixir from the hymenopteran insect force, apart from its aforementioned applications in the field of medicine, has a wide array of other uses. Their wax is used to manufacture candles, polish and other cosmetic products. Enriched with antioxidants that can protect the skin from free-radical damage, honey is known to reduce wrinkles and is an excellent anti-ageing agent that makes skin glow. Aside from this, bee pollen contains several nutrients, including proteins, vitamins, minerals, beta-carotene and so on.

Insects as cultural connotation

Let us add some salt to our discussion by adding the cultural relevance of insects. Insects have long been a part of cultural myths. For instance, American tribes believe that water beetles have bought mud off the surface of the water and have a significant role in the creation of the universe. References to seven different insects, including lice, leafcutter ants, mosquitoes, fireflies, bees, yellowjackets and wasps, are found in the Mayan topic of the dawn of life, the *Popul Vuh*. Aquatic insects were associated with rain and considered water symbols. Another interesting instance is that of the scarab of ancient Egypt. As a symbol of Sun God Khepera, they were considered responsible for moving Sun, similar to how the beetle moved the dung.

Insects are magnificently illustrated in art and literature. Beginning with an inscription of cave-dwelling rhaphidophorid cave cricket on a biston bone by Cro-Magnon people, the drawings of insects can be traced back to 20,000 years ago. Since then, they have become an inevitable part of the walls of temples, caves and textiles. Jewellery made out of insects like flies, beetles, viz. ironclad beetles and buprestid beetles, butterflies and bees are fascinating. Insects find relevance in Indian cultural scenarios as well. Goddess Brahmari, an incarnation of Goddess Durga, is known as the Goddess of Bees. And the black ants are treated as divine messengers of Lord Ganesh and are considered auspicious when they enter Indian homes. The termite mounds are considered a significant symbol in Hindu mythology of worship.

Conclusion

There is so much to learn from insects. Insects are so crucial that they should be mainstreamed into biodiversity conservation strategies as soon as possible. About 70% of the decline in pollinators was observed due to air pollution that makes it harder for them to find flowers. Creating insect-friendly habitats that include the growth of native plants, and a reduction in the use of harmful chemicals and artificial night lights that pollute the insect environment are critical to conservation strategies. Making local people aware of the necessity of insect diversity will make us one step closer. With climatic change being one of the driving factors for insect population decline, it all begins with us as an individual reducing one's carbon footprint. Let us keep them in a sound state, as the earth will fall to pieces, and the product of 9.5 billion years of evolution, humankind, will vanish without the traces of foot marks of these six-footed creatures.

