SOUNDS OF INSECTS / Recorded and Annotated by A. T. Gaul / SCHOLASTIC RECORDS SX 6178

he European Hornet, photographed by A. T. Gaul / Cover design by Ronald Clyne

SCHOLASTIC RECORDS SX 6178

SOUNDS OF INSECTS

SIDE I

Band 1 Suburban Sounds
(Crickets and temperature; Crickets chirp at slow speed)

Band 2 Insect Flight
(Inside a hornet; pre-flight warm-up; fatigue experiment)

Band 3 Insect Flight
(Wing-beat vs. load; flight-light experiment; in a hornet nest)

Band 4 Flying Insects
(Mosquitoes; bumble bee; May beetle; Japanese beetle; warble-fly; flow-erfly; European hornet)

Band 5 Cicada Warm-Up and Flight
(Tent caterpillar moth; underwing moth; large long-horn beetle screaming; click beetles)

Band 6 Wasp Chewing
(False katydid; cicada song; cicada and plane; evening insects)

SIDE II

Band 1 Katydids
Band 2 Longhorn Beetle Walking
Band 3 Small Longhorn Beetle Shriek
Band 4 Viceroy Butterfly Walking
Band 5 Viceroy Butterfly In Flight
Band 6 Harpalus Beetle Walking
Band 7 Fly Caught On Flypaper
Band 8 Underwing Moth Walking
Band 9 Grape-Leaf Beetle Walking
Band 10 Dragonfly In Flight
Band 11 Mud-Dauber Wasp Flight
Band 12 Crabre Argus (Wasp) In Nest
Band 13 Hover Fly
Band 14 Deerfly
(Chrysops niger)
Band 15 Deerfly
(Chrysops vittatus)
Band 16 Japanese Beetles On A Rose
Band 17 Drone Fly
(Eristalis)
Band 18 Bumblebee
(Two toned flight)
Band 19 Cicada Song
Band 20 Spider (Salticus sp.) Walking

DESCRIPTIVE NOTES ARE INSIDE POCKET

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SCHOLASTIC RECORDS SX6178

SCHOLASTIC RECORDS Album No. SX 6178
Produced by Folkways Records, New York, ©1960

SOUNDS of INSECTS

The horsefly, a powerful two-winged biting fly, uses his flight sounds to roar from your loudspeaker in this recording.

Photo from: The Wonderful World of Insects by Albro T. Gaul Rinehart, 1953.

RECORDED AND EDITED BY ALBRO T. GAUL

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ABOUT INSECT SOUNDS

There are three-quarters of a million known species or kinds of insects. In one way or another most of these make sounds. They make these sounds in response to a number of stimuli, or situations in which they may find themselves. Some sounds, like the shriek of the longhorn beetles, are protective in nature. Other sounds may be courtship calls, or proclaim territorial rights. Still others are the result of activities in which sound is simply a by-product of motion. Among the latter are the wing beat tones, the scuffling of walking, and the crunching sounds which result from eating.

INSECT FLIGHT SOUNDS:

Perhaps the most familiar of the insect sounds are the tones produced by the wings while flying. Certainly the buzz of the fly and the whine of the mosquito are familiar to us all. Such sounds are produced as the wings beat in flight. The tone or sound frequency produced is identical with the frequency of the beat of the wings themselves. Since the wings beat up and down, much like the tines of a tuning fork, the wing beat tones are made by a series of compression waves in the air. Among the insects, the flight tone may vary from 7 strokes per second up to 300 or more strokes per second. The actual rate of normal wingbeat depends upon a number of factors-the ratio between the weight, or mass, of the insect and the area of the wings-the configuration of the thorax (the insect mid-body, to which the legs and wings are attached)-air temperature (particularly among the smaller insects)-visibility conditions-fatigue factors- and perhaps other elements of which we are not yet fully aware. Insects of the same species usually have the same mass-to-wing area ratio, and thus tend to have the same wing beat frequency. This is particularly true among the larger insects whose wing beat does not vary with temperature.

