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From Scent to Action: Understanding the Chemical Language of Pheromones

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Abstract

Pheromones are chemical signals that mediate communication between individuals of the same species and regulate a wide range of physiological and behavioral processes. This review summarizes the biological significance, chemical diversity, detection mechanisms, and neural processing pathways of pheromones in animals. Semiochemicals are broadly categorized into pheromones and allelochemicals, each playing distinct ecological roles in intraspecific and interspecific communication. Various classes of pheromones including releaser, primer, signaling, aggregation, and sex pheromones are involved in regulating reproductive behavior, social interactions, and survival strategies. Detection of pheromonal cues occurs through specialized chemosensory structures such as the vomeronasal organ and main olfactory epithelium, which transmit signals to the main and accessory olfactory bulbs and subsequently to limbic brain regions. These neural pathways ultimately influence neuroendocrine responses through the hypothalamic–pituitary axis. Understanding pheromone-mediated communication provides important insights into animal behavior, reproductive physiology, and potential applications in livestock management and pest control.

1. Introduction:

Chemosensation is a specialized sensory modality through which animals perceive and interpret chemical cues from their external environment, enabling the detection and discrimination of a vast array of structurally diverse molecules. Throughout evolution, living organisms have developed complex chemical communication systems that facilitate interactions with the external environment and improve survival. These systems enable organisms to detect a broad spectrum of chemical cues and transform them into sensory signals. When such chemical cues are transmitted between individuals, the signaling molecules involved are referred to as semiochemicals. These compounds are commonly released through biological excretions and secretions such as urine, feces, saliva, and various skin gland secretions, and are often deposited in the environment through stereotyped behavioral patterns. Chemical communication plays a crucial role in regulating several

biological processes, including social interactions, reproductive behavior, foraging activities, and predator avoidance. This significance arises partly because chemosensory pathways project to the limbic system, which governs functions such as emotion, memory, feeding behavior, reproductive drive, and overall behavioral responses. Furthermore, semiochemical signaling often functions synergistically with other sensory modalities such as auditory, visual, and tactile cues to convey information related to species identity, sex, social hierarchy, and the physiological or developmental status of individuals. Based on the physicochemical characteristics, which determine the mobility and mode of dispersion in different environmental media, chemical signals can be categorized into four classes: volatile-soluble, volatile-insoluble, non-volatile-soluble, and non-volatile-insoluble compounds.

2. Types of Semiochemicals

Living organisms maintain continuous communication through the exchange of diverse chemical signals that facilitate essential biological functions such as foraging, defense, and reproduction. These signaling molecules can be broadly categorized into hormones, which exert their effects within the same organism that produces them, and semiochemicals, which mediate communication between different individuals.

Semiochemicals are chemical substances utilized by organisms to communicate with conspecifics or other species and to interpret environmental cues. The term semiochemical originates from the Greek word semeon, meaning “mark” or “signal.” Such chemical communication systems are widely distributed across biological taxa, including microorganisms, plants, insects, and vertebrates. The production and release of semiochemicals involve specialized secretory mechanisms, and their detection by recipient organisms can trigger alterations in physiological processes, metabolic pathways, or behavioral responses through chemosensory signaling pathways.

Semiochemicals are broadly classified into pheromones and allelochemicals based on the species involved in the communication (figure 1). Pheromones mediate chemical signaling between individuals of the same species, whereas allelochemicals facilitate interactions between individuals of different species. These signaling molecules may occur either as a single chemical compound or as complex blends of multiple constituents.

Pheromones play a critical role in intraspecific communication by regulating various biological processes, including growth and development, physiological status, social interactions, reproductive behavior, and territorial marking. In contrast, allelochemicals are categorized according to the organism that derives a benefit from the interaction. They include allomones, where the emitting organism benefits; kairomones, where the receiving organism

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benefits; synomones, where both the emitter and receiver gain advantages; and apneumones, which are chemical cues released from non-living materials that elicit adaptive behavioral or physiological responses in the receiving organism.

2.1. Allelochemicals

Allomones

Allomones, a term derived from the Greek roots allos "other" and hormonas "to excite", are defined as interspecific chemical signals that confer an adaptive advantage to the organism that produces them. These compounds have been reported across a wide range of organisms, from lower plants to higher animals. In ecological interactions, allomones released by predators often function to attract prey, whereas those produced by prey typically act as deterrents that repel predators. Certain bioactive substances such as venoms and antibiotics also function as allomones, as they are chemical compounds synthesized by microorganisms to suppress or inhibit the growth of competing microbial species.

