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Insect Sound and Communication

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Insects were the first land animals to communicate through sound waves over 100 million years ago, playing a crucial role in animal evolution. Insects can make sounds in five principal ways: stridulation, vibration, percussion, click mechanisms, and air expulsion. Insect sounds have been documented since ancient Greek philosophers, but only in the last 50-60 years have they become a subject of rigorous scientific study. Insect hearing likely originated as a means for detecting and avoiding predators, while sound signaling in insects may have originated through coevolution between female perception and male signaling. Terrestrial animals, particularly vertebrates and insects, have a sense of hearing, which helps them detect air pressure changes and communicate with mates. The human ear is sensitive to vibrations with frequencies between 30 Hz and 15 kHz, but many animals, including insects, have acoustic sensitivity above human ear, making ultrasound crucial for their survival.

Insects use specialized organs for remote sensing, including eyes, auditory and olfactory organs, and internal proprioceptors. Hearing is relatively uncommon among most insect species, but it is essential for conspecific interactions. Acoustic signals are generated by vibrations of sound-producing structures and require detection by mechanoreceptive organs. Substrate signals can be propagated through the substrate and air, but are part of a general class of signals. Those insects sensitive to substrate signals are no longer a small minority.

Bioacoustics as a scientific discipline was established by the Slovene biologist Ivan Regen who began systematically to study insect sounds. In 1925 he used a special stridulatory device to play in a duet with an insect. Later, he put a male cricket behind a microphone and female crickets in front of a loudspeaker. The females were not moving towards the male but towards the loudspeaker. Regen's most important contribution to the field apart from realization that insects also detect airborne sounds was the discovery of tympanal organ's function. Humans can hear the sound within the range of 20-20,000 Hz. Some insects can produce ultrasonic sounds, not hearable for humans E.g. Some grasshoppers and moths produce sounds of 80,000 Hz. These high-pitch sounds are studied by an electronic device called "Audio transducer". It converts inaudible high frequency sounds into audible low frequency sounds.

Mechanisms of insect sound production

Many authors have attempted to classify sound producing mechanisms in insects. The most useful is probably the entirely mechanistic one of Ewing (1989), who recognised five categories of sound producing mechanisms:

1. Vibration
2. Percussion
3. Stridulation
4. Click mechanisms
5. Air expulsion

Vibration – Including Tremulation

Animal sounds, including tremulation, are produced by vibrations of unspecialized parts of the insect body, such as the abdomen. These sounds are transmitted through legs to the insect's substrate, with lacewing flies being well-known. Wing vibrations, especially in swarming mosquitoes, are used for communication and species recognition. In courtship dances of Drosophila species, pulsed songs stimulate antennal receptors, allowing the insects to communicate.

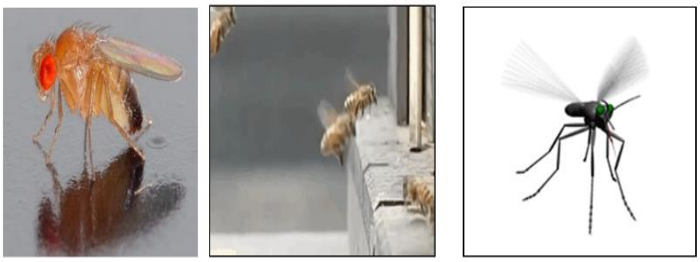

Fig 1: Vibration sound production in Drosophila, Honey bee and Mosquito

Percussion: Tremulation is a separate mechanism in insects, not involving percussion of the substrate or other body parts. It can develop as a communication system, as seen in Australian moths and cicadas. Insects like termites and stoneflies use percussion of the substrate. Meconema, a bushcricket species, produces patterned signals without stridulatory mechanisms.

Fig 2: Percussion sound in death watch beetle, plecopteran, termites

Stridulation: Stridulation, a term used to describe sound production in insects, is primarily confined to frictional mechanisms involving the movement of two specialized body parts against each other. This system has been described in at least seven insect orders, with most evolving separately. Orthoptera sensu lato groups have well-documented stridulatory mechanisms.

