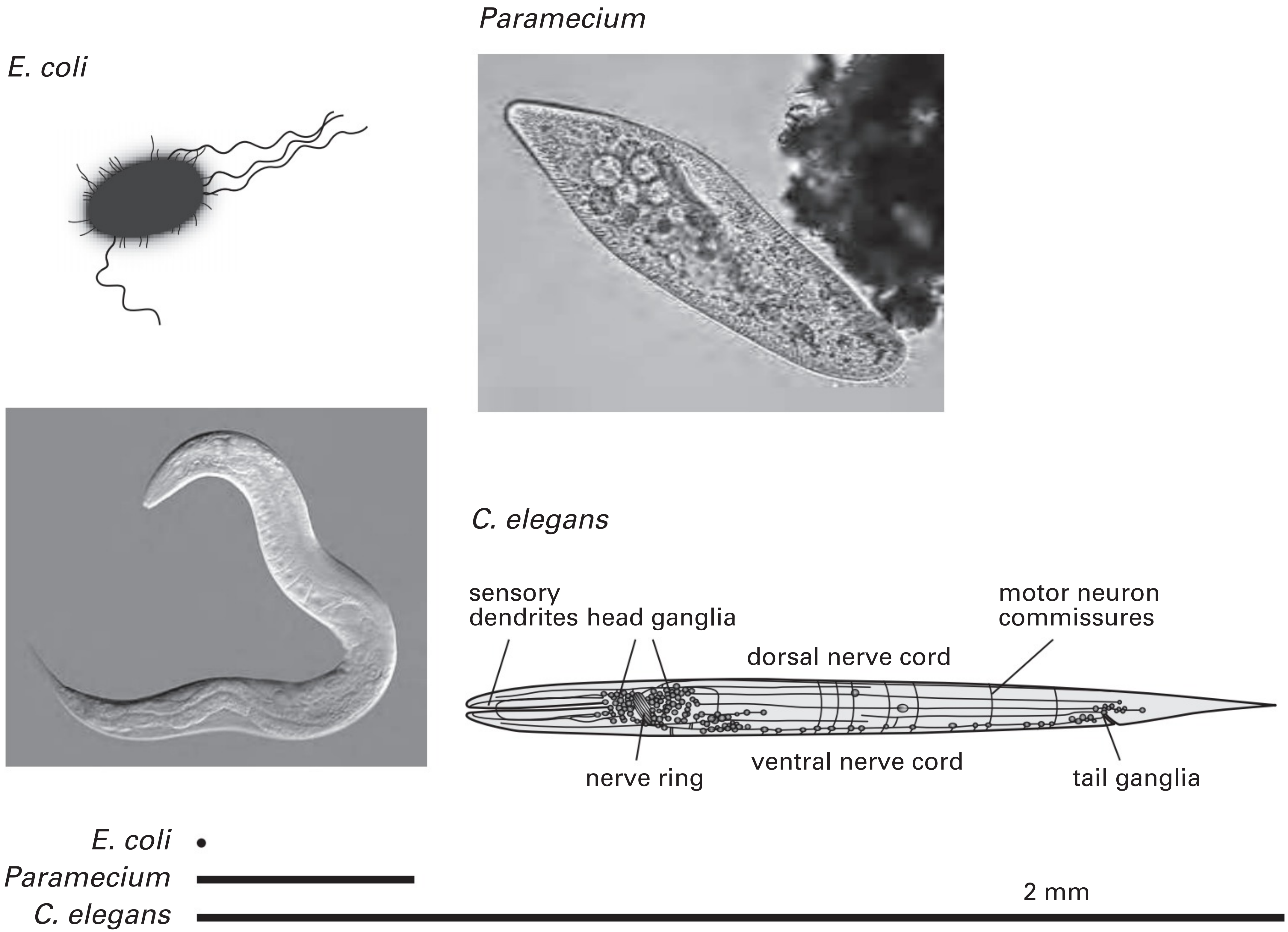
Animal Behavior

2 Why an Animal Needs a Brain

Brain books generally begin at the lowest levels—neurons, axons, synapses, and ion channels. But that approach ill suits our goal of reverse engineering. One cannot explain a B-29 by starting with the nuts and bolts. So we postpone the parts lists and detailed schematics to consider first a larger question: why do we *need* a brain?

One's first thought, of course, is that we need it for the magical activities and feelings it confers: art, music, love . . . consciousness. But although these features arouse intense curiosity—as Pavlov emphasized—we shall see that they are merely baroque decorations on the brain's fundamental purpose and should not be mistaken for the purpose itself. What we identify here as the brain's purpose, especially because we are seeking principles, should apply not only to humans but as well to the nematode worm, *C. elegans*, and to flies. The deep purpose of the nematode's brain of 302 neurons, the fruit fly's brain of 10^5 neurons, and our own brain of 10^{11} neurons (Azevedo et al., 2009) must be the same. By identifying the basic purpose, we set a context for later considering the "decorations." We expect that research on the mammalian cerebral cortex will not reveal many new principles—rather it will elaborate the core ones. In general, it should be easier to discover them in simpler brains.

(Sterling & Laughlin 2017)


E. coli
Paramecium
C. elegans
sensory
dendrites
head ganglia
motor neuron
commissures
dorsal nerve cord
ventral nerve cord
nerve ring
tail ganglia
E. coli
Paramecium
C. elegans
2 mm