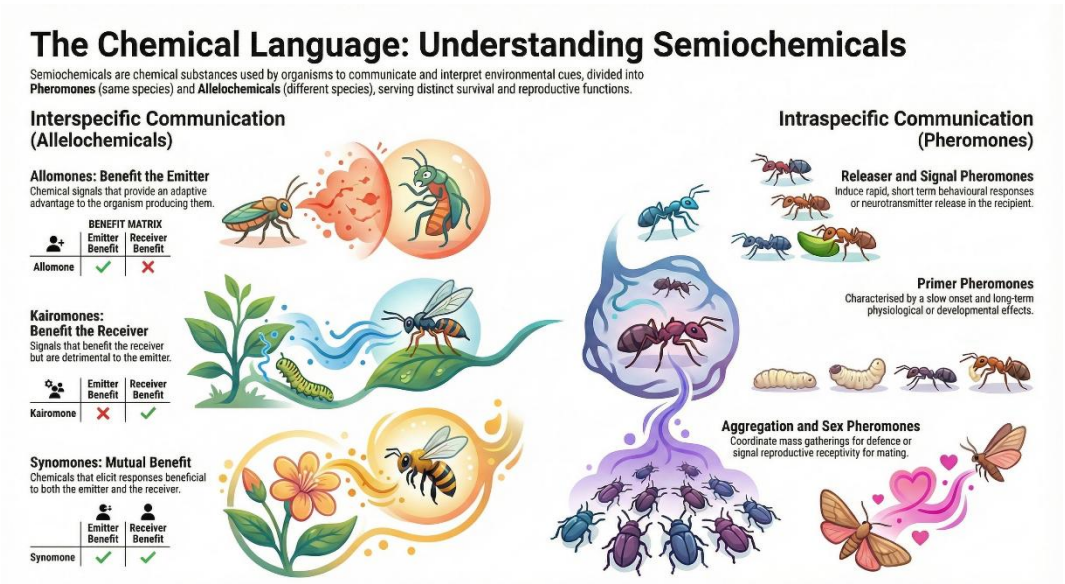

Figure 1: Biology of semiochemicals

Kairomones

Kairomones are a class of allelochemicals that, upon detection by an individual of another species, elicit behavioral or physiological responses that are adaptively beneficial to the receiver but detrimental to the emitter. Based on their effects on the benefiting organism, kairomones are broadly classified into two categories: releaser kairomones, which trigger immediate behavioral responses, and primer kairomones, which induce longer-term physiological or developmental changes in the receiver. Kairomones can also be categorized according to their functional role in the receiving organism into four principal groups: foraging kairomones, anti-predator kairomones, sexual kairomones, and aggregation kairomones. Foraging kairomones facilitate the localization of food resources, whereas anti-predator

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kairomones help organisms reduce or avoid the adverse effects of natural enemies. Sexual kairomones assist in mate location or other reproductive interactions. In contrast, aggregation kairomones promote the formation of conspecific groups involving both sexes of the receiving species, serving functions such as efficient exploitation of food resources, mate searching, or collective defensive responses.

Synomones

Synomones are defined as allelochemicals released by one organism that, upon perception by an individual of another species, elicit behavioral or physiological responses that are adaptively beneficial to both the emitter and the receiver. Synomones may function either as repellents or attractants. For instance, certain repellent synomones serve as warning signals indicating potential hazards such as plant toxicity. Conversely, some synomones are emitted following parasitic or herbivore attack, functioning to attract natural enemies of the parasite and thereby contributing to indirect defense mechanisms of the host organism.

Apneumones

Apneumones constitute a group of allelochemicals originating from non-living sources; the term is derived from the Greek root a-pne, meaning “breathless” or “lifeless.” These chemical cues benefit the receiving organism but differ from kairomones in that the source does not experience any adaptive disadvantage. Apneumones are typically associated with inanimate materials that indicate the presence or prior activity of certain prey or hosts within a particular environment. Consequently, these cues may be detrimental to organisms of another species that are closely associated with such substrates. For instance, predators and parasites can utilize apneumones to locate inanimate materials linked to the presence of their hosts or prey.

2.2. Pheromones

Pheromones can be classified into several categories based on their chemical nature, mode of action, and the type of interactions they mediate. Accordingly, different classes of pheromones have been identified according to their functional roles in communication, including aggregation pheromones, alarm pheromones, epideictic pheromones, territorial pheromones, trail pheromones, information pheromones, and sex pheromones. These classifications are primarily based on the specific behavioral or physiological responses they elicit and the ecological functions they perform in mediating intraspecific interactions (table 1).

