

# Pheromones

(exohormones, ectohormones)



# Pheromones

**Substances ensuring chemical communication among individuals of the same species.**

- excreted by the exocrine glands into the environment (excretion or secretion)
- invertebrates (insects, echinoderms), some vertebrates, plants, but also unicellular organisms (fungi)
- neural and hormonal regulation
- mostly volatile, but also liquid in nature
- usually active in minute amounts and low concentrations (several molecules)
- act over long distances
- affected by atmospheric conditions
- effect on behavior, development processes



# Types of pheromones

According to the chemical structure of the pheromone.

By type of behavior that is affected:

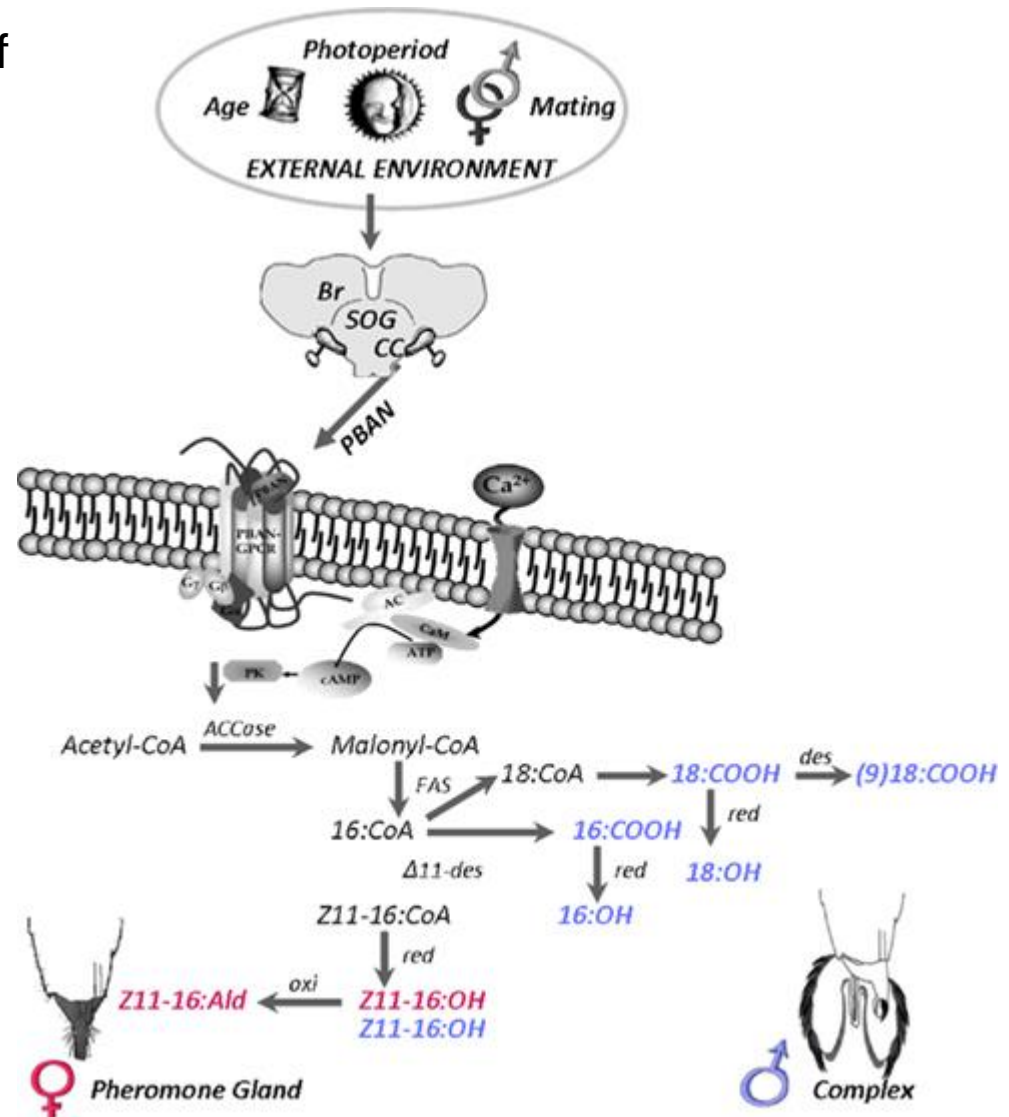
- **sex** - Partner localisation, pre-mating behavior, but also pheromones regulating reproduction (e.g. marking a place for the egg laying)
- **warning / alarm** - defensive behavior and escape reactions (e.g. aphids) or aggression (e.g. ants or bees)
- **aggregation / antiaggregation (dispersing)** - act independently of sex for the purpose of defending, reproducing or designating a food source (e.g. Coleoptera, Diptera, Hemiptera, or Orthoptera)
- **territorial** (e.g. in the urine of dogs and cats)
- **tracking** (e.g. marking of food routes by ants)
- **migratory** (e.g. synchronised migration of caterpillars)
- **triggering** (releaser) - act for a short time, but elicits a strong response (e.g. pheromones produced by a female rabbit during lactation trigger and strengthen nursing behavior)

# Pheromones – mode of action

- neuronal and hormonal control of pheromone production (e.g. pheromone biosynthesis-activating neuropeptides, PBAN)
- synthetic pathway according to the chemical structure of the pheromone