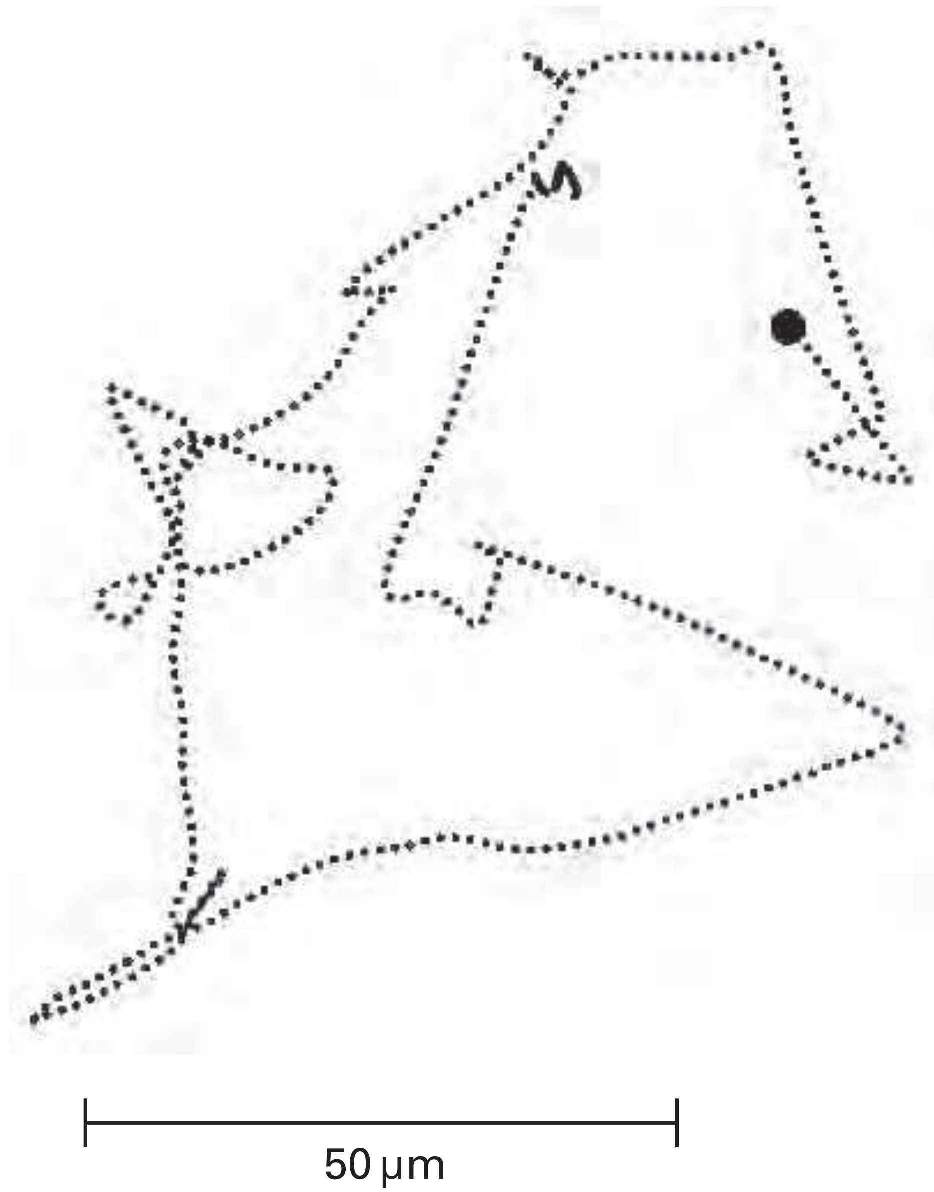
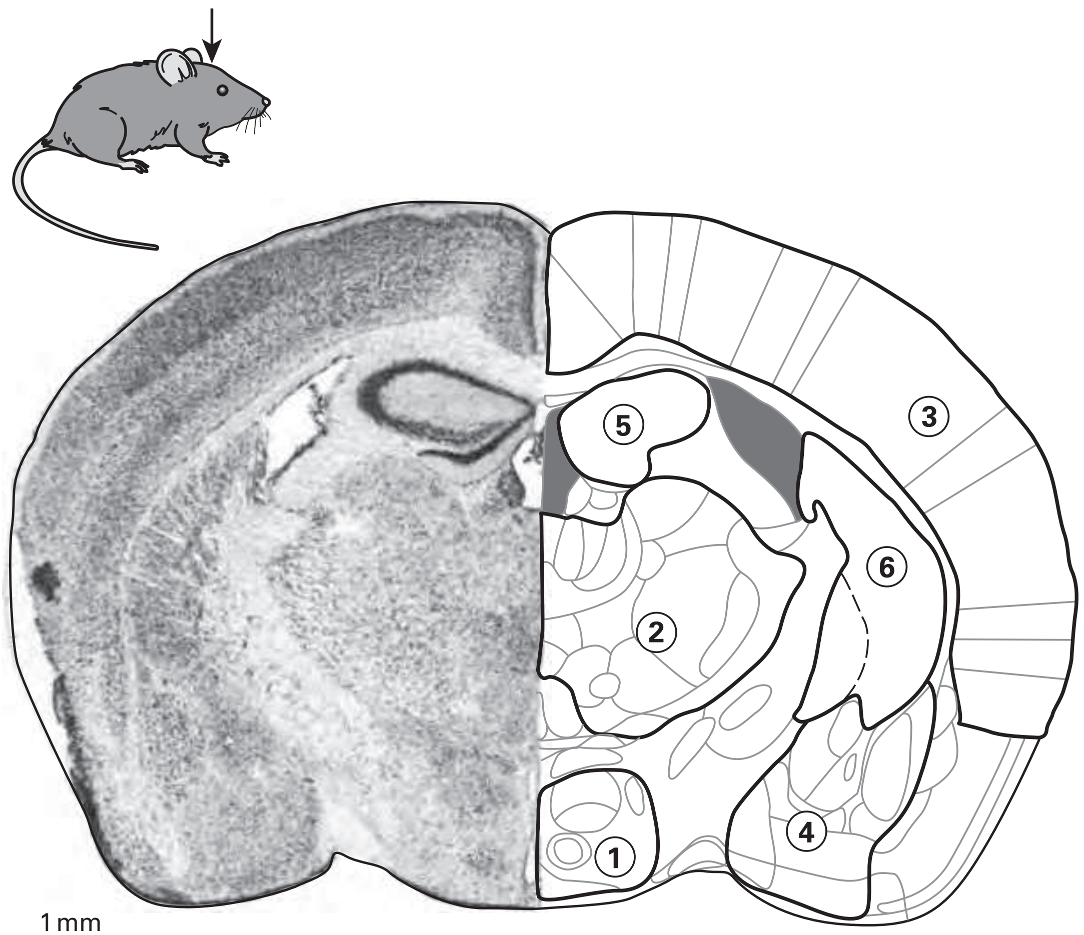
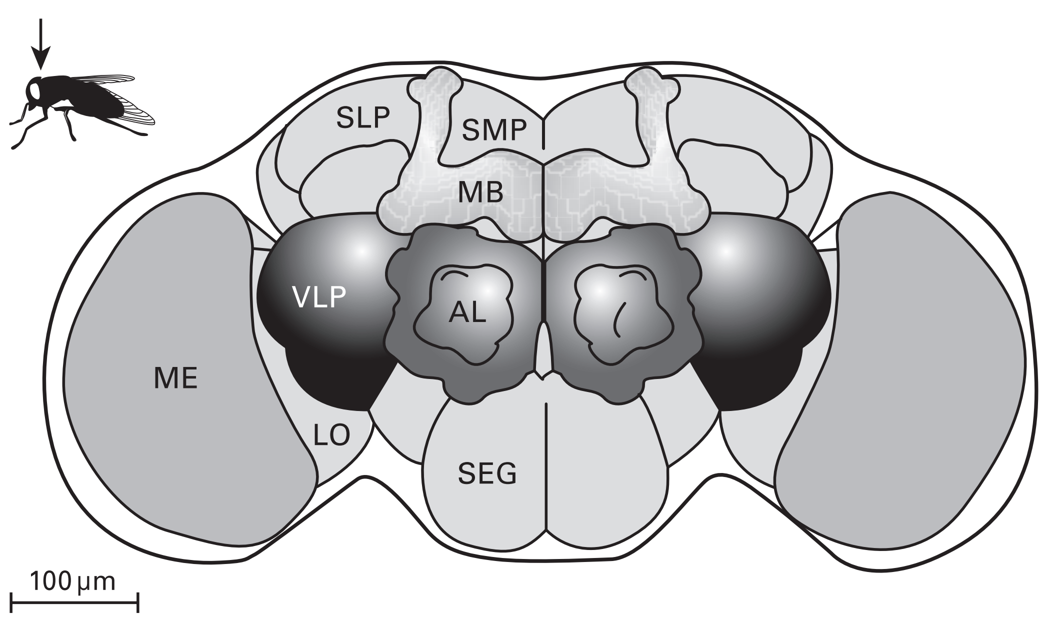


Figure 2.3

***E. coli*'s biased random walk**. By moving forward more and turning less, as the concentration of attractant increases, *E. coli* approaches the attractant's source. Tracing shows 26 runs over about 30 s with a mean speed of 21.2 μm/s. Reprinted with permission from Berg and Brown (1972). For videos of *E. coli* swimming see http://www.rowland.harvard.edu/labs/bacteria/index_movies.html/.

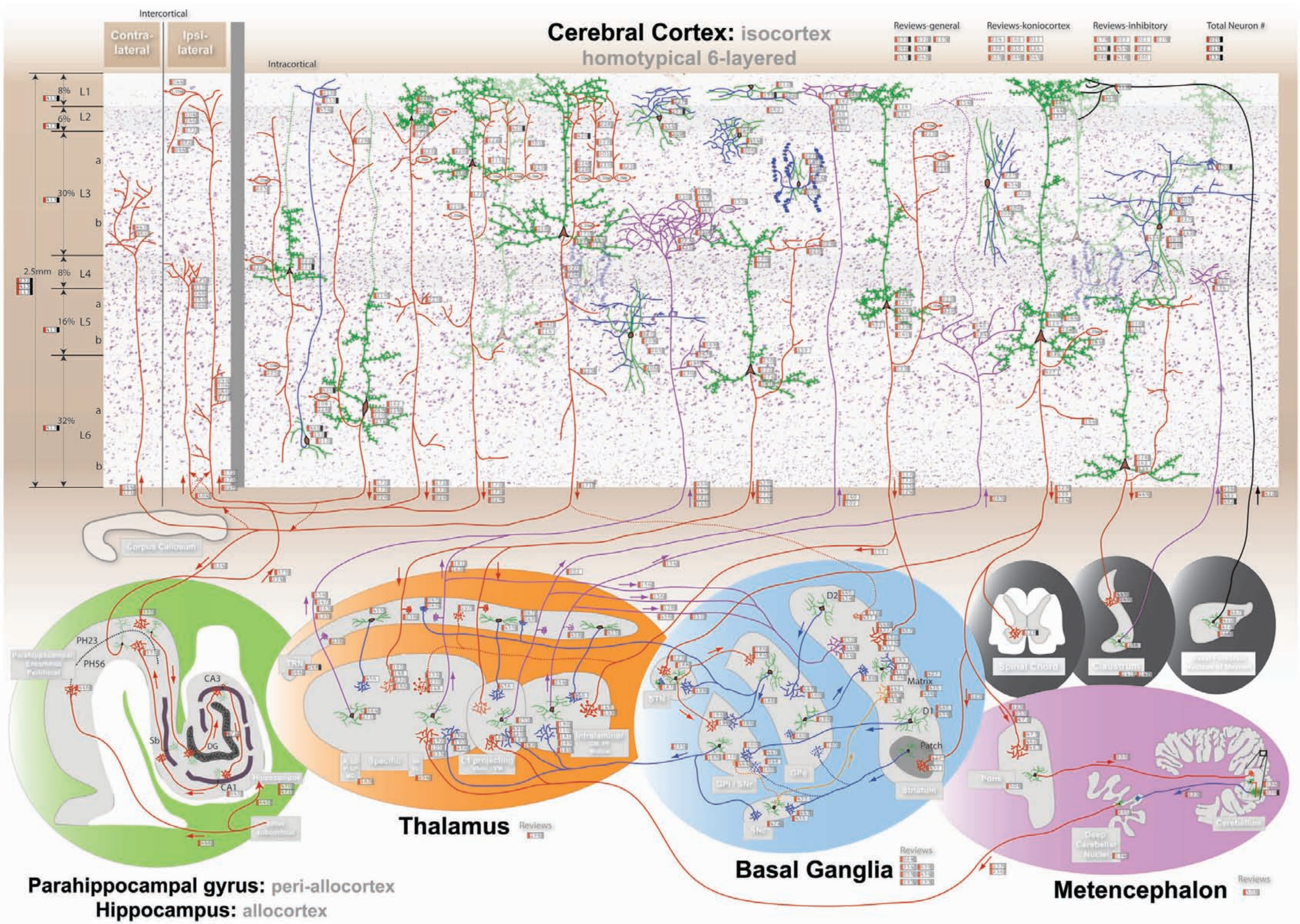


1. Generate patterns for wireless signaling and appetitive behaviors. (hypothalamus)
2. "Preprocessing" to shape signals for higher processing. (thalamus)
3. High-level processing: assemble larger patterns, choose behaviors. (cerebral cortex)
4. "Tag" high-level patterns for emotional significance. (amygdaloid complex)
5. Store and recall. (hippocampus)
6. Evaluate reward predictions. (striatum - basal ganglia)



ME, medulla - detect and map local visual patterns
LO, lobula - assemble local visual patterns into larger patterns
AL, antennal lobe - preprocess olfactory signals for pattern recognition
VLP, ventrolateral protocerebrum - high-level integration
SLP, superior lateral protocerebrum - high-level integration
SMP, superior medial protocerebrum - high-level integration
MB, mushroom body - store and recall
SEG, subesophageal ganglion - integrate information for wired and wireless output to body

“Cognitive Consilience” - Solari & Stoner (2011)



What does a brain need to do?

