The Biochemistry and Psychology of Perfumery

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"To mark out those fields of experience which, on the basis of the present state of our knowledge, are still inaccessible to scientific understanding, often constitutes a valuable, though negative, contribution to scientific progress." W. S. Jevons[1]

Some recent results from the Warwick Olfaction Research Group, probably for the first time, employ the terms biochemistry and psychology together in relation to the subject of perfumery. One might ask the question *"What relationship can there be between these two disciplines and present day perfumery?"* It is apparent that the perfumery phenomena are related to our sense of smell. There is a biochemistry of the sense of smell,[3] therefore, we can also have a biochemistry and psychology of perfumery.

There are two daily events found in the lives of people in the occident which have great interest: some people would be observed to pour or spray fragrant liquids on their skin with the interesting result that they feel happier, more self-confident and more attractive. Some people would be observed to gain a state of

happiness by swallowing a small pill. Differences in the general psychology of the two classes of people would be apparent, reflecting the fact that one of these activities is regarded as *"normal"* and the other as a treatment for depression. We may ask whether there is a common link between these phenomena.

We can see, as shown in figure 1, that the two categories of human activity are similar in formal biological sense. In both cases we have chemicals, either perfumes or tranquilizers, reaching the appropriate receptors and bringing about a change in the mood of the recipient. We pass imperceptively from the obvious biochemistry of the receptor events to the obvious psychology of the mood change. Biochemistry and psychology meet at the axis of the body-mind interaction. If we are to have a complete understanding of perfumery this must include an account of both the biochemical and psychological dimensions.

There are striking differences in the academic investigation of the two aspects of human behavior described above. The mechanism of action of tranquilizers is intensively studied in university departments of pharmacology and psychology and there is a healthy cooperation between universities and the pharmaceutical industry. Perfumery, in contrast, is seldom investigated in universities. Our research group at Warwick is one of the few having a perfumer as part of a multidisciplinary team. With notable exceptions there is little industrial interest in stimulating perfumery research in universities.

Biochemistry of Perfumery

Major problems confront us when we begin to study this subject.[3] For example, the methods of biochemistry require access to living tissues and this means that we cannot study the biochemistry of perfumery using humans. Pharmacology shares the same methodological dilemma and, in consequence, our extensive knowledge of drug receptor mechanisms comes from studies using animals. Since the fundamental biochemical laws apply to all living tissues, we can, for example, validly study the effects of an anaesthetic intended for human use, by investigating its effect on suitable animals. A similar approach is taken in studies on olfactory mechanisms.[2] In our research group we have a parallel programme on humans and animals, emphasizing behavioural research with the former and biochemical studies with the latter.

Since laboratory animals do not use extrait perfumes or perfumed products, though their normal behaviour changed when they are exposed to such perfumes at a critical stage of their development,[4] we must ask whether they can be a valid animal model for the human reaction to perfumes. Two features of animal behaviour come to our rescue. First, rats and other mam-

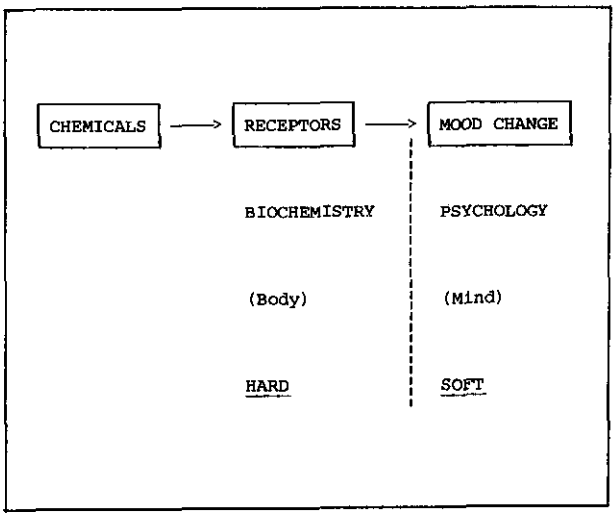

Figure 1. The biochemical and psychological events which are common to both perfumes and "mood" drugs.

mals respond with great sensitivity to most perfumery chemicals. This and other evidence suggests that our olfactory system is basically similar to that of other mammals.[5] Second and more important, animals, not humans, are the "inventors" of perfume. The perfumes of animals, including mammals, constitute a sophisticated chemical communication system which governs many aspects of animal life.[3] There is a natural link between the signalling chemicals of animal perfumes and human perfumery. Animal perfumes have been used empirically for thousands of years as *"animal notes"* in perfumery. Also in mammals, olfaction appears to be a primary information sense.

