Chemical Signals

- Types
- Production
- Transmission
- Reception
- Reading: Ch 10 except boxes 10.1 and 10.2

What is chemical communication?

- Movement of molecules from sender to receiver
- Methods of propagation
  - Diffusion
  - Current flow
  - Contact with receiver
- Olfactory reception
- Contact reception
  - Food detection
  - Social signals (vomeronasal organs)

Olfactory signal features

- Directionality
  - Generally propagate away, often irregular
- Transmission speed
  - Depends on diffusion rates, wind speeds
- Temporal pattern
  - Difficult to turn on and off
- Spectrum
  - Multi-dimensional

Types of chemical signals

- Hormone
  - Chemical signals used within individuals
  - Produced by endocrine glands
- Pheromone
  - Chemical signals used between conspecifics
  - Produced by exocrine glands
- Allomone
  - Chemical signals used between species

Pheromone examples

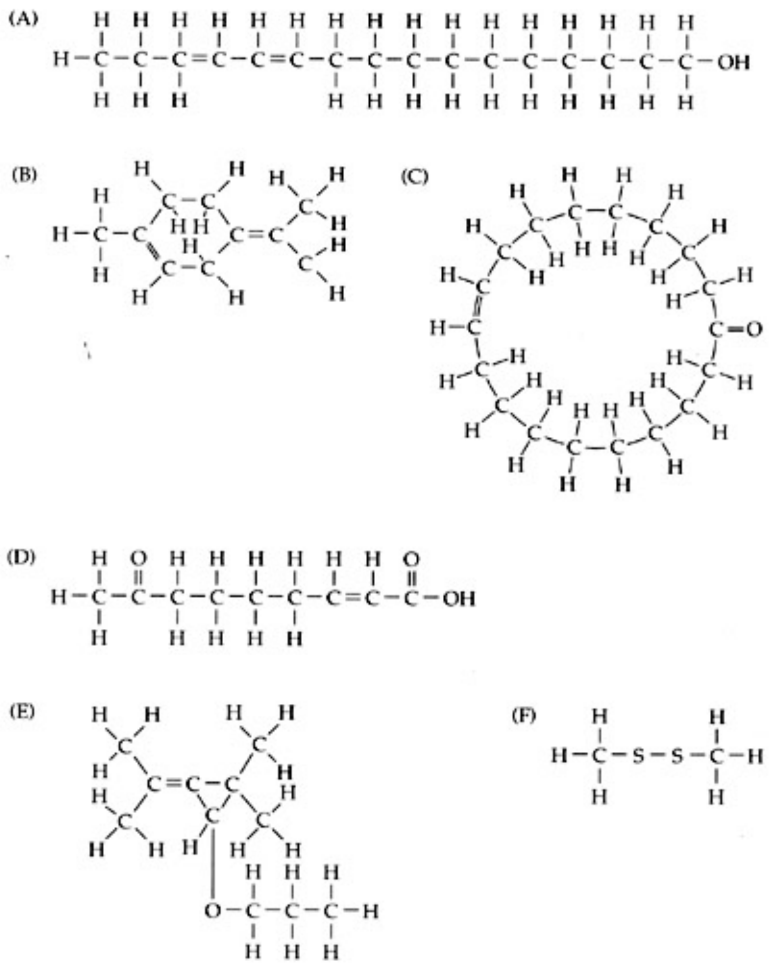


Figure 10.1 Some examples of airborne chemical odorants. (A) Silkworm moth (*Bombyx*) sex attractant, (B) a common termite alarm substance, (C) civet (*Civettictis civetta*) sex attractant, (D) honeybee (*Apis mellifera*) queen substance, (E) cockroach (*Periplaneta americana*) sex attractant, and (F) hamster (*Mesocricetus auratus*) mounting pheromone. In many cases, the pheromone is a mixture of very similar chemicals. (After Wilson 1963; Moore 1968; Johnston 1977.)

Diffusion rate is inversely related to molecule size.

Small compounds are volatile.
- 5-20 carbon compounds
- carbon (MW=12) + hydrogen is less dense than oxygen (MW = 16) + hydrogen ($H_2$0)

Large compounds can persist.
- proteins and lipids

No size restriction for waterborne or deposited chemicals

Production of odors

- Endocrine glands
  - Can influence waste products in urine or feces
- Exocrine secretory glands
  - On skin or internal with ducts to surface
- Body orifices
  - Food digestion (including saliva)
  - Reproduction

Odor glands in mammal skin

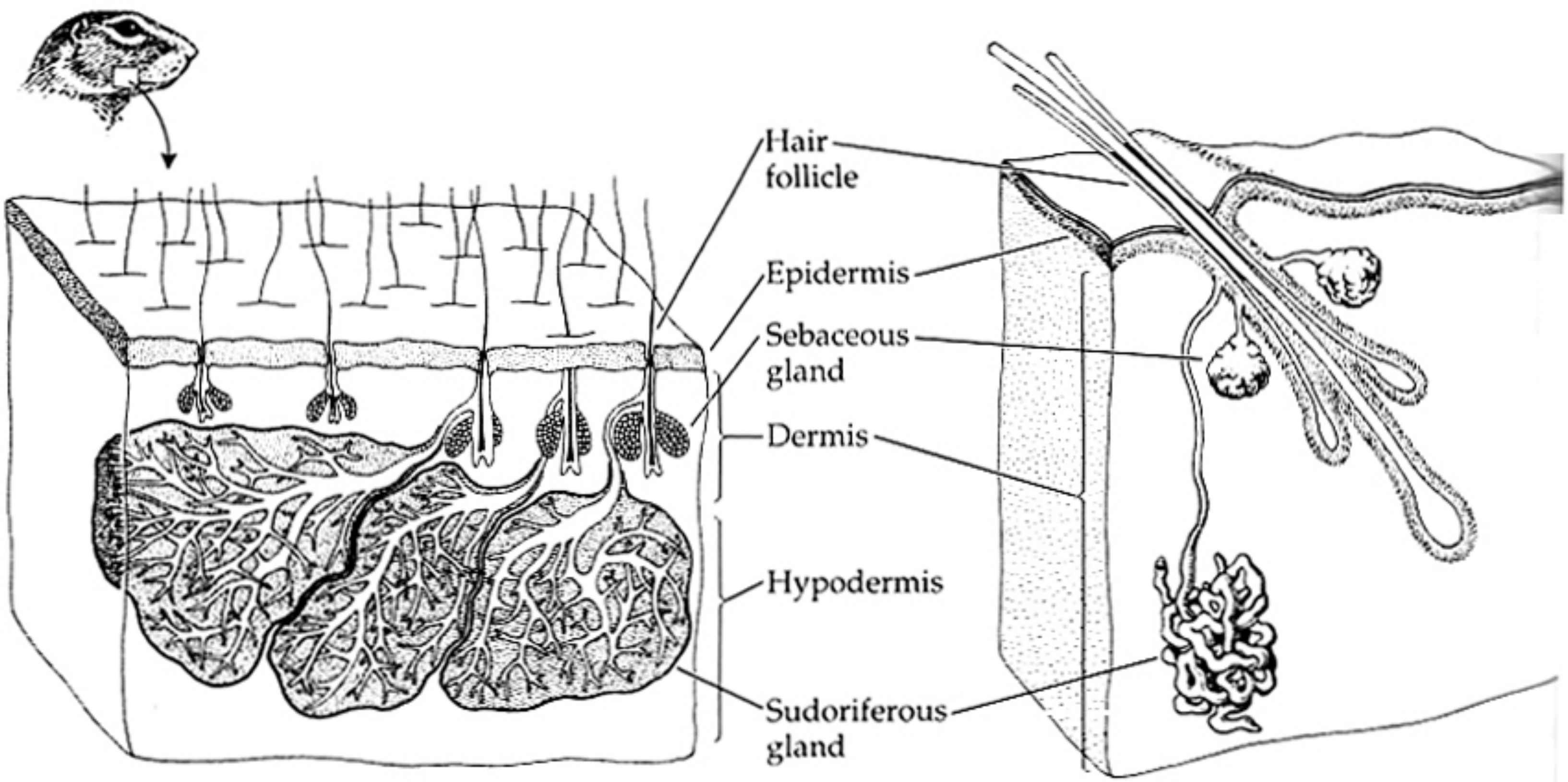
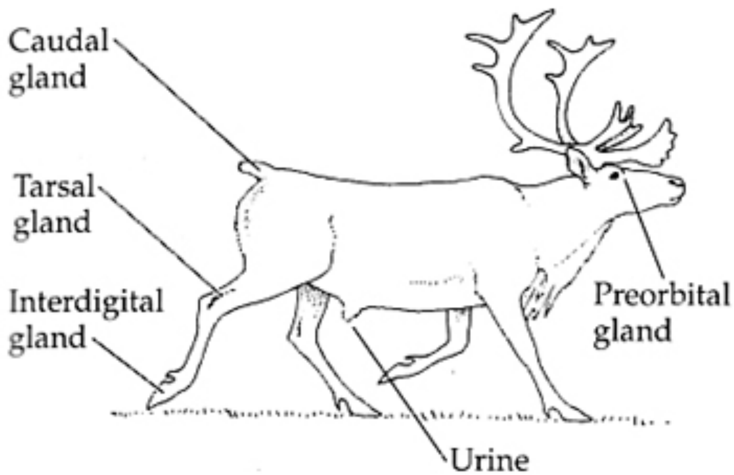