Navigation, locomotion

Motion perception

Pattern recognition

Learning and memory

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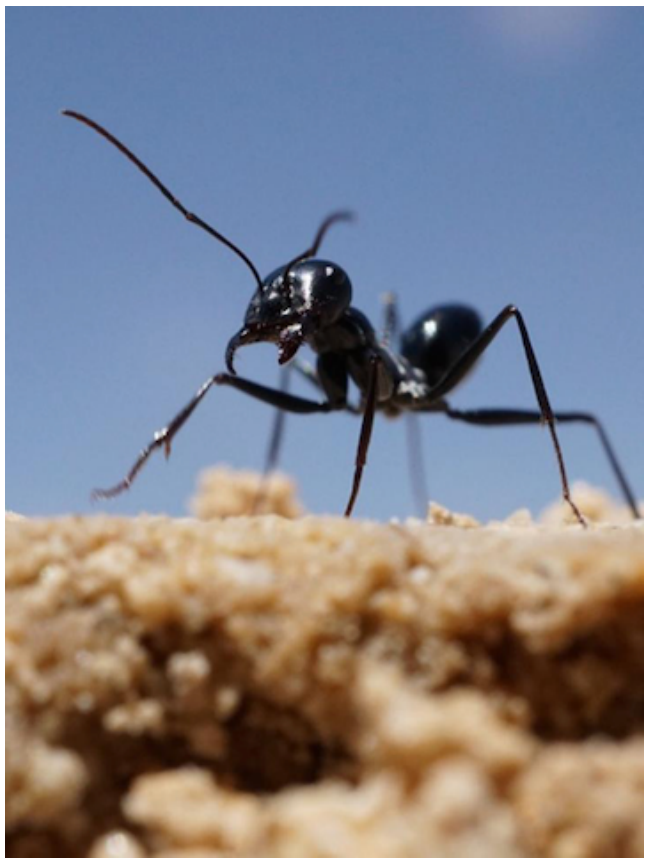
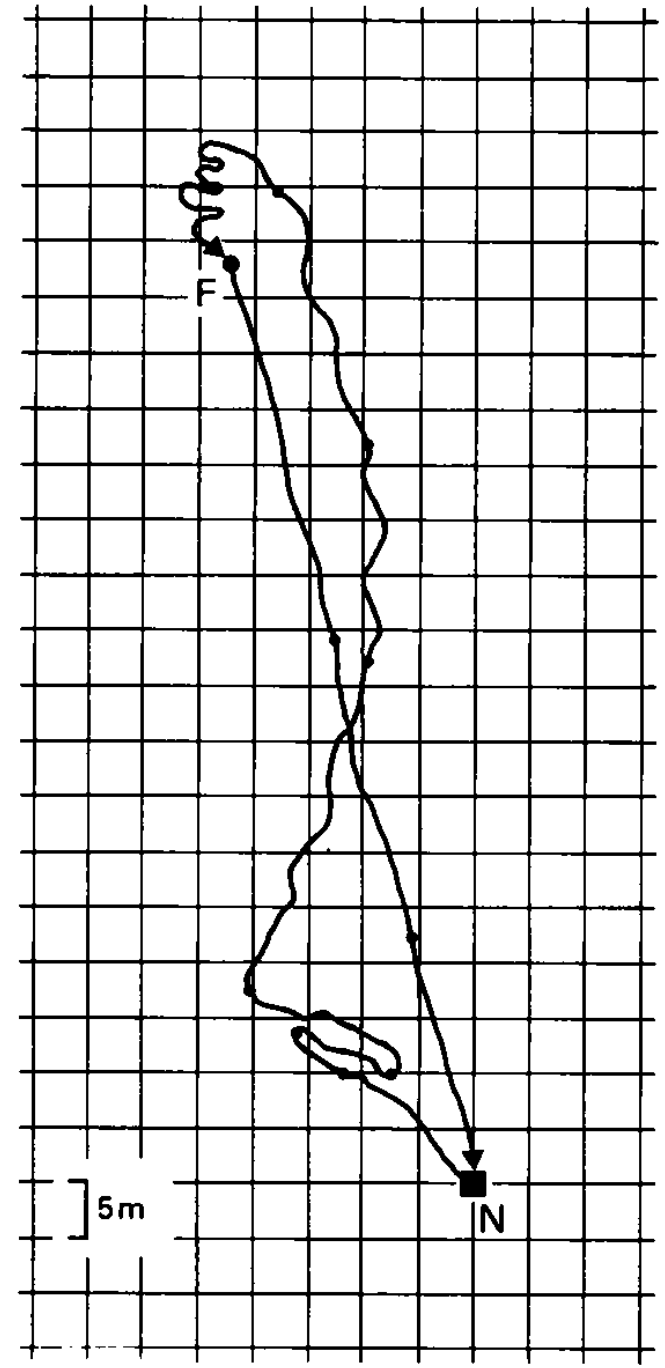
Path integration in desert ants





(R. Wehner, S. Wehner, 1986)

Control of Chasing in Flies

(Land & Collett 1973)

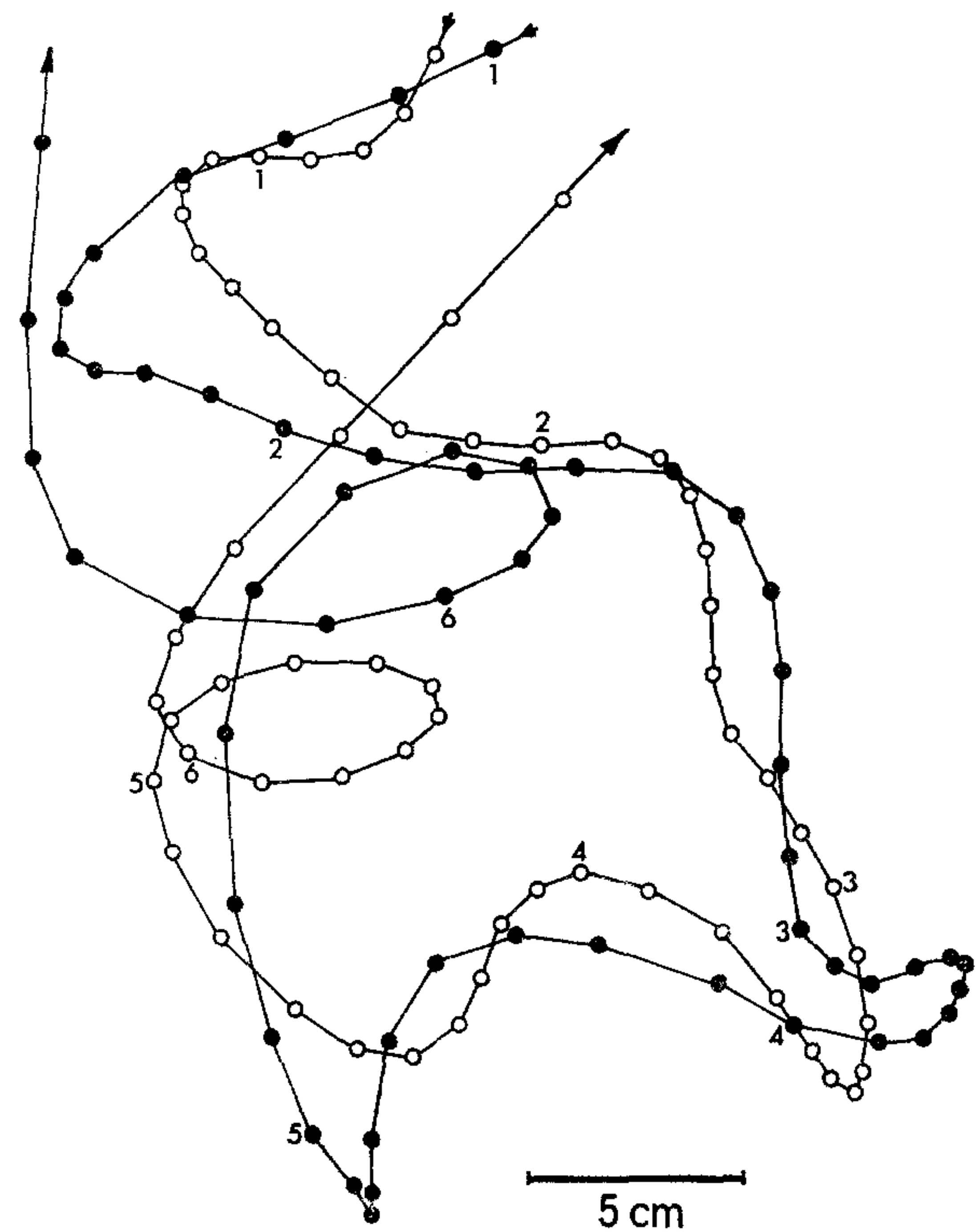


Fig. 4. Flight paths of chasing (●) and leading (○) flies during the longest recorded chase. Points at 20 ms intervals. Corresponding instants on the two paths numbered at 200 ms intervals

with *Philanthus*. In our summer camps we had developed what we called the ‘slave system’. Young undergraduates volunteered to join us in the long vacation and to help us with the field work of the graduates, thus gaining experience as well as doing a useful job. One summer Van Beusekom, then engaged in the *Philanthus* work described in Chapter Four, fell ill and had to forgo a whole season. Two slaves had already arrived and were keen to start work. Discussing emergency plans, they expressed an eager desire to tackle *Ammophila*. And that was how G. P. Baerends and Miss J. van Roon (now Mrs. Baerends) began a study, the results of which grew, over a period of seven summers, into a most wonderful, exciting and in some respects unique story. My pride in this matter is mixed with a great deal of embarrassment, for in spite of my own preoccupation with homing, the Baerendses went their own way and studied several other aspects of the Sand Wasps’ life, and discovered many very remarkable things.

