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Human Chemosignals and Olfactory Cues in Attraction

What Is Known, and Not Known, About "Pheromones" in Humans

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Abstract

This paper evaluates the scientific evidence on chemical communication in human attraction and close relationships. Popular and commercial accounts often assert that human pheromones exist, that they operate below awareness to steer desire and partner choice, and that they can be bought, amplified, or managed. The paper separates three questions that such accounts tend to merge: whether human body odor carries socially relevant information, whether that information influences perception and behavior, and whether any specific molecule meets the criteria that define a pheromone in other animals. It reviews the definitional history of the pheromone concept, the anatomy of human chemosensation (including the vomeronasal organ), the androstene and estratetraenol literature, odor preferences linked to the major histocompatibility complex, menstrual synchrony, emotional chemosignals, partner odor and stress, olfactory memory, and the evidence offered for commercial "pheromone" products. Each claim is graded on a five-level evidence scale. The central position is that human body odor demonstrably carries information about identity, sex, health, and emotional state, and can modestly shift social perception, but that no human pheromone has been conclusively identified, the best-known candidate steroids have not survived rigorous testing, and claims about genetic compatibility, cycle synchrony, and product efficacy are contested or unsupported. The literature is limited by small samples, heterogeneous odor-collection methods, supraphysiological doses, predominantly heterosexual and WEIRD samples, and publication bias. The paper closes with ethical considerations and a pre-registrable research agenda.

Keywords: *chemosignals; putative human pheromones; body odor; olfaction; vomeronasal organ; major histocompatibility complex; attraction; emotion*

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1. Introduction

Claims that people are drawn together by invisible chemical signals are common in advertising, self-help writing, and popular science. They draw on a real and productive scientific field: the study of chemical communication in animals, where pheromones are among the best-characterized signals in biology (Wyatt, 2014). The difficulty is that findings from moths, mice, and pigs are often transferred to humans without the evidence needed to justify the transfer, and that a defensible proposition (body odor carries social information) is often run together with much stronger ones (specific molecules control human desire and partner choice).

This paper is part of the Institute for Human Evolution (IHE) whitepaper series on attraction, bonding, and relationship loss. It sits beside the series' conceptual framework (IHE-WP-01), its analysis of the neurobiology of romantic loss (IHE-WP-02), its discussion of evolutionary explanations of mating behavior (IHE-WP-03), and its examination of probabilistic models of romantic outcomes (IHE-WP-05). Its aim is to state what the evidence on human chemosignals supports, what it does not, and what research would be needed to settle the open questions.

1.1 Scope and definitions

The series uses *seduction* as an umbrella term for consensual, communicative behavior by which one person seeks to elicit or increase another person's romantic or sexual interest. Coercion, deception about material facts, harassment, and attempts to influence a person who has not consented are outside this definition and are not treated anywhere in the series as skills to be improved. This matters for the present topic in a specific way: much commercial interest in "pheromones" rests on the idea of influencing other people covertly, below their awareness. Sections 11 and 14 return to that point.

The following terms are used throughout.

- *Semiochemical*: any chemical that carries information between organisms.
- *Chemosignal*: a chemical, or mixture of chemicals, emitted by one individual that affects the perception, physiology, or behavior of another of the same species. The term is neutral about mechanism and does not imply that the chemical is a pheromone.
- *Pheromone*: a molecule, or a defined combination of molecules, that is species-wide, that elicits a specific and reproducible response in conspecifics, and whose activity can be reproduced with the synthetic compound at natural concentrations (criteria discussed in Section 2).
- *Signature mixture*: the variable, individually distinctive blend of chemicals that allows animals to recognize individuals, kin, or groups. Signature mixtures are learned and differ from one individual to the next, which distinguishes them from pheromones (Wyatt, 2014).
- *Cue and signal*: a cue is information an observer can use; a signal is a trait that evolved, at least in part, because of its effect on receivers. Much human body odor may function as a cue rather than a signal.

- *Putative human pheromone*: a compound that has been proposed as a human pheromone but has not met the criteria. This paper uses this term, or "chemosignal," rather than "pheromone," for every human compound discussed. Nonstandard coinages for chemical attraction circulate in popular writing; they are not used here.

1.2 Evidence-strength vocabulary

Every empirical claim in this paper is graded using the five categories defined in Table 1, which are applied consistently across the IHE series. Claims for which direct evidence is absent, or for which the available evidence is predominantly negative, are additionally labeled **Not supported**.

Table 1. Evidence-strength categories used in this paper.

Category	Meaning
Established	Replicated across laboratories, convergent methods, large-sample or meta-analytic support
Supported	Consistent findings, but limited replication, samples, or methods
Preliminary	Few or small studies, or a single method or laboratory
Contested	Credible evidence on more than one side, or failed replications
Speculative	Plausible hypothesis without direct evidence

1.3 Claims examined

The paper examines claims that appear frequently in popular and commercial accounts: that humans have a functioning vomeronasal organ; that specific steroids in sweat act as sex pheromones; that people are drawn to the odor of partners with complementary immune genes; that women living together synchronize their cycles; that people detect each other's emotions through scent; that scent compatibility predicts relationship outcomes; that loss of a partner's scent drives distress after a breakup; and that commercial "pheromone" products increase attractiveness. For each, the paper presents the strongest supporting evidence, the strongest objection, and a graded verdict.

What this paper does not claim

This paper does not claim that any human pheromone has been identified, that body odor determines whom a person desires or should choose, or that odor-based or genetic "compatibility" can or should guide partner selection. It does not endorse any fragrance, additive, or "pheromone" product, and the Institute has no commercial interest in such products. It does not offer therapy, diagnosis, or clinical guidance. IHE provides preventive education, not treatment; people experiencing significant distress after a relationship ends, or any olfactory loss or disorder, should consult licensed clinicians. Where the paper discusses possible future research, it describes questions to be tested, not findings.

