

Human pheromones

Communication through body odour

Aron Weller

Human communication is dominated by auditory and visual information. In contrast, many animals use smell to communicate — both immediate and long-term effects of chemical signals have been documented within many species, from yeasts to mammals. This contrast raises two questions. Are humans well-equipped for broadcasting and receiving social chemical messages? And do we communicate through such messages? A study reported by Stern and McClintock¹ on page 177 of this issue suggests that the answer to both of these questions is 'yes'.

Almost 40 years ago, Karlson and Luscher² coined the term pheromone, meaning a chemical that, when emitted from one animal, exerts a behavioural or physiological response in another animal of the same species. Releaser pheromones stimulate rapid behavioural changes, whereas primer pheromones result, through the neuroendocrine system, in delayed physiological or behavioural changes. Other, information pheromones are indicators of an animal's identity or territory.

Mammals usually (although not exclusively) detect pheromones through receptors found in a specialized structure called the vomeronasal organ (VNO). This is a small tubular structure lined with receptor cells, and it is close to the nasal cavity. Pheromonal information sensed by the VNO is transferred to the accessory olfactory bulb and other regions of the brain, including the anterior part of the hypothalamus. This region controls the neuroendocrine systems responsible for aspects of reproductive physiology and behaviour^{3,4}. The VNO-to-brain pathway constitutes the accessory olfactory system, and it is distinct from the main olfactory system, the receptors for which are in the olfactory epithelium in the nose.

Until a few years ago, the human VNO was considered to be atrophied in adults. However, a clearly identifiable VNO was then found near the base of the nasal septum in adults⁴. Initial studies applying chemicals derived from adult human skin to the VNO showed changes in the autonomic nervous system, and in the periodicity of follicle-stimulating hormone and luteinizing hormone from the pituitary gland^{4,5}. These results indicate that a potentially functional VNO–hypothalamic–pituitary–gonadal axis exists. But can humans actually use this system to process and respond to chemical signals emitted by other humans?

Humans, like other animals, emit odours

from many parts of their bodies⁶. Personal body odour represents secretions from several types of skin gland, most of which are concentrated in the underarm (axillary) area⁷. The biochemical composition of these secretions (and the resulting individual body odour) depends on genetic, hormonal, metabolic, dietary, psychological, social and environmental influences⁶. It is not known whether the olfactory signals from an individual's secretions are perceived consciously, and processed through the main olfactory system, or whether a portion of the signals are pheromones, which are presumably processed unconsciously through the accessory olfactory system.

Studies have shown⁸ that a mother can identify the odour of her newborn infant or older child by smelling a T-shirt worn previously by the child, correctly discriminating it from a shirt worn by another child of the same age. In turn, infants prefer breast or axillary pads from their own mothers over pads from unfamiliar mothers. Moreover, children discriminate and prefer their mother's odour, and the body odours of other kin (such as siblings and grandchildren) can also be differentiated⁶. Thus, body odours can provide important identifying information in humans. But can they serve as releaser or primer pheromones? More specifically, can chemical signals from one human be detected by another without being consciously experienced as an odour? And might

they have immediate, or delayed, effects on the neuroendocrinological reproductive systems of other humans?

Research pioneered by McClintock almost 30 years ago⁹ showed that the menstrual cycles of women who are room-mates or close friends tend to converge over time. This suggests that some factor related to social closeness and interaction can shift the timing of the biological clock in the brain that determines ovulation and cycling. The function of this phenomenon — menstrual synchrony¹⁰ — is unclear¹¹. It has often been quoted as evidence for (primer) pheromonal communication in humans. However, this conclusion is incorrect because the mode of communication between women that results in synchrony is unknown. Although VNO olfaction has been proposed as the most likely candidate, it is also possible that menstrual synchrony is mediated by visual or auditory signals, through mutual social activities, similar daily schedules or exposure to similar stimuli.