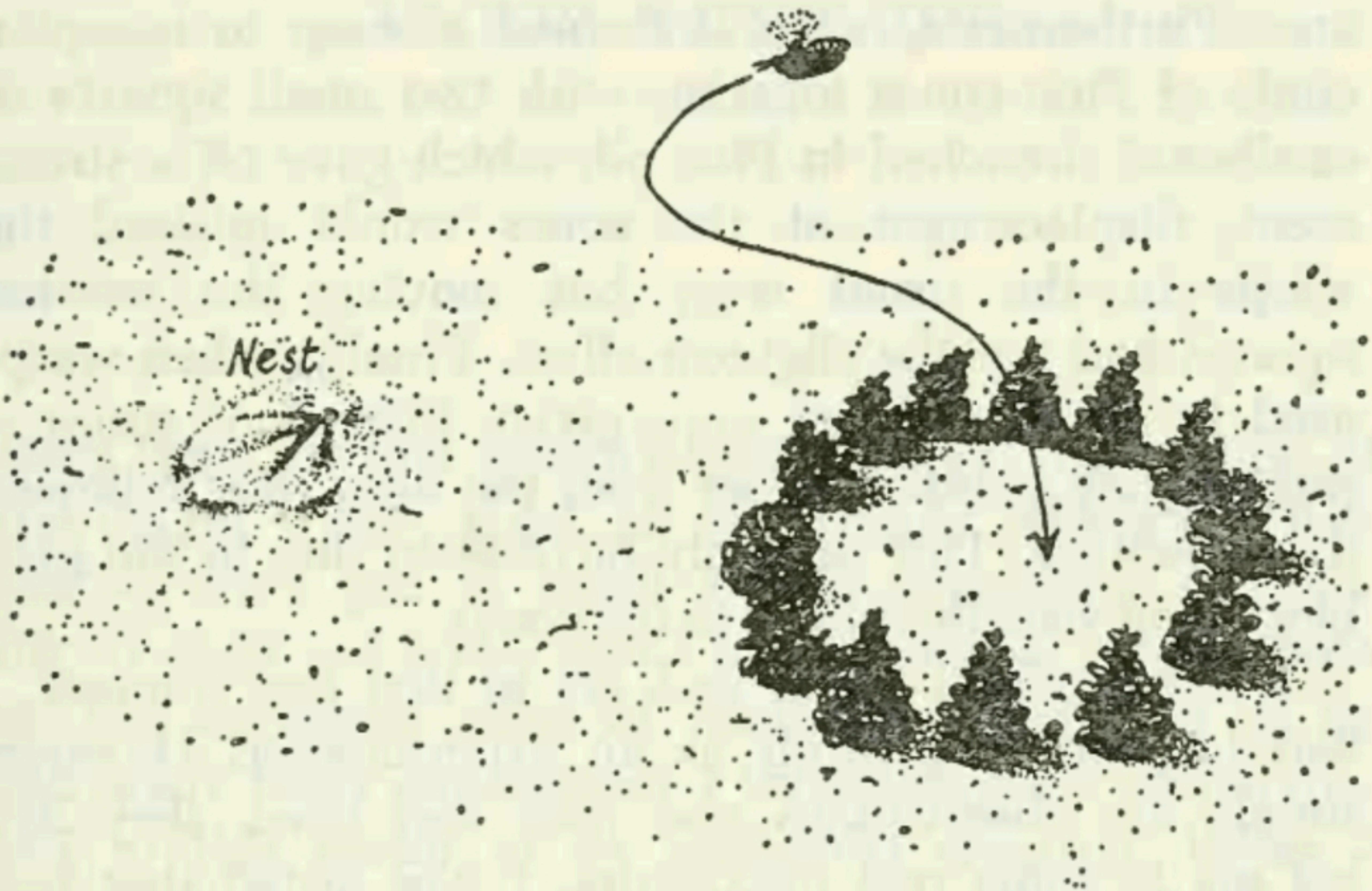


Fig. 1. A homing test. Philanthus returns to the displaced pine cones and fails to find her burrow.

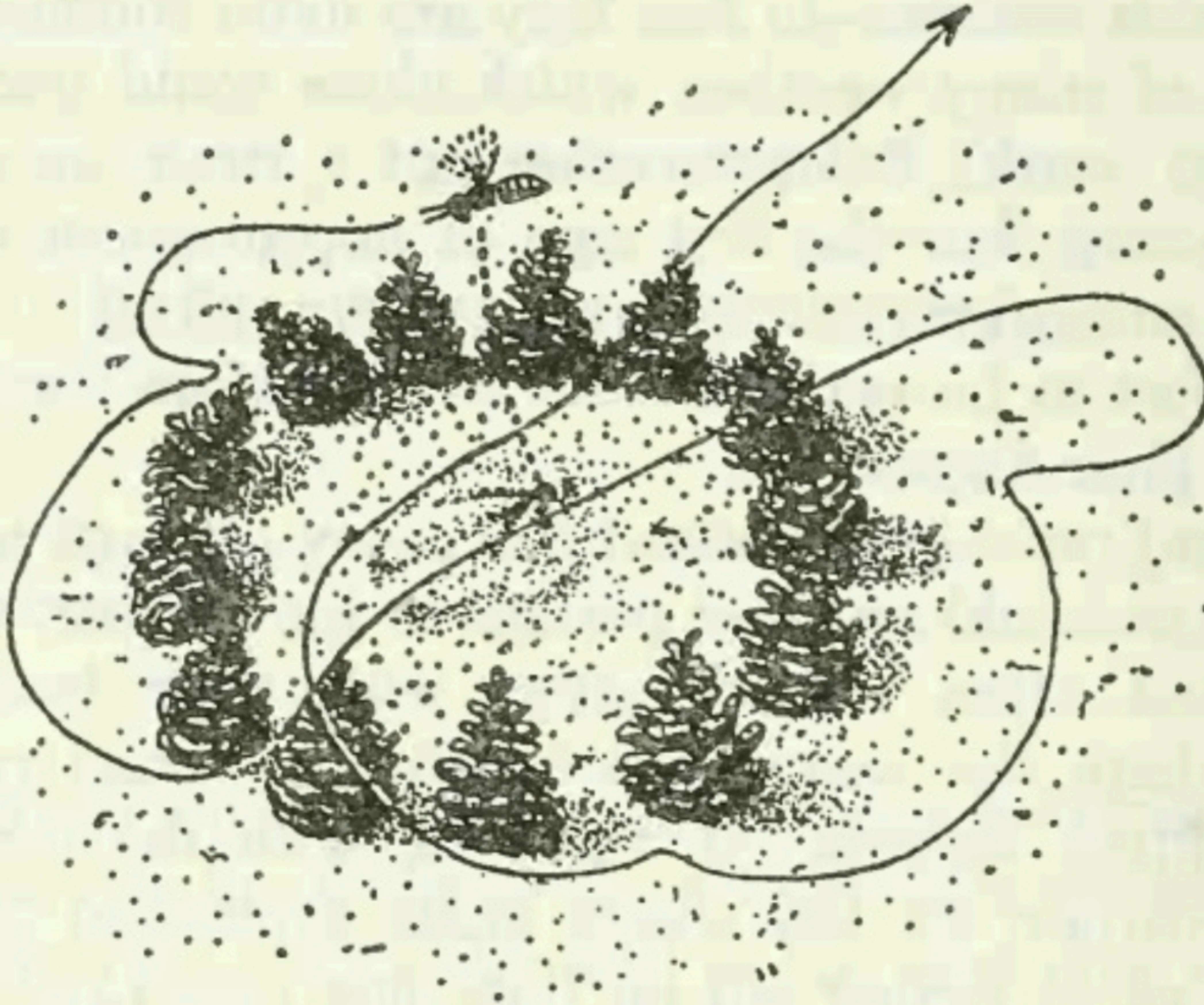
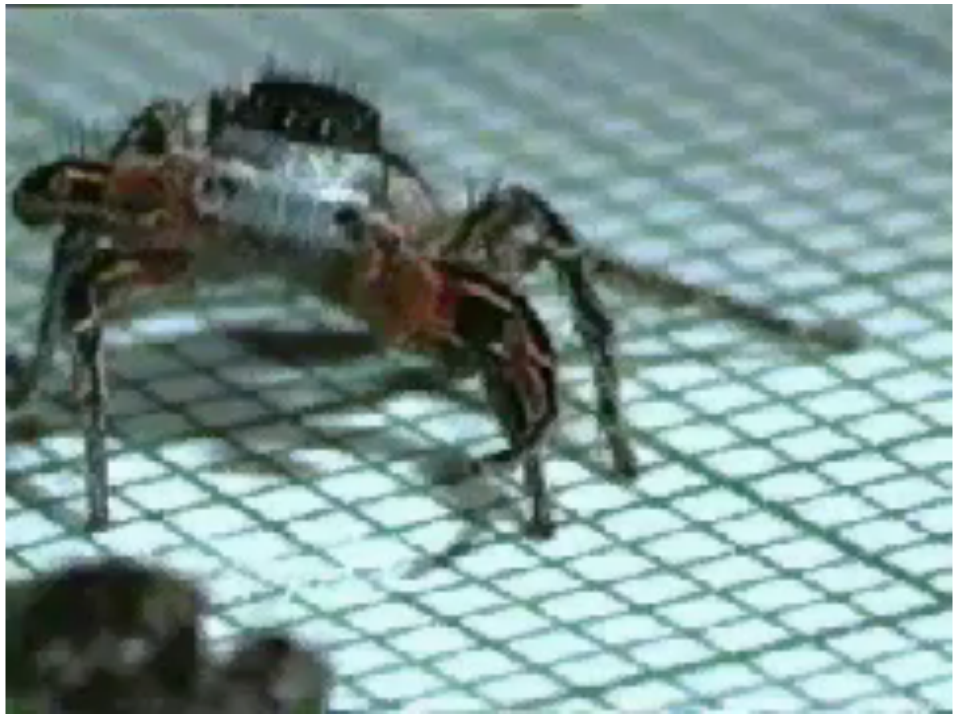