Figure 10.2 Cutaneous glands in mammals. (A) Mongolian gerbil (*Meriones unguiculatus*) cheek gland. (B) Human skin. (After Kivett 1978; Flood 1985.)

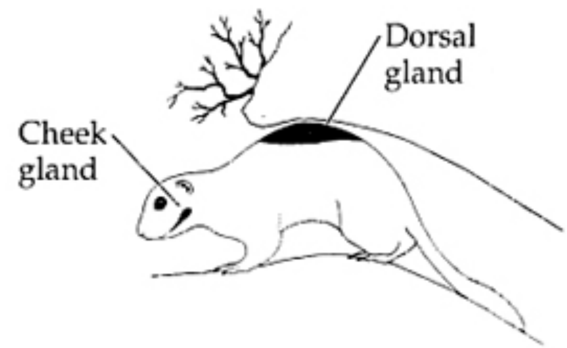
Sebacous - flask-shaped, sloughing cells create sebum - carries pheromones
Sudoriferous - coiled tubes containing liquid pheromones, faster secretion

Vertebrate glands

Reindeer

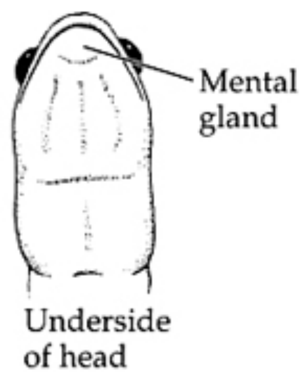


Ground squirrel



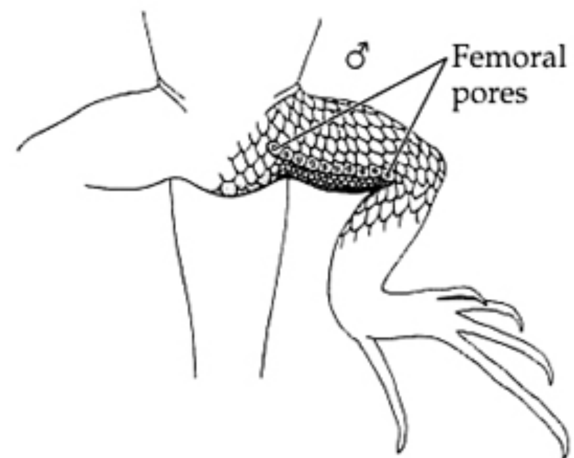
(C)

Salamander



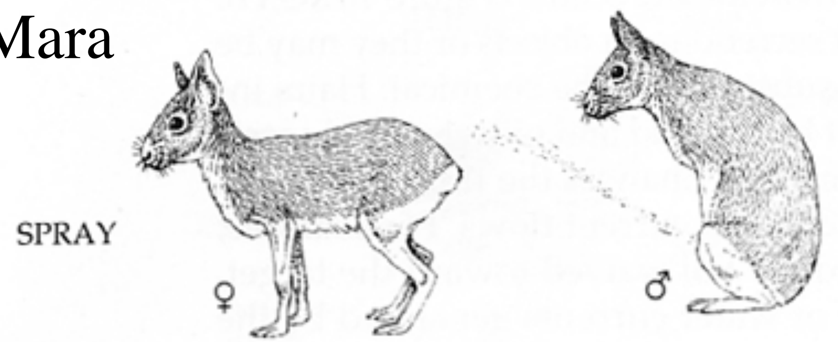
(D)