*Helicoverpa armigera*



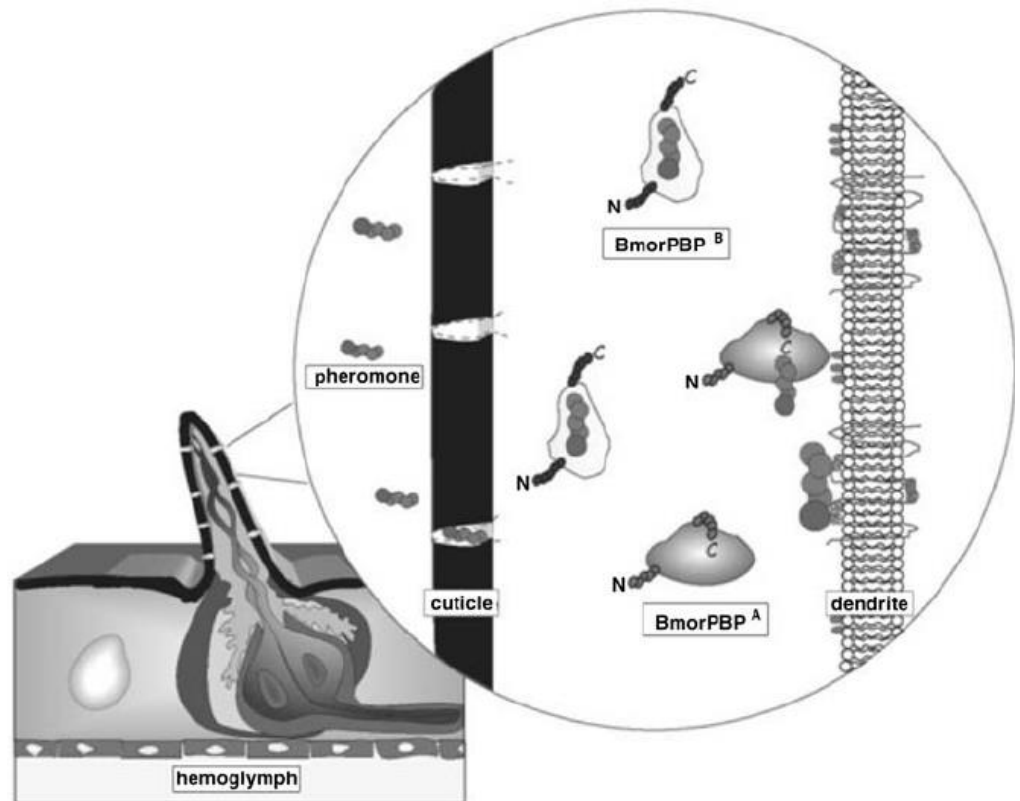


# Pheromones – mode of action

- affect recipients through the activation of nerve pathways, including the autonomic nervous system
- crossing the body surface > providing protection against degrading enzymes and binding to receptors in the olfactory organs (tentacles, sensills) > depolarization of neuronal receptor > brain > response of target organism
- physiological changes, affecting the immune system (inflammatory response) or behavior

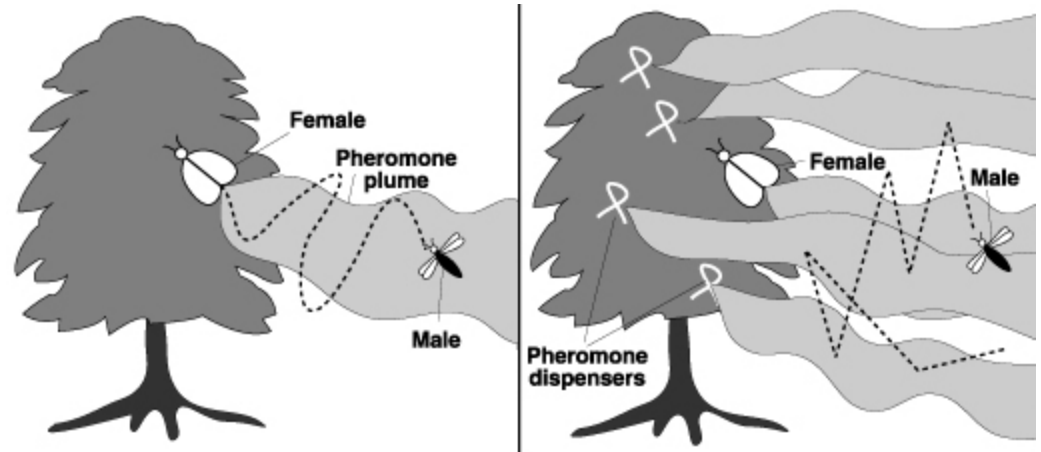
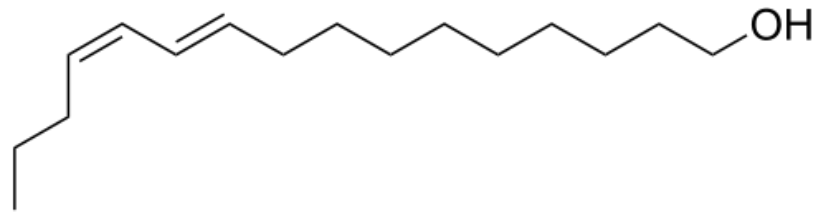