One of the approaches we have taken to perfumery phenomena has been to study chemicals which occur as signalling chemicals in animal perfumes and which are related to materials used in human perfumery. We have a parallel approach studying the biochemistry in animals and the psychology in humans.

Are there special receptors for odorants with "animal notes"?

This question illustrates the biochemical approach to perfumery phenomena. We will use as an example our studies on the urinous odorant 5-α-androst-16-en-3-one.[6,7] This material is a constituent of human axillary sweat and is a signalling chemical in the pig. It is secreted as a perfume by the boar and the smell both facilitates the sexual response of the sow and induces an aggressive reaction in other boars.[8]

Since urinous-type odours are common in other animals, it is probable that related chemicals are found in other species. This signalling chemical has a rigid molecular structure with a characteristic shape (figure 2) making it, in many respects, an ideal molecular probe for studying the receptors. Once the biochemistry begins, there is no formal difference between studying the binding of a drug or an odorant to their respective receptors; the methodology is the same in each case.

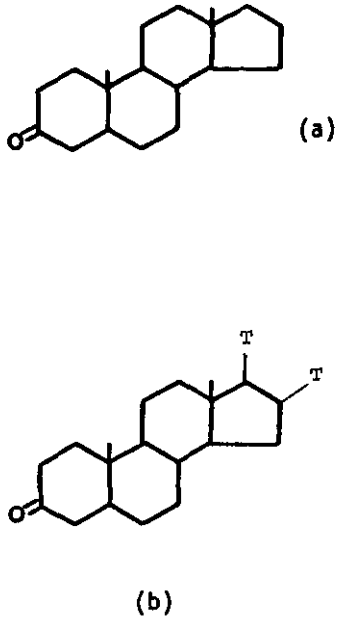

Figure 2. Structures of the ligand used in the binding experiment and in some of the behavioural experiments. a) 5-α-androstan-3-one. b) [16-17^{3}H]-5-α-androstan-3-one. The natural odorant androstanone and the synthetic odorant androstanone have identical odors.

The first task is to synthesise a radio-labelled chemical with a high specific radioactivity. The molecule we synthesised is shown in figure 2. The double bond has been removed—this is not an important structural feature for the odour of the molecule. The tritium atoms in this molecule are well removed from the carbonyl group and do not exchange easily. The high specific radioactivity of the molecule, 52Ci/mmole, enabled us to work with aqueous solutions in the range $\geq 10^{-10}$M.

Radio-labelled odorants like this one are not only valuable for fundamental studies on the biochemical features of olfaction; they are also useful in studying the adsorption behaviour of odorants. High molecular weight odorants, such as this one and related molecules with musk, amber and woody odours have low thresholds and are important base notes in perfumery. In products such as detergents it is important that odorants should adsorb with sufficient strength to survive the washing process and yet with sufficient weakness to release odorants above the threshold level when the garments are dry.

The adsorption or binding behaviour of odorants to fabric or other materials is studied using the same methods that are used for investigating the binding of the odorant to olfactory tissue. The methods are simple in principle. The tissue or fabric is exposed to a solution of pure radioactive odorant and the binding is allowed to come to equilibrium. The free, unbound odorant is removed by washing or other methods and the concentrations of bound and unbound ligands can then be measured using standard radiochemical methods.

While the method is simple in principle, in practice there are many difficulties. This odorant is one of the most hydrophobic ligands (small molecules) which have been used in binding studies and it binds (sticks) to all surfaces. This adsorption behaviour can give rise to serious errors in experimental manipulations with the substance, such as occur in serial dilution of an aqueous solution when determining an olfactory threshold. If the concentration is not corrected for the adsorption effect during dilution, the accumulation of errors will result in a spurious threshold value. We would expect many odorants to have adsorption behaviour of this kind, but it is seldom taken into account in the measurement of an olfactory threshold.

The general "*stickiness*" of this odorant presents us with a problem. We are interested in detecting binding sites in the olfactory tissue which will bind this and related odorants but which will not bind dissimilar odorants. However, this specific binding takes place in the presence of a great excess of non-specific binding to other proteins and membranes of the tissue, analogous to the binding which takes place to fabrics. The problem is related to that of finding the proverbial needle in the haystack—can we detect the specific binding (and on theoretical grounds we would expect a small number of binding sites per unit area of the tissue) in the presence of a great excess of weak

binding to the other parts of the tissue or tissue fractions.