1. Grimaldi, D. *et al*., *Evolution of the Insects*, Cambridge University Press, Cambridge, 2005.
2. https://www.sci.news/paleontology/article00314.html
3. Cane, J. H., Lifetime monetary value of individual pollinators: the bee *Habropoda laboriosa* at rabbit eye blueberry (*Vaccinium ashei* Reade). *Acta Hortic*., 1997, **446**, 67–70.
4. Van Itterbeeck, J. and Pelozuelo, L., How many edible insect species are there? A not so simple question. *Diversity*, 2022, **14**, 143.
5. Castro-López, C. *et al*., An insight to fermented edible insects: a global perspective and prospective. *Food Res. Int*., 2020, **137**, 109750.
6. Rumpold, B. A. and Schlüter, O., Insect-based protein sources and their potential for human consumption: nutritional composition and processing. *Anim. Front*., 2015, **5**, 20–24.
7. Mahajan, S. S. *et al*., Nutritional aspects of entomophagy as future food for livelihoods. *IJAAS*, 2022, **7**, 18–24.
8. Sales-Campos, H. *et al*., An overview of the modulatory effects of oleic acid in health and disease. *Mini Rev. Med. Chem*., 2013, **13**, 201–210.
9. Tang, C. *et al*., Edible insects as a food source: a review. *FPPN*, 2019, **1**, 1–13.
10. Kouřimská, L. and Adámková, A., Nutritional and sensory quality of edible insects. *NFS J.*, 2016, **4**, 22–26.
11. Laurance, W. F. and Engert, J., Sprawling cities are rapidly encroaching on Earth's biodiversity. *PNAS*, 2022, **119**, e2202244119.
12. Van Huis, A. and Oonincx, D. G. A. B., The environmental sustainability of insects as food and feed. A review. *Agron. Sustain. Dev*., 2017, **37**, 43.
13. www.cfsan.fda.gov/~dms/dalbook.html
14. Sharma, S. *et al*., Insect pests and crop losses. In *Breeding Insect Resistant Crops for Sustainable Agriculture*, Springer, Singapore, 2017, pp. 45–66.
15. Thurman, J. H. *et al*., Weaver ants provide ecosystem services to tropical tree crops. *Front. Ecol. Evol.*, 2019, **7**, 120.
16. Miller, G. L. *et al*., Lacewings and scale insects: a review of predator/prey associations between the Neuropterida and Coccoidea (Insecta: Neuroptera, Raphidioptera, Hemiptera). *Ann. Entomol. Soc. Am*., 2004, **97**, 1103–1125.
17. Kalyanasundaram, M. and Kamala, I. M., Parasitoids. In *Eco Friendly Pest Management for Food Security* (ed. Omkar), Elsevier, USA, 2016, pp. 109–138.
18. https://ipm.ucanr.edu/natural-enemies/trichogramma-parasitoids/
19. Colmenarez, Y. *et al*., Use of parasitoids as a biocontrol agent in the neotropical region: challenges and potential. In *Horticultural Crops*, Intech Open, London, 2018, pp. 171–185.
20. Stankiewicz, M. *et al*., Nervous system of *Periplaneta americana* cockroach as a model in toxinological studies: a short historical and actual view. *J. Toxicol*., 2012, **2012**, 143740.
21. Mikulak, E. *et al*., *Galleria mellonella* L. as model organism used in biomedical and other studies. *Przegl. Epidemiol*., 2018, **72**, 57–73.
22. Wang, X. *et al*., The locust genome provides insight into swarm formation and long-distance flight. *Nat. Commun*., 2014, **5**, 2957.
23. Panthee, S. *et al*., Advantages of the silkworm as an animal model for developing novel antimicrobial agents. *Front. Microbiol*., 2017, **8**, 373.
24. Adamski, Z. *et al*., Beetles as model organisms in physiological, biomedical and environmental studies – a review. *Front Physiol*., 2019, **10**, 319.
25. McKnight, B. E., *The Washing Away of Wrongs: Forensic Medicine in Thirteenth-Century China*, University of Michigan, Ann Arbor, 1981, p. 181.
26. Catts, E. P. and Goff, M. L., Forensic entomology in criminal investigations. *Annu. Rev. Entomol*., 1992, **37**, 253–272.
27. Weiss, H. B., Entomological medicaments of the past. *J. N. Y. Entomol. Soc.*, 1947, **55**, 155–168.
28. Costa-Neto, E. M., Entomotherapy or the medicinal use of insects. *J. Ethnobiol*., 2005, **25**, 93–114.
29. Mohd Zubir, M. Z. *et al*., Maggot therapy in wound healing: a systematic review. *Int. J. Environ. Res. Public Health*, 2020, **17**, 6103.
30. Eteraf-Oskouei, T. and Najafi, M., Traditional and modern uses of natural honey in human diseases: a review. *Iran J. Basic Med. Sci*., 2013, **16**, 731–742.
31. Gudger, E. W., Stitching wounds with the mandibles of ants and beetles. A minor contribution to the history of surgery. *JAMA*, 1925, **84**, 1861–1864.
32. https://earthlife.net/insects/ancient-entomotherapy
33. Bhuvaragavan, S. *et al*., Insect galectin stimulates the human CD4+ T cell proliferation by regulating inflammation (T cell and monocyte) through Th2 immune response. *Process Biochem*., 2023, **125**, 15–35.

Received 7 January 2023; revised accepted 21 April 2023

doi: 10.18520/cs/v125/i3/241-246