*Bombyx mori*



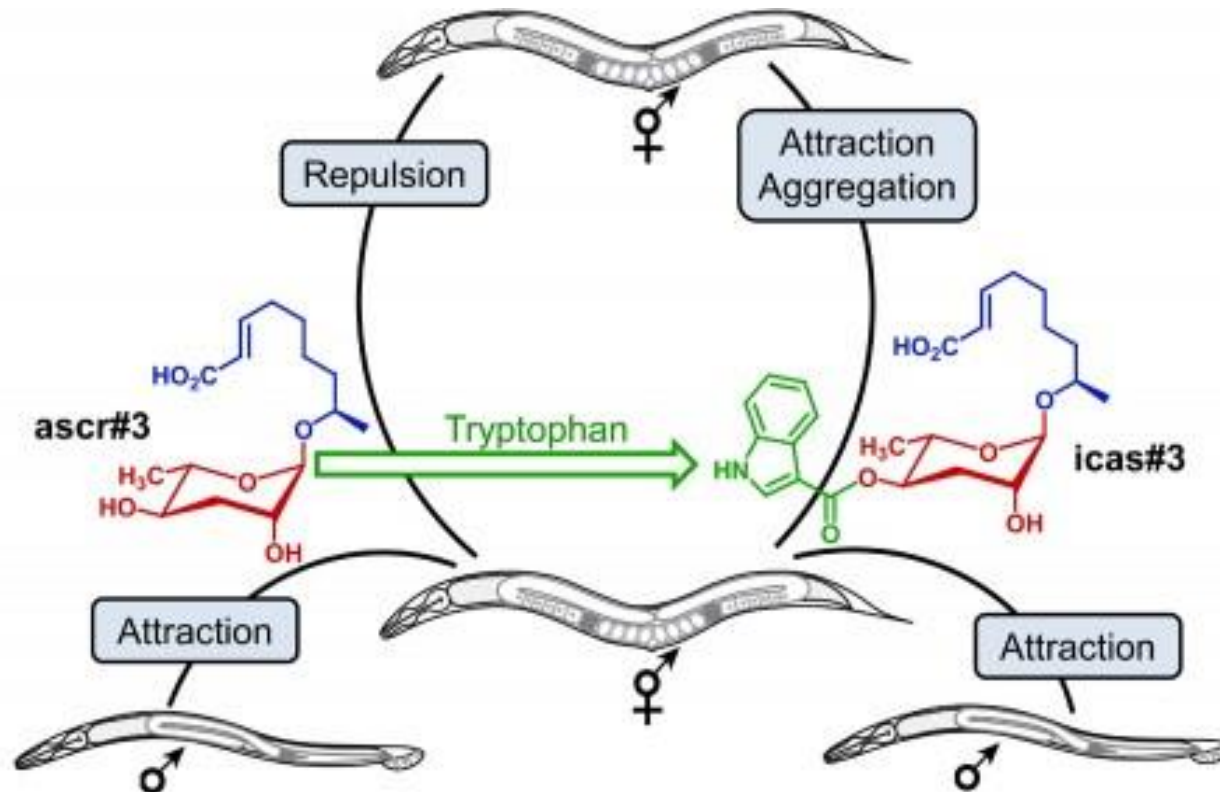
# Bombykol – the first described pheromone (Adolf Butenandt, 1959)

- E10,Z12-hexadecadien-1-ol
- pheromone produced by female silkworms (*Bombyx mori*) attracting males
- binding to the pheromone-binding protein (BmorPBP), which transfers the pheromone to its own receptor
- used in pheromone traps to confuse males who do not subsequently find females



# Pheromones of invertebrates

- e.g. neamtode ascarosides (wormbook.org)
- simple molecules > rearrangement produces pheromones with different effects
- ascaroside 3 attracts males but repels hermaphrodites
- modified ascaroside 3 is the strong attractant even for hermaphrodites



# Honey bee pheromones

„Primer“ pheromones - trigger physiological changes without immediate effect on behavior (control of caste development and reproduction)

"Releaser“ pheromones - cause immediate changes in behavior (aggregation, foraging, caring for offspring, etc.)

## Queen's pheromones

- effect on activity of workers, suppresses the production of new workers and queen

## Pheromones of workers

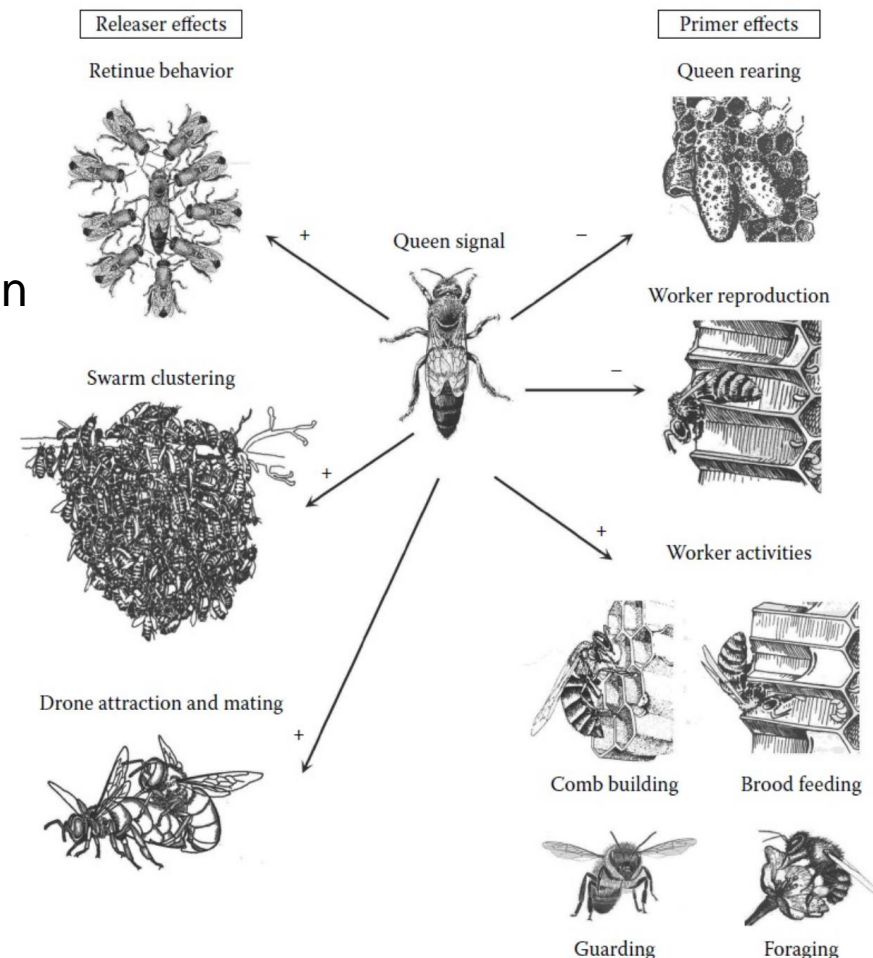
- ethyl oleate inhibits onset of foraging