The wing tones thus produced are so closely matched among individuals of the larger species, that the species can sometimes be named quite accurately simply by reading an audio frequency meter into which the wing tones are fed.

Strange as it seems, the wing muscles of insects are biologically and biochemically much like our voluntary muscles. We cannot wiggle our fingers much faster than ten times per second, and the insect muscles cannot contract in excess of 12 or 18 times per second. How then can we account for a mosquito wing beat of 307 cycles per second? Obviously the wing muscles cannot beat the wings at such a rate. Yet the wings <u>do</u> beat at that rate.

There are two sets of muscles involved. The true wing muscles are attached to the base of the wings. But these simply move the wings from the "rest" to the "ready-for-flight" positions. They are small, weak, and cannot beat the wings at all. The greater part of the thorax of the flying insects contains a mass of paired muscles, the flight muscles.

These are not attached to the wings at all, but they alternately contract to distort the shape of the thorax. In so doing, they exert a lever action at the base of the wings, causing the wings to move up and down in a typical flight stroke. (Figure 1) These muscles can contract no more rapidly than the other muscles, and the thoraces distortion can be no greater than 12 to 18 times per second. The heavy clad thorax, however, is not solid, and although the flight muscles cause it to distort with each contraction, there are produced by the contours of the thorax shell, harmonic vibrations which activate the wings at a great rate. Actually the maximum possible wing beat, based on the harmonic distortions produced, far exceeds the normal wing beat, and the normal wing beat frequency is therefore limited by the loading factor- the mass to wing area ratio. One effect of this is demonstrated on the record, where a small weight is placed on an insect thus altering the mass-to-wing-area ratio, and resulting in a higher frequency wing beat.

The activities described above can all be heard in the startling sound track made of the internal sounds of an insect during flight. We can easily distinguish the hum of the wings in their normal flight tone; this hum is modulated by a much slower pulsing sound, which is the contraction of the flight muscles within the thorax. At lower volume may be detected a slight grating sound- the sound of the abdominal segments as they contract and expand, like a bellows, in the respiratory motions of the insect.

Muscular fatigue is demonstrated in another sound track of internal sounds, in which the insect flew continuously for 14 minutes. Here the fatigue of the muscles decreases the harmonic vibrations of the thorax to a point below the limit imposed on wing frequency by the mass-to-wing-area ratio. In this way the wing beat frequency decreases with fatigue. Decreased muscle action is also clearly evident after the first few minutes. Ample oxygen and ample glucose are required for use by the flight muscles if an insect is to sustain its flight. Air exchange is almost 100% with each contraction of the flight muscles since the tracheal system provides direct aeration of the muscle fibers, and since the contraction of these fibers squeezes the tracheae flat in each cycle. It is primarily the depletion of glucose, then, that causes fatigue, and indeed, this fatigue effect can be averted by feeding glucose.