The crucial feature which determines the outcome of such an experiment is the difference in the affinity for binding to the specific and non-specific sites. If, as in the case of many hormones, there is high affinity (K_D-10^{-10}M) for the specific sites and weak affinity for the non-specific sites, the problem is soluble since the dissociation kinetics of the ligand from a binding site is determined by the value of the affinity constant. The weakly binding ligands can be removed from the non-specific sites before there is significant removal of the ligand from the specific sites. However, as the difference between the affinity of the odorant or ligand for the two types of sites decreases, the problems become increasingly intractable. Considerations of this kind have inhibited ligand-binding studies on the olfactory system.[2]

Animal of Choice–Sheep

The animal we chose for our experiments was the sheep and this choice requires an explanation. Although there is evidence for behavior mediated by signalling chemicals in the sheep, no specific chemicals have been identified and it is not known whether androstenone or related odorants contribute to the odour effects observed. The pig uses androstenone as a signalling chemical and binding to pig olfactory mucosa has been studied.[9] No electrical response from the pig olfactory cells could be obtained using androstenone as a stimulant, but specific binding sites were detected.[8,9] We were unable to detect specific sites in pig tissue, but this may have been due to damage caused to the tissue during processing. Because of the current health regulations it is not possible to obtain unprocessed tissue, and this means that the pig is an unsuitable animal for investigation of the olfactory system. The claim that pig olfactory mucosa contains specific binding sites for androstenone has now been withdrawn.[10]

Sheep olfactory tissue which has undergone no processing can be obtained immediately after death and is a convenient source of tissue on a large scale. We have developed a perfusion method for keeping the tissue alive after the death of the animal and this enables us to measure the electrical signals (EOG) induced in the sensing neurones by the odorants.[2]

Androstenone is the highest molecular-weight odorant which has been used in an olfactometer and because of the adsorption problem mentioned above there are severe problems in handling it in an olfactometer. However, it is possible to obtain a weak but definite signal (*figure 3*) indicating that the sheep can smell this odorant. Binding studies on a fraction from the olfactory mucosa has given evidence for specific sites (fig. 3). The experiments are difficult due to the great amount of non-specific binding. The odorant binds to the sites with K_a = 7.0 $10^8 M^{-1}$ which is comparable with the binding of many neurotransmitters and hormones to their receptor sites. The tissue also contains at least one enzyme, linked to NADP, which interconverts androstenone and the corresponding 3-α-alcohol.

This is the first evidence for specific odorant binding sites in the olfactory mucosa of a mammal. However, the evidence from binding studies, although consistent with the presence of specific receptor sites for the odorant, is insufficient to lead to the conclusion that the receptor sites observed are involved in the olfactory transduction step. For example, the tissue might have intracellular proteins with binding sites for

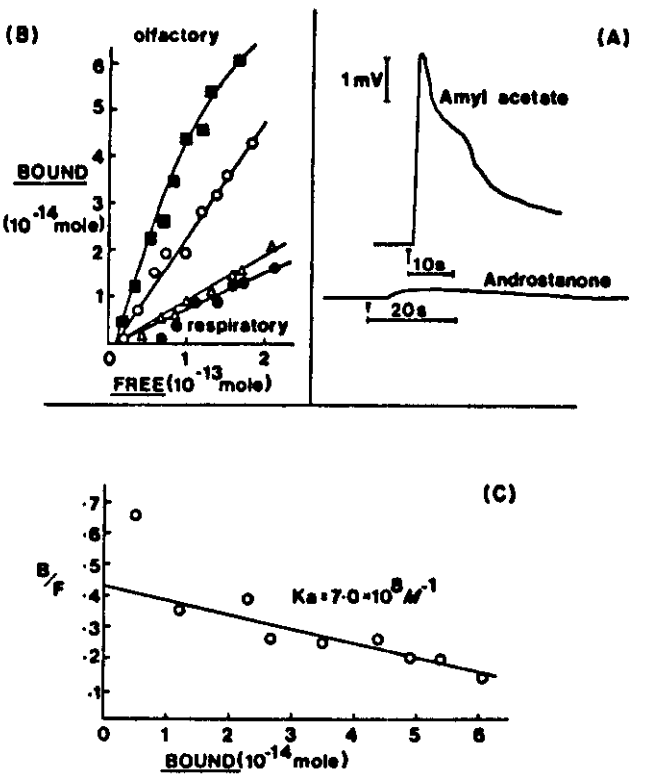

Figure 3. Binding of 5α-[16, 17], ^{3}H)androstan-3-one to sheep olfactory epithelium. (A) EOG from intact sheep olfactory epithelium in response to stimulation by androstanone and amyl acetate. (B) Binding of androstanone to the supernatant fractions of sheep olfactory and respiratory epithelia, following centrifugation at 12,000 g for 15 minutes. The nonspecific binding (o, •) was determined by adding excess unlabeled androstanone to the tissue and labeled steroid. The free and bound ligands were separated using the standard charcoal method. (C) Scatchard plot of binding data shown in (B). (From Reference 2.)

steroid hormones, such as androgens, which have a structure similar to that of androstenone.