## Pheromones of drones

- mandibular gland - engagement flights

## Pheromones of brood

- together with queen's pheromone regulate ovarian development





# Honey bee pheromones

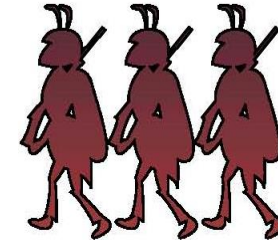
- a chemically very diverse group of substances



**isopentyl acetate**



This might smell like bananas to you, but to a bee it means war.



This molecule signals bees to attack an intruder.



**terpenoid citral**



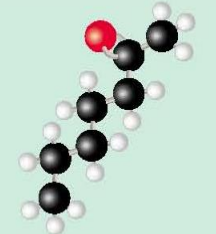
This molecule says it's moving day to a bee.



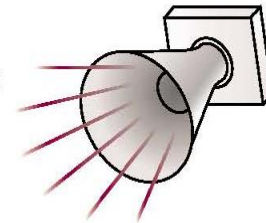
Bees smelling this molecule swarm and move to a new hive.



**2-heptanone**



Feel alarmed when you smell this? A bee would.



Guard bees release this molecule to call for help when there is an intruder.

**9-oxo-2-trans-decenoic acid**



Although we humans can't smell this molecule, it is a perfume for bees.



Queen bees release this molecule to attract males.

# Honey bee pheromones

## Mandibular gland

- queen signal (17 major chemical components; e.g. 9-oxo-2-trans-decenoic acid or 4-hydroxy-3-methoxyphenyl ethanol)

## Koschevnikov gland

- produces alarm hormone in workers (released after using a sting)