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Releaser pheromone

Releaser pheromones induce rapid, short-term behavioral responses in the receiving individual and typically function as attractants or repellents. These pheromones directly alter the behavior of the recipient shortly after detection. For example, certain organisms release highly potent attractant molecules capable of drawing potential mates from distances of up to several kilometers. Generally, releaser pheromones trigger immediate behavioral responses but are rapidly degraded in the environment. In pigs, the boar elicits the immobilization reflex in the sow through sex pheromones present in its saliva. These pheromonal compounds have been identified as the steroids 5α-androst-16-en-3-one and 5α-androst-16-en-3α-ol. They are synthesized in the testes and subsequently secreted into boar saliva, where they function in reproductive communication.

Primer pheromone

Primer pheromones are characterized by a slower onset of action but exert prolonged physiological and developmental effects in the receiving organism. Unlike releaser pheromones, which induce immediate behavioral responses, primer pheromones produce long-lasting changes by influencing endocrine pathways, often through activation of the hypothalamic-pituitary-adrenal axis. An example is observed in rabbits, where lactating females release mammary pheromones that stimulate nursing behavior in their offspring. More broadly, primer pheromones regulate physiological processes by modulating endocrine, reproductive, and other systemic functions. Evidence of primer pheromone activity has also been documented in cattle. Exposure to bull urine influences the onset of puberty in crossbred beef heifers, with a greater proportion of prepubertal heifers receiving weekly oronasal treatments with bull urine attaining puberty within a seven-week experimental period compared to water-treated controls. In domestic animals, primer pheromones released by males play a significant role in reproductive regulation, including the induction of puberty, termination of seasonal anestrus, and reduction of postpartum anestrus in females. These effects are associated with the stimulation of reproductive endocrine activity leading to the resumption of estrous cycles. For instance, exposure of gilts to a mature boar accelerates the onset of puberty and synchronizes the first estrus. Similarly, administration of a synthetic signaling pheromone preparation (“Boar Mate”) to postpartum sows has been reported to exert a primer effect, resulting in an earlier return to estrus.

Signaling pheromone

Signal pheromones induce short-term physiological or behavioral responses in the recipient, often through the release of neurotransmitters that activate specific neural pathways.

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For example, gonadotropin-releasing hormone acts as a neurotransmitter in rats and can stimulate lordosis behavior. Signal pheromones typically trigger immediate behavioral responses and operate through a classical stimulus–response mechanism mediated by the central nervous system. In livestock, behavioral responses to pheromonal cues are commonly observed during reproductive interactions. For instance, during estrus detection, a teaser bull perceives estrus-specific chemical cues released by females and subsequently exhibits flehmen behavior, which facilitates pheromone detection. Quantitative observations of bull behavior during interactions with cows are considered reliable biological indicators of the presence of pheromonal signals and provide a basis for the laboratory identification and characterization of compounds involved in chemical communication. Furthermore, pheromones may transmit information regarding the sender, including individual or group identity, which plays a critical role in processes such as parent-offspring recognition and mate selection.

Aggregation pheromone

Aggregation pheromones mediate the gathering of conspecific individuals at a specific location and play important roles in activities such as defense against predators, mate selection, and overcoming host resistance through coordinated mass attack. An aggregation refers to the assembly of multiple individuals at a single site and may involve members of one sex or both sexes. In many species, male-produced sex attractants are referred to as aggregation pheromones because they attract individuals of both sexes to the signaling location, thereby increasing the local density of conspecifics around the pheromone source. Aggregation pheromones are also widely recognized as ecologically selective tools for pest management, as they are highly specific to target species, non-toxic, and effective even at very low concentrations.

Sex pheromone

Sex pheromones in animals function as chemical signals that indicate the reproductive receptivity of females. In addition, males may release pheromones that communicate species identity and genetic characteristics to potential mates. In most species, sex pheromones are predominantly produced by females, while only a small proportion of sex attractant pheromones are synthesized and emitted by males.

Table 1: Species-specific pheromones in farm animals and their function

Species	Pheromone	Source	Function
Cow (Bos taurus)	Estrus-related volatile compounds (exact compound not clearly identified)	Urine, vaginal secretions, milk, perineal glands	Indicates impending estrus to bulls and facilitates mating behaviour