In our results which are reported in more detail elsewhere,[2,11,12] we show that androgens do not compete with the binding of the odorant. However, since a binding experiment alone cannot prove that the observed binding is functionally part of the receptor process, we have developed methods for studying the olfactory receptors which are complementary to the binding studies.[2,6,13-16] Of these methods, vapour phase affinity labelling has the potential for specific blocking of an olfactory receptor and has been successful with the sites for fruity odorants.[2] Using this method we should in principle be able to selectively abolish the response of the tissue to urinous odorants while retaining its response to other types of odours. If the binding of the odorant decreased with increasing specific inactivation of the tissue to urinous odorants, we would have conclusive evidence that the observed binding was due to a specific olfactory receptor protein. The poor response of high molecular weight odorants in current designs of olfactometer means that the affinity labelling approach cannot be carried out for the present on this receptor type.

Measuring the Psychological Response to Perfumes

From figure 1 we see that we must use animals to study the biochemistry of perfumery because we cannot use humans. Conversely, when we come to examine the emotional changes induced by either a drug or an odorant we find that there are no satisfactory animal models available and we must turn to humans who are, of course, our primary interest. The sources of possible evidence for the psychological effects of smells and perfumes are listed below.

Anecdotes
Consumer Research
Introspection
Novelist and Poet
Experimental Research

In investigating the changes in emotion or mood induced by a smell present at low levels we encounter crucial methodological problems which are responsible for some of the current crises in the subject of psychology.[17] The facets of human behaviour which we can quantify and study in the laboratories are often trivial in comparison with the repertoire of responses which we view at a party or some similar social encounter. There is a methodological crisis in the area of *"mood"* measurement. The richness of

the responses captured by the novelist who has the inestimable advantage of being privy to the introspection of his characters is difficult to capture in the laboratory experience.

Indeed, just as it is impossible to measure aspects of the behaviour of subatomic particles, such as electrons, without disturbing the properties of the system under observation, so experimental psychology has its own version of the Heisenberg Uncertainty Principle which manifests itself in the psychology of interpersonal attraction. We cannot easily simulate in a laboratory, a meeting, for the first time, between a young man and a young woman and estimate the contribution of her perfume to his estimate of her attractiveness. In a laboratory we lose the context which so frequently confers meaning and significance to a fragrance.[18]

Types of Evidence for the Effects of Perfume on Human Behaviour

It is instructive to review briefly the kind of evidence which we obtain on the effect of perfumes on human behaviour.

- *Anecdotal*

There is probably no aspect of human biology which has such a rich fund of anecdotal evidence as that of human olfaction. There are books full of entertaining and often thought-provoking stories about our reactions to smells. Anyone who is slightly familiar with the popular literature of olfaction will have come across many stories akin to the following.

Somerset Maugham, curious to discover the secret of H. G. Wells's way with women, reports: *"He was fat and homely. I once asked one of his mistresses what especially attracted her in him. I expected her to say his acute mind and sense of fun; not at all; she said that his body smelt of honey."*[9] Again we are left in the dark as to whether this attractive odour was usual or one exhaled only during his tenderer moments.[19]

A Wigan teacher is reported to have sent a boy home because of his smell. The boy's mother sent her this note. *"Dear Miss, our Johnny smells the same as his dad and his dad smells lovely. I should know I've slept with him for 25 years. The trouble with you, Miss, is that you're an old maid and don't know what a proper man smells like."*[20]

How do we judge anecdotes as evidence of the psychology of perfumes? The answer is with circumspection. We can never check on the supposed olfactory prowess of historical figures, neither can we reconstruct many of the situations which constitute the essence of popular olfactory stories. It is instructive to look back at the analogy we drew in figure 1 and reflect that the modern science of pharmacology came into being when anecdotal evidence was discarded and controlled experiments were performed. There is every reason to suppose that the scientific study of perfumery will have a similar history.