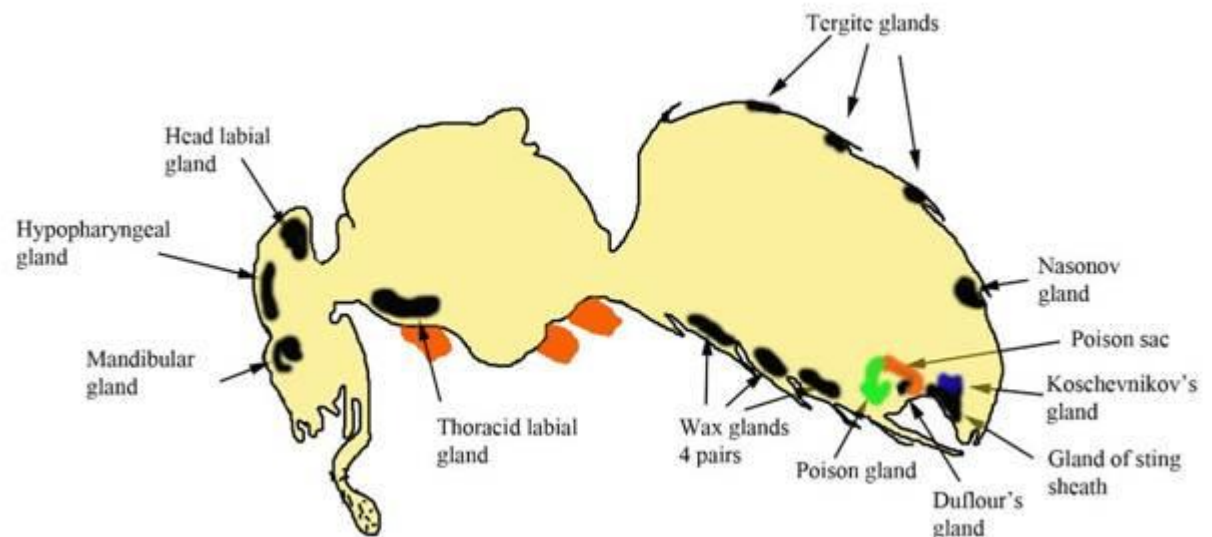
## Dufour's gland

- fertility signal important for egg laying and worker defense

## Tarsal glands

- oily product – foraging workers, suppresses the development of new mother

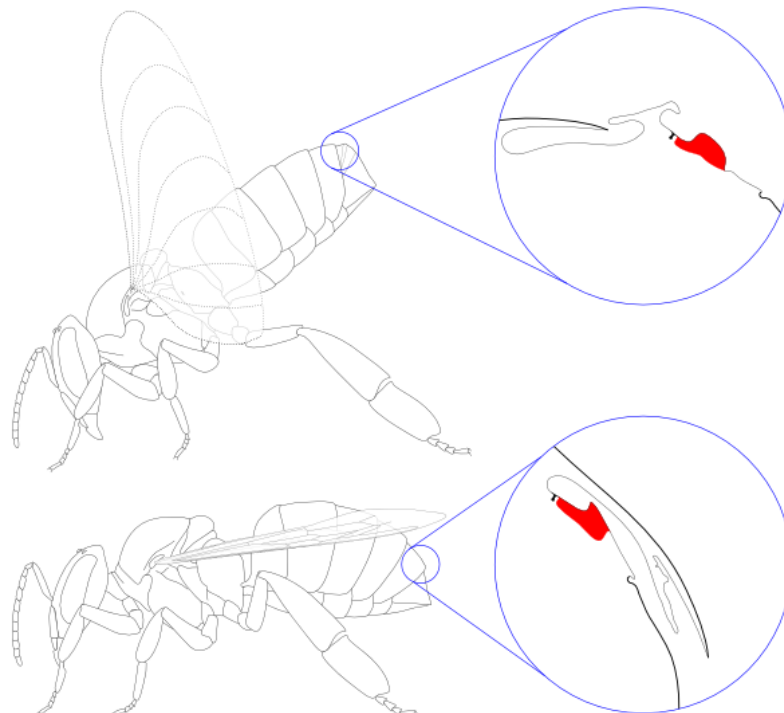
## Nasonov gland



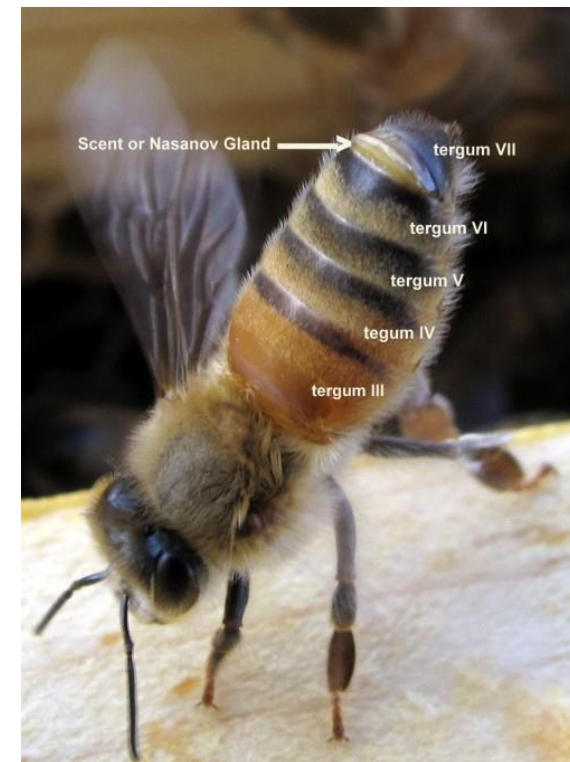
# Honey bee pheromones

## Nasonov pheromone

- released only by workers (Nasonov gland on the dorsal side of abdomen)
- a mixture of several substances (citral, ditral, nerol, geraniol, nerolicacid, geranicacid, farnesol); produced artificially (attracting swarms, pollination)
- guiding other individuals to the hive or to a source of food and water that does not have its own characteristic odor trace