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Buffalo (Bubalus bubalis)	4-methyl phenol	Urine	Acts as a sex attractant and stimulates flehmen behaviour in bulls
	9-octadecenoic acid	Urine	Induces penis erection and mounting response in bulls
Sheep (Ovis aries)	1,2-hexadecanediol and 1,2-octadecanediol	Hair/skin extracts of rams	Stimulates LH secretion and ovulation in ewes (male effect)
	Unidentified estrus pheromones	Wool wax and vaginal secretions	Sexually attract rams
Goat (Capra hircus)	Male-derived pheromones (specific compound not identified)	Hair/skin and scent marks	Induce estrus synchronization and ovulation in females
Pig (Sus scrofa)	5α-androst-16-en-3-one (androstenone)	Boar saliva	Induces immobilization/standing reflex in estrus sow
	5α-androst-16-en-3α-ol (androstenol)	Boar saliva	Sexual attractant facilitating mating behaviour
	Pig appeasing pheromone (PAP)	Maternal secretion	Reduces aggression and stress in piglets
Horse (Equus caballus)	p-Cresol	Estrous urine	Sex pheromone component signalling estrus
	Equine appeasing pheromone (EAP)	Mare mammary/skin secretions	Reduces stress and provides reassurance to foals
Dog	Methyl p hydroxybenzoate	Urine	Sexual attractant facilitating mating behaviour

3. Chemistry of Pheromones

Pheromones exhibit considerable chemical diversity; consequently, they are generally classified based on their biological functions rather than their structural characteristics. For instance, attractant pheromones facilitate the attraction of conspecific individuals, whereas alarm pheromones signal the presence of external threats to other members of the same species, often eliciting defensive or aggressive responses. In mammals, pheromones have been shown to mediate a wide range of behavioral responses across different species. Interestingly, certain pheromonal compounds may be conserved among unrelated species, where they can perform distinct functional roles depending on the species-specific context (Table - 2).

MUP Molecule

Male mouse urine contains an exceptionally high concentration of proteins known as major urinary proteins (MUPs). These proteins constitute a large family of highly homologous, androgen-dependent proteins synthesized in the liver and subsequently excreted in urine. MUPs, along with their rat homologs, the α2-urinary globulins, belong to the lipocalin superfamily, which is characterized by the ability to bind and transport small volatile

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ligands. Accordingly, MUPs function as carriers that bind and release volatile pheromonal compounds, many of which are also produced in an androgen-dependent manner.

In addition to hepatic synthesis and urinary excretion, MUPs are expressed in several exocrine tissues, including the mammary, parotid, sublingual, submaxillary, lacrimal, and nasal glands, as well as modified sebaceous glands such as the preputial and perianal glands. However, their biological activity has been primarily demonstrated when MUPs are isolated from urine. MUPs have been reported to function as both primer and releaser pheromones, although some of their physiological effects appear inconsistent. This variability is partly attributable to their high-affinity binding with volatile pheromones, which themselves play key roles in regulating several social and reproductive processes. These include estrus synchronization, female attraction, inter-male aggression, estrus induction (e.g., via α- and β-farnesene), acceleration of female puberty, and territorial marking. The formation of pheromone–protein complexes offers several functional advantages, including enhanced concentration and controlled release of chemosignals, stabilization of otherwise labile pheromonal molecules, and efficient delivery of these signals to the appropriate sensory receptors.

Exocrine gland-secreting peptides

In mice, a family of peptides of varying lengths known as exocrine gland-secreting peptides (ESPs) is secreted from the extraorbital, Harderian, and submaxillary glands into exocrine fluids such as tears, nasal mucus, and saliva. The ESP gene family comprises 38 members in mice and approximately 10 in rats, whereas it is absent in the human genome. Among these peptides, at least two members produced by the extraorbital lacrimal gland exhibit sex-specific expression: ESP1 is secreted exclusively by males, whereas ESP36 is specifically produced by females. Although these peptides are detected by sensory systems specialized for pheromone perception, their precise physiological roles remain largely unresolved.

Table -2: Cemistry and fucntion of different mammalian pheromone/peptides and their functions

Animal Order	Pheromone /Peptide	Functions
Proboscidea (Elephant)	Frontalin (1,5-dimethyl-6,8-dioxabicyclo[3.2.1]octane)	Associated with male musth; modulates aggression and reproductive behavior and influences female responses depending on reproductive state.
	(Z)-7-dodecenyl acetate	Female estrus pheromone that signals reproductive receptivity and attracts males.