- *Consumer Research*

It is common knowledge that large perfumery companies conduct considerable research on consumers' reactions to different odours and perfumes in the *"product mix."* Fragments of the information obtained appear in print.[21] Because of the kinds of fragrances which are usually tested, there is unlikely to be any body of systematic research from which we might be able to formulate some general principles of human reactions to smells. Such knowledge as might contribute to this end is likely to remain cloistered for sound commercial reasons. It may well be that the most interesting studies on the reactions of people to smells are currently carried out in this category of investigation.

- *Introspection*

Our intensely personal reaction to smells is often a matter of comment in the literature of olfaction. Recent studies on olfactory memories strengthens the evidence that we can, with little effort, remember smells and that the context of our olfactory experience may determine our preference for a particular odour.[18] The subjective nature of the olfactory experience means that introspection, though a useful method in psychoanalysis, is unlikely to yield general results of interest in olfaction.

- *The Novelist and Poet as Sources of Evidence*

This category might be considered a mixture of anecdotal and introspection but it is useful to consider it as a source of its own right. The perceptive novelist, poet or playwright can encapsulate the mystery of our response to smells in a single sentence. Many examples could be quoted in support of this, for example

Hast thou inhaled–O reader, say!-
With zest and lazy greed, the old
Incense that chapel arches hold
Or the stale musk of a sachet?

O magic spell, O ecstasy!
To make the present yield the past!

It's thus on a beloved breast
Love culls the flowers of memory.

The tresses long about her face
A living censer, left the place
With strange wild odours all astir,

And in her velvet, muslin, lace,
Candid and girlish, over her
Hovered a perfume, faint, of fur.

Charles Baudelaire[22]

• *Experimental Research*

We can divide this approach into two categories: studies in a natural situation and studies in a laboratory. It is timely to remind ourselves of the peculiar advantages and limitations of laboratory research. The great advantage of a laboratory study is the opportunity it provides for controlling all the variables except the one we wish to manipulate. As an example we can take the Whitten effect. This is the synchronisation of the menstrual cycle in mice produced by the odour of male mouse urine.

If we wanted to verify the Whitten effect we would choose to work in a laboratory with matched animals of the same strain, kept under the same pattern of light and darkness, fed on the same diet, with control of other variables. In this way we can virtually remove all non-olfactory factors which are likely to influence the dependent variables and thus we can measure the treatment effect with greater precision. Related studies are being carried out on the effects of odours on the menstrual cycle in humans. Because in such a study we must necessarily study subjects with different diets, lifestyles and differences in other relevant variables, it is found, as it frequently is in olfaction, that we are hunting for a small difference in a very noisy signal.

Laboratory studies with humans allow us to control extraneous stimuli such as noise, but at the same time they introduce an artificial element in that we encourage subjects to smell more actively than they do in most situations in their lives. Since the level of awareness of olfactory stimuli is an important point in the human olfactory response we have this dilemma; should we attempt to improve our signal-to-noise ratio by working in a laboratory or should we try and study the *"real event"* in a shop or other *"real place."*

Before looking at some results I would like to mention a common fallacy which for want of a better term I will call the *"Simple Simon Fallacy"* or the *"familiarity breeds understanding fallacy."* The essence of the fallacy is this: because we feel we know a lot about smells and their effects in products, we feel, in consequence, that we should be able to understand research on the human olfactory response without any technical background. In other words we feel that it should be so simple that it is readily explicable without the benefit of technical terms.

Turning back to the biochemistry of olfaction, we find that the fallacy does not appear on this topic. People feel, quite reasonably, that if they are to understand concepts such as *"the influence of the phospholipid phase transitions on the allosteric transitions of the adenyl cyclase in the olfactory cilia"*, they must have the necessary biochemical and mathematical background. The reason technical knowledge is necessary to understand the significance of research on the effects of low levels of odours on human behavior can be understood by looking at Table I.

Table I. Types and Strengths of Effects in Experiments

Effect	Strong	Intermediate	Weak
Simple	Cyanide Poisoning	Bacterial Chemotaxis	Biological Effects of Electrical Fields
Complex	Insect Response to Pheromone	Copulin Effects	Human Response to Odour or Touch

The olfactory events of chief interest to perfumery, the influence of fragrances which may be below the threshold of conscious awareness on mood, are examples of weak, complex effects. Looking at a range of biological research we see that fields like molecular biology have made spectacular advances during the past two decades because it was possible to study many strong, simple effects in quick, efficient experiments.[23] Weak, complex effects usually require analysis of covariance (ancova) and other less familiar statistical methods.