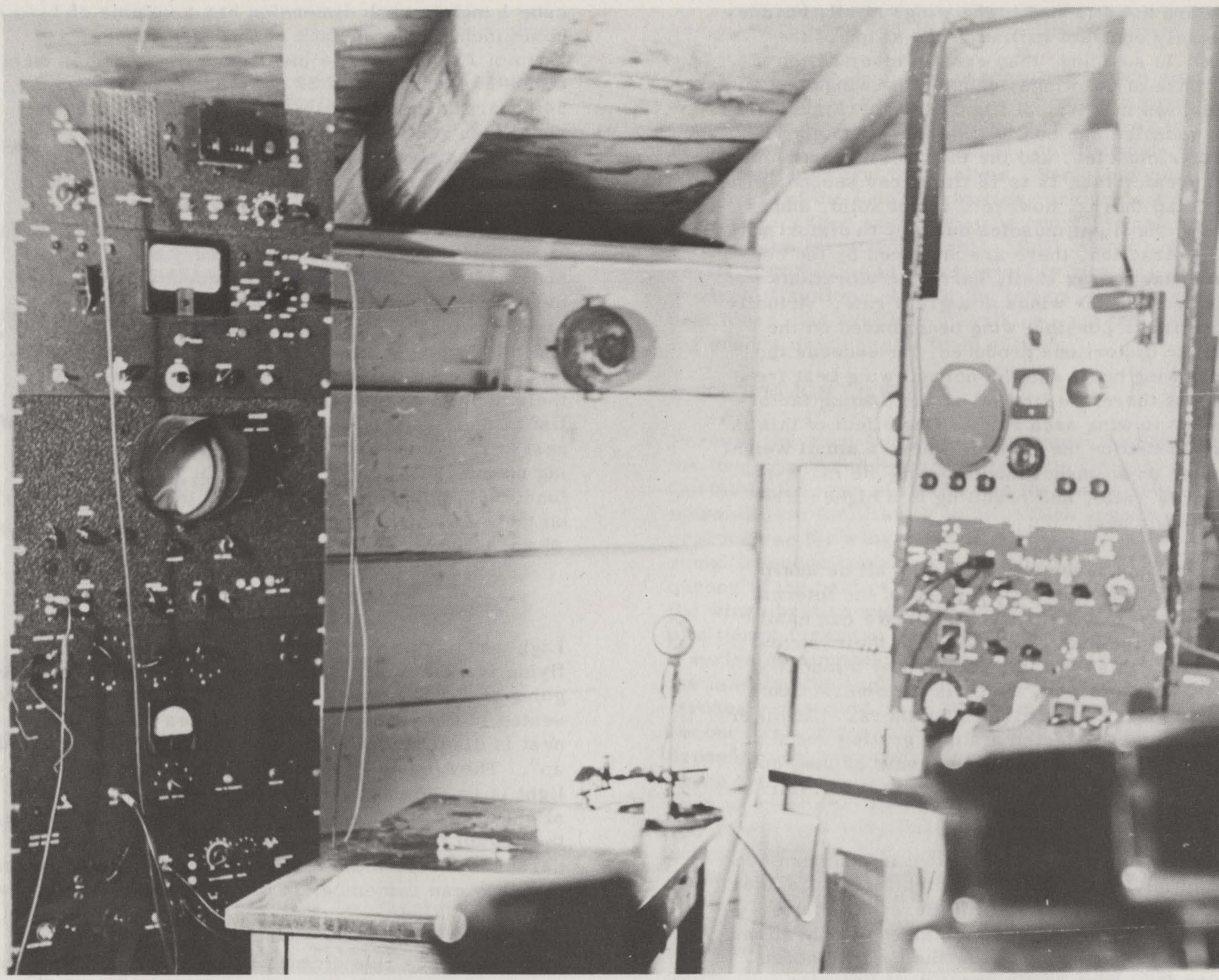
Smaller insects have imposed upon their normal wing frequency, a limit of temperatures. Insects are cold blooded. To function at a given speed the flight muscles must be at a certain temperature- depending upon the species involved. Smaller insects with small bodies lose their heat faster than larger insects, and all flying activities are strenuous enough to generate heat. The smaller insects have a greater relative surface area through which heat can be lost. Larger insects have a relatively smaller surface area through which heat can dissipate. This is the same principle of surface-to-volume ratios which we see in a cube. A cube 1 inch in each dimension has a volume of 1 cubic inch, and a surface of 6 square inches- a ratio of 1 to 6. A cube measuring three inches on a side has a volume of 27 cubic inches, an area of 54 square inches, a ratio of 1 to 2. Thus if each cubic inch generated the same amount of heat, the smaller cube would remain cooler because it has a greater relative area for heat loss. Therefore smaller insects tend to have a varient wing frequency, related to temperature, while larger insects have a constant wing frequency because their body heat increases the wing frequency potential beyond the limits imposed by the mass-to-wing-area ratio. Insects take advantage of this principle, and this is heard in the sound track of the warming-up exercises of wasps. Here the wasps awaken in their nest on a cold morning. The air temperature limits their wing frequency. So they remain in the nest, exercising their wings a few seconds, building up internal temperatures, until the wings can function at normal frequency, and then they fly away on their missions.