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Marsupialia (Opossum)	Scent gland secretions	Attract females and stimulate estrus through vomeronasal signaling.
Rodentia (Mouse)	2,5-Dimethylpyrazine	Suppresses estrous cycle in grouped females (Lee–Boot effect).
	2-sec-butyl-4,5-dihydrothiazole (BT)	Induces estrus synchronization, accelerates puberty, attracts females, and stimulates male aggression.
	2,3-dehydro-exo-brevicomin (DB)	Promotes estrus induction, female attraction, and inter-male aggression.
	α- and β-farnesene	Involved in territorial marking, female attraction, and puberty acceleration.
	6-Hydroxy-6-methyl-3-heptanone	Accelerates puberty onset in females.
	2-Heptanone	Extends estrus duration in females.
	n-Pentyl acetate	Suppresses estrus cycle in females.
	Isobutylamine	Induces estrus acceleration and vaginal opening.
	Major Urinary Proteins (MUPs)	Convey individual identity; regulate mate recognition, territorial signaling, puberty acceleration (Vandenbergh effect), and male aggression.
	MHC class I peptides	Provide genetic identity cues influencing mate selection and recognition; associated with pregnancy block (Bruce effect).
	Exocrine gland-secreting peptides (ESP1, ESP36)	Gender-specific peptide pheromones detected by vomeronasal receptors; regulate social and reproductive behaviors.
Rodentia (Rat)	α2u-globulins (urinary proteins)	Act as pheromone carriers and signaling molecules that activate vomeronasal pathways.
	Dodecyl propionate	Induces anogenital licking behavior.
Rodentia (Hamster)	Aphrodisin	Stimulates male sexual and copulatory behavior.
Lagomorpha (Rabbit)	2-Methylbut-2-enal	Mammary pheromone that attracts newborn pups and triggers nipple searching and suckling behavior.
Carnivora / Ungulata (Pig)	Androstenone	Male pheromone that attracts estrous females and induces the standing reflex for mating.
Primata	Androstadienone (AND)	Modulates brain activity, endocrine responses, mood, and sociosexual behavior.
	Estratetraenol (EST)	Candidate pheromone influencing hypothalamic activity and sexual communication.

4. Chemosensory detection system

Pheromone detection in mammals involves multiple chemosensory structures within the nasal cavity, primarily the vomeronasal organ and the main olfactory epithelium, along

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with additional organs such as the septal organ of Masera and the Grueneberg ganglion. These systems contain specialized sensory neurons with distinct receptors that detect pheromonal molecules and transmit signals to specific brain regions controlling social, reproductive, and defensive behaviors (Table -3).

Vomeronasal organ

The vomeronasal organ (VNO), also called Jacobson's organ, is a tubular chemosensory structure located at the base of the nasal septum. It detects pheromonal molecules dissolved in nasal mucus, which are actively drawn into the lumen through a vascular pump mechanism involving vasodilation and vasoconstriction. Access of stimuli to the VNO can be facilitated by behaviors such as flehmen, particularly in ungulates. Vomeronasal sensory neurons project to the accessory olfactory bulb (AOB) and subsequently to the amygdala and hypothalamus, influencing reproductive and social behaviors. The activity of the VNO is not purely passive; it can be modulated by physiological factors such as norepinephrine release, which may alter vascular tone and glandular secretion

Olfactory Epithelial lining

The main olfactory epithelium (MOE) is responsible for detecting a wide range of volatile odorants, but it also contributes to pheromone detection. Sensory neurons in the MOE express odorant receptors and project to the main olfactory bulb (MOB), which then relays signals to higher brain regions such as the piriform cortex and cortical amygdala. Some pheromones, including milk- and urine-derived signals, can evoke electrical responses in the olfactory epithelium via cAMP-mediated signaling pathways. Certain pheromones (e.g., MHC peptides) are detected by olfactory neurons expressing CNGA2 channels, demonstrating that the MOE can detect pheromonal cues in addition to conventional odorants. Evidence suggests that multiple transduction mechanisms exist in the MOE for pheromone detection

Septal organ of Masera

The septal organ is a small patch of sensory epithelium located on the nasal septum near the nasopalatine duct. It resembles the main olfactory epithelium but has a thinner neuroepithelium and sensory neurons with shorter dendrites and larger dendritic knobs. Axons from these neurons project to specific glomeruli in the ventromedial region of the main olfactory bulb. Its anatomical location suggests a role in the early detection of biologically relevant molecules, especially those associated with behaviors such as licking.

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Grueneberg ganglion

The Grueneberg ganglion is located in the anterodorsal nasal cavity near the nasal roof and septum. Neurons are grouped in small clusters and project axons to necklace glomeruli in the main olfactory bulb. These neurons express specific receptor types (e.g., V2R83 and TAAR receptors) involved in chemosensory signaling. The ganglion is thought to detect alarm pheromones, which are volatile signals released by stressed animals. Lesions of this organ abolish the freezing response, a defensive behavior triggered by alarm pheromones

Chemosensory receptors

Chemosensory receptors for detecting the pheromone signalls are classsified into following tyores, namely., 1. Vomeronasal Receptors (V1Rs, V2Rs, Ligands of vomeronasal receptors, Formyl peptide receptors), 2. Odorant Receptors, 3. Trace Amine-Associated Receptors, 4. Olfactory-Specific Guanylyl Cyclase Type D Receptor. These receptor families collectively enable mammals to detect a broad spectrum of pheromonal and chemosensory signals, ranging from volatile odorants and amines to peptide and protein pheromones. Their activation initiates neural signaling pathways that ultimately regulate social communication, reproductive behavior, individual recognition, and defensive responses.