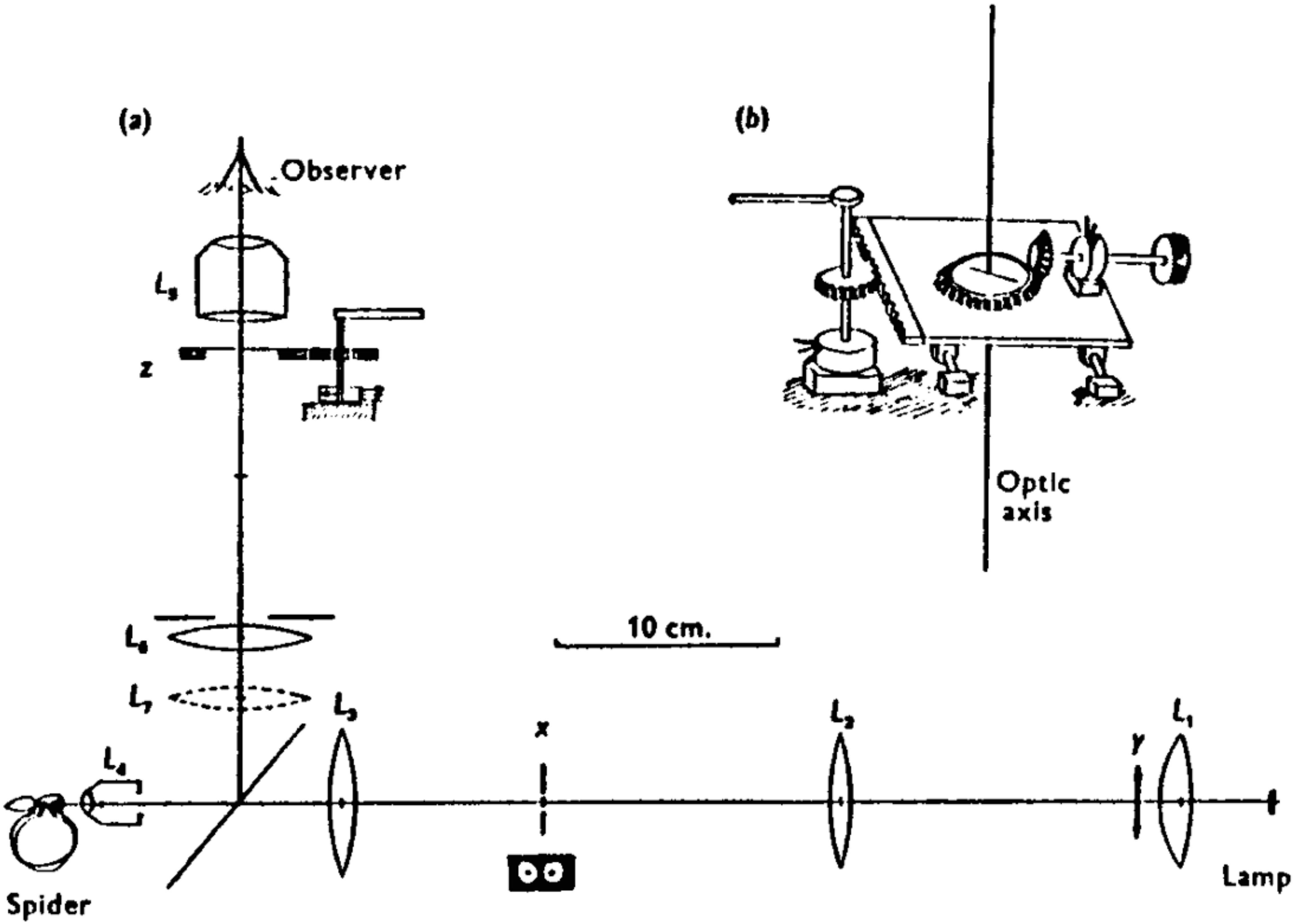
Fig. 3. Philanthus making a locality study.

Jumping spiders



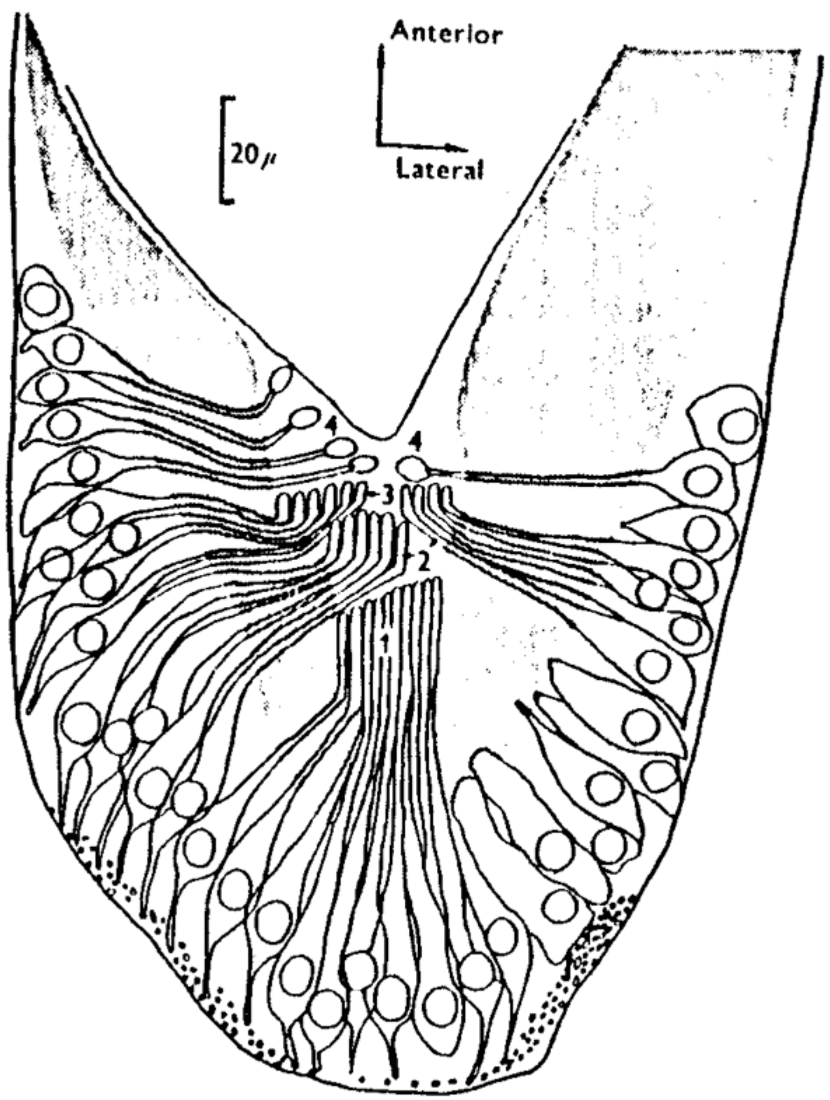
Jumping spider visual system

Spider opthalmoscope
(Michael Land)