Iguanid lizard

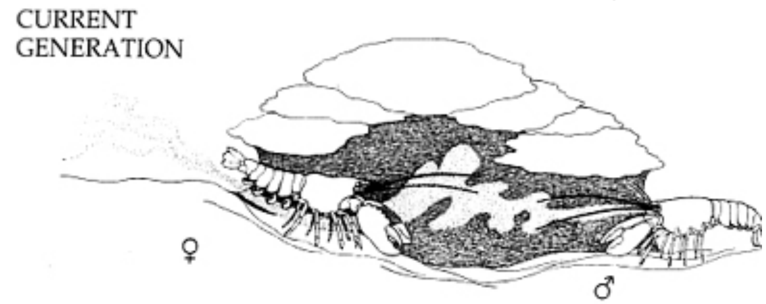


Scent dissemination strategies

Mara



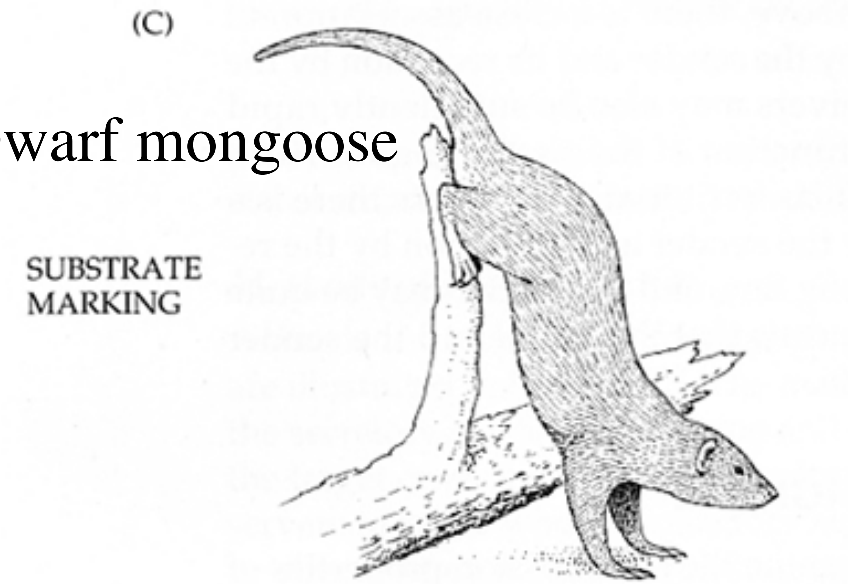
Lobster



Often UV reflectant

Chapin's Free-tailed bat

Dwarf mongoose



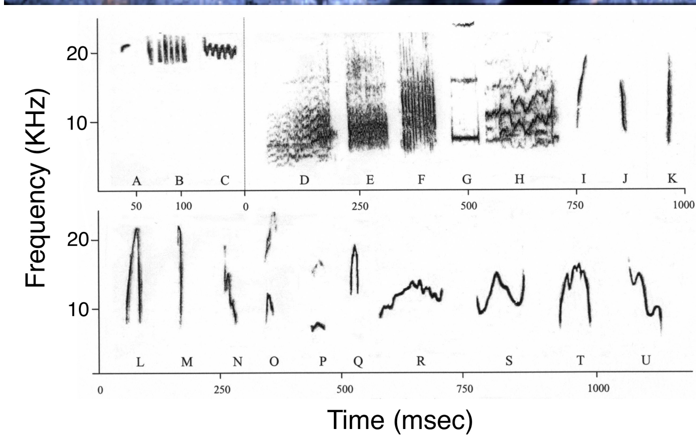
Crested mane rat

Female marking by greater spear-nosed bats

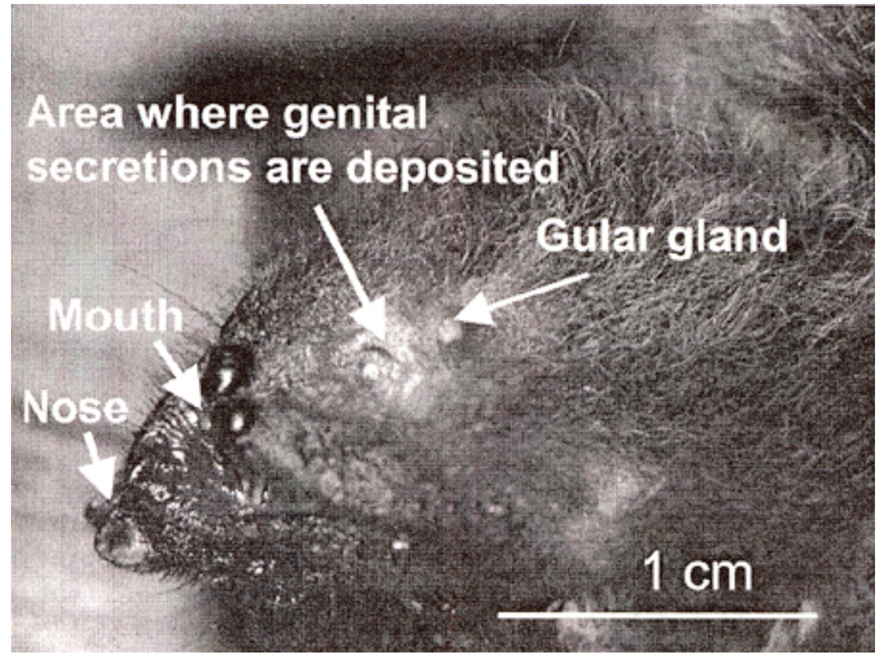
Multi-modal signaling in sac-winged bats

Multi-modal signaling in sac-winged bats

Males sing to and spray females

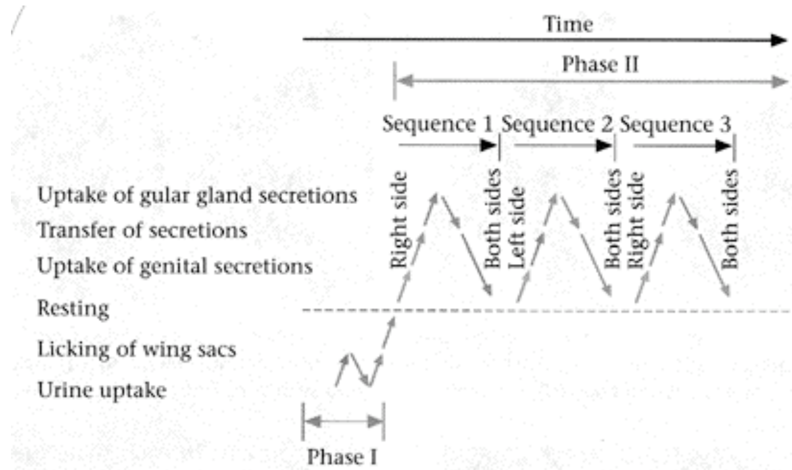


Mark territory boundaries



Davidson, S.M. & Wilkinson, G.S. 2004
Animal Behaviour 67:883-891

Perfume blending in sac-winged bats



Voigt, C. 2002 Anim. Behav. 63:907-913

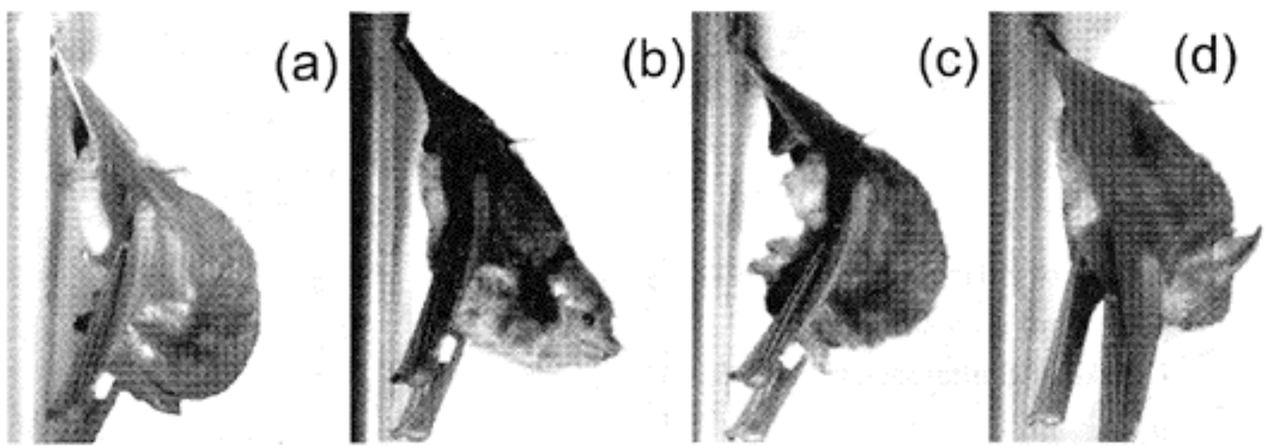


Figure 3. Behavioural elements of perfume blending in male *Saccopteryx bilineata* (photographs modified from Voigt & von Helversen 1999). (**a**) Male bending towards the genital region for urine uptake during the first phase of perfume blending, (**b**) male in resting position, (**c**) male bending towards genital region for secretion uptake, (**d**) and male transferring secretions from gular region into one of the wing sacs.