Table-3: Major pheromone-related receptors biology

Receptor Type	Location / Expression Site	Type of Ligands Detected	Key Characteristics	Biological Functions
Vomeronasal Receptors (V1Rs)	Apical layer of vomeronasal sensory neurons in the vomeronasal organ (VNO)	Small volatile pheromonal molecules (e.g., 2-heptanone, isobutylamine, n-pentyl acetate, 6-hydroxy-6-methyl-3-heptanone)	G-protein–coupled receptors; each neuron expresses a single receptor gene; highly selective ligand recognition	Detection of volatile pheromones involved in reproductive and social communication
Vomeronasal Receptors (V2Rs)	Basal layer of vomeronasal sensory neurons in the VNO	Larger peptide or protein pheromones (e.g., MHC peptides, major urinary proteins)	GPCR family often co-expressed with nonclassical MHC molecules; associated with detection of complex pheromonal cues	Recognition of social identity, genetic compatibility, and alarm signals
Formyl Peptide Receptors (FPRs)	Subset of vomeronasal sensory neurons (mainly	Formyl peptides from bacteria, viruses, or endogenous sources	GPCRs also involved in immune signaling; present on microvilli, dendrites, and	Detection of pathogen-related chemical cues and possible participation in

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	apical region of VNO)		cell bodies of sensory neurons	pheromonal communication
Odorant Receptors (ORs)	Main olfactory epithelium of the nasal cavity	Wide range of volatile odorant molecules	Largest GPCR family (~1000 genes in mammals); neurons express only one receptor; operate via combinatorial coding	Detection and discrimination of diverse odors; may contribute to perception of social chemical signals
Trace Amine-Associated Receptors (TAARs)	Subset of neurons in the main olfactory epithelium and in the Grueneberg ganglion	Small volatile amines (e.g., β-phenylethylamine, isoamylamine, trimethylamine)	GPCRs related to receptors for biogenic amines; each receptor tuned to specific amine ligands	Detection of social cues such as urine-derived signals influencing reproduction, behavior, and social status
Olfactory-Specific Guanylyl Cyclase Type D (GC-D)	Specialized sensory neurons in the dorsal main olfactory epithelium	Peptides such as uroguanylin and guanylin, as well as signals in dilute urine and CO_2	Receptor guanylyl cyclase producing cGMP; distinct from GPCR olfactory receptors	Detection of physiological and environmental chemical cues related to internal homeostatic states and social signals

5. Pheromone signalling pathways from Chemosensory epithelium to brain

Main and Accessory Olfactory Bulbs

The main olfactory bulb (MOB) and accessory olfactory bulb (AOB) represent the first central processing stations for chemosensory signals originating from the olfactory epithelium and the vomeronasal organ, respectively. The main olfactory bulb receives axonal projections from olfactory sensory neurons, whereas the vomeronasal sensory neurons project to the accessory olfactory bulb, located in the dorsal–posterior region of the olfactory bulb. The MOB is present in almost all vertebrates except aquatic mammals, while the AOB is absent in adult Old-World monkeys, apes, and humans, reflecting evolutionary differences in pheromonal communication systems. These two bulbs process different types of chemosensory information but share similar neural circuitry that integrates sensory signals before transmitting them to higher brain regions involved in behavior and endocrine regulation (figure -2). Both the main and accessory olfactory bulbs exhibit a layered structural organization. The outermost nerve layer contains the axonal projections of chemosensory

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neurons from the olfactory epithelium or vomeronasal organ. Beneath this lies the glomerular layer, which represents the first synaptic relay where sensory neuron axons form synapses with the dendrites of mitral and tufted cells. Additional layers include the external plexiform layer, where the cell bodies of mitral and tufted cells are located, and the internal plexiform layer, containing granule cells, which function as inhibitory interneurons.

