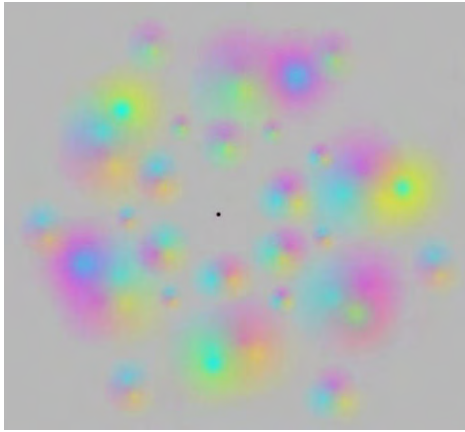


Find your dominant nostril



Focus your attention to the center of the image and enjoy as the colors disappear

1

announcements

2

## Smell outline

- Intro to smell
- What can be smelled?
- Can smell affect behavior?
- Brain mechanisms of olfaction
- Human pheromones?

3



Smell: "The fallen angel"



"For some inexplicable reason the sense of smell does not hold the high position it deserves among its sisters. There is something of the fallen angel about it.

When it woos us with woodland scents and beguiles us with the fragrance of lovely gardens, it is admitted frankly to our discourse.

But when it gives us warning of something noxious in our vicinity, it is treated as if the demon had got the upper hand of the angel, and is relegated to outer darkness, punished for its faithful service."

Helen Keller

4

## An ocean of odors

We live in an ocean of odors, produced by everything imaginable (technically, anything that is volatile, i.e., anything that evaporates)

What are "pleasant" and "unpleasant" odors? Variability is high.  
-Most universally-rated "pleasant" odorant is vanilla.

smelling and breathing go hand-in-hand: when we stop smelling things, we will have stopped breathing (approximately 23,000 breathes a day)

- Being inhaled through the nose.
- Through the mouth (vapors circulate up through throat)

"sniffing": what we do to consciously detect odors.

More vapors are given off when an odorant is heated!! (warm soup smells better than cold soup, pizza in a microwave)

gravity and air currents are necessary for distribution of volatile substances

- odors spread more readily when there is moisture in the air
- odors are dispersed more rapidly at higher altitudes, where air pressure is low
- smelling in water?

5



smelling in water?



6

## Language and smell

try to describe the appearance of:

- a soccer ball

try to describe the taste of:

- lemon juice

try to describe the smell of:

- butter

*Unlike in the case of taste, there are no agreed upon primary odor qualities.*

7

without referring to objects, substances (cant say crayon smells like crayon), or primary qualities borrowed from other senses, eg. sweet.

### RESPONSES:

#### Crayon:

- smells dry and sweet
- like creamy plastic
- waxy
- old candles and grass
- a plastic like smell that also takes me back to grade school when i smell it.
- toxic

#### Baby's head:

- baby powder, freshness, soap, "new baby smell"
- clean, fresh, powdery

#### Blood:

- musty iron smell, iron, clean
- nauseating, chemical

#### Butter

- suave

#### Forearm:

- sweaty, warm and fatty
- soap, chlorine

I don't have a crayon, baby's head, blood, or butter to smell so I can't describe them! I keep smelling my forearm and the people next to me think something is wrong with me! I just showered so I think my forearm smells like soap.

without referring to objects, substances (cant say crayon smells like crayon), or primary qualities borrowed from other senses, eg. sweet.

**RESPONSE:** So, you didn't specify what state the objects had to be in...

- 1) After being kept in the attic all day with moths, the traumatized baby's head smelled **musty**
- 2) My favorite blue crayon by Crayola, called "God's tears," was not enjoyed by the other children because of its **acidic** scent.
- 3) The evening after I came in first place in the 100 meter sewer relay, my forearm remained **fetid**
- 4) While I've tried to hide it, my blood has that **musky** odor which is a telltale sign that my real father is a deer.
- 5) My butter now smells **rancid** and **putrescent**...I must fix my refrigerator

p.s. in English we seem to focus on bad smells.

11

## Language and smell

we have trouble describing odors without referring to objects or substances

try to describe the smell of:

- a crayon
- the top of a baby's head
- blood
- butter
- your forearm

8

without referring to objects, substances (cant say crayon smells like crayon), or primary qualities borrowed from other senses, eg. sweet.