Scent glands in ants

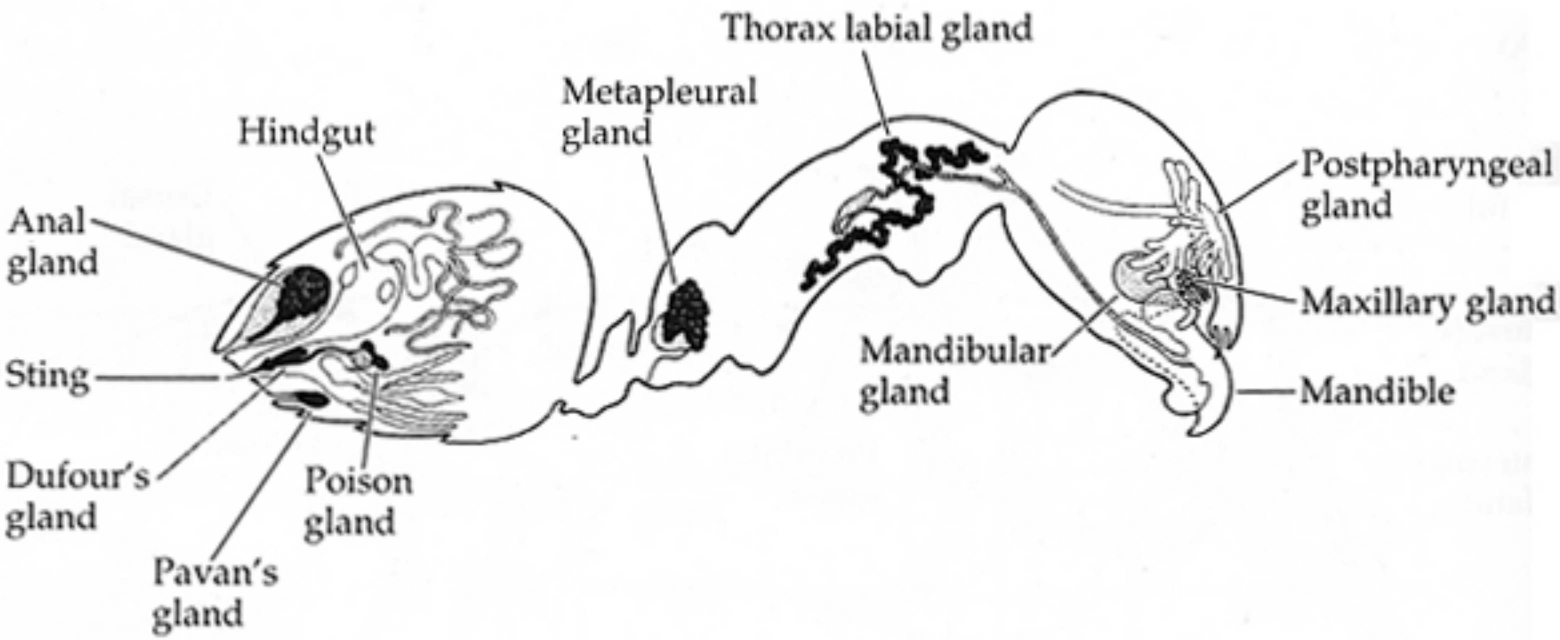
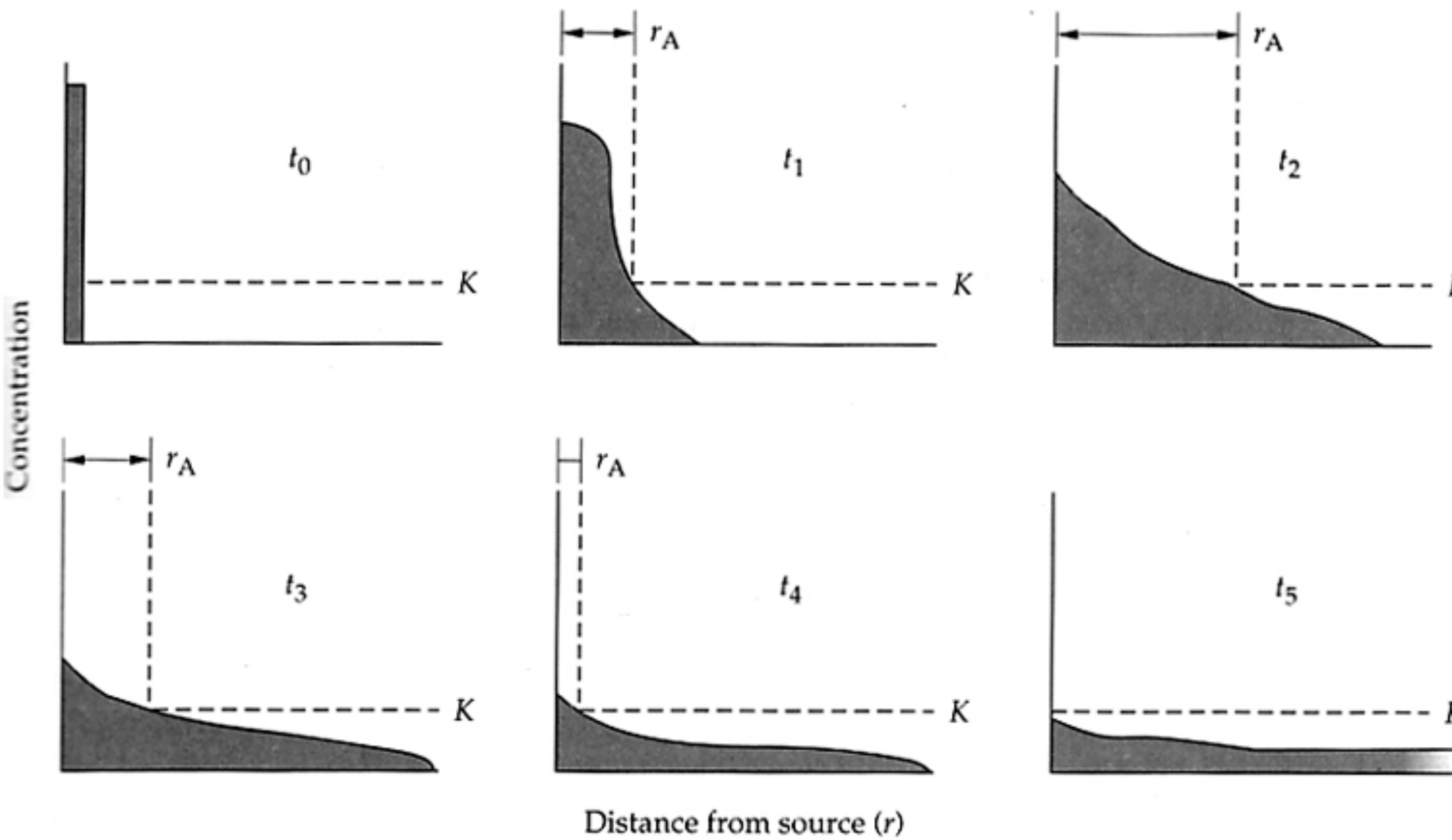


Figure 10.4 Glands of a worker ant (*Iridomyrmex humilis*). (After Wilson 1971.)

Diffusion

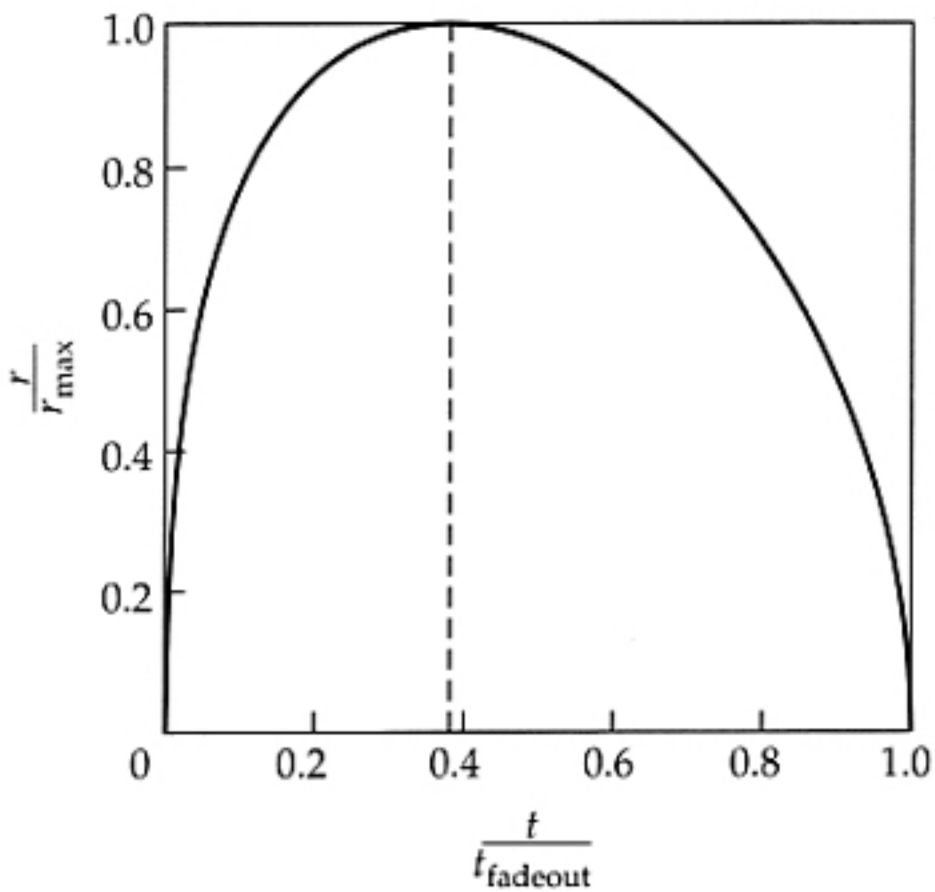
- Movement of molecules from areas of high concentration to low
- Rate depends on
  - Steepness of concentration gradient
  - Molecule size
  - Medium type
- Described by Fick's first law

Diffusion of a scent puff



K = threshold of detection, r_A = active space, t = time

Active space is dynamic



There is a maximum size of active space which is set by the detection threshold and amount of odorant released. Independent of diffusion rate.

Figure 10.9 Change in the diameter of the active space over time. The active space increases, then decreases with time. The time to reach r_{max} is always 0.37 times the time to fadeout.

Media affects transmission

Table 10.1 Typical values of r_{max}, $t_{r_{max}}$ and $t_{fadeout}$ in air and water for a Q/K ratio of 1500

	Q/K	D	r_{max}	$t_{r_{max}}$	$t_{fadeout}$
Air	1500	0.5 cm^2/sec	6 cm	13 sec	35 sec
Water	1500	0.00005 cm^2/sec	6 cm	33.5 hr	92 hr

Q = number of molecules released
K = detection threshold
D = diffusion rate

Diffusion is slow in water. Need to be close, sessile or utilize current.