Despite these structural similarities, the MOB and AOB differ in their detailed organization. In the main olfactory bulb, glomeruli are well-defined, relatively uniform in size (about 50 μm in mice), and surrounded by numerous periglomerular cells. In contrast, the glomeruli in the accessory olfactory bulb are smaller, irregularly organized, and highly variable in size, with fewer surrounding periglomerular cells. Furthermore, mitral cells in the MOB typically possess a single apical dendrite projecting to one glomerulus, whereas mitral cells in the AOB often possess multiple apical dendrites (up to six), each connecting to different glomeruli, enabling integration of signals from multiple vomeronasal receptors. A remarkable feature of olfactory organization is the precise topographic mapping of sensory neuron projections to the olfactory bulbs. In the main olfactory system, sensory neurons expressing the same odorant receptor gene converge onto the same pair of glomeruli in the olfactory bulb, producing a highly ordered spatial map. In mice, approximately 2,000 glomeruli exist, and their spatial arrangement is relatively consistent among individuals. In contrast, the vomeronasal system exhibits a different projection pattern. Neurons expressing the same vomeronasal receptor do not converge into a single glomerulus but instead project to multiple small glomeruli within specific regions of the accessory olfactory bulb. Axons from neurons expressing the same receptor typically converge into 10-30 glomeruli, and individual glomeruli may receive input from neurons expressing different receptor types. In addition, neurons expressing V1R receptors project mainly to the anterior region of the accessory olfactory bulb, whereas neurons expressing V2R receptors project to the posterior region, creating a functional spatial organization within the AOB.

Transduction of pheromonal information

The olfactory bulbs play a critical role in encoding and integrating pheromonal signals before transmitting them to higher brain centers. Mitral cells act as the principal projection neurons, receiving excitatory input from sensory neurons via glutamatergic synapses. The signal is further modulated by inhibitory interneurons such as granule cells and periglomerular cells, which create dendrodendritic synapses that regulate mitral cell activity through GABA-mediated inhibition. This interaction refines the spatial and temporal pattern of neuronal firing and enhances odor discrimination. Experimental studies using functional magnetic resonance

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imaging (fMRI) have demonstrated that exposure to pheromonal stimuli such as mouse urine activates specific regions of both the main and accessory olfactory bulbs. For example, urine-derived pheromones primarily stimulate the ventral region of the main olfactory bulb and the anterior region of the accessory olfactory bulb, consistent with the involvement of V1R receptors in detecting urinary pheromones. Electrophysiological recordings have also shown that mitral cells in the accessory olfactory bulb respond selectively to stimuli from conspecifics, with neuronal activity reflecting factors such as sex, genetic background, and hormonal status of the interacting animal.

Targeting Beyond the Olfactory Bulbs

After initial processing in the olfactory bulbs, pheromonal information is transmitted to higher brain regions through the lateral olfactory tract. The main olfactory bulb projects primarily to cortical areas such as the piriform cortex, olfactory tubercle, and cortical amygdala, which are involved in odor perception and associative processing. In contrast, the accessory olfactory bulb sends projections mainly to limbic structures such as the medial amygdala and bed nucleus of the stria terminalis, which are closely associated with the regulation of reproductive and social behaviors. These pathways form part of the accessory olfactory system, which is specialized for processing pheromonal cues that influence innate behavioral responses rather than learned odor perception.