Weak, complex effects are studied in several areas of psychology and a common error of interpretation is frequently made. This is to equate the degree of statistical significance with the practical significance of the effects found. A second error is the failure to recognise that the test of scientific truth is replication. These comments may seem obvious but it is a common experience for those of us working on human olfaction to find that popular accounts of re-

search papers oversimplify the complexity of the experiments, and often overestimate effects claimed.

Some Recent Experiments on the Psychology of Smells and Perfumes

We will illustrate current work on the psychology of perfumery by giving three examples of work from our research group.

- *Can we create a preference difference for a fragrance by manipulating a biochemical factor?*

At first this may appear to be a strange thing to do. Our motivation is to gain insight into some of the factors which determine an individual's odour or perfume preference. It is known that there are social and cognitive contributions to odour preference,[18] but it is usually difficult to identify specific factors in the odour of a product which are responsible for its performance in preference tests. We are interested in both innate and learned factors which can determine odour preference. In the experiment discussed here we look at one of the innate factors.

The phenomenon of specific anosmia has been recognised throughout this century but it has only been studied systematically in the laboratory of John Amoore.[24] Individuals are said to have a specific anosmia for a chemical if they cannot detect it in the concentration range which is satisfactory for *"normal"* members of the population while they can detect other classes of odorants in the *"normal"* range. Amoore has ascribed this kind of defect to a biochemical lesion in the sensory cell analogous to a mutation in a bacterial chemoreceptor. He has established in some cases and assumed in others that there is a bimodal distribution of thresholds in the population. It must be remembered that because of the small number of researchers there is virtually no replication of published work in olfaction. Until last year there were no serious attempts to repeat Amoore's work. However, recent studies confirm the basic observations but suggest that both the description of the phenomenon and its interpretation may be more complex than had been realised before.[25]

We chose androstenone for our experiments since it has the highest incidence of specific anosmia of those presently recorded. The simple hypothesis which we tested was as follows. Androstenone is perceived as a strong urinous/sweaty note by about half of the normal population and is not a preferred odour. The other half of the population are poor at detecting it. Therefore, it may be possible to effect a preference difference between the two groups by taking a sample of a perfume and adding various amounts of androstenone. At some level of the added compound it may be detected by the perceivers as an *"off-note"* (though at the levels used they may not be consciously aware of this) and give rise to a preference difference while the specific anosmics would not detect the *"off-note"* and therefore would exhibit no preference difference.

The experimental details and complete results are given elsewhere.[26] Appropriate randomisation and other precautions were taken and are described. We studied nine different perfumes and found effects with seven of them using 125 male and female subjects. An example of the effect we found is shown in Table II. The subjects were presented with a standard concentration of an oeillet perfume on smelling strips containing the amounts of androstenone shown. They were asked to rank the perfume on the four strips in order of their preference on a 1—4 scale. The ranks were analysed using a two-way analysis of variance.

Table II. Rank Totals of the Odours in Preference Experiment

Odour	Group	Level of Androstenone (%)(u/v, w/v) Added 0	0.1	1.0	10.0	χ^2	p
Oeillet	O	156	160	156	196	34.3	<0.001
	A	147	142	152	151	NS	

The Table indicates the rank totals of the osmic (O) and anosmic (A) groups separately. The lower the rank total, the more the odour was preferred.

If no effect was observed there should be no significant difference between the rank totals obtained for the various levels of the androstenone. As can be seen from the data in the table, no effect was found with subjects known to be anosmic to androstenone at the levels encountered on the strip, but an effect was found with the osmatic subjects. Further analysis of this effect using specific F test comparisons between ranks shows that the effect is found at the highest level of the added material. Our hypothesis is borne out for this example and for seven of the nine perfumes used. The subjects had no prior knowledge of the experiment and were not aware that the differences they detected were due to the odour of androstenone.

Though effects of this kind have undoubtedly been studied in perfumery laboratories, this is the first published account of such a study. It should be noted that we used a conservative statistical test and we found a modest effect. It is

likely that the effect is larger but is disguised in this experiment by the high variance of the threshold measurements and other olfactory parameters of the subjects. A repetition using analysis of covariance will probably find a larger effect and may be able to verify our observation (which did not reach an acceptable level of statistical significance) that in some cases, the perfume which was *"doped"* lightly (0.1%) with the androstenone was preferred to the undoped perfume. This kind of effect is known in perfumery but no quantitative studies have been published.