Diffusion from a trail

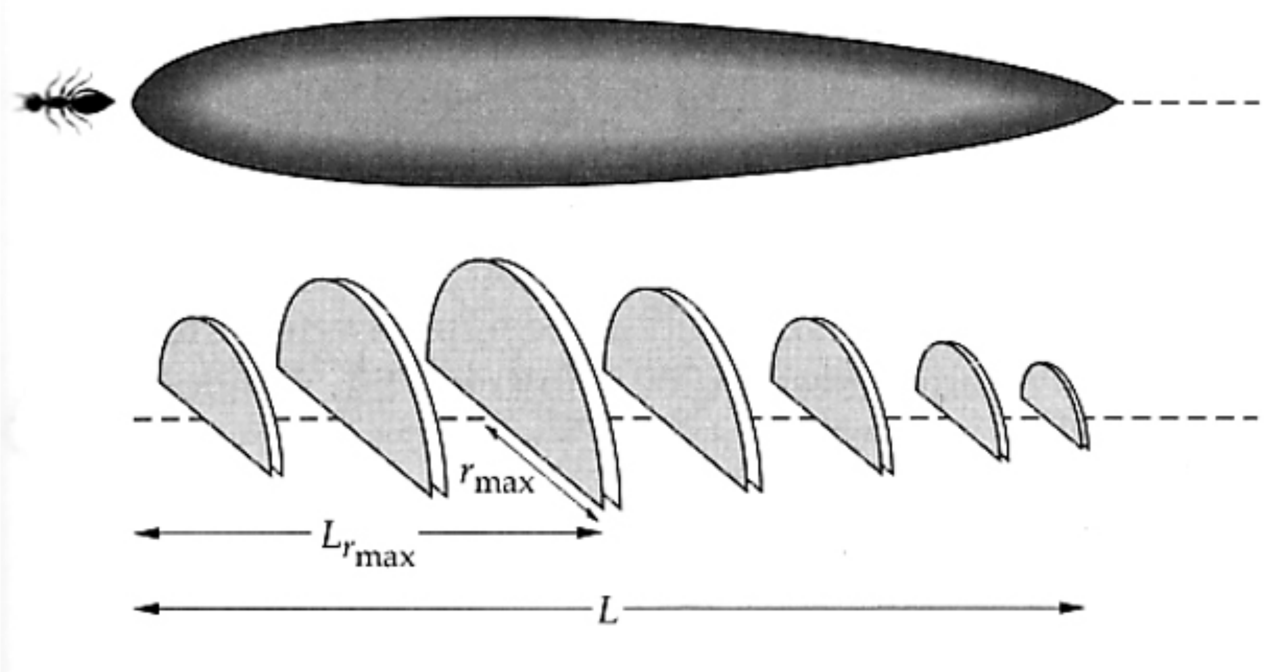


Figure 10.11 Active space of an ant trail. A trail is essentially a sequential series of small single puffs along a linear transect. L is the length of the active space, r_{max} is the width of the active space, and $L_{r_{max}}$ is the distance of the maximum radius point from the ant.

Modeled as a series of single emissions from a moving source
Width depends on Q/K. r_{max} occurs at 0.37 of length.

Diffusion in laminar flow

Laminar flow: smooth, parallel motion of media

In theory R_{max} is independent of flow

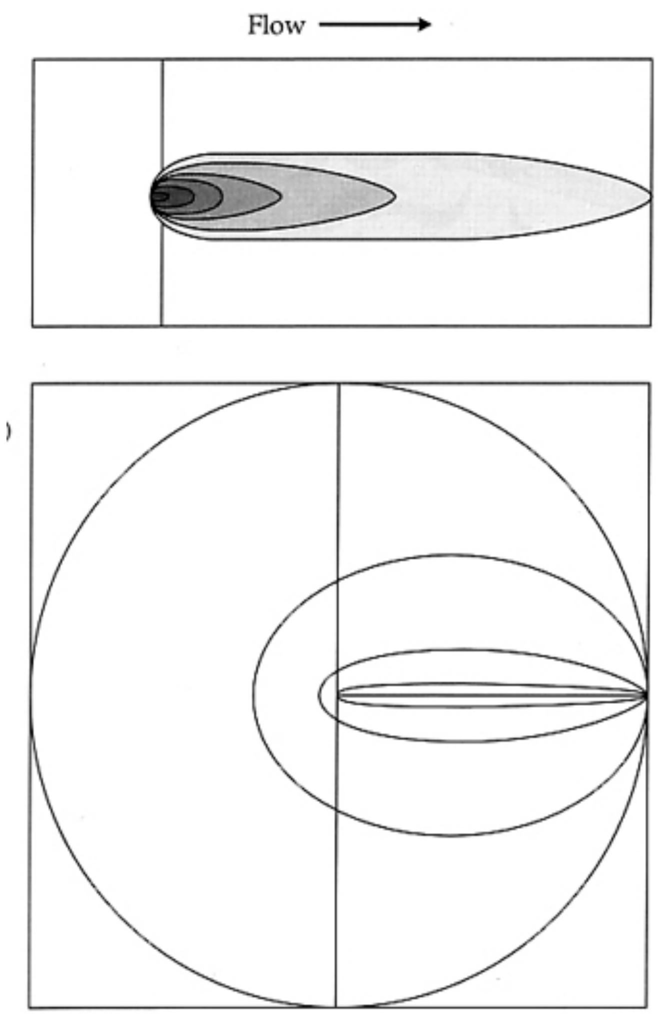
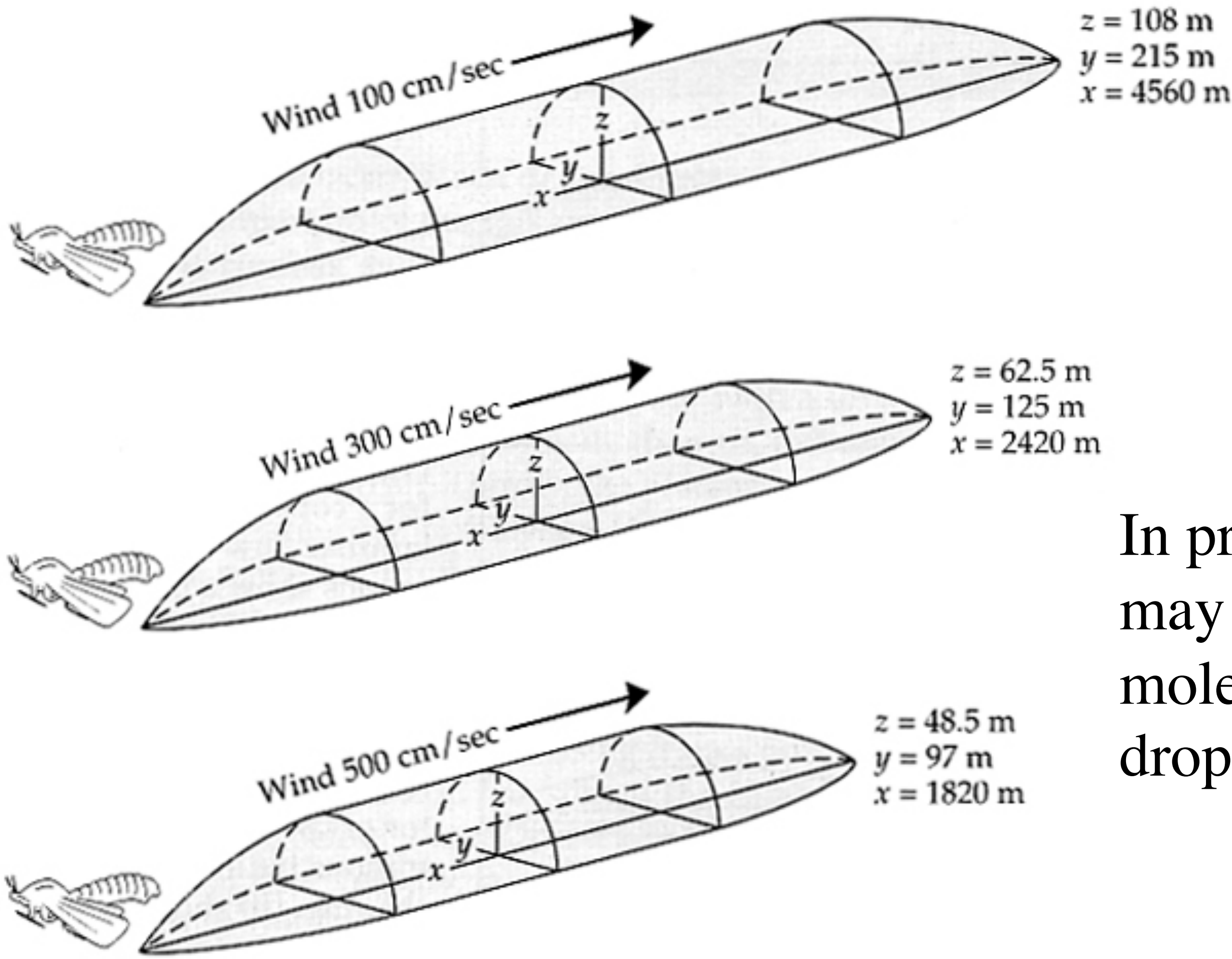