2. What Counts as a Pheromone

2.1 Definitional history

The word *pheromone* was introduced by Karlson and Lüscher (1959), who defined pheromones as substances secreted to the outside by an individual and received by a second individual of the same species, in which they release a specific reaction. The term was introduced in the same year that bombykol, the sex attractant of the silk moth, was chemically identified (Wyatt, 2014), and the definition was built around a model in which a single identified molecule produces a stereotyped effect. Subsequent work distinguished *releaser* pheromones, which trigger relatively immediate behavioral responses (for example, mate attraction in moths), from *primer* pheromones, which produce slower physiological changes, such as shifts in reproductive timing or endocrine state, in the receiver (Wyatt, 2014; Liberles, 2014).

Pheromones in mammals are now well documented. Reviews of mammalian chemical communication describe identified molecules that elicit specific behavioral or endocrine responses in mice and other species, detected by both the vomeronasal and the main olfactory systems (Liberles, 2014). A widely cited example is the rabbit mammary pheromone, a single volatile compound that elicits nipple-searching in newborn rabbits; another is androstenone, a component of the boar's sex pheromone, which elicits the mating stance in receptive sows (Wyatt, 2014). These cases establish a benchmark: an identified compound, a bioassay that measures a specific response, and reproduction of that response with the synthetic molecule at natural concentrations.

2.2 Criteria and why they matter

Wyatt (2015) argues that research on human pheromones has largely skipped the steps that produced success in other species. In the animal literature, candidate molecules are found by bioassay-guided fractionation: a behavioral or physiological response to a natural secretion is first established, the secretion is separated into fractions, and the active fraction is progressively narrowed down until the responsible molecule (or blend) is identified and confirmed synthetically. By contrast, the most studied human candidates were chosen largely because they are steroids found in, or related to compounds in, human secretions, and were then tested for many possible effects; Wyatt calls the resulting period the "lost decades" of the field. Doty (2010) goes further, arguing that the pheromone concept as usually applied to mammals overstates the specificity and innateness of chemical communication, much of which is better described in terms of learning and context.

Two distinctions are needed. First, Meredith (2001) urges separating the question of whether humans communicate chemically from the question of whether that communication involves pheromones, and proposes a working definition: chemical substances released by one member of a species as communication with another member, to their mutual benefit. Second, most of the human evidence reviewed below concerns *signature mixtures* and learned associations (for example, recognizing a partner's odor) rather than species-wide signals. Showing that body odor matters socially does not show that a pheromone is involved.

Verdict. The pheromone concept is **Established** in insects and many mammals. Applying it to humans requires evidence of a species-wide molecule with a specific, reproducible effect at natural concentrations; as the following sections show, no human compound currently meets that standard.

3. The Anatomy of Human Chemosensation

3.1 The vomeronasal organ

It is often claimed that humans possess a functioning vomeronasal organ (VNO), the septal chemosensory structure that detects pheromones in many mammals. The best evidence is anatomical: small pits or ducts in the anterior nasal septum can be observed in many adults, and a few studies in the 1990s reported electrical responses to applied steroids at these sites (Meredith, 2001).

The weight of evidence is against a functioning human VNO. Reviews of the histology find that the human vomeronasal epithelium lacks the receptor neurons characteristic of a functional organ, and that no neural connection to an accessory olfactory bulb has been demonstrated in adults (Witt & Hummel, 2006; Meredith, 2001). Molecular evolution points the same way. *TRPC2*, a gene essential for vomeronasal signal transduction in mice and expressed only in the VNO, is a pseudogene in humans; primate comparisons indicate that selective pressure on it relaxed in the common ancestor of Old World monkeys and apes, when the organ likely became vestigial (Liman & Innan, 2003). Most directly, Frasnelli et al. (2011) found that functionally occluding the VNO did not change perception of, sensitivity to, or brain responses (measured with positron emission tomography) to androstadienone, and that people with and without an identifiable VNO did not differ in sensitivity to it.

Verdict. That the adult human VNO is vestigial and lacks a demonstrated sensory function is **Supported** to **Established**. A role for the human VNO in processing chemosignals is not supported.

3.2 The main olfactory system

The absence of a functional VNO does not mean that humans cannot process social chemical information. In other mammals, some pheromones are detected by the main olfactory epithelium rather than the VNO (Liberles, 2014). In humans, social odors are processed through the main olfactory system. Humans have roughly 400 types of functional olfactory receptor, and the claim that human olfaction is poor relative to other mammals has been challenged as a historical misconception rather than a measured finding (McGann, 2017). Olfactory projections reach the amygdala and related limbic structures with fewer intervening relays than other senses, and aversive odors activate the human amygdala (Zald & Pardo, 1997).

Perception of putative chemosignals also varies genetically. Keller et al. (2007) showed that the human olfactory receptor OR7D4 is selectively activated by androstenone and androstadienone, and that common genetic variants in this receptor alter how intense and how pleasant or unpleasant androstenone smells. A compound that smells markedly different to different receivers is a poor

candidate for a uniform, species-wide signal, and this variation is uncontrolled heterogeneity in studies that treat all participants as equivalent receivers.

Verdict. That the main olfactory system can carry socially relevant chemical information to emotion-related brain regions is **Established** at the anatomical level. Its specific role in attraction is addressed below.

4. Body Odor as a Source of Social Information

4.1 What shapes body odor

It is often claimed that natural scent is a "biological signature" shaped by genetics, diet, hormones, immune genes, and the skin microbiome. This claim is broadly sound, with important qualifications.