### RESPONSES:

#### Crayon:

- smells dry and **sweet**
- like creamy **plastic**
- waxy
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- a **plastic** like smell that also takes me back to grade school when i smell it.
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#### Blood:

- musty iron smell, **iron**, clean
- nauseating, chemical

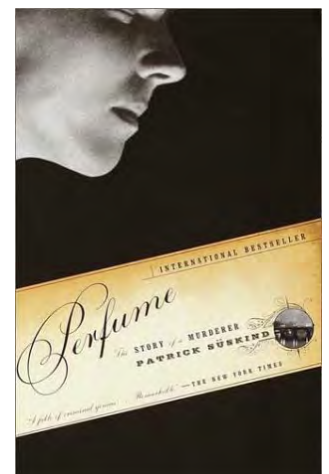
#### Butter

- suave

#### Forearm:

- **sweaty, warm** and fatty
- **soap, chlorine**

I don't have a crayon, baby's head, blood, or butter to smell so I can't describe them! I keep smelling my forearm and the people next to me think something is wrong with me! I just showered so I think my forearm smells like soap.



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## Odors as Warnings

### Odors as warnings

- smoke
- gas leak
- spoiled food
- unfaithful spouse or lover
- overindulgence (e.g., alcohol)
- disease

14

## Odors in Navigation

- Birds, insects and fish migrate using smell to guide them
- Animals hunt by smell
- Scent hounds track by smell
- Young infants "navigate" to mother's breast, drawn by the compound *isobutyraldehyde* (malty smell in breast milk)
- Finding a suitable mating partner
  - A pheromone substance can attract moths from 7 miles away.



"You idiot! We want the scent on the pillow! On the pillow!"

## Odors in Navigation



*Nature Neuroscience* **10**, 27 - 29 (2007)  
Published online: 17 December 2006 | [Corrected](#) online: 4 January 2007 |  
doi:10.1038/nn1819

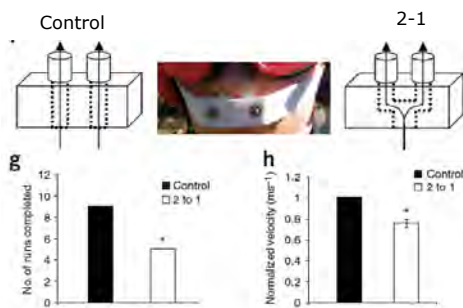
There is a [Corrigendum](#) (February 2007) associated with this Brief Communication.

### Mechanisms of scent-tracking in humans

Jess Porter<sup>1</sup>, Brent Craven<sup>2</sup>, Rehan M Khan<sup>3,4</sup>, Shao-Ju Chang<sup>5</sup>, Irene Kang<sup>6</sup>, Benjamin Judkewitz<sup>2</sup>, Jason Volpe<sup>2</sup>, Gary Settles<sup>2</sup> & Noam Sobel<sup>1,2,3,5,6</sup>

16

## Odors in Navigation



Stereo smelling

17

## Odor Identification: Diagnosis and treatment of disease

### When Doctors Used to Smell

At one time, family physicians used their sense of smell to help diagnose the illness or disease of a patient. That practice has gone by the wayside in the past years. Perhaps it would be a good idea if doctors would learn and use this technique again.

from Ernest Monin, *Les Odeurs du corps humain* (1885)

"Smell is the subtle soul of clinical instruction...With practice, medical nostrils learn to sniff the air constantly, attempting to take note of the mysterious similarities and secret affinities of olfactory symptoms."

18

Odor Identification: Diagnosis and treatment of disease

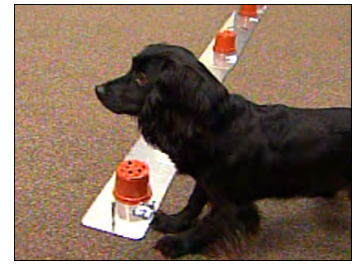
Can we do better?



House begins to smell Cuddy-- her hair, her breath, her rash...  
**Cuddy:** You're creeping me out. As he continues to sniff her...  
**House:** *Pseudomonas smell yeasty, staph smells musty, some liver diseases smell like ammonia.* Not terribly accurate but until Nunavut open an ER, it'll have to do.  
 House now sniffs her below the waist.  
**Cuddy:** House, I'm not in heat.  
**House:** Citrusy on the nose with a blush of toasted coconut.

Odor Identification: Diagnosis and treatment of disease

Dog's Smell out Disease



**Researchers showed that dogs can be more accurate than current cancer tests**  
 (Bladder, skin, lung, breast cancers)

Odor Identification: Diagnosis and treatment of disease

Dog's Smell out Disease



**Researchers showed that dogs can be more accurate than current cancer tests**  
 (Bladder, skin, lung, breast cancers)

<http://www.youtube.com/watch?v=JZd4rKiyBe4>

Odor Identification: Diagnosis and treatment of disease

Dog's Smell out Disease



**Researchers showed that dogs can be more accurate than current cancer tests**  
 (Bladder, skin, lung, breast cancers)

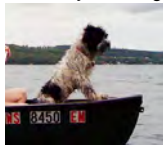
<http://www.youtube.com/watch?v=tML1DJQt0Og>

Odor Identification: Identifying others

People can use smell alone to accurately identify:

- Males vs females
- Their infant vs unfamiliar infant
- Their mate vs a stranger

Know thy own dog!