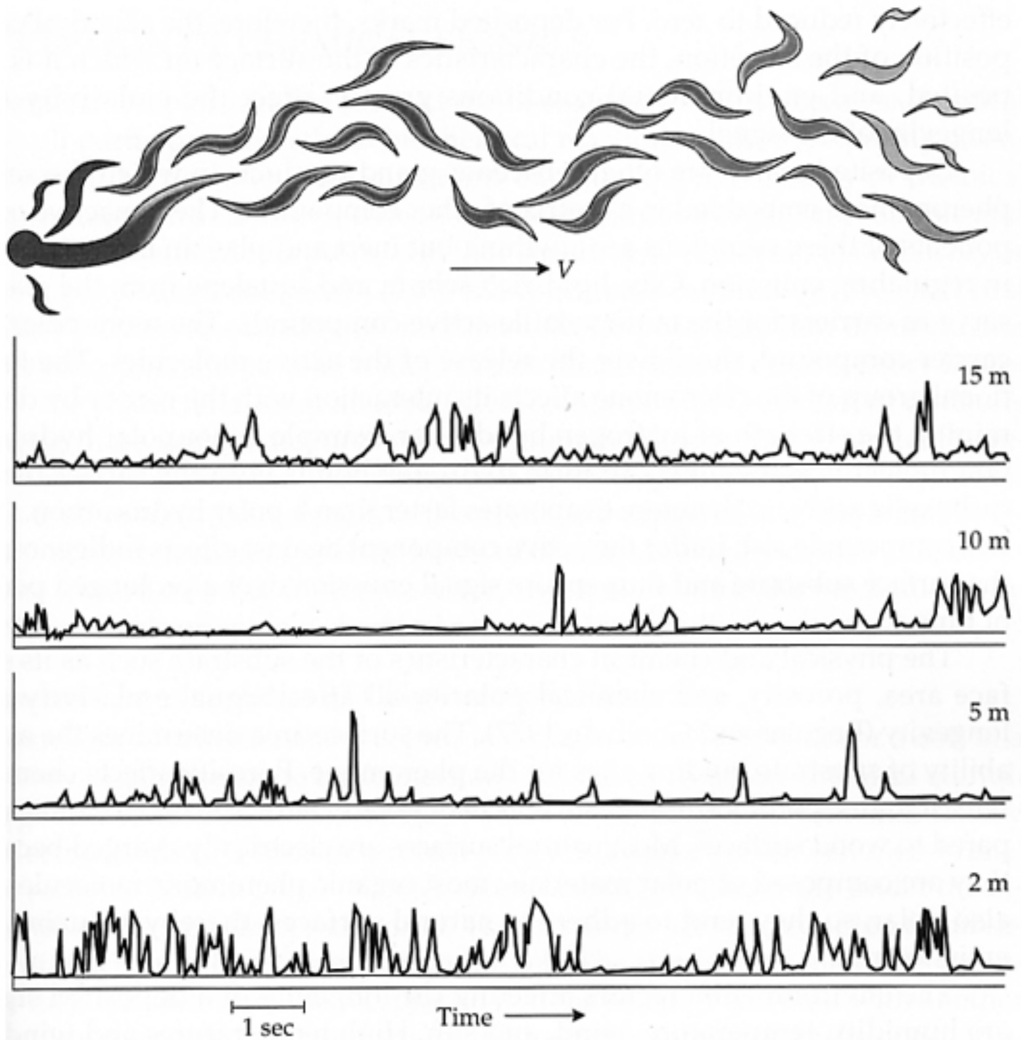
Figure 10.13 Active space for a constant source in a laminar flow field. Both graphs show a continuous source emitting at a constant rate from a point on the thin vertical line. (A) shows contours of equal intensity, with the contours differing by a factor of two and higher concentrations indicated with darker shading. (B) shows a single intensity contour for different flow speeds. The sphere represents the active space with no flow, and increasing flow narrows the space but does not increase r_{max}. (From Dusenbery 1992, © W. H. Freeman.)