Human axillary odor is produced largely by the interaction between odorless precursor molecules secreted by specialized glands and enzymes from commensal skin bacteria, which release odorous carboxylic acids and sulfur compounds (Natsch & Emter, 2020). Genetics contributes at several points. A loss-of-function variant in the *ABCC11* gene abolishes secretion of the relevant precursors, and its high frequency in East Asian populations explains why a large proportion of people there produce little typical axillary odor (Natsch & Emter, 2020). Chemical analysis of sweat, urine, and saliva samples from 197 adults identified reproducible, individually distinctive profiles of volatile compounds and consistent differences between the sexes (Penn et al., 2007). Immune activation also changes body odor: in a placebo-controlled experiment, healthy volunteers injected with bacterial endotoxin had body odor rated as more aversive within hours, an effect statistically mediated by their level of immune activation (Olsson et al., 2014).

The qualification concerns immune genes specifically. Natsch and Emter report that genes in the human leukocyte antigen (HLA) complex, the human major histocompatibility complex (MHC), did not affect the pattern of key odorous carboxylic acids in the small population studies available (Natsch & Emter, 2020). A link between MHC genotype and body odor is plausible and is supported by animal work, but the chemical pathway in humans has not been demonstrated.

4.2 What perceivers can extract

People can extract socially relevant information from body odor: individual identity and sex (Penn et al., 2007; Roberts et al., 2020), recent illness (Olsson et al., 2014), and some emotional states (Section 8). These capacities are typically measured in forced-choice or rating tasks with collected samples. They show that the information is present and usable in controlled conditions, not how much it shapes everyday behavior, where it competes with visual, vocal, verbal, and contextual information and is usually overlaid by fragrances (Section 9.4).

4.3 Hormones and body odor

It is often claimed that testosterone, estrogen, progesterone, and cortisol all change how a person smells, communicating fertility, emotional state, and stress. The evidence is mixed and should be stated hormone by hormone.

For women's reproductive hormones, the evidence is moderate. In one study, men rated axillary odor samples collected from 12 women across the menstrual cycle, and samples from the follicular (fertile) phase were rated as most attractive and least intense (Havlíček et al., 2006). In a later study, 57 men rated odors of 28 naturally cycling women collected at peak fertility; men agreed substantially on which odors were attractive, and attractiveness was predicted by higher estradiol and lower progesterone levels, but not by cortisol or testosterone (Lobmaier et al., 2018). These findings are consistent with the idea that body odor varies with ovarian hormones, but both studies used small donor samples, and the broader literature on cycle-related shifts in attraction is itself contested (see IHE-WP-03 and Section 9.2). For men's testosterone, and for cortisol as an odor-borne stress signal in everyday contexts, direct evidence is thinner.

Verdict. That body odor carries information about individual identity, sex, and acute illness is **Supported**. That it varies with women's ovarian hormones is **Preliminary** to **Supported**. That it reliably "communicates fertility status" to observers in natural settings is **Contested**. That cortisol or testosterone produce odor changes that others detect and act upon in daily life is **Preliminary** at best.

5. Putative Human Pheromones: Androstenes and Estratetraenol

5.1 The compounds

Three steroids dominate the literature. *Androstenone* is present in human axillary secretions and is a component of the boar's sex pheromone. *Androstadienone*, present in male axillary secretions, is the most studied human candidate. *Estratetraenol* has been proposed as a female counterpart. Popular accounts associate androstenone with dominance, androstadienone with mood and arousal, and estratetraenol with femininity and fertility.

How these compounds came to be studied is relevant to how the evidence should be weighed. Wyatt (2015) notes that androstadienone and estratetraenol entered the research literature through claims associated with commercial development, rather than through bioassay-guided isolation of a compound responsible for a demonstrated response, and that the evidence that estratetraenol is present in women's secretions in biologically meaningful amounts is weak. In addition, many studies have applied the compounds at concentrations far above those found in natural secretions, often at levels that are consciously perceptible as odors (Wyatt, 2015).

5.2 The strongest supporting evidence

Several studies report effects of androstadienone on psychological state, physiology, and brain activity. Jacob and McClintock (2000) reported that exposure to androstadienone modulated women's self-

reported mood and psychological state, with effects that depended on context. Wyart et al. (2007) found that smelling androstadienone maintained higher salivary cortisol levels in women, relative to a control odor. In a positron emission tomography study, Savic et al. (2001) reported that androstadienone activated the hypothalamus in women, and estratetraenol activated it in men, a sex-differentiated pattern that the authors interpreted as a potential substrate for sex-specific responses. In a speed-dating setting, Saxton et al. (2008) reported that women exposed to androstadienone gave higher attractiveness ratings to men, although the effect was not uniform across events and the authors interpreted it as a modulatory influence. Zhou et al. (2014) reported that androstadienone biased the perceived gender of ambiguous point-light walkers toward male in heterosexual women and gay men, and that estratetraenol biased it toward female in heterosexual men, with effects depending on the observer's sex and sexual orientation.

5.3 The strongest objections

First, the effects are inconsistent and frequently fail to replicate. Hare et al. (2017) tested the specific predictions that follow if androstadienone and estratetraenol signal gender. In double-blind, within-subject designs, exposure had no effect on judgments of the gender of gender-neutral facial morphs (46 participants), or on ratings of opposite-sex faces for attractiveness and probable unfaithfulness (94 participants). Ferdenzi et al. (2016) found that androstadienone affected ratings of facial and vocal attractiveness in both men and women, rather than in the sex-specific way that a sex pheromone would predict, and concluded that the results favor general effects (such as heightened attention or arousal) over sex-specific signaling.

Second, the dose and perceptibility problem. Effects obtained with concentrated compounds, often detectable as odors, cannot be attributed to pheromonal action: a strong or unfamiliar smell can alter mood, arousal, and cortisol through ordinary odor perception and expectation. Blinding is difficult when the experimental compound can be smelled and the control cannot. Perceptual variation among receivers (Section 3.2) also means that the same nominal dose is experienced differently by different participants (Keller et al., 2007).