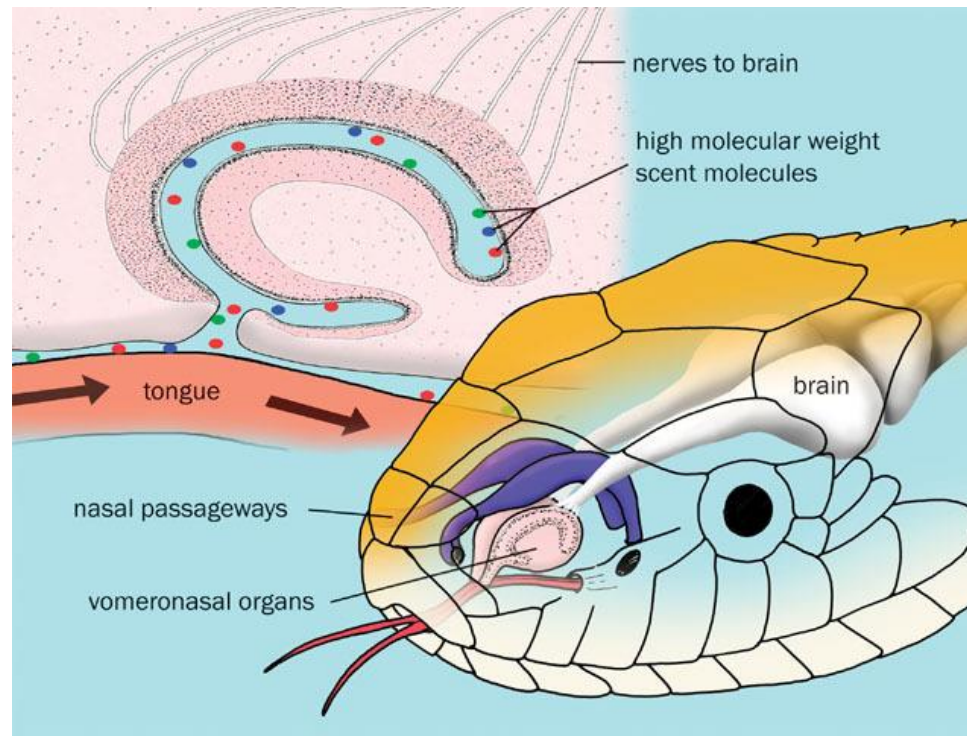


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# Vertebrate pheromones

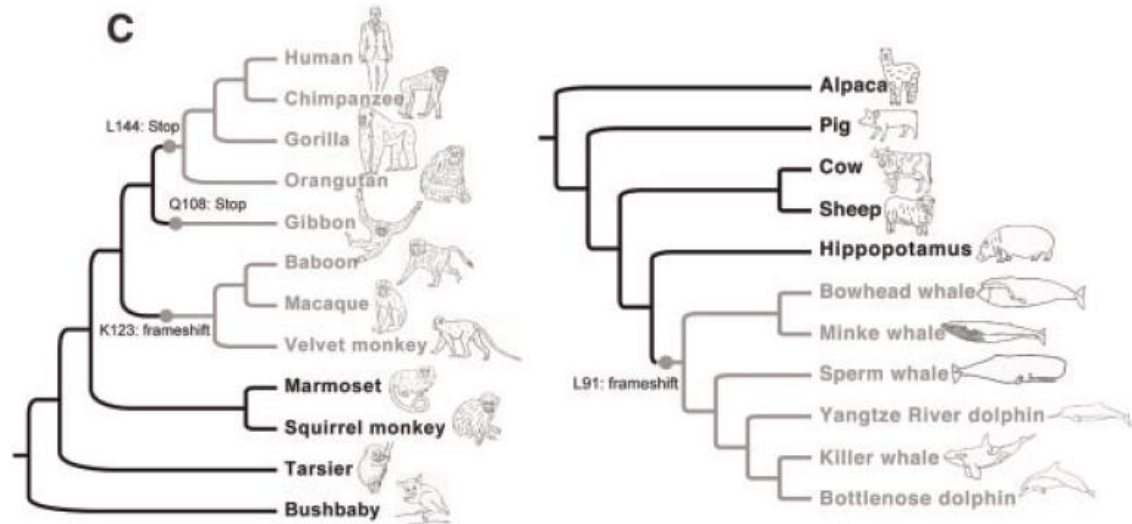
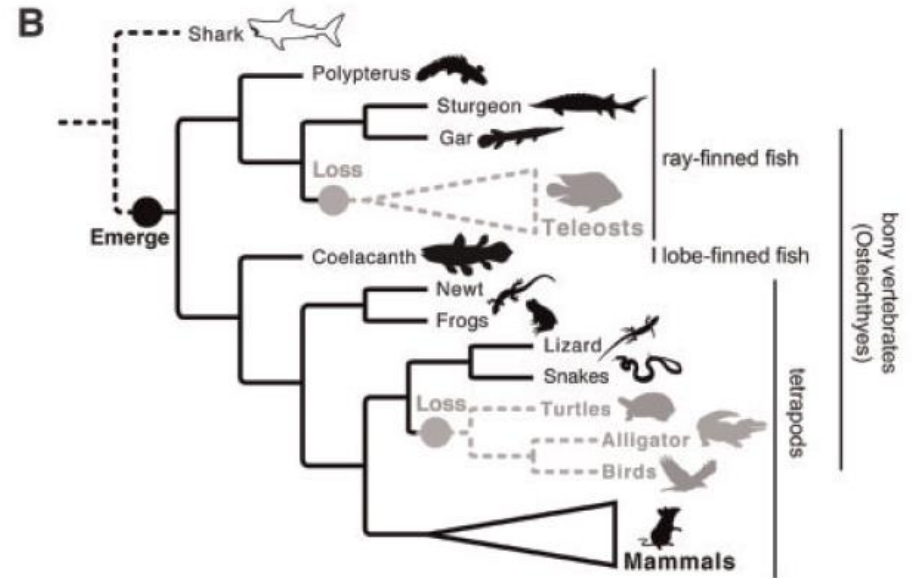
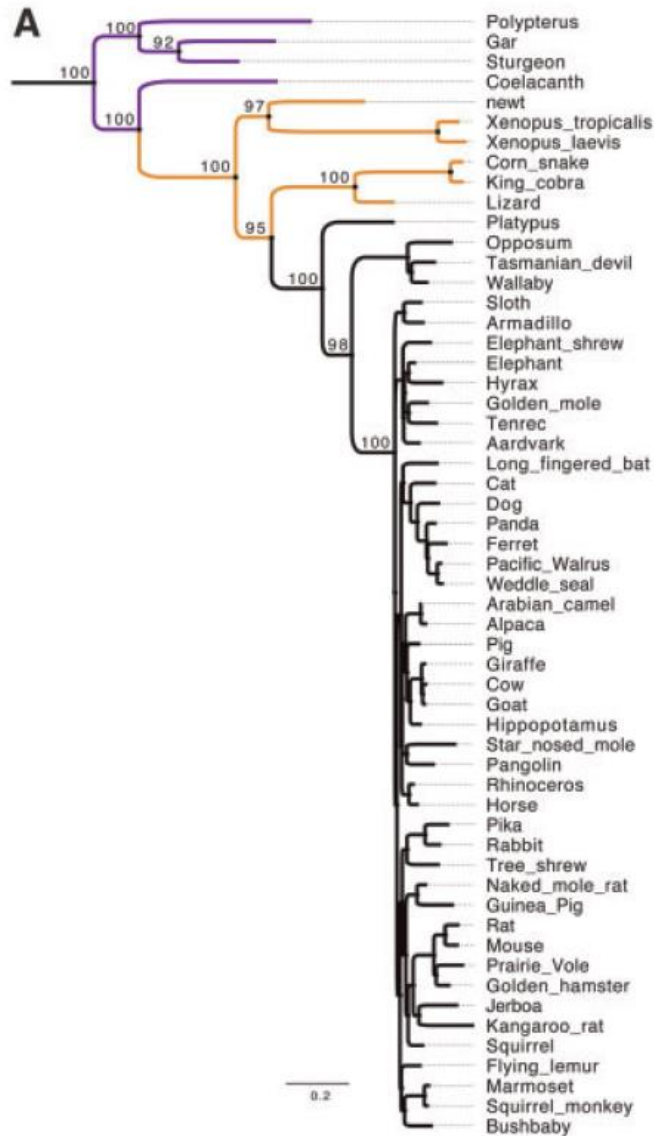
- captured generally by olfactory cells (small volatile molecules), by cells in vomeronasal organ (VNO, Jacobson's organ) or both
- VNO in amphibians, reptiles and mammals (except of most of the primates), it is not present in birds
- the role of VNO in humans is still a question (present in the fetus, then apparently atrophies)
- a number of G protein-coupled VNO receptors identified (V1Rs, V2Rs and V3Rs families); they can be used to detect pheromones