**88.5%**

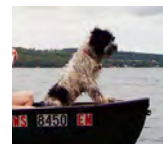
26 dog owners tested in a 2AFC discrimination ("your dog's blanket vs an age/sex/breed matched strange dog's blanket"). How accurate do you think they were?

Perception. 2002;31(4):511-2.

**The discrimination of cat odours by humans.**  
 Courtney N, Wells DL.

We explored the ability of humans to identify individual cats by smell. Twenty-five cat owners were required to indicate which of two odours (one belonging to their own cat and one belonging to an unfamiliar cat) belonged to their own cat. Only thirteen (52% - **chance!**) of the participants were able to recognize the odour of their own cat.

Know thy own dog!



**88.5%**

## Anosmia: Inability to Smell Odors



Results from nasal blockage (acute or chronic), injury, medications, infection, exposure to caustic environmental agents

- affects approximately 2 million Americans
- reduces appetite and sex drive; increased risk of injury
- some anosmias are general, others are specific for odorants such as camphor/mothballs, cinnamon/cloves, jasmine/violets, fish, garlic
- presbyosmia is the normal loss of odor sensitivity with age

25 [www.anosmiafoundation.org](http://www.anosmiafoundation.org)

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## Commercialization of Smell

We drench ourselves in smells, and businesses use odors to encourage our purchasing habits

- perfumes, cosmetics, deodorants
- scented laundry detergent, house sprays, toilet paper
- smell of leather sprayed on vinyl products
- new car smell
- bakeries that channel smells from the oven onto the street
- shopping malls add "pizza smell" to the air to coax shoppers into restaurants
- fresh coffee and real estate sales

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## Aromatherapy

- LAVENDER - Treats burns and promotes healing
- TEA LEAVE - Antiseptic
- PEPPERMINT - Anti-inflammatory, bad breath, migraines
- CHAMOMILE - Teething, diarrhea
- EUCALYPTUS - Cools body in summer, deodorizing
- GERANIUM - Works on emotions
- ROSEMARY - Flu
- THYME - Antiviral, antibiotic
- LEMON - Insect bites, slim down cellulite
- CLOVE - cure toothache

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The screenshot shows a Google search for 'Aromatherapy'. The search bar contains 'Aromatherapy' and the search button is highlighted. Below the search bar, the results show 'Results 1 - 16 of about 11,800,000 for Aromatherapy [definition] (0.42 seconds)'. The first result is 'Aromatherapy and Essential Oils' from www.aromaweb.com. Other results include Wikipedia, a home holistic site, and various product sites. A section titled 'Does it work?' is visible, discussing the scientific basis of aromatherapy.

29

## Smell Influences "Kindness"

(probably by influencing mood)

People more likely to help others in a scented environment (shopping mall study)

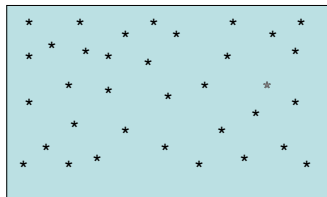
- request to break a dollar
- help picking up dropped objects

30

## Odor Affects Vigilance

3 groups of undergraduate students tested on a 'vigilance' task in the presence of either peppermint, orange/citrus-like smell or no odor.

**Task:** monitor video monitor for 15 minutes, pressing key whenever one asterisk within an array of irregularly spaced asterisks briefly dimmed



31

## Odor Affects Vigilance

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**Task:** monitor video monitor for 15 minutes, pressing key whenever one asterisk within an array of irregularly spaced asterisks briefly blinked

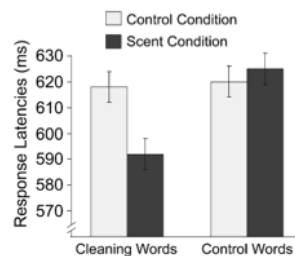
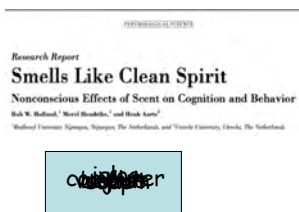


32

### Result:

significantly fewer detections when exposed to orange/citrus-like smell; no difference between peppermint and no odor