Third, the neuroimaging evidence is vulnerable to reverse inference. Inferring "sexual" processing from activation of the hypothalamus, a region involved in many functions, is valid only to the extent that the region responds selectively to that process (Poldrack, 2006). Small imaging samples compound the problem, because underpowered studies inflate effect estimates and yield many false positives (Button et al., 2013).

Fourth, there is no evidence that these compounds meet the definitional criteria. No study has shown that a species-wide response to a natural secretion is produced by any of these molecules at natural concentrations (Wyatt, 2015; Doty, 2010).

5.4 Verdict

That androstadienone can affect mood, attention, or physiology under some laboratory conditions is **Contested**: positive findings exist, but so do well-designed null results, and the positive findings are

confounded by dose and perceptibility. That androstadienone, androstenone, or estratetraenol are human sex pheromones is **not supported**; on current evidence it should be regarded as unlikely. Claims linking these compounds to specific traits such as "dominance," "confidence," "softness," or "nurturing" have no direct evidential basis and are **Speculative** at most.

6. MHC-Associated Odor Preferences

6.1 The hypothesis and the best evidence for it

It is often claimed that people are attracted to the scent of partners whose immune genes differ from their own, and that this unconscious preference guides them toward genetically compatible mates and more resilient offspring. The hypothesis has a serious scientific basis. In mice and several other vertebrates, MHC genotype influences odor and mate choice, and preferences for MHC-dissimilar or MHC-diverse mates are well documented (Havlicek & Roberts, 2009; Winternitz et al., 2017).

The best-known human study is the "sweaty T-shirt" experiment of Wedekind et al. (1995). Male students wore T-shirts for two nights; female students, typed for HLA genes, rated the odors. Women rated odors of MHC-dissimilar men as more pleasant than those of MHC-similar men, and this pattern was reversed in women taking oral contraceptives. Jacob et al. (2002) reported a more complex pattern: women's odor preferences were associated with the number of HLA alleles that a donor shared with alleles the woman had inherited from her father, suggesting a preference for intermediate rather than maximal dissimilarity. At the genomic level, Chaix et al. (2008) analyzed genome-wide data from couples and reported that European American spouses were more MHC-dissimilar than random pairs, whereas African (Yoruba) spouses showed no such pattern.

6.2 The objections

The evidence has not converged. Derti et al. (2010) reanalyzed the genomic data and found that the European American result depended on a small number of extreme data points, was not robust to conservative changes in analysis, and could not be reproduced in an independent sample of European American couples. Probst et al. (2017) tested men's preferences for women's body odors collected at peak fertility, when any MHC-linked preference should be strongest; men readily distinguished odors they found more and less attractive, but their preferences were unrelated to HLA dissimilarity, heterozygosity, or allele rarity.

Meta-analytic evidence is the most informative. Winternitz et al. (2017) combined 58 effect sizes from 30 studies across seven primate species. In humans, they found a statistically significant preference for MHC-diverse partners, but no overall tendency toward MHC-dissimilar mate choice; human studies produced effect sizes in both directions, and apparent preferences for MHC similarity in observational studies appeared to be an artifact of ethnic heterogeneity in the samples. The overall effects were weak. A later set of meta-analyses by Havlíček et al. (2020) found no association between MHC dissimilarity and mate choice in genomic studies of actual couples, no significant association with relationship satisfaction (with evidence of publication bias in that literature), no significant association with odor

preferences, and no significant overall effect when all study types were combined. The authors called for much larger, more geographically and culturally diverse samples that control for genome-wide similarity.

A further limitation is conceptual. MHC-linked effects, where reported, concern laboratory ratings of odor pleasantness. Partner choice is shaped by proximity, social networks, culture, personality, appearance, and much else; a small effect on odor ratings need not translate into a detectable effect on whom people partner with.

6.3 Relationship outcomes

It is also claimed that couples with strong scent attraction or MHC complementarity have more satisfying and more stable relationships. The most relevant study is indirect. Roberts et al. (2012) compared women who were or were not using oral contraception when they met the partner who fathered their first child. Women who had been using oral contraception reported lower sexual satisfaction and partner attraction, but greater satisfaction with their partner's paternal provision, and their relationships lasted longer on average. The authors interpreted the pattern in terms of cycle-related preference shifts, which hormonal contraception suppresses. The study is observational and retrospective, women who use oral contraception differ in many ways from those who do not, and it did not measure odor or MHC directly. As noted above, the meta-analytic association between MHC dissimilarity and relationship satisfaction is not significant (Havlíček et al., 2020).

6.4 Verdict

That MHC genotype influences human odor preferences is **Contested**. That humans choose MHC-dissimilar mates is **Contested**, with the most recent meta-analyses finding no overall effect. A weak preference for MHC diversity has some meta-analytic support but is **Preliminary**. That odor-based or MHC "compatibility" predicts relationship satisfaction or stability is **not supported**. The Institute does not provide, and does not endorse, genetic or odor-based partner matching; even if MHC effects were robust, effects of this size would provide no basis for individual decisions (see IHE-WP-05 on the limits of individual-level prediction).

7. Menstrual Synchrony and Primer Effects

7.1 The initial findings

McClintock (1971) reported that women living together in a college dormitory showed increasing synchrony in the onset of their menstrual cycles over the academic year, and proposed a pheromonal mechanism. Stern and McClintock (1998) later reported that odorless compounds collected from the axillae of women at different cycle phases, when applied under recipients' noses, shortened or lengthened the recipients' cycles depending on the donors' phase. These studies are the most frequently cited evidence for human primer pheromones.