Since her initial report⁹, McClintock has been examining reproductive behaviour in rodents. By isolating female rats in cages connected only by a common air supply, she showed¹² that the donor rat produces one signal that accelerates ovulation (and shortens oestrus) in the recipient, and another signal that has the opposite effects. Aided by a computer simulation, Schank and McClintock¹³ proposed a model of how the two signals interact to produce oestrous synchrony. The model spans three levels of organization — the group, the rat and the neuroendocrine component — and relies on two hypothetical pheromones, one that delays and one that advances the phase of the ovarian system. This model is in accordance with other diverse biological systems that show syn-

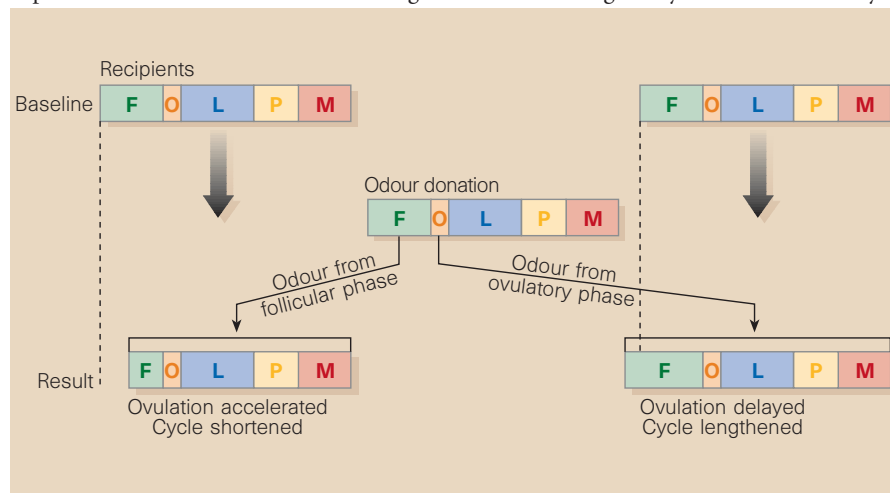


Figure 1 Phases of the menstrual cycle for the women participating in Stern and McClintock's study¹. The menstrual cycle, which is broadly divided into the follicular and luteal phases, is represented here by its sub-phases: follicular (F), ovulatory (O), luteal (L), premenstrual (P) and menstrual (M). Axillary (armpit) odours from the donors' F phase accelerated the latency to ovulation and shortened the cycle length of the recipients (left side). Donations from the O phase delayed ovulation and lengthened the cycles of the recipients (right side). Only the F phase of the recipients was regulated — shortened or lengthened, respectively.

chronization of cycles, such as the flashing of fireflies.

Stern and McClintock¹ now provide support for the generality of the previous model. They collected body odour on cotton pads from female donors. The pads were wiped above the upper lips (under the noses) of other women (recipients), who were asked not to wash their faces for the next six hours. This procedure was repeated daily over two continuous menstrual cycles. The authors found that the biological clocks of the recipients were affected — the timing of their ovulation and menstruation were systematically changed. Specifically, axillary odours from women in the follicular phase of the ovulatory cycle shortened both the time to ovulation and the length of the menstrual cycle in the recipients. Odours taken on the day that the donors ovulated (and the next two days) delayed ovulation and lengthened the total cycle of the recipients (Fig. 1). These phase-advancing and phase-delaying effects show that human axillary compounds can regulate biological rhythms.

This carefully controlled study clearly shows, for the first time, that the potential for chemical communication involving sexual function has been preserved in humans during evolution. Moreover, humans respond to body-odour signals in a neuroendocrinological manner that is similar to (and, in fact, was predicted from) animal models. However, we still do not have evidence that humans actually do communicate by pheromones in modern society. To test this, we could examine whether a phenomenon such as menstrual synchrony exists in women with no sense of smell. Or we could prevent a social odour from acting in a natural social human situation, and assess the result. Elimination of the phenomenon in such a study would support chemical communication. But a negative result would still not exclude the possibility that pheromones are one of the many modes of human communication.