Light and dark are important flight factors for day flying insects. Day fliers cannot see where they are going at night- so they don't go. The experiment presented in the recording demonstrates this. A hornets' nest is disturbed at night, and the hornets are "riled up". They leave the nest and fly around while the light is on. As soon as the light is turned off, they alight where they can. When the light goes on again, they again fly around in anger. This shows that darkness forces them to inactivity, and it also shows that they can remember to be angry when the light is again turned on.

Like the wasps, the cicadas also experience a warming-up exercise and this, together with the normal flight sound of the cicada,is recorded here. Most of us know the loud shrill of these insects (which are misnamed locusts) but few of us are familiar with their wing tones.

A number of typical insect flight sounds are recorded here. These are the sounds which many of us can hear on a warm summer day, or which may elicit feelings of nostalgia for summer evenings in the country. The whine of mosquitoes is present to remind us of these pests, and two species are recorded to show that even among mosquitoes, different species have different wing tones.

Some of the flying insects seem to have two distinct flight tones. Some insects really do have two tones; while other tone variations may be caused by the Doppler effect. The distinct double pitch of the bumblebee is very real. In flight, the bee beats its wings at a lower frequency than when it hovers over a flower. In flight its wing load is greatest because it is generating maximum thrust, in hovering it needs minimum thrust, has less wing load, and therefore beats its wings faster- although through a smaller angle or at less amplitude. The hover flies, and even the housefly can produce this double frequency effect.



This is some of the equipment used in the preparation of this recording, and used in the study on insect sounds. A special pre-amplifier, a Williamson type power amplifier, oscilloscope, audio frequency meter, microwattmeter, etc.

Some of the flight sounds demonstrate the Doppler effect, the most familiar example of which is the change in apparent tone of an auto horn as the car approaches and then passes. In the approach situation the car or insect seems to emit a higher frequency sound than the receding car or insect. The apparent frequency of the sound is modified by the velocity of the emitting object. In the approach condition the frequency N is increased by an amount equal to the velocity of sound in air (V) plus the velocity of the emitting object (V_e). In the receding situation, the frequency N is modified by V minus V_e and a lower frequency is apparent. As an example, the velocity of sound in air at 65°F is about 1029 feet per second. A honeybee flies toward us at 20 miles per hour (29 feet per second) emitting a frequency of 220 cycles per second.

$$N_{(apparent)} = N_{(actual)} \left[\frac{V + Ve}{V - Ve}\right] \text{ or } 220 \left[\frac{1029 + 29}{1029 - 29}\right] \text{ so } N_a = 220 \left[\frac{1058}{1000}\right]$$

By arithmetic it can then be shown that the approaching bee will appear to hum at a frequency of 226.6 cycles per second, while as it goes away the frequency will drop to 213.4 cycles per second. Since the bee is neither moving toward or away from itself, it might hear itself at a constant tone of 220 cps. In the recording, this effect is notable in the deer fly. The effect might be used in reverse, to determine the actual flying speeds of insects given accurate enough instruments.

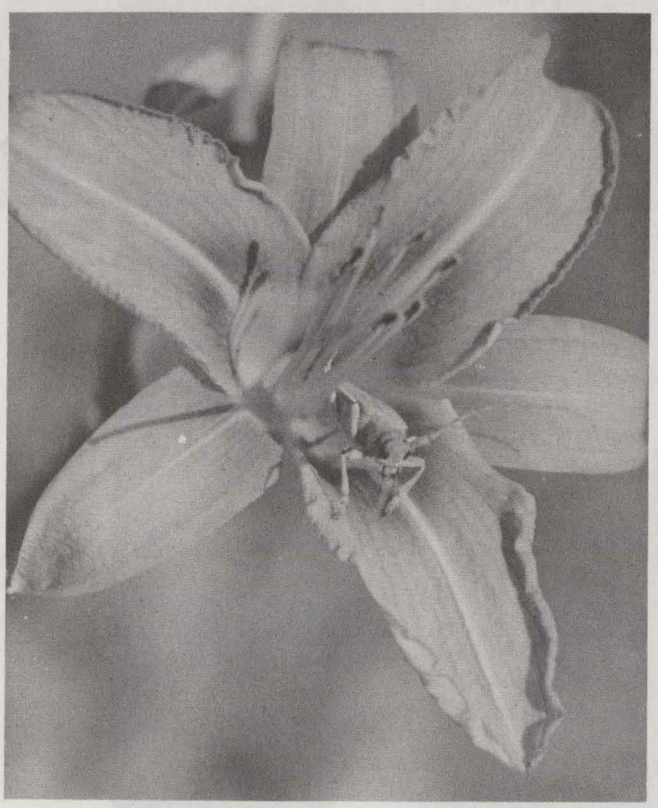
Insects fly at many rates of speed. At one time the deer fly was credited with flight at 54 miles per hour. This has never been proven and his typical velocity is listed at a much more modest figure.