7.2 The objections

Subsequent studies have often failed to find synchrony, and methodological critiques have identified ways in which apparent synchrony can arise by chance. Yang and Schank (2006) studied women living together in dormitories over a full year and found no synchrony; they showed that natural variability in cycle length produces repeated convergence and divergence of cycle onsets, which can create an impression of synchrony if cycles are observed over short windows or analyzed with methods that do not account for this variability. The intuitive appeal of the phenomenon, and the fact that two cycles of different lengths will periodically appear aligned, help explain its persistence in popular belief. The Stern and McClintock study used a small sample, the active compounds were not identified, and critics note that the result has not been established by independent replication (Wyatt, 2015; Doty, 2010).

7.3 Partner "synchronization"

Popular accounts extend the synchrony idea to couples, claiming that partners with strong pheromonal compatibility harmonize their sleep, libido, and mood. No study known to the Institute has tested a pheromonal mechanism for such effects. Couples do share schedules, environments, and emotional exchanges, all of which could produce correlated sleep and mood without any chemical signal. One experimental finding is relevant but distinct: in a study of 155 participants, sleeping with a partner's scent, compared with a control scent, increased actigraphy-measured sleep efficiency by somewhat more than 2% on average, regardless of whether participants believed they were smelling their partner (Hofer & Chen, 2020). This is evidence that familiar partner odor can affect sleep, discussed further in Section 9.3. It is not evidence of synchronization or of a pheromone.

Verdict. Menstrual synchrony in women living together is **Contested**, and the better-controlled studies suggest that it is largely a statistical artifact. Pheromonal regulation of ovulation in humans is **Preliminary** and unreplicated. Pheromone-driven synchronization of partners' sleep, libido, or mood is **Speculative**.

8. Emotional Chemosignals

8.1 Evidence

It is often claimed that humans can detect fear, anxiety, anger, and arousal through scent. For fear and stress, this is the best-supported area of human chemosignal research. Chen and Haviland-Jones (2000) collected axillary odor from 25 donors while they watched frightening or amusing films; raters identified the "fear" and "happy" samples above chance in some conditions, with differences by donor and rater sex. Zhou and Chen (2009) found that fear-related sweat biased women toward interpreting ambiguous facial expressions as more fearful, with no effect when the expression was clear. In a double-blind experiment, de Groot et al. (2012) found that fear chemosignals elicited fearful facial expressions and increased sensory sampling (sniff magnitude, eye scanning) in receivers, whereas disgust chemosignals elicited disgust expressions and reduced sampling.

A meta-analysis of 26 studies with 1,652 participants found a small-to-moderate pooled effect of fear, stress, and anxiety chemosignals (Hedges' $g = 0.36$, 95% CI 0.31 to 0.41), p-curve evidence consistent with a true effect, and no evidence of publication bias (de Groot & Smeets, 2017). The authors noted that the meta-analysis did not assess the internal validity of the included studies, and the samples were predominantly male donors and female receivers.

Emotional tears provide a second, less replicated example. Gelstein et al. (2011) reported that men who sniffed odorless, negative-emotion tears collected from women rated women's faces as less sexually attractive and showed reduced self-reported and physiological arousal, reduced testosterone, and reduced activity in brain regions associated with sexual arousal.

8.2 Limits

These findings concern emotional contagion and perceptual biasing in laboratory settings, with odor collected under controlled emotion induction and presented in isolation. They do not show that people detect a partner's emotional state through scent in ordinary interaction, where visual, vocal, and verbal cues are far richer. The specific popular claim that partners detect a "cortisol-based stress scent" during conflict has not been directly tested; cortisol itself is not volatile, and the chemical identity of the active components in stress sweat remains unknown. Emotional chemosignals are best described as *cues* that can shift perception at the margin, consistent with findings that their effects are strongest when other information is ambiguous (Zhou & Chen, 2009).

Verdict. That human body odor collected during fear or stress can modestly influence receivers' emotional perception and expression in laboratory settings is **Supported**. The chemosignaling function of emotional tears is **Preliminary**. Detection of a partner's emotional state through scent during everyday conflict is **Speculative**.

9. Olfaction in Attraction and Close Relationships

9.1 How much does smell matter in attraction?

Popular accounts often state that scent contributes significantly to first impressions, sexual interest, and "chemistry." The evidence for this comes mainly from self-report. In questionnaire research, women rated olfactory information as more important to their choice of partners than men did, while men gave greater weight to visual information (Herz & Inzlicht, 2002). Self-reports about the importance of a sense are not measures of its causal influence, and people's stated preferences in partner choice often diverge from their revealed choices (see IHE-WP-01 and IHE-WP-03). Experimental evidence that natural body odor changes real-world attraction decisions, independently of appearance and behavior, is limited.

Sexual orientation matters for this literature, which has mostly studied heterosexual participants. Martins et al. (2005) found that preferences for body odors differed according to both the gender and the sexual orientation of donors and raters, suggesting that odor production, odor preference, or both

vary with orientation. This argues against assuming a single, reproduction-oriented model of odor-based attraction; it awaits replication in larger, more diverse samples.

9.2 Body odor attractiveness across the menstrual cycle

The studies reviewed in Section 4.3 suggest that women's odor may be rated as more attractive near ovulation (Havlíček et al., 2006; Lobmaier et al., 2018). These findings belong to the larger and contested literature on ovulatory-cycle effects, in which two meta-analyses reached different conclusions about whether women's mate preferences shift across the cycle: one found robust shifts for preferences relevant to short-term attraction (Gildersleeve et al., 2014), while the other found little support for such shifts (Wood et al., 2014). IHE-WP-03 discusses this dispute in detail. For present purposes, the odor findings rest on small samples and should be graded **Preliminary**.