Moth active space in wind



In practice, Rmax may decrease if molecule density drops sufficiently fast

Diffusion in turbulent flow



Much more common to have turbulence

Makes it difficult to follow odor trail

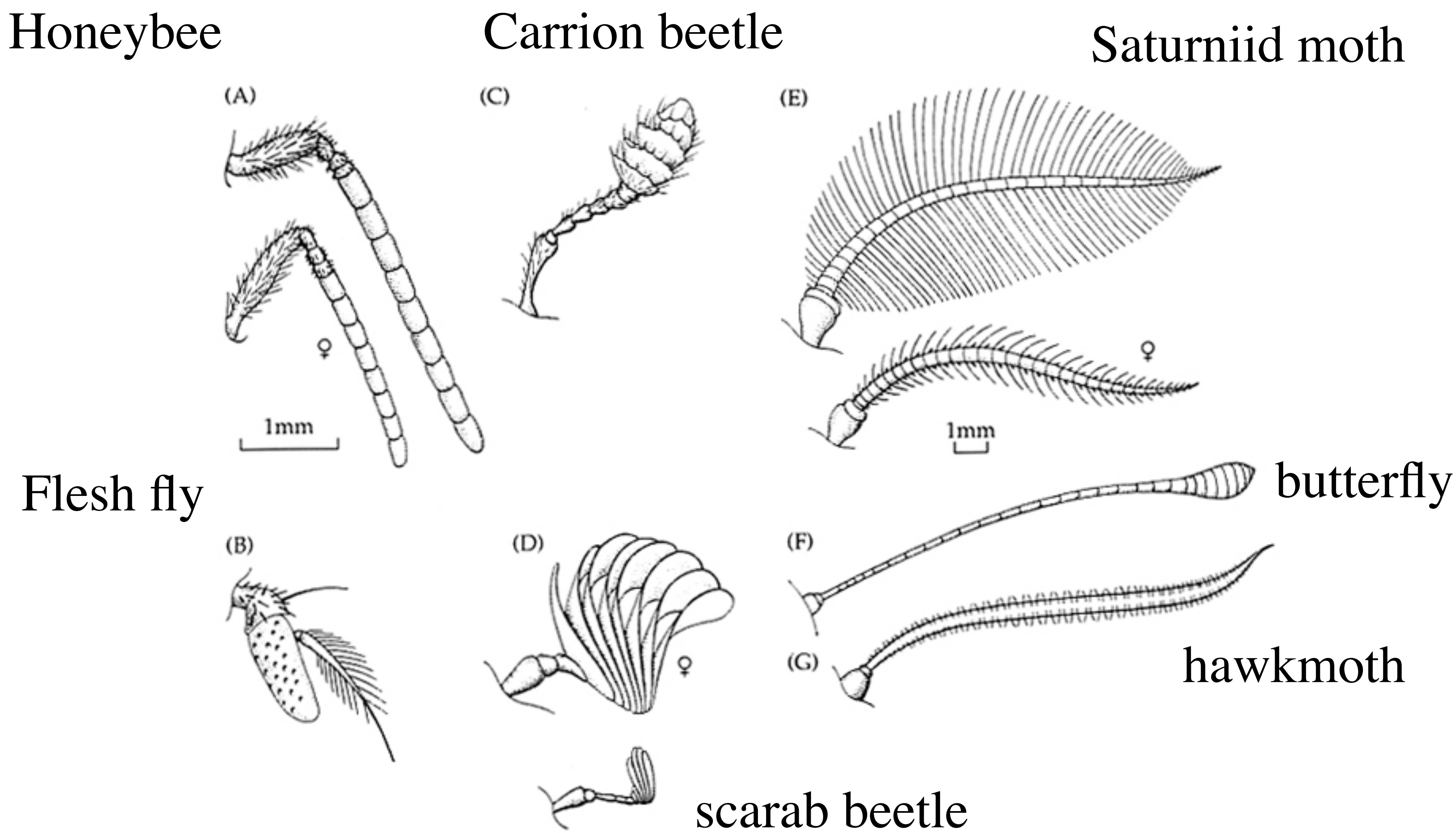
Transmission of deposited odors

- Scent marks are often designed to maximize fadeout time
  - Embedded in sebum matrix
  - Large molecular weight
  - Deposited on porous material to impede loss
- Volatile in presence of water
  - Licking releases pheromone to receiver - lizards
  - But, degrade quickly in humidity

Strategies for chemoreception

- The ideal chemosensory organ
  - Responds to range of different chemicals
  - Sensitive to low concentrations
- Labeled-line coding
  - Individual receptors respond to single chemicals
  - Organ has many different cells types
  - Higher sensitivity, lower generality
- Across-neuron coding
  - Receptors respond broadly but with different profiles
  - Stimuli encoded by response across receptor population
  - Lower sensitivity, greater generality

Insect odor receptor organs



Insect olfactory sensilla

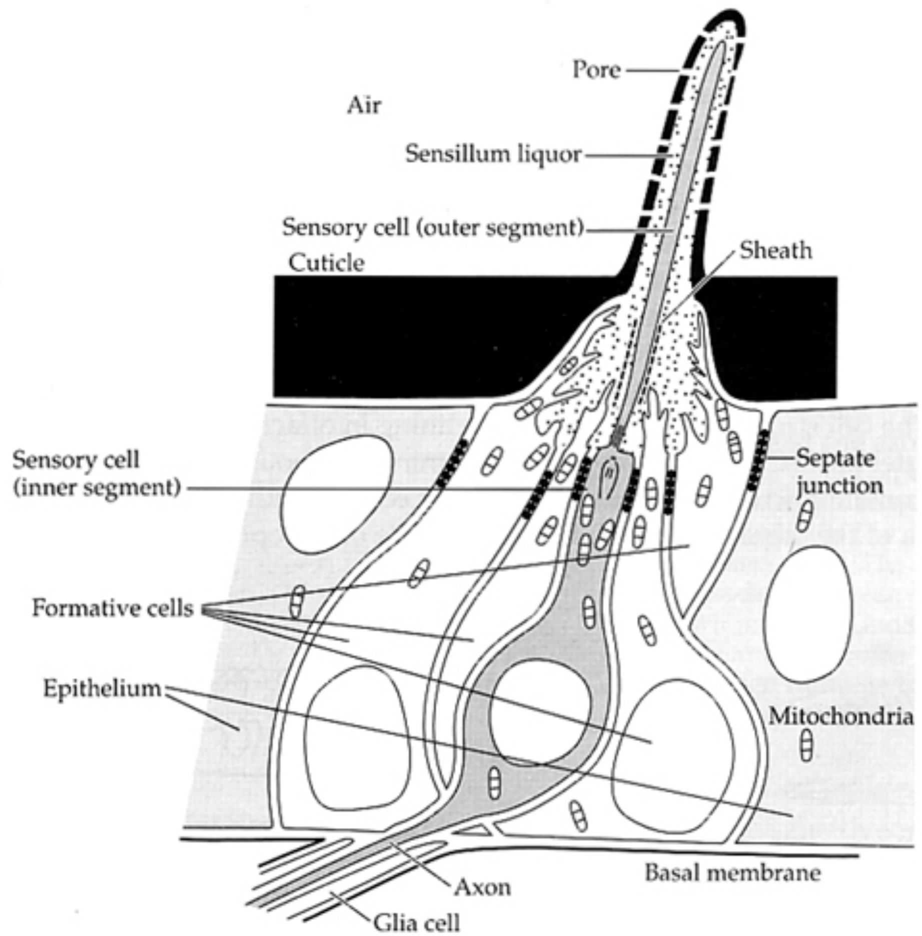
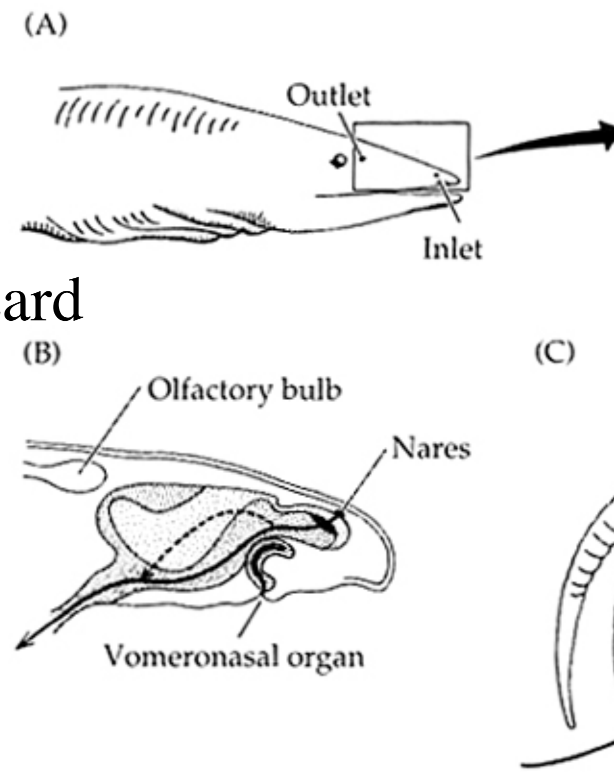


Figure 10.17 Insect olfactory sensillum. An olfactory sensillum looks like a simple hair, but the surface of the hair possesses pores to permit the passage of olfactory molecules into the interior. Inside, the outer segments of from one to three sensory cells are bathed in a liquid medium. The sensory cells are directly connected to the brain. (After Kaissling 1971.)