Any aviation engineer can tell us that the monoplane is more efficient than a biplane, largely because the second pair of wings create considerable drag. The members of the fly group (order Diptera) are the only true insect "mono-

The tent caterpillar, which matures into a brownish moth, flutters its irregular wing beat in this record of Insect Sounds.

Photo from: The Wonderful World of Insects by Albro T. Gaul, Rinehart, 1953. Also exhibited at American Museum of Natural History N.Y.

planes" because they have only one pair of wings. The horsefly, deerfly, housefly, drone fly, and mosquitoes are members of this group. All flying insects of other groups have two pairs of wings, yet many fly quite efficiently. Some of these use interesting devices to become effective monoplanes, even though they may be built like biplanes. The bees, wasps, and hornets have a series of hooks along the leading edge of their hind wings, and these engage with the front wings to present a single airfoil surface. Some moths and butterflies engage a long "crank handle" type spike between fore and hind wings. Most other four-winged insects are rather slow and inefficient fliers, and follow known engineering principles for inefficiency. Among these four-winged fliers, the dragonflies present a unique divergence from inefficiency. They are among the most rapid insect fliers, yet at first blush they should not be. Studies have shown that the dragonfly makes the thrust stroke with his hind wings first. Then with the hind wings low and out of the way, the fore wings begin their thrust stroke, with no drag or eddy currents from the hind wings. Then both wings rise together for the next series of thrust strokes. The "rustling old paper" sounds of the dragonfly flight result as the wings snap from upstroke to airfoil thrust, and then into a position where they brush into each other when both thrust strokes are completed.



The longhorn beetle, a wood borer, rests on a lily. This insect makes protective shrieks by rotating its head from side to side when captured.

Photo from: Wonderful World of Insects, by Albro T. Gaul, Rinehart, 1953.

OTHER INSECT SOUNDS:

It is not certain whether the shrill of the cicada is a courtship call, or an announcement of territorial rights. It is certainly among the loudest insect sounds. Only the male cicada is equipped with the tympanic mechanism within his abdomen for the production of these sounds. Cicadas do not always make these sounds, and even in areas where many cicadas may be feeding, no sound may be heard for hours. As soon as one male breaks silence by shrilling his song, however, others within hearing take up the cry, and cicadas may sing lustily for quite a time. It is interesting that sounds from low-flying aircraft seem to stimulate the cicadas into singing. Apparently the cicadas cannot, or do not, distinguish between airplane motors and other cicadas.

The chirping of crickets may be territorial or for courtship. The chirp is produced by rubbing the rough edges of the wings together at high speed. The grating sound produced is amplified by the acoustic properties of wing surfaces and spaces between the folds of the wings. The chirping rate is largely a function of temperature. The standard formula for determining temperature by cricket is to count the number of chirps in 15 seconds, add 40, and the sum is the temperature in degrees Fahrenheit.

Katydid calls are thought to be courtship calls exclusively. They are also subject to temperature controls, and the formula: number of "katydid" or "she did" calls in 20 seconds, plus 53 gives the temperature on the Fahrenheit scale also. Like the cricket, only the male katydid makes the typical song of his kind.