9.3 Partner odor, comfort, and stress

The most consistent recent evidence concerns the familiar odor of a romantic partner rather than any specific chemical. A questionnaire study found that deliberately smelling an absent partner's clothing during separation was a common practice, described by respondents as comforting (McBurney et al., 2006). Experimental studies have since tested the idea. In a study of 96 women exposed to a standardized laboratory stressor, smelling a partner's scent reduced perceived stress, whereas a stranger's scent elevated cortisol, relative to a neutral scent (Hofer et al., 2018). In a smaller study ($N = 34$), partner odor reduced subjective discomfort during mild electric shocks relative to one's own odor, and attenuated skin conductance responses among participants high in attachment security (Granqvist et al., 2019). The sleep study described in Section 7.3 is consistent with these findings (Hofer & Chen, 2020).

These are promising results, and they are framed in terms of familiarity, learned association, and attachment rather than pheromones. They are also limited: most samples are small to moderate, drawn mostly from North American or European university communities, and focused on heterosexual couples; the active components of the partner odor are unknown; and expectations may contribute, although the sleep effect did not depend on participants' beliefs.

Verdict. That a romantic partner's familiar body odor can reduce perceived stress and improve sleep efficiency in some contexts is **Preliminary** to **Supported**: effects are consistent across a handful of independent studies, but replication with larger and more diverse samples is needed.

9.4 Fragrances

It is often claimed that perfumes and colognes can be "layered" to project personality traits such as warmth, mystery, or dominance. Research on fragrance use is more modest. Allen et al. (2016) found that applying fragrance altered how body odors were perceived and partly disrupted perception of odor cues to mate quality, with sex-specific effects. Fragrances can therefore mask or modify natural odor information, complicating claims about natural chemosignals in everyday life. No peer-reviewed evidence known to the Institute shows that particular fragrance combinations reliably communicate

specific personality traits. The Institute has no commercial interest in fragrance and does not offer fragrance recommendations.

9.5 Scent and long-term compatibility

Claims that couples who report strong scent attraction have higher satisfaction, lower breakup risk, or better conflict communication lack direct evidence. The partner-odor studies concern short-term stress and sleep, not relationship trajectories, and the MHC literature does not support a link with satisfaction (Havlíček et al., 2020). These claims are **Speculative**.

10. Olfactory Memory, Emotion, and Relationship Loss

10.1 What is known about odor-evoked memory

It is often observed that the scent of a former partner's perfume, shampoo, or laundry can trigger a flood of emotion. The underlying psychological phenomenon has a reasonable evidential basis. Odors activate the amygdala (Zald & Pardo, 1997), and research on odor-evoked autobiographical memory finds that memories cued by odors tend to be rated as more emotional and evocative than memories cued by words or pictures, although not necessarily more accurate (Herz, 2016). The anatomical proximity of olfactory processing to limbic structures is a plausible pathway for this effect, but direct evidence connecting the anatomy to the subjective experience is limited, and odor-cued memories are not uniquely powerful in every respect.

10.2 Claims about breakup distress

Popular accounts sometimes assert that loss of a partner's scent is one of the strongest triggers of emotional collapse after a breakup. No direct evidence supports this ranking. Reminders of a former partner, including possessions, places, photographs, music, and messages, can evoke distress, and odors may be among the more evocative of these reminders, but no study known to the Institute has compared the effect of olfactory reminders with other reminders in people recovering from relationship loss. Equally important, most people recover from loss without intervention: research on bereavement and other aversive events finds that resilience is common rather than exceptional (Bonanno, 2004). IHE-WP-02 discusses heterogeneity in recovery after romantic loss.

10.3 A hypothesis for future preventive-education research

The Institute treats the relation between odor and relationship loss as a research question, not as a basis for any program or intervention. A testable hypothesis is that, among people who have recently experienced a breakup, unexpected exposure to odors associated with the former partner produces larger short-term increases in negative affect and intrusive thoughts than exposure to matched non-olfactory reminders, and that the size of this effect is moderated by attachment anxiety and time since separation. A further hypothesis, suggested by the partner-odor comfort studies (Hofer et al., 2018; Granqvist et al., 2019), is that partner odor may function as an attachment-related cue whose effects change valence when the relationship ends. Both could be tested with ecological momentary

assessment under IRB supervision, with safeguards and referral pathways. Whether any finding would justify educational content (for example, explaining that scent reminders can be evocative and that such reactions are usually transient) would depend on the results. The Institute does not offer interventions for distress after loss; anyone experiencing persistent or severe distress should consult a licensed clinician.

Verdict. That odor-evoked memories tend to be emotionally intense is **Supported**. That partner odor is a uniquely strong trigger of distress after relationship loss is **Speculative**.

11. Commercial "Pheromone" Products: An Appraisal of the Evidence

Products marketed as containing human pheromones, usually the steroids discussed in Section 5 or proprietary blends, are sold with claims that they increase the wearer's attractiveness. The evidence base for these claims is thin.

The most frequently cited supporting studies were small, placebo-controlled trials in which participants applied a product to their usual fragrance and recorded their sociosexual behavior. Cutler et al. (1998) reported that men using the additive showed increases in some sociosexual behaviors that involve a partner's cooperation, but not in masturbation. The lead author was affiliated with an organization that markets such additives, a potential conflict of interest that does not by itself invalidate the findings but heightens the need for independent replication. Winman (2004) reexamined this line of evidence and concluded that the data did not support the claim that the substances increase the wearer's attractiveness to the other sex, noting the need for better-controlled research with matched participant groups.

Beyond these specific studies, the general problems described in Section 5 apply: the active compounds have not been shown to be pheromones; doses in products are unrelated to any demonstrated natural signal; effects found with concentrated compounds in the laboratory are inconsistent; and any effect of wearing a product could arise from the wearer's own expectations and changed behavior rather than from effects on others (Wyatt, 2015; Doty, 2010).