Vertebrate odor receptor organs

Eel

Lizard



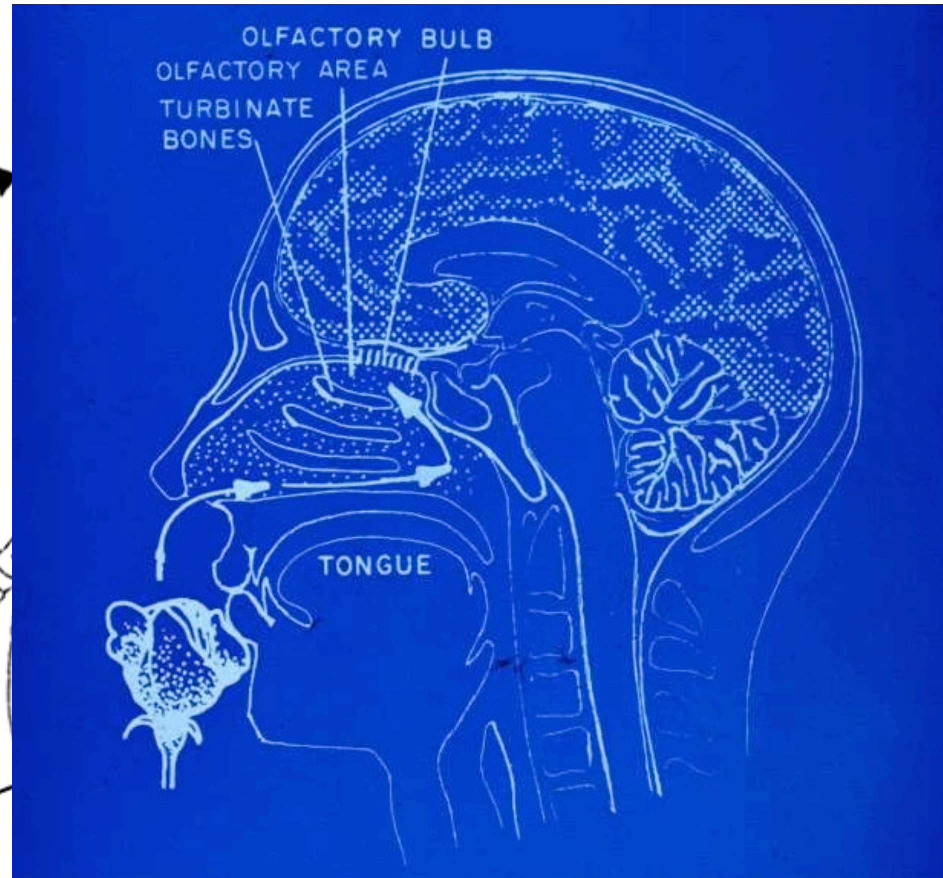


Figure 9.112. Parasagittal cross-section of the head showing the three turbinate bones, the olfactory area, and the termination of the endings of nerves from the olfactory bulb in the olfactory epithelium. The passage of air-bearing odorous substances is shown by *arrows*. [From Amoore et al. (1964).]

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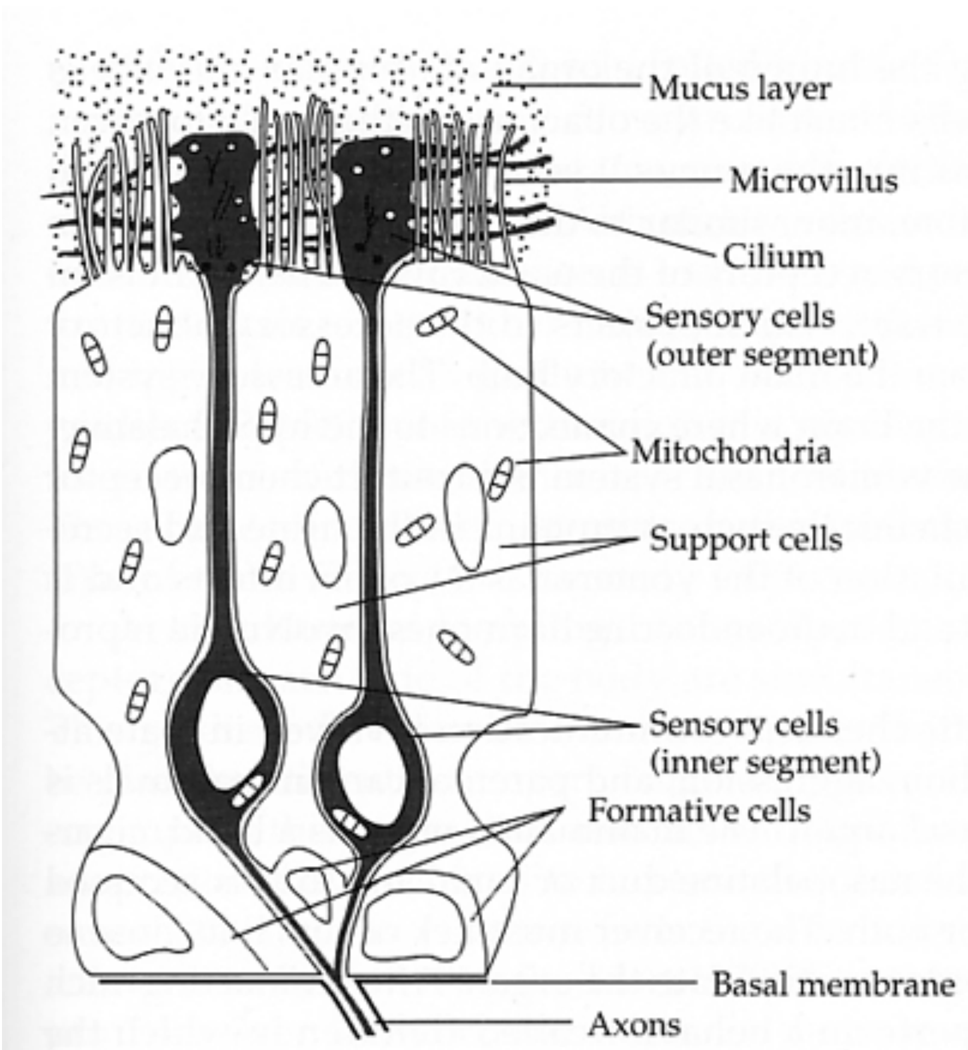
Vomeronasal organ de

Olfactory receptor cell



Found in olfactory epithelium

Receptor cells
are short-lived (< 60 d),

Axons travel to olfactory bulb where there is an odor-topic map

Olfactory receptor genes

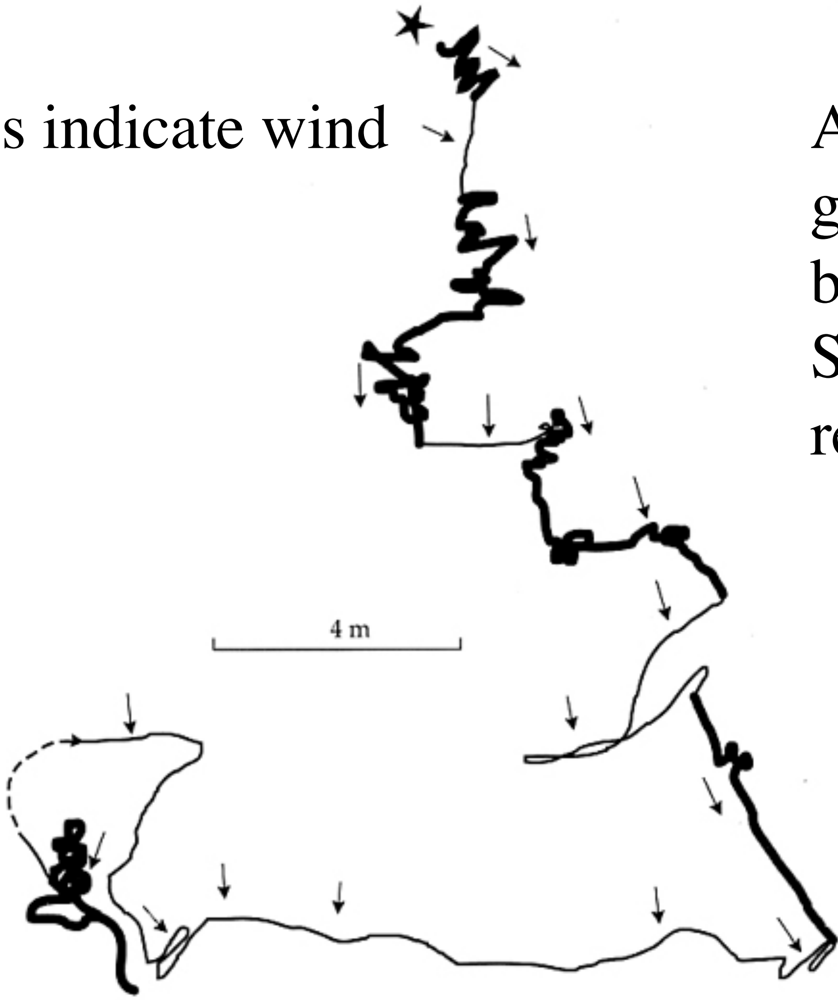
- Largest gene family in vertebrates
  - 1296 different genes in mice
  - Less than 400 genes in humans
  - Why?
- Olfactory receptor proteins have 7 trans-membrane domains (like opsins)
  - Each receptor type binds a specific odor molecule

Gradient detection and orientation

- Simultaneous sampling
  - Requires paired olfactory receptors at sides of body.
  - Need wide head or nose on appendage (antenna)
- Sequential sampling
  - Animals follow concentration gradient, requires tracking back and forth across trail.

Moth scent tracking

Arrows indicate wind



Animals follow concentration gradient, requires tracking back and forth across trail. Some have paired olfactory receptors at sides of body.