The false katydid is another grasshopper-like insect. It makes a sharp clucking sound by vibrating its hard outer wings like a bellows.

The shrieking of the longhorn beetles is heard only if these insects are captured or grasped, and if the listener's ear is close enough to hear them. These shrieks of "agony" are produced by rotating the head rapidly about the center axis of the neck. Both head and neck have sawtooth edges, and these engage to make the shriek, much as if a washboard were rubbed along the top of a picket fence at high speed. It is thought that such shrieks cause insect-eating birds to drop the beetle in alarm. Whether this is true or not may be doubtful; but it is certain that sound conduction through the bill and skull bones of a bird would be intense enough to be startling.

Incidental insect sounds are made, like their flight sounds, as by-products of some other activity. Since all insects have six legs, many of their walking sounds are similar. Cadence may be quicker or slower, depending upon the length of legs; the longer legged species having the slower cadence. In contrast to the insects, a spider, is also recorded because spiders have eight legs, and an entirely different walking pattern.

The chewing of insects results in low amplitude sounds. Some insects have piercing and sucking mouthparts, and no equipment has yet been made to record such sounds as, for instance, a mosquito piercing the human skin. The eating noises recorded here are those of a hornet, ripping meat from the bones of a dead fish. These sounds seem almost metallic. The insect has two jaws, both hinged to the head for side-to-side chewing. Air spaces in the head lower the density of the hornet for flight, but they also modulate the chewing sounds and make them resonate in a metallic fashion, but then the hornet must get used to it.

The click beetles are the parents of the well known and destructive wireworms. They are flattened, short-legged beetles which get into trouble if they land on their backs, as they often do when they fall. To overcome this disadvantage of their shape, they are provided with a hinge between thorax and abdomen. With the hinge is a hook-and-cleat mechanism. When the click beetle lands on his back, he bends thorax and abdomen as close together as he can in a sort of jacknife position. This engages the hook to the cleat. Then the beetle bends backward, arching his back as it were, in the reverse of the jacknife. When he exerts enough force, the hook suddenly releases, with the result that the beetle snaps into the air, turning somersaults, and we suppose, hoping to land on its feet. The way it lands is a 50-50 proposition, and if it lands on its back, it repeats the snapping maneuver until it succeeds in attaining its normal position. With each effort, a definite "click" is audible to us at some distance.

The Japanese beetle is a pest which afflicts the northeastern states. In early June these abundant beetles flock over flowers and leaves, devouring all alike. They prefer the rose family, and particularly the blooms of the roses themselves. In the sound track of the Japanese beetles on the roses, we can hear the beetles climbing over each other, we can hear them eating the petals, and because of the proximity of the microphone (which they did not like) we can hear them flying away from the flower one-at-a-time.

There are thousands of other insect sounds. Some are similar, others are not. Those presented here are recorded as representative samples of the sounds made by North American insects. They may be listened to as a technical study, or as a background to thoughts of summertime and days spent in the country.