The finding that humans can communicate by pheromones¹ is, nevertheless, ground-breaking and opens many possibilities for future study and application. The active components of body odours (when clearly identified) could be used as natural, alternative ways to control the time of ovulation; for example, as an aid in contraception. Furthermore, as implied by the authors, we may yet discover that other aspects of our behaviour and physiology are affected by covert olfactory messages from other people during social interactions. Because odours have well-known influences on emotions, perhaps human pheromones complement other sources of interpersonal information. This may result in feelings such as emotional contagion¹⁴ (experiencing another person's feelings), sympathy, empathy and their accompanying physiological reactions. □

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Condensed matter

One substance, two liquids?

Pablo G. Debenedetti

Water, like any other liquid, can be supercooled — cooled below its freezing point without crystallizing. The physical properties of supercooled water are unusual: the lower its temperature, the easier it is to compress, and the more pronounced its anomalous tendency to expand when cooled. Most other liquids contract when cooled, and are more difficult to compress the lower their temperature. As if these characteristics were not peculiar enough, on page 164 of this issue¹, Mishima and Stanley offer new evidence for the notion that two different forms of supercooled water may coexist. Although coexistence of liquid mixtures with different compositions is common, a phase transition between two liquid forms of a pure substance, both lacking long-range order, has never been observed.

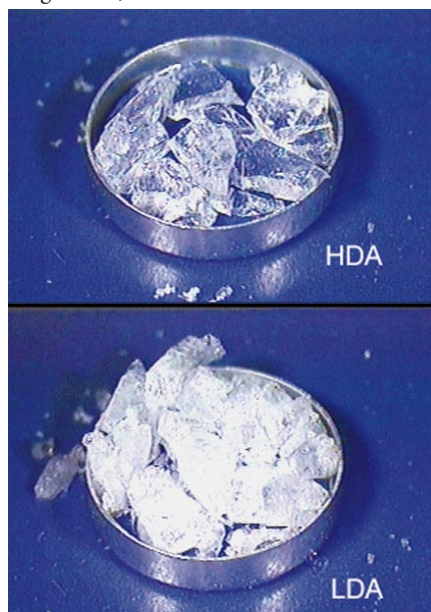


Figure 1 The two forms of glassy water. LDA is formed by rapidly cooling water at atmospheric pressure; HDA is formed by compressing either LDA or ordinary ice at low temperature. These amorphous solids might be able to coexist, as might two structurally similar liquid waters, LDL and HDL.

When liquid water is cooled fast enough to avoid crystallization, it forms a glass². Such vitreous water is found as frost on interstellar dust in dense molecular clouds, and comets are made of it³. In 1985, Mishima and co-workers⁴ proposed the existence of a transition between two forms of glassy water: low-density and high-density amorphous ice (LDA and HDA; Fig. 1). They observed

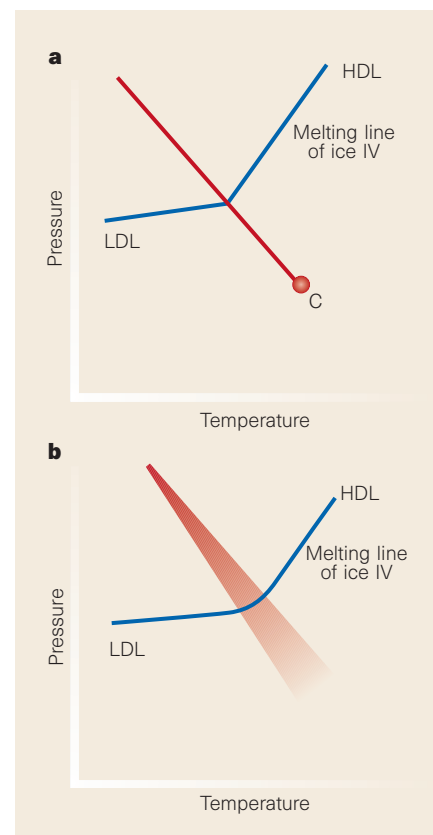


Figure 2 The melting line of ice IV. The sharp change in its slope implies a sudden change in the density and entropy of liquid water¹. This could occur, (a) along a line of coexistence between a low-density and a high-density liquid (LDL, HDL), terminating at a critical point⁵, C; or (b) over a limited range of temperatures and pressures that becomes progressively narrower at low temperatures and high pressures⁷.