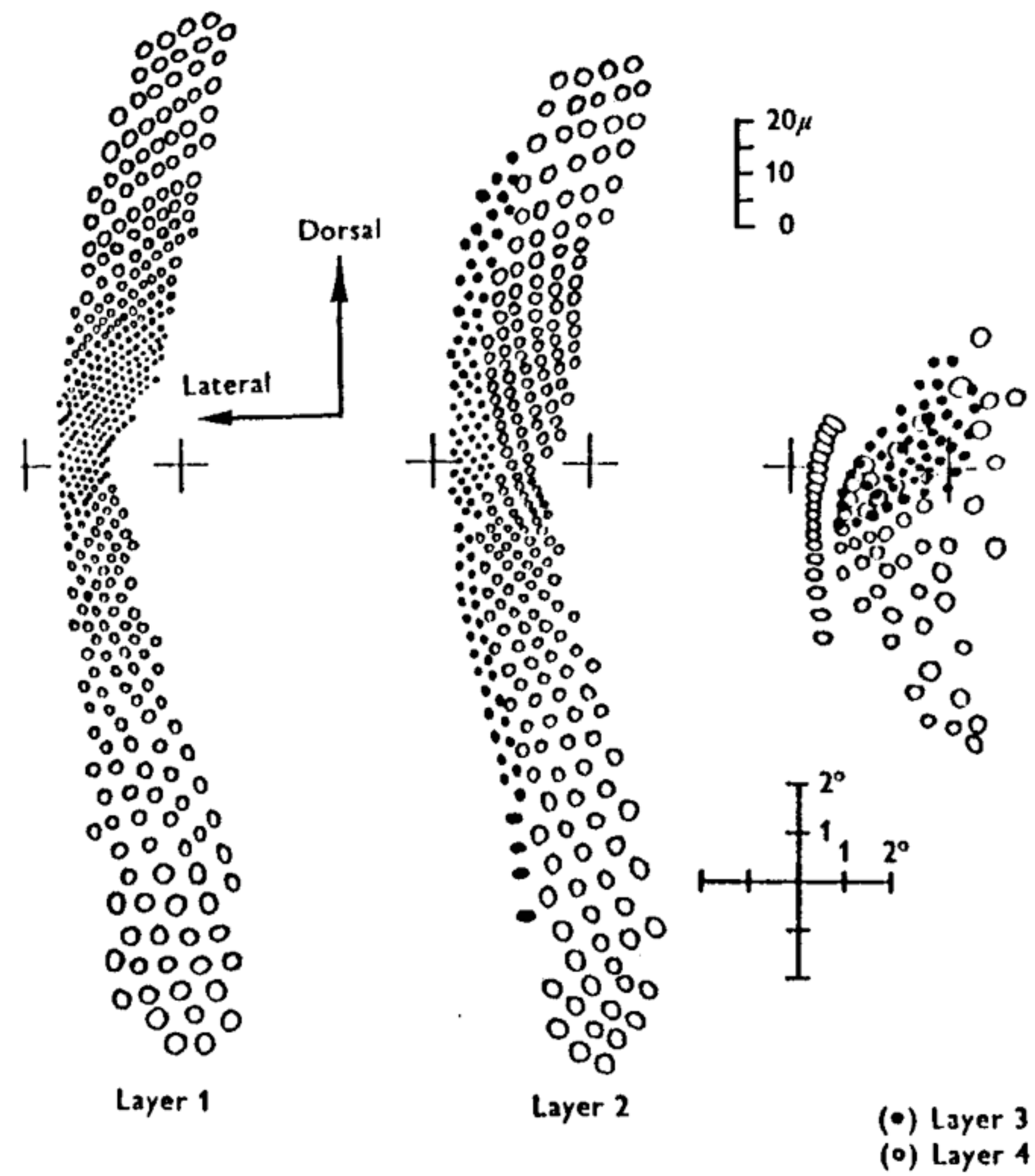


Jumping spider retina

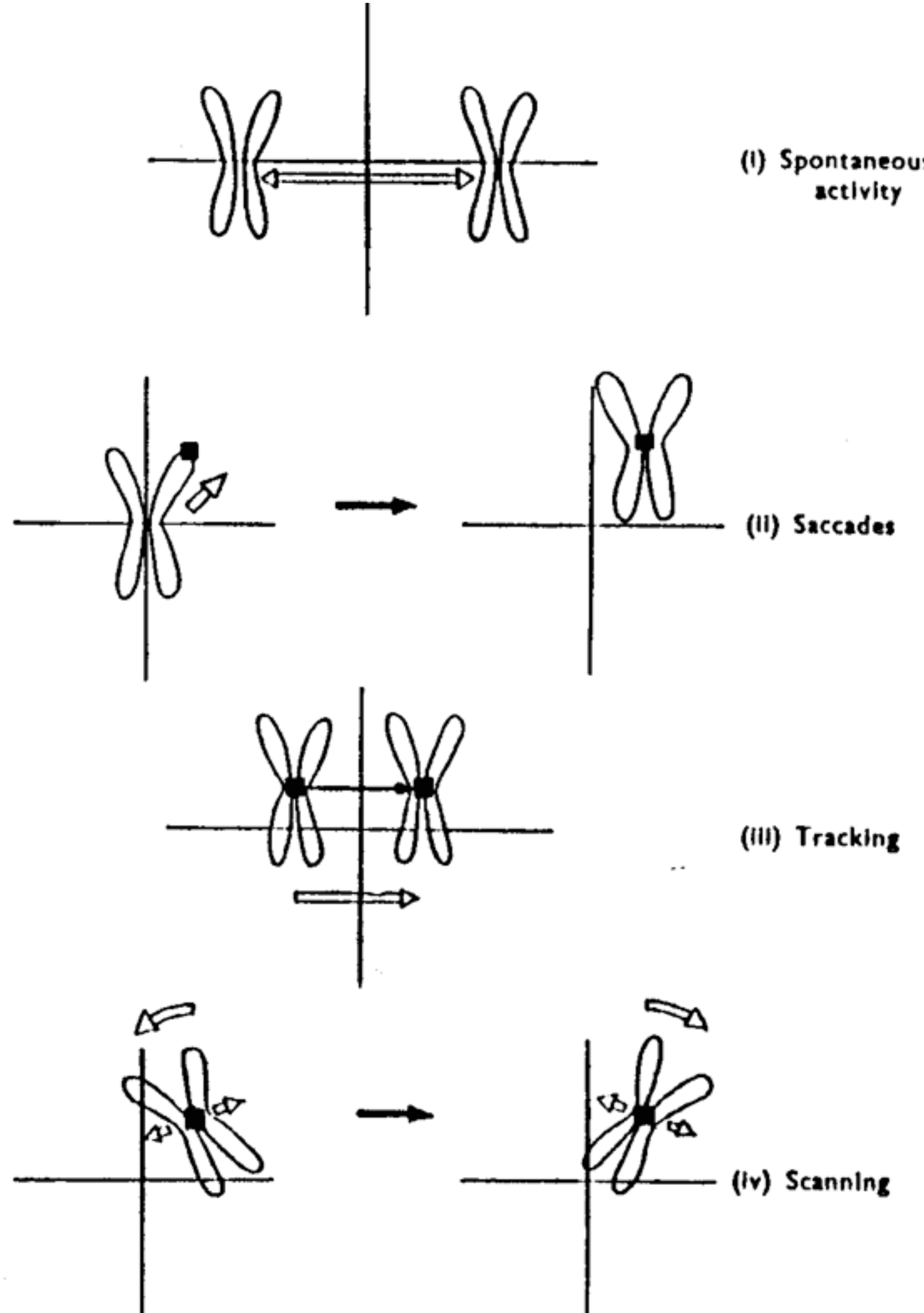
horizontal section



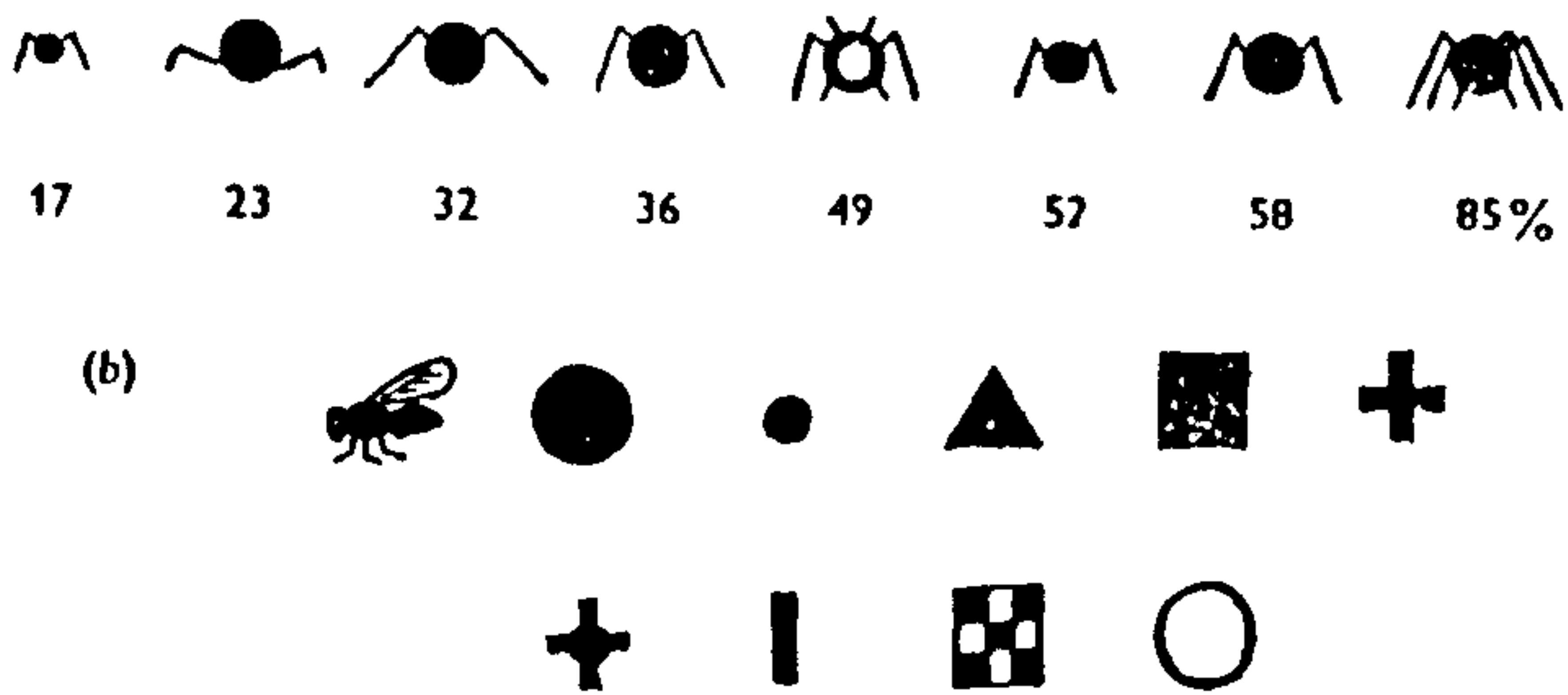
photoreceptor array



Jumping spider eye movements



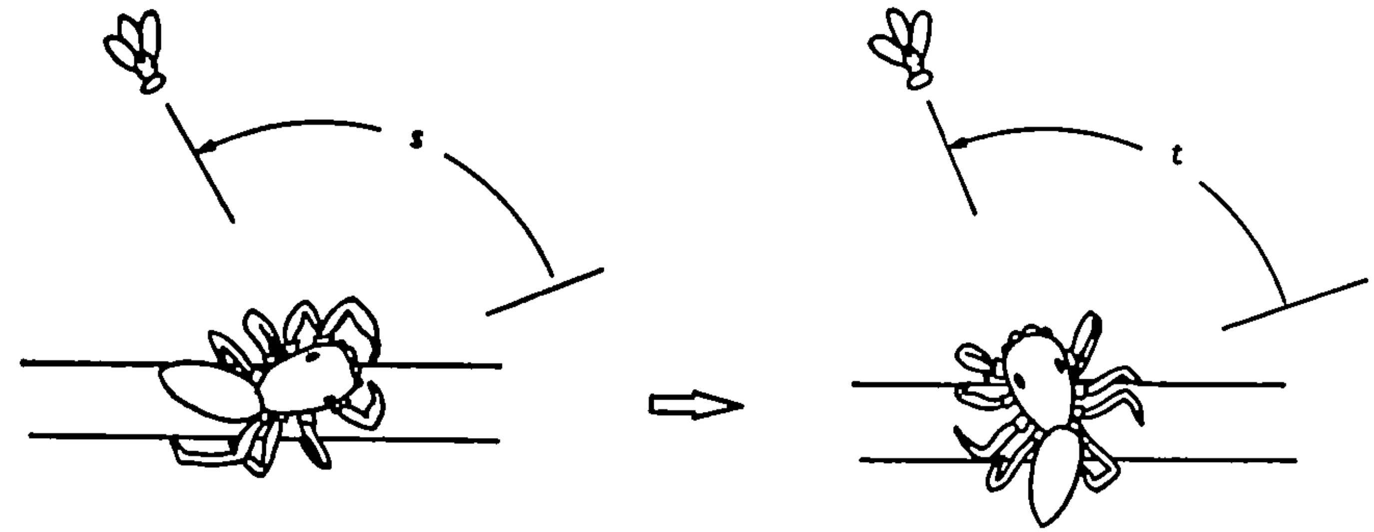
Jumping spiders do object recognition