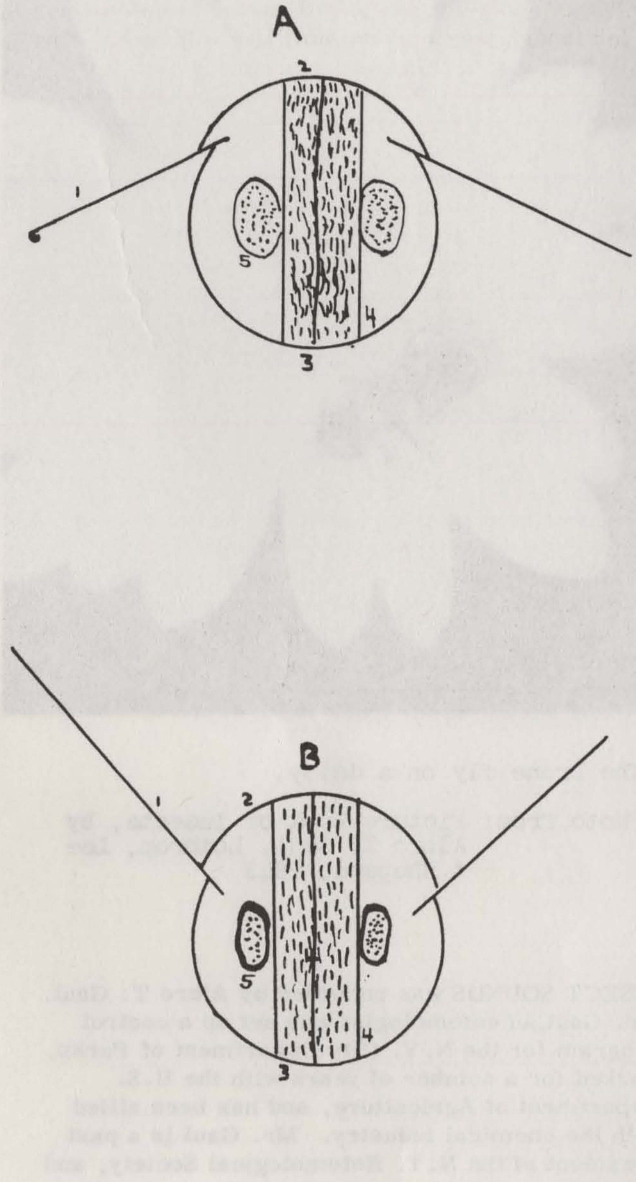


Figure 1: Cross section of a typical insect thorax, showing how thoracic distortion causes the wings to beat in flight. 1-wings; 2-notum (top of thorax); 3-sternum (lower part of thorax; 4-vertical flight muscles; 5-horizontal flight muscles. Position A, wings down, vertical muscles relaxed and stretched, horizontal muscles contracted. Position B, wings up, vertical muscles contracted, horizontal muscles relaxed. Note lever type action of thorax on base of wings.

The Drone fly on a daisy.

Photo from: Picture Book of Insects, by Albro T. Gaul, Lothrop, Lee & Shepard, 1943

INSECT SOUNDS was recorded by Albro T. Gaul. Mr. Gaul, an entomologist who set up a control program for the N.Y. City Department of Parks, worked for a number of years with the U.S. Department of Agriculture, and has been allied with the chemical industry. Mr. Gaul is a past president of the N.Y. Entomological Society, and has been conducting research on insect sounds for the past several years. He is the author of "The Wonderful World of Insects" (Rinehart 1953), the "Picture Book of Insects" (Lothrop, Lee and Shepard 1943) and other popular books on science.

Recording Data on Insect Sounds

Wherever there is motion, some of the energy of the motion is liable to be transmuted to sound energy. Even though most of the insects are small, their motions can produce sounds. Some of the sounds are of such low amplitude that they remain inaudible to us without amplification; other sounds made by insects may be loud enough to become annoying.

Wing beat tones, and other of the audible insect sounds were picked up directly by an Astatic 77 dynamic cardioid microphone. The internal sounds of the activity of insect flight muscles were picked up through a special probe affixed to RCA 5734 electro-mechanical transducer tube feeding into a specially built preamp. The most troublesome sounds to record proved to be those of insect footsteps. The specimens either clung to the protective mesh on the microphone, or they scampered or flew away too quickly to obtain a useable recording. Attempts were made with paper and with aluminum foil attached to a wire "needle" in a phono cartridge; further attempts were made with a specially built ribbon microphone, large enough for the insects to walk on the ribbon, but the results were poor. The footsteps recorded here were achieved by placing the specimens in a small cardboard box, whose bottom was replaced by a tightly stretched sheet of tissue paper. This was placed with the tissue paper only a fraction of an inch from the dynamic microphone. In effect this provided a double diaphragm of the microphone itself - and the results were not only loud and clear, but they sounded alike each time the same insect was permitted to walk.

Many of the sounds included on this record were fed into specially designed preamplifier circuits, and thence to a 20-watt Williamson type amplifier. Output was fed to a VM model 711 tape recorder operating at 7 1/2 IPS, and recorded on Scotch brand 111 A 12 magnetic tape.

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