- *Are there objective methods for studying the emotional response to an odour?*

There a number of psychophysiological methods which can be used to detect the response to a sensory stimulus.[27] The electrophysiological concomitants of a sensory response can be measured by various levels of the sensory system. Van Toller and coworkers have recently completed an extensive investigation using skin conductance (SC) as an index of response to a smell.[28,29] This method has been used in olfactory studies by several previous authors,[30] but all the previous experiments had faults in either the design or methodology which gave rise to uncertain results.

The skin conductance is measured by placing small electrodes on the surface of the skin and is measured using conventional electrophysiological equipment. The equipment is similar to the lie-detector. The initial experiments represent the antithesis of a *"natural"* design. The subjects rested on a couch and wore goggles to exclude light. External sounds were removed by playing white noise through headphones. The subjects were breathing regularly and their breathing pattern was monitored. This small point was an important part of the methodology since an altered breathing pattern can trigger SC responses. This particular experimental strategy was adopted because the skin conductance is, in some ways, an alerting response to a novel environmental stimulus. The subjects were in a quiet ventilated cubicle and the odour stimulus was presented on a smelling strip. The experimenter used a mechanical device to position the strip beneath a nostril so as to avoid alerting the subject to a presentation. The subjects were not told that they were about to receive a stimulus and under the conditions used they did not detect an odourless strip. The experimenters communicated with the subject through headphones and the subject indicated a response by pushing a button with his foot, not by talking.

These conditions were an attempt to do what is mainfestly impossible, to eliminate any extraneous olfactory stimulus. Because we breathe we must continually bring odorised air over our olfactory mucosa no matter how much we try to reduce external olfactory stimuli. In experiments on vision it is possible to dark-adapt the visual system by putting subjects in a dark room. A comparable zero stimulus situation is not possible for olfaction but the conditions used provided a constant low level odour background with minimal disturbance from the other senses. A subject in this kind of experiment is very comfortable despite the electrodes and it is quite easy to become drowsy. Because there are fewer sensory processes competing for our attention, an odour stimulus has much greater impact than it would have in an unrestricted environment.

Table III. Mean values (umho's) of the amplitude of the SC for subjects who perceive androstenone as pleasant and unpleasant

	pleasant		unpleasant	
	male (N=6)	female (N=10)	male (N=10)	female (N=10)
androstanone	2.03	1.82	2.93	2.07
aurantiol	1.96	1.25	1.58	1.26

Using this method an electrical signal can be detected when a subject smells an odour (figure 4). We tried to determine if it is possible to detect any difference in the signal when subjects are smelling odours which, in independent experiments, they have rated as pleasant or unpleasant. The variability in the response because of adaptation and other factors makes clear cut differences difficult to see in individual traces. An example of a difference found is shown in Table III. In this experiment all the subjects perceived the well-known perfumery chemical aurantiol as pleasant. Most subjects perceive the urinous/body odour note of androstenone, the odorant used in the binding studies, as unpleasant but a minority of subjects perceive it as pleasant. Overall, the amplitude of the SC responses to androstenone were approximately 1.5 times that of the response to aurantiol ($F\ 1/33 = 5.7$, $p<.02$) and the effects were stronger for the subjects who perceived a hedonic difference between the two odours.

The conditions we used had a dramatic effect on the olfactory ability of many subjects. For example, a high proportion of subjects who had