Fig 3: Stridulation mechanism in crickets, longhorned beetle and grasshopper

Click Mechanisms: Tymbals, a type of insectic signal, are produced by deformation of a modified cuticle area, often through contraction and relaxation of special muscles. These signals can be amplified in various ways, with the basics of this mechanism known to ancient Greek philosophers.

Air Expulsion: Insects have unique exhalatory sounds, often expelled via tracheal spiracles. The Death's Head Hawk, European hawkmoth, produces a distinctive piping sound, similar to African Sphingid moths.

Fig 4: Air explusion mechanism in Sphingid moth

Defense sound

Defense sounds, acoustic signals produced by insects in response to predator or parasite attacks, are crucial for survival. They are found in 12 insect orders and vary between species. The sounds can be directed at predators or non-predators and have potential functions like startle, aposematism, jamming, and alarm. The evolutionary origins of these sounds are not well understood, but they are believed to have evolved from incidental sounds associated with non-signaling behaviors. Future research should focus on testing these hypotheses.

Fig 5: Defence sound production in grasshoppers, kattydids and cicada

Aposomatic sound

Aposematism is the honest advertisement of dangerous or unpleasant attributes, such as distastefulness, toxicity, and stinging spines. Experienced predators associate the signal with the unpleasant attribute and reject prey based on the signal alone. Red is a common aposematic color that causes naïve predators to hesitate and facilitates learning. A. polyphemus caterpillars produce clicking sounds after simulated attacks, while Saturnia pyri produce short chirping sounds. Visual aposematic signals are simple, symmetrically patterned, and conspicuous, similar to warning coloration.

Fig 6: Aposomatic sound production in *Cisthene martini*

Why insect sound

- Mainly insect needs sound for communication.
- Recognition of kin or nest-mates
- Locating or identifying a member of the opposite sex
- Facilitation of courtship and mating
- Giving directions for location of food or other resources
- Establishing and maintaining a territory
- Warning of danger; setting off an alarm
- Advertising one's presence or location
- Expressing threat or submission
- Deception / mimicry

Insect vibration communication

Vibrational communication is a prevalent form of communication in insect social and ecological interactions, with 92% of insect species using substrate vibrations alone or with other mechanical signaling. This communication differs significantly from airborne insect sounds, often having low frequencies and pure tones. Plants are the most widely used substrate for transmitting vibrational signals, and host plant use may influence signal divergence. Vibration-sensitive species, including insects and spiders, can mine this wealth of information directly by monitoring vibrations to detect predators or prey and introducing vibrations into structures to communicate with other individuals. Studying vibrational communication will provide important insights into insect social behavior, ecology, and evolution.

Behavior of insect sound and communication

Acoustic signals (sounds) can be associated with several insect behaviours, mainly mate attraction, courtship and territorial behavior. For instance, the mature unmated female cricket Gryllus campestris and long-horn grasshopper *Thamnotrizon apterus*, are attracted by the singing (chirping) of the males. Even flight noises in mosquitos are used for mate attraction. However, insect sounds can also be used in other behaviours, as mentioned below

Conclusion

Many insects have ears for the sole function of detecting predators. Nocturnally active insects tuned to the ultrasonic vocalizations of insectivorous animals and also designed for conspecific communication between insects. The study of insect hearing has inspired the scientist to discover new theories with medical implications. Hearing regulates aggression behavior in Drosophila with an important role in obtaining food, mates, territory and social status. Insect hearing research can be medically relevant in that can help define causes of human ciliopathies and hearing disorders and in that it might offer strategies to control insects that transmit human diseases. Above all, insect auditory systems remain fascinating; they still hold many secrets, and deciphering their function, development, and evolution remains a scientific challenge.

Insects are highly acoustic animals that have fascinated nature since many centuries ago. Insects, small living species in large ecosystems, require specific communication methods to overcome distances and find mates. They have evolved behavioral strategies, visual, chemical, and acoustic systems, including sound production and hearing organs. Insects produce acoustic signals that can be linked to various behaviors like mate attraction, courtship, territorial communication, sexual communication and defensive purpose. Sound is one of crucial way in insect communication. Studying animal communication offers biological knowledge and potential strategies for controlling insect pests and acoustic communication of animals still has unrevealed mysteries, which future research will help to discover.

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