The related claims that "confidence increases natural pheromonal emission," that exercise "boosts testosterone-related cues," or that stress reduction "increases positive bonding signals" have no direct supporting evidence. Confidence, physical activity, and stress reduction plausibly affect attraction through behavior, appearance, and mood; there is no evidence that they do so through a chemical signal.

Verdict. That commercial "pheromone" products increase the wearer's attractiveness is **not supported**. The Institute makes no product claims and has no commercial interest in fragrances, additives, or any other products.

12. Methodological Problems Across the Literature

Several problems recur across the research reviewed above.

Small samples and low statistical power. Many studies in this field include a few dozen participants or fewer, and some rely on odor from a dozen or fewer donors. Underpowered studies both miss true effects and, when they do find significant results, overestimate their size (Button et al., 2013). A simple calculation illustrates the problem. For a two-group comparison with a two-sided α of .05, detecting a standardized mean difference of $d = 0.5$ with 80% power requires about 64 participants per group, and detecting $d = 0.2$ requires about 394 per group. With 20 participants per group, the power to detect $d = 0.5$ is only about 35% (normal approximation). Within-subject designs, common in this field, are more efficient, but they still require roughly 200 participants to detect a within-person effect of $d = 0.2$ with 80% power. Detecting a correlation of about .04, the size of the pooled MHC-dissimilarity effect (Winternitz et al., 2017), would require about 4,050 couples.

Donor sampling. Each odor sample is a single donor's output under particular conditions of diet, hygiene, and health. Studies with few donors confound the effect of interest with idiosyncrasies of those donors, and the number of donors, not only the number of raters, limits generalization.

Dose and perceptibility. As discussed in Section 5.3, many studies of putative pheromones have used concentrated compounds that are consciously detectable, making it difficult to separate chemosignaling from ordinary odor perception, and making blinding fragile.

Flexible analyses and publication bias. Studies that test multiple outcomes, subgroups, and time points create opportunities for selective reporting. Publication bias has been detected in parts of this literature, such as research on MHC and relationship satisfaction (Havlíček et al., 2020), and has been raised in the ovulatory-cycle literature (Wood et al., 2014). Replication-focused designs have repeatedly produced null results for claims that once appeared well established (Hare et al., 2017; Derti et al., 2010; Probst et al., 2017).

Reverse inference from imaging. Brain activation in a region associated with a function does not establish that the function was engaged (Poldrack, 2006).

WEIRD and heterosexual samples. Most participants have been drawn from Western, educated, industrialized, rich, and democratic populations, which are unrepresentative of human diversity (Henrich et al., 2010). Olfaction is a domain in which cultural variation is marked: speakers of Jahai, a language of the Malay Peninsula, name odors as easily as colors, whereas English speakers struggle to do so (Majid & Burenhult, 2014). Genetic variation also differs by population, as with *ABCC11* (Natsch & Emter, 2020). Most studies of attraction have examined heterosexual, cisgender participants, often in male-donor and female-receiver configurations; evidence on same-sex attraction, bisexual and transgender participants, and nonbinary people is very limited (Martins et al., 2005).

Ecological validity and receiver differences. Laboratory paradigms present isolated, often frozen, odor samples without other information, whereas everyday perception integrates odor with many cues, usually alongside fragrances (Allen et al., 2016). Receivers also differ in what they can smell because of receptor genetics, specific anosmias, and age (Keller et al., 2007), differences that are rarely measured.

13. Evidence at a Glance

Table 2 summarizes the paper's central claims and their evidence grades.

Table 2. Summary of central claims, evidence strength, and principal limitations.

Claim	Evidence strength	Representative sources	Principal limitation
A conclusively identified human pheromone exists	Not supported	Wyatt (2015); Doty (2010)	No bioassay-guided identification
Adult human VNO is vestigial and nonfunctional	Supported to Established	Meredith (2001); Liman and Innan (2003); Frasnelli et al. (2011)	Few direct functional tests
Body odor carries identity, sex, and illness information	Supported	Penn et al. (2007); Olsson et al. (2014)	Lab tasks; small donor samples
Androstadienone affects mood, attention, or physiology	Contested	Wyart et al. (2007); Hare et al. (2017); Ferdenzi et al. (2016)	Supraphysiological, perceptible doses
Androstenes or estratetraenol are sex pheromones	Not supported	Wyatt (2015); Hare et al. (2017)	Criteria unmet; failed replications
MHC genotype shapes odor preference and mate choice	Contested	Wedekind et al. (1995); Winternitz et al. (2017); Havlíček et al. (2020)	Weak, inconsistent effects
Menstrual synchrony via pheromones	Contested	McClintock (1971); Yang and Schank (2006)	Chance convergence of cycles
Fear and stress chemosignals shift receivers' perception	Supported	de Groot and Smeets (2017); Zhou and Chen (2009)	Lab settings; donor-receiver sex imbalance
Partner odor reduces stress and improves sleep	Preliminary to Supported	Hofer et al. (2018); Hofer and Chen (2020); Granqvist et al. (2019)	Moderate, homogeneous samples
Odor-evoked memories are emotionally intense	Supported	Herz (2016); Zald and Pardo (1997)	Mechanism inferred, not shown
Scent compatibility predicts relationship outcomes	Speculative	Roberts et al. (2012); Havlíček et al. (2020)	No direct test; indirect proxies
Partner scent loss is a uniquely strong breakup trigger	Speculative	Bonanno (2004)	No comparative studies
Commercial "pheromone" products increase attractiveness	Not supported	Cutler et al. (1998); Winman (2004)	Small, conflicted, unreplicated

14. Ethical Considerations

Consent and covert influence. The appeal of "pheromones" in popular culture often lies in the idea of influencing another person without their awareness. Even if such influence were possible,

attempting to alter another person's sexual or romantic response covertly would be inconsistent with the consent-based definition of seduction used in this series. The Institute does not study covert chemical influence as a skill, and research on chemosignals in attraction should be framed around understanding perception, not around techniques for influencing non-consenting people.