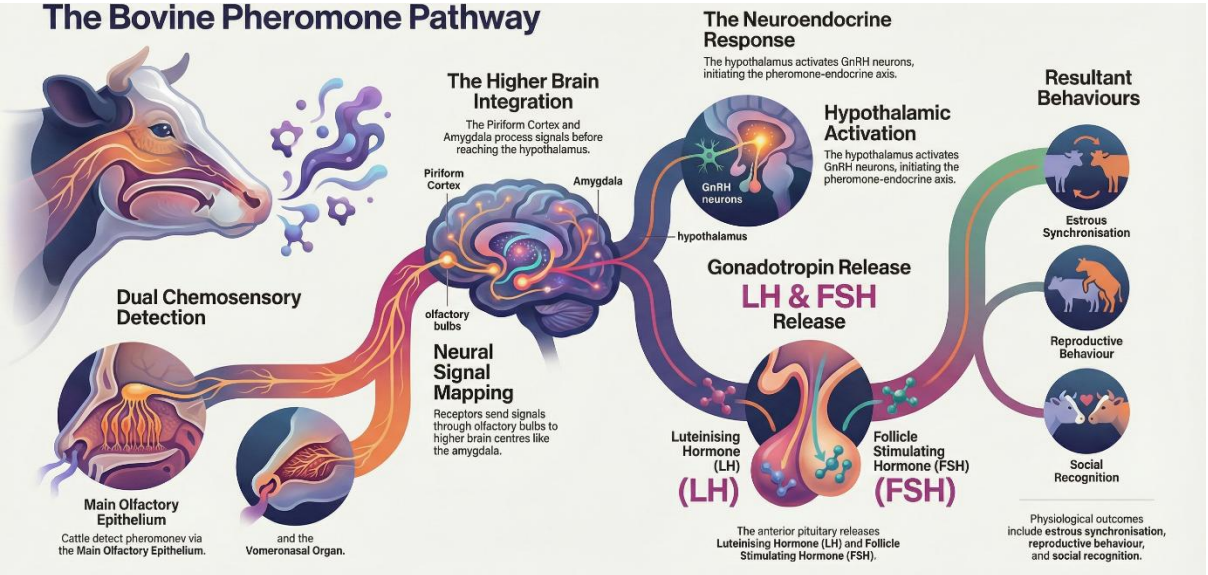

Figure 2: Pheromone signaling pathway

Pheromone-Endocrine axis

One of the most significant outcomes of pheromonal signaling is the regulation of neuroendocrine functions through the pheromone–endocrine axis. Signals from the accessory olfactory bulb ultimately reach the hypothalamus, a key neuroendocrine center that controls

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hormonal secretion through the pituitary gland. Activation of hypothalamic nuclei by pheromonal cues can lead to changes in the release of hormones such as gonadotropin-releasing hormone, which regulates reproductive hormones including luteinizing hormone and follicle-stimulating hormone. Through this pathway, pheromones can influence numerous physiological processes, including sexual maturation, estrous synchronization, reproductive behavior, territorial aggression, and maternal responses. Thus, the pheromone–endocrine axis represents a direct mechanism by which chemical communication in animals can translate into coordinated behavioral and hormonal responses essential for survival and reproduction.

6. Conclusion

Pheromones represent an essential form of chemical communication in animals, playing a crucial role in regulating reproductive physiology, social interactions, and behavioral responses. These signaling molecules are secreted through body fluids such as urine, sweat, glandular secretions, and genital mucus and are detected by specialized chemosensory systems in conspecific individuals. Advances in molecular and neurobiological research have significantly improved our understanding of the mechanisms through which pheromones influence behavior and physiology. Earlier views suggested that pheromone detection occurred exclusively through the vomeronasal system, while the main olfactory system was responsible only for detecting conventional odors. However, recent studies have demonstrated that both the main olfactory epithelium and the vomeronasal organ contribute to pheromone perception and processing, indicating a more integrated olfactory communication system than previously believed. After detection, pheromonal signals are transmitted to the main and accessory olfactory bulbs and then to limbic brain regions such as the amygdala and hypothalamus. These pathways ultimately influence neuroendocrine centers that regulate hormone secretion through the hypothalamic–pituitary axis. Activation of hypothalamic neurons leads to the release of gonadotropin-releasing hormone, which stimulates the pituitary gland to secrete luteinizing hormone and follicle-stimulating hormone, thereby modulating reproductive physiology and associated behaviors. Overall, the integration of sensory detection, neural processing, and endocrine responses enables pheromones to coordinate complex biological functions such as mating behavior, territoriality, aggression, and social recognition. Despite significant progress in identifying pheromonal molecules, receptors, and neural pathways, many aspects of pheromone signaling remain incompletely understood. Future research focusing on molecular mechanisms, receptor specificity, and neural circuits will further clarify how pheromonal communication shapes animal behavior and physiology.

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References:

Rixon M, Pappuswamy M, Chaudhary A, Ansar SS. The puzzle of pheromones in nature and their mysterious influence: a comprehensive review. J App Biol Biotech. 2025;13(1):24-36. https://doi.org/10.7324/JABB.2024.184515

Torres MV, Ortiz-Leal I, Sanchez-Quinteiro P. Pheromone Sensing in Mammals: A Review of the Vomeronasal System. Anatomia. 2023; 2(4):346-413. https://doi.org/10.3390/anatomia2040031

Brennan, P. A. (2010). Pheromones and Mammalian Behavior. In A. Menini (Ed.), The Neurobiology of Olfaction. CRC Press/Taylor & Francis.

Wyatt T. D. (2017). Pheromones. Current biology : CB, 27(15), R739–R743. https://doi.org/10.1016/j.cub.2017.06.039

KekanP.M., Ingole S.D., Sirsat S.D., Bharucha S.V., Kharde S.D., Nagvekar A.S. (2017). The role of pheromones in farm animals - A review . Agricultural Reviews. 38(2): 83-93. https://doi.org/10.18805/ag.v38i02.7939

Tirindelli, R., Dibattista, M., Pifferi, S., & Menini, A. (2009). From pheromones to behavior. Physiological reviews, 89(3), 921–956. https://doi.org/10.1152/physrev.00037.2008