## Smell affects behavior



Cookie crumbs study

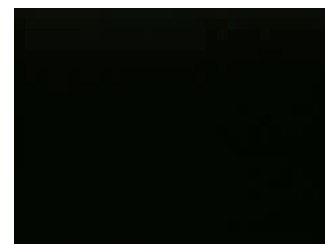
33

**NEW RED ZONE BODY SPRAY**

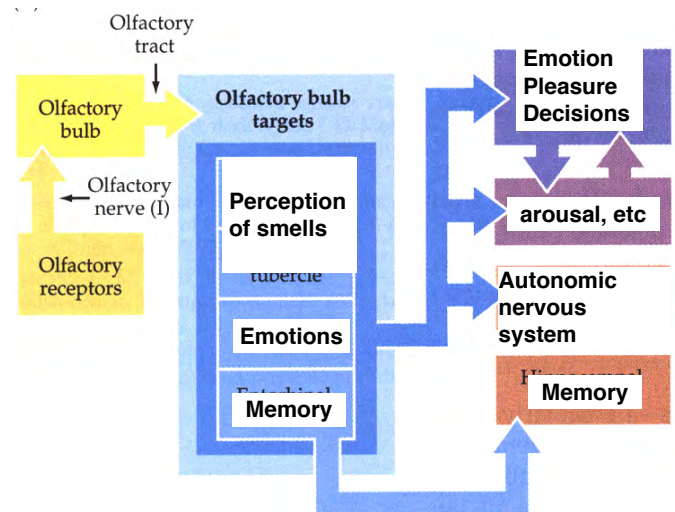
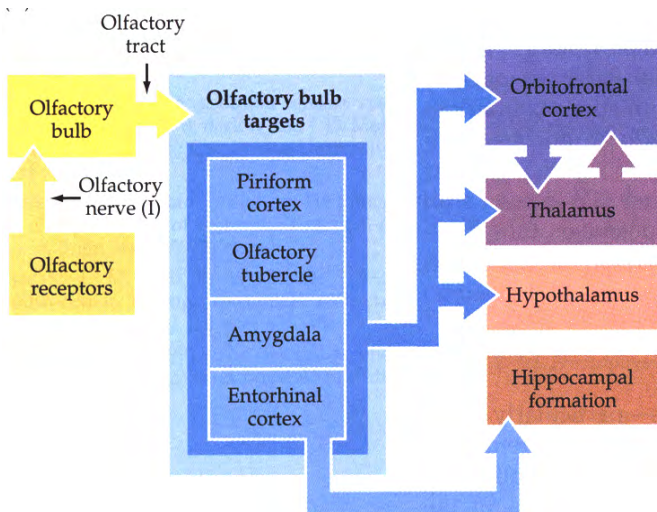
The strongest sense tied to memory is scent. So how will you be remembered? Pure Sport, Aqua Reef, Glacial Falls, or Metallic Ice? New Red Zone Body Spray comes in 4 great scents that all last longer than the leading body spray. Good news when your Friday night doesn't get started until Saturday morning.

AFTER HOURS, PURE SPORT, GLACIAL FALLS, AQUA REEF and METALLIC ICE

BACK



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# Smell outline

- Intro to smell
- What can be smelled?
- Can smell affect behavior?
- Brain mechanisms of olfaction
- Human pheromones?

## Brain mechanisms of olfaction

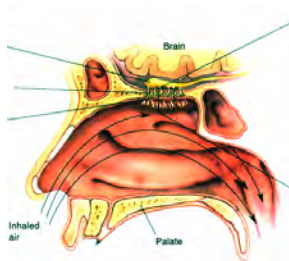
1. Bio-mechanical properties of the nose
2. Olfactory epithelium
3. Olfactory bulb
4. Olfactory cortex

Nose  
 -warms and humidifies air  
 -cleans debris (nose hairs)  
 -controlled by nasal cycle

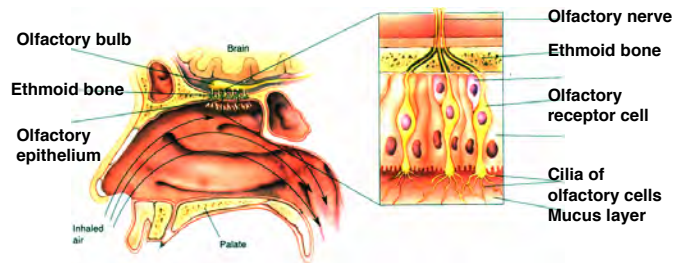


## Brain mechanisms of olfaction

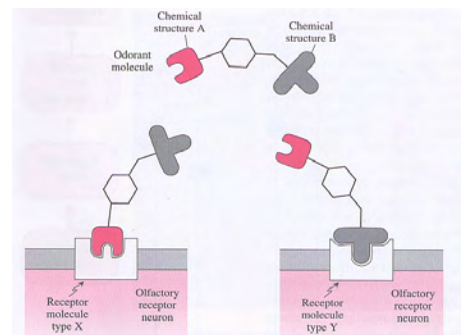