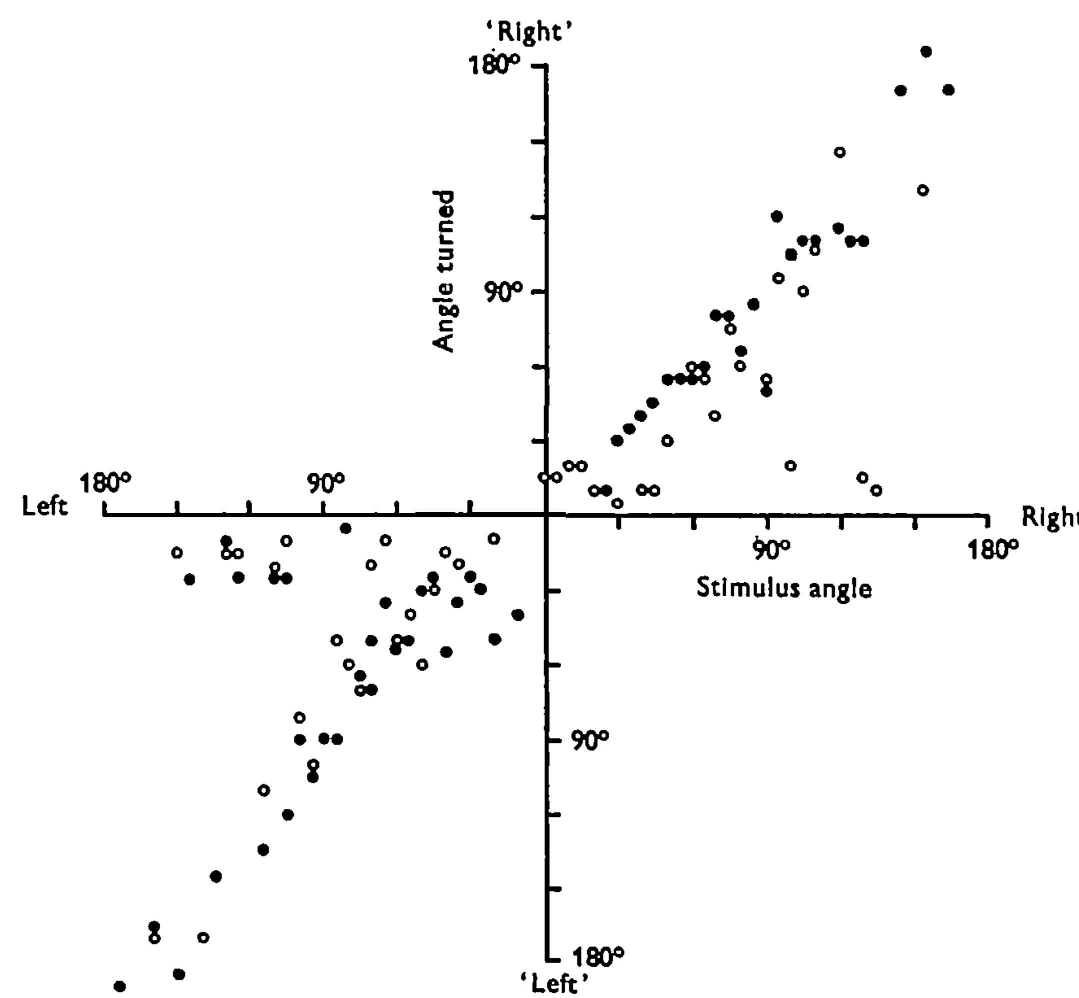


Text-fig. 12. Stimuli found by Drees to evoke courtship (*a*) and prey capture (*b*) in male jumping spiders (*Epiblemum scenicum*). The numbers beneath each figure in (*a*) are the percentage of trials on which courtship was evoked. After Drees (1952).