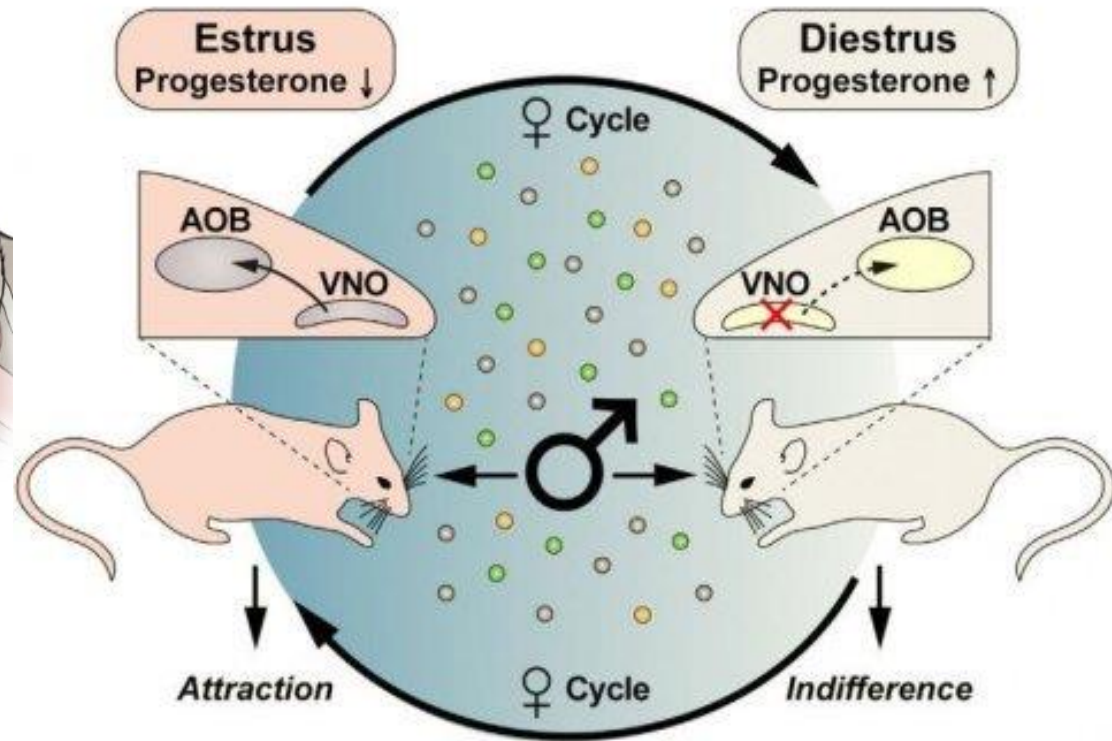
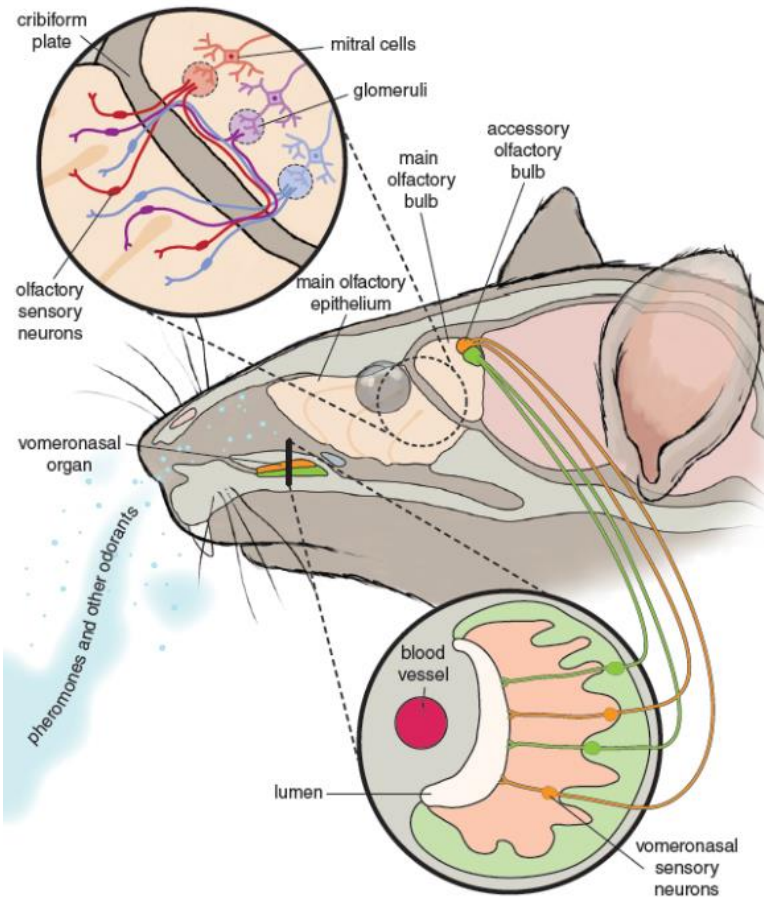
# Vertebrate pheromones - gene for ancestral V1 receptor