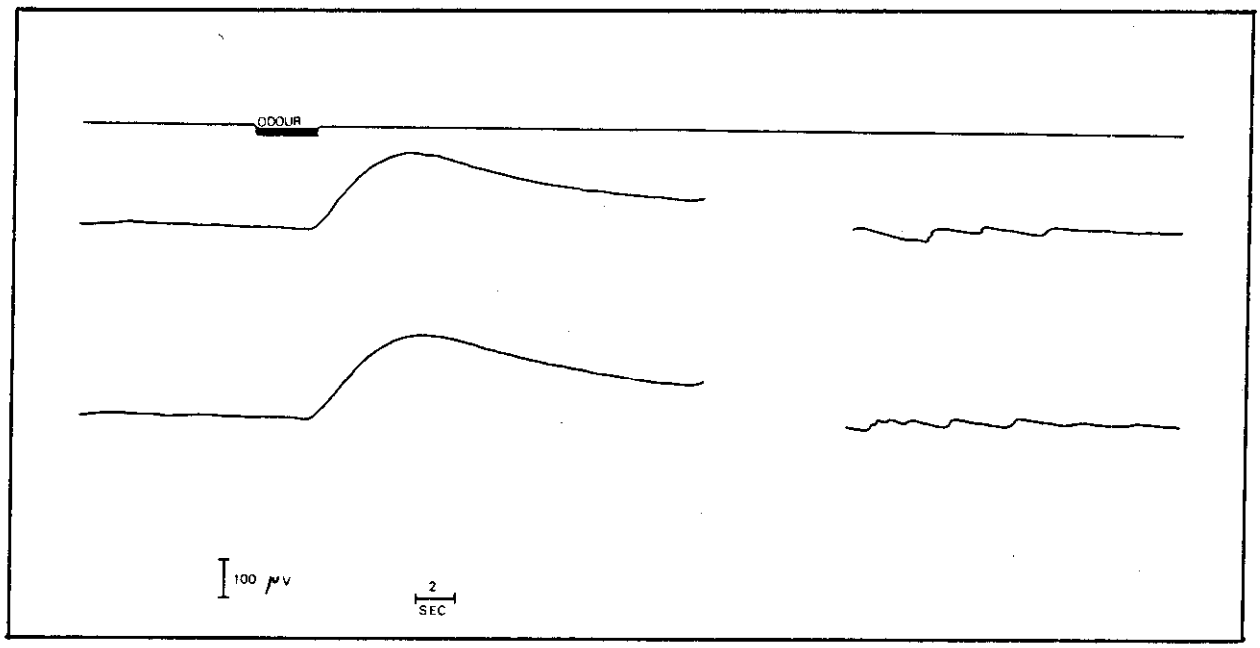

Figure 4. A typical skin conductance response to an odorant. This figure shows the conductance obtained from both wrists of a single subject. Note the steady baseline before the stimulus and the gradual decline of the signal from the maximum amplitude.

been designated as anosmic to androstenone in threshold experiments were able to detect this odorant under the conditions used. This finding vitiated several important experiments.

The experiments also revealed a cognitive effect which has interesting consequences for perfume evaluation. We had a small number of subjects who gave a SC response to androstenone but who failed to give a behavioural response. This at first sight looked like an example of unconscious detection of the stimulus. However subsequent investigation showed that their problem appeared to be one of not having a verbal label for the odour. This made them appear to be unable to detect it. Labelling effects of this kind are important in odour discrimination.[18]

• *Unconscious odour conditioning*

This is widely supposed to be one of the magical effects of perfumes. There is anecdotal evidence to support the thesis but no reported experimental verification of the effect. In our experiments we used trimethylundecylenic aldehyde.[30] This aldehyde is representative of the aliphatic aldehydes and contributes to the characteristic odour-nuancing effect of aldehydes in perfumes of the aldehydic family. The odour of the chemical is not recognised by most untrained subjects and has no particular associations. The aim of this experiment was a simple one—could we pair an odour with a certain mood and then at a latter stage examine the effects of the odour on certain attitudes? In both cases the odour would be present at a low level, and since the experiment would purport to examine explicit non-olfactory effects, any effect found would take place at an unconscious level. The full details are given elsewhere.[31]

Essentially there were two experiments. In the first experiment the subjects (N = 24) completed a block completion task devised by Van Toller as a simple and reliable stressor. The subjects had to complete a design using blocks in a stress-inducing pre-assigned time. There was considerable ego involvement in the task and the subjects found the task stressful. With certain subjects the stressful task was performed in the presence of the odour. On the second occasion the subjects completed mood scoring scales and judged photographs of people both in the absence and presence of the odour. Analysis of variance on the changes of mood scores indicated that female subjects increased on an *"anxiety"* factor throughout the session and this effect is attributed to pairing of odour to the emotional state (stress). Other effects were also found. This is the first reported experimental demonstration showing that if an unfamiliar odour is first paired with an emotional state, at a later time this odour may elicit a similar emotional state.

The Future of Perfumery Research

The experimental work described int his paper represents some of the first attempts to study perfumery phenomena in an academic environment. Many complex questions to be asked about our reactions to fragrances are best tackled in a research group which is removed from the daily pressures of a manufacturing environment. There is increasing interest in chemoreception research.

Organisations such as the European Chemoreception Research Organisation (ECRO) have, with the help of funding from perfumery houses, encouraged a multi-disciplinary approach to the problems of taste and smell. The first institute wholly devoted to chemoreception, the Monell Center in Philadelphia is now well established.

There remains a need to have a small multidisciplinary research group committed to investigating some of the fundamental aspects of perfumery phenomena. Such a group would, ideally, be funded by the international perfumery industry. The literature on olfaction already shows hints that some new and exciting areas of perfumery will result from fundamental studies on our sense of smell.

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