Prey capture

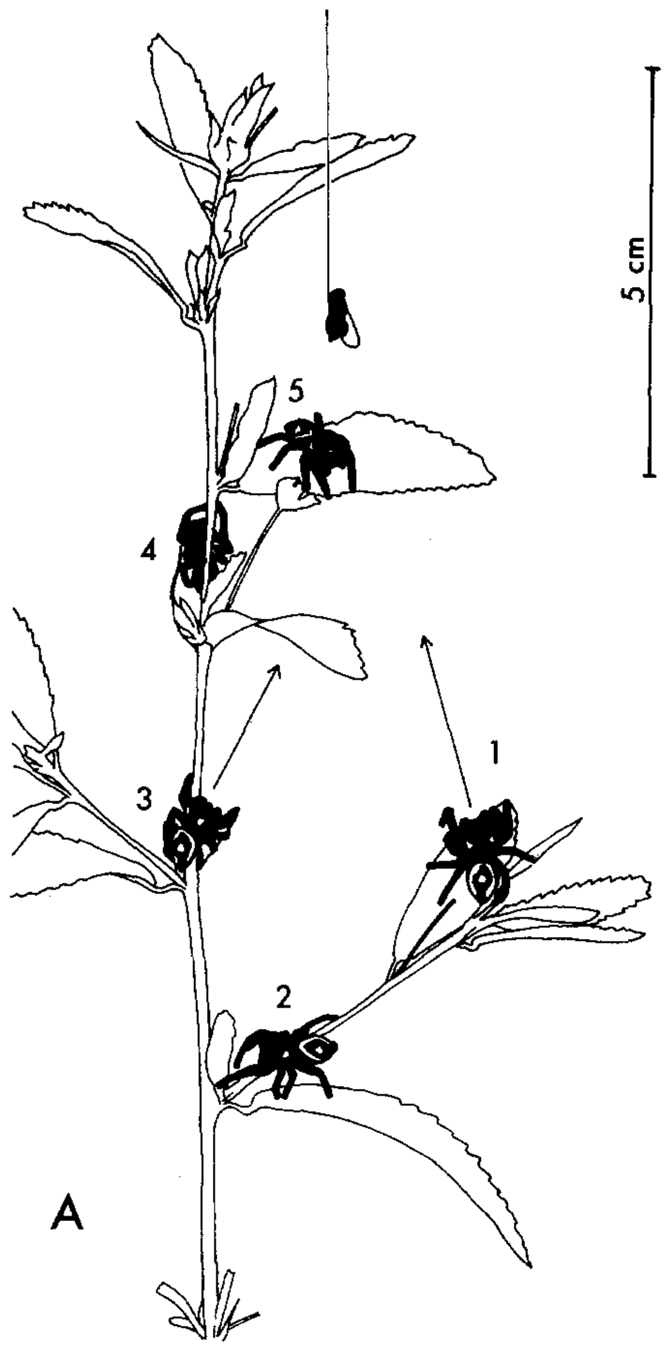
- attention
- orienting
- tracking

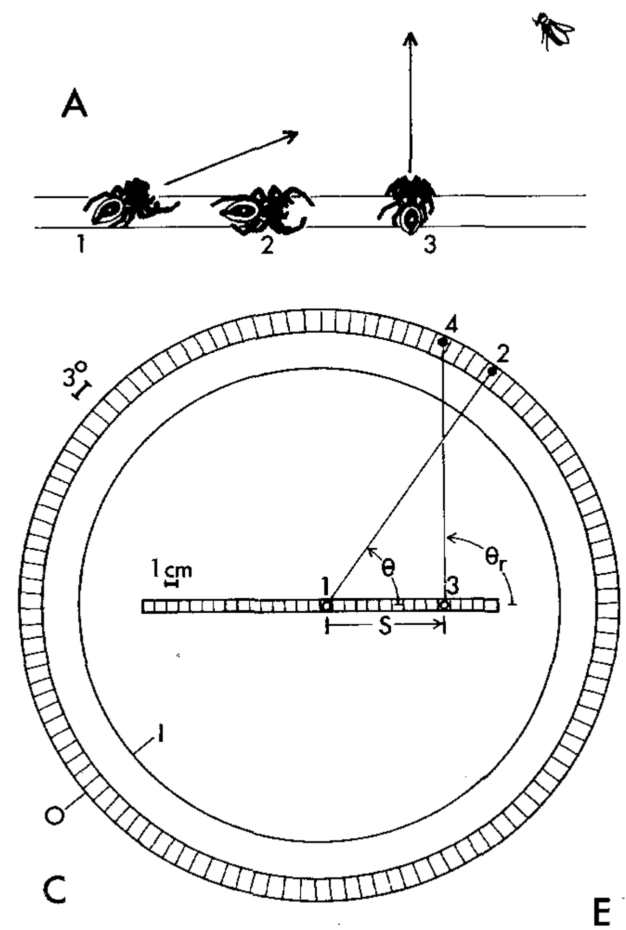


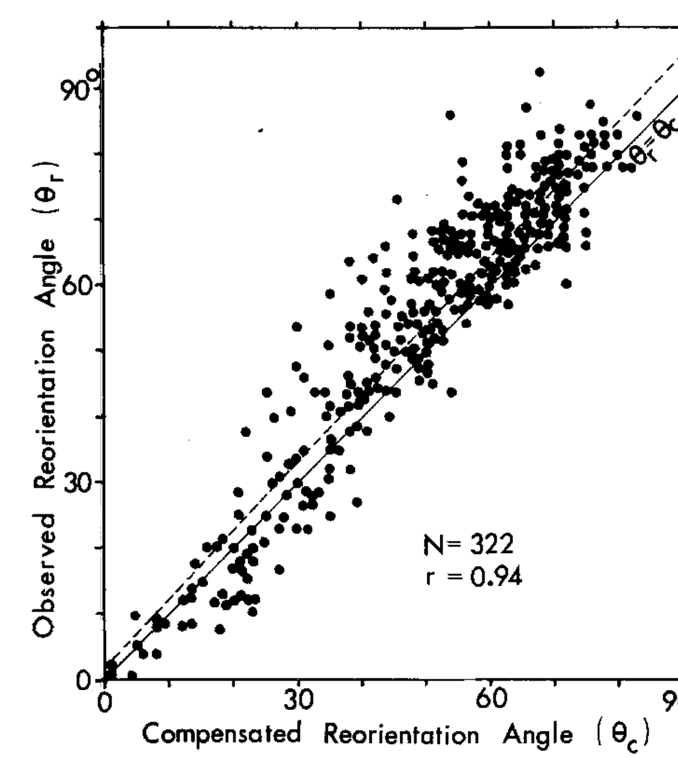


Orientation by Jumping Spiders During the Pursuit of Prey

(D.E. Hill, 1979)







Navigation

(Tarsitano & Jackson 1997)

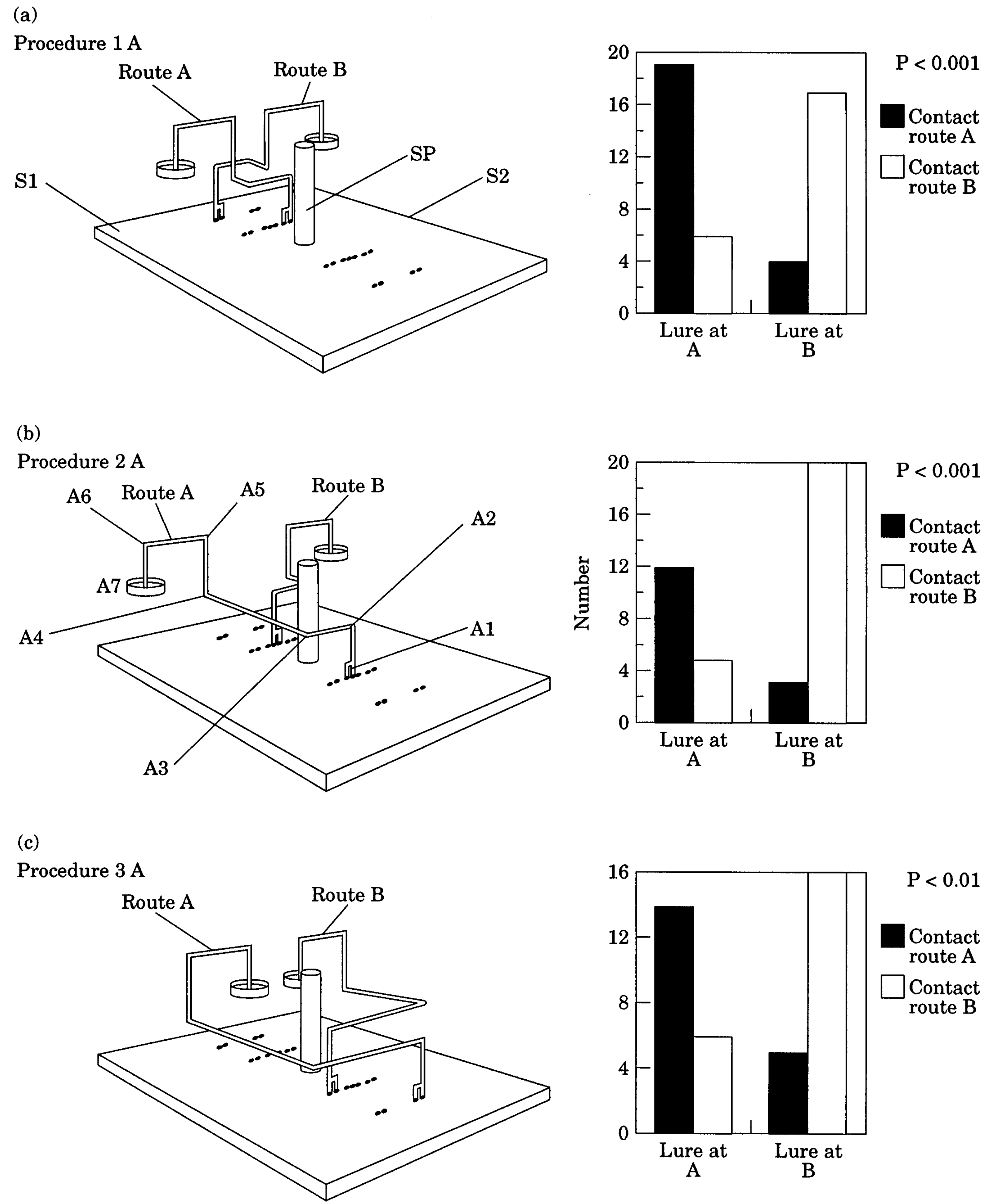
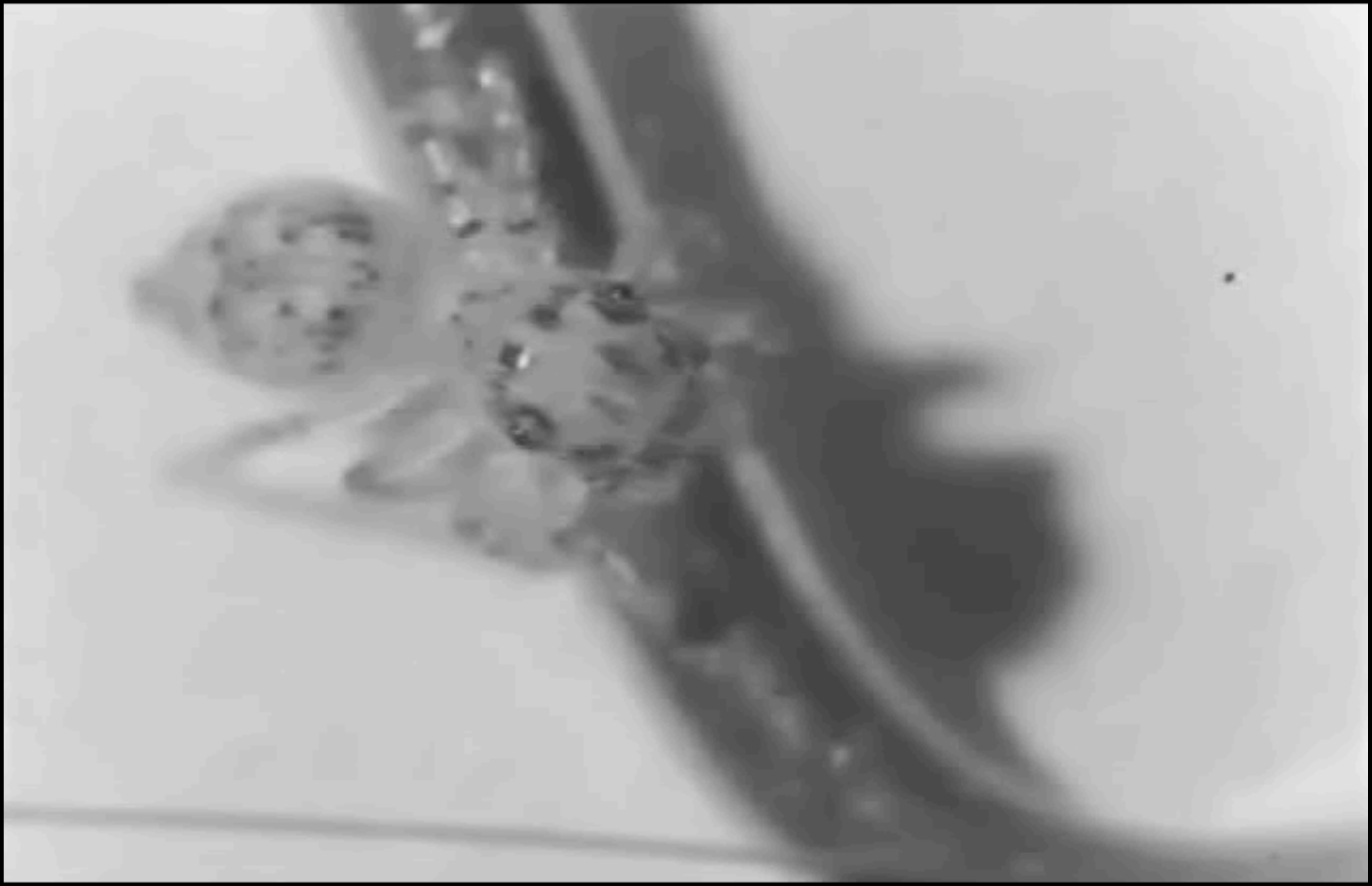


Figure 1 a-c.

One-day old jumping spider
(filmed in the Bower lab, Caltech 1991)



One-day old jumping spider
(filmed in the Bower lab, Caltech 1991)

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(filmed in the Bower lab, Caltech 1991)

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(filmed in the Bower lab, Caltech 1991)

Spatial perception in weakly electric fish