*Mol. Biol. Evol.* 2018 35(12):2928–2939 doi: [10.1093/molbev/msy186](https://doi.org/10.1093/molbev/msy186)



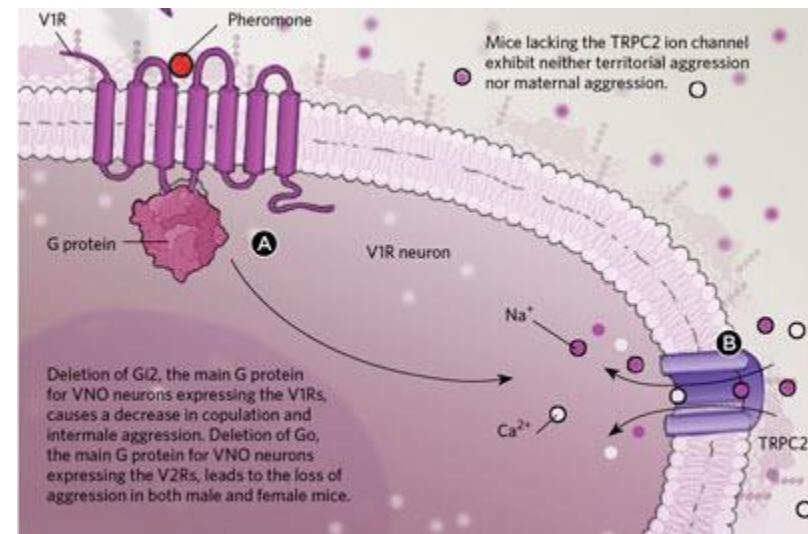
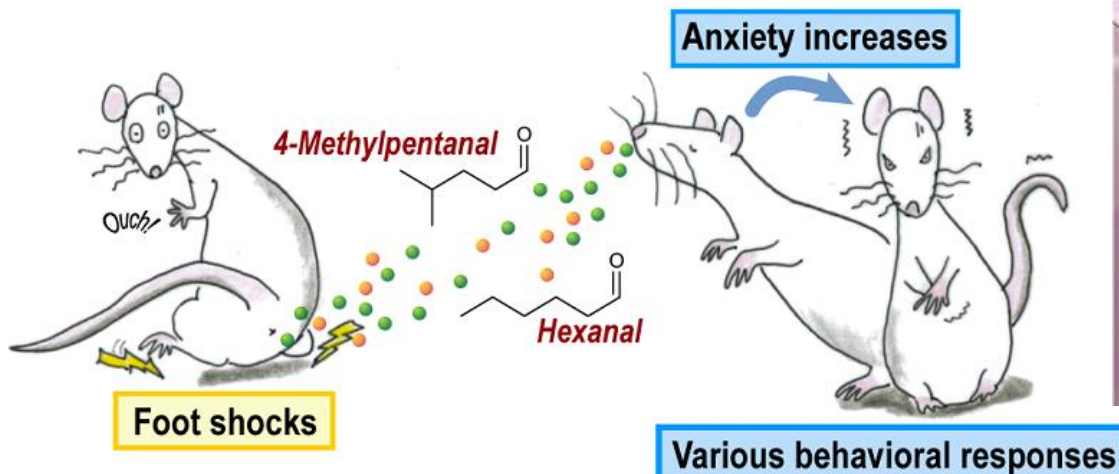
# Vertebrate pheromones

- receptor in VNO > primary neural processing in accessory olfactory bulbs (AOB) > progression to deeper areas of the brain (amygdala, hypothalamus) > influencing behavior and physiological processes (e.g. endocrine activity)



# Vertebrate pheromones

- hypothalamic-pituitary-adrenal / gonadal axis stimulation
- male pigs secrete steroid hormones in their saliva (3 $\alpha$ -androstenediol and 5 $\alpha$ -androstenedione), to which the sows respond with a mating behavior
- mice differentiate close relatives based on olfactory signals, thus minimizing the risk of inbreeding in mating (*Science*. 1994 Oct 14;266(5183):271-3)
- anxiety in rats can be caused by the pheromone from perianal glands (*PNAS*. 2014 Dec 30;111(52):18751-6. doi: 10.1073/pnas). Two substances > binding to V1Rs and MOS receptors (*main olfactory system*) > activation of olfactory systems > behavior change.





# Mammalian pheromones

- research of human pheromones problematic (presence in mixtures x purity)
- the main sense is sight, but olfactory system is present > pheromones
- genes encoding VNO receptors dysfunctional, no evidence of VNO association with CNS x pheromone receptors have been identified in the olfactory mucosa
- potentially, steroids are used as pheromones (androstenol, androstenone, androsterone and others released in the armpit)



*Synchronisation of the menstrual cycle?*

*Androstenone as an attractant for women?*

*Underarm pheromones provide information about the immune system (the role of MHC in partner selection)?*