Autonomy and determinism. Narratives in which molecules "control" desire can undermine people's sense of agency and can be used to excuse behavior. The evidence does not support such narratives: chemosignals, where they have effects, bias perception modestly and in context.

Dignity, stigma, and inclusivity. Body odor is a source of stigma, and its perception varies with culture, genetics, and health. Research and education should avoid reinforcing stigma related to ethnicity, class, illness, or disability, should recognize people with anosmia as full participants in intimate life, and should not generalize findings from heterosexual, cisgender, Western samples to other groups without evidence.

Privacy of biometric and genetic data. Body odor contains individually distinctive chemical profiles (Penn et al., 2007), and studies of MHC-linked preferences require genetic data. Both are sensitive biometric information. Studies should collect only what is necessary, store it securely, and avoid uses beyond the consented purpose. The Institute does not perform genetic matching and does not support consumer products that claim to match partners by genotype or odor.

Commercial misuse of science. Scientific findings about chemosignals are routinely cited to market products whose efficacy has not been demonstrated (Section 11). Researchers have a responsibility to state the limits of their findings clearly so that they are harder to misrepresent. The Institute has no commercial interest in any product discussed here.

15. Limitations and Open Questions

This paper is a narrative review, not a systematic review or meta-analysis. The Institute searched the literature selectively, emphasizing primary studies, meta-analyses, critiques, and failed replications in the areas most often cited in popular accounts. Some relevant work, especially non-English-language research and unpublished null results, is likely to have been missed. Evidence grades reflect the Institute's judgment and are open to revision.

Several questions remain open. It is not known whether humans have any pheromone in the strict sense; the most promising candidate context may be early infancy rather than adult attraction, since secretions from the areolar glands of lactating women elicit selective appetitive responses in newborns, although the active molecules have not been identified (Doucet et al., 2009; Wyatt, 2015). It is not known which chemical components of body odor carry information about emotion, illness, or individual identity, or how these interact with the skin microbiome. It is not known whether reported MHC-linked preferences reflect a real but very small effect, a population-specific effect, or no effect. It is not known how partner-odor effects on stress relate to attachment processes over time, or whether they generalize across cultures and relationship types. Finally, the field lacks standardized protocols

for odor collection, storage, and presentation, which makes studies difficult to compare (Roberts et al., 2020).

16. Research Agenda

The following questions are framed as aspirations of a young institute, to be pursued with partner universities, under IRB supervision and review by the Institute's Independent Ethics Committee, and pre-registered before data collection. None has been carried out.

1. **Bioassay-first identification.** Establish a robust, replicated behavioral or physiological response to a natural human secretion, then use bioassay-guided fractionation to identify the active components (Wyatt, 2015). Falsifiable prediction: if a releaser chemosignal exists for a given response, the response will survive fractionation and be reproduced by a synthetic blend at natural concentrations.
2. **Multi-site replication of androstadienone effects.** A pre-registered, multi-laboratory study using natural concentrations, an active odor control matched for intensity, measured individual sensitivity (including *OR7D4* genotype), and samples sized to detect effects of $d = 0.2$. Prediction under the pheromone hypothesis: sex-specific effects on attractiveness judgments; under the general-arousal account, effects of similar size in both sexes (Ferdenzi et al., 2016).
3. **MHC and partner choice at scale.** Analyses of large, ancestrally diverse couple samples that control for genome-wide similarity and population structure (Havlíček et al., 2020). Prediction: if MHC-linked mate choice exists, MHC dissimilarity between partners will exceed that expected from genome-wide relatedness across multiple independent populations.
4. **Partner-odor comfort in diverse relationships.** Replication of partner-odor stress and sleep effects in larger samples that include same-sex couples, nonbinary participants, and non-Western populations, with attachment measured at baseline (Hofer et al., 2018; Granqvist et al., 2019). Prediction: effects depend on familiarity and attachment security rather than on partner sex.
5. **Odor reminders after relationship loss.** An ecological momentary assessment study of the hypothesis stated in Section 10.3, comparing olfactory and non-olfactory reminders, with safeguards and referral pathways in place. Prediction: if odor is a uniquely evocative reminder, olfactory reminders will produce larger short-term increases in negative affect than matched non-olfactory reminders. This study would connect with the research agenda of IHE-WP-02.
6. **Methods infrastructure.** Development and public sharing of standardized protocols for odor collection, storage, and presentation, and power analyses for planned studies using the modeling approaches discussed in IHE-WP-05.

17. Conclusion

Human body odor is a genuine channel of social information. It carries individually distinctive signatures, differs by sex, changes with illness and possibly with hormonal state, and, for fear and stress, can modestly shift how others perceive and respond. A partner's familiar odor may reduce stress and improve sleep. These findings make olfaction a worthwhile topic for the science of attraction and close relationships.

The stronger claims that dominate popular accounts are not supported by the same evidence. No human pheromone has been conclusively identified. The adult human vomeronasal organ appears to be nonfunctional. The steroids most often described as human pheromones have not met the criteria for that label, and their reported effects are inconsistent. The evidence that people choose partners with complementary immune genes, that women's cycles synchronize, that scent compatibility predicts relationship outcomes, or that commercial products increase attractiveness ranges from contested to unsupported. Chemical communication in humans is best understood as one modest, context-dependent input among many, not as a hidden system that governs desire. The most useful next step is not further confident claims, but larger, pre-registered, and more inclusive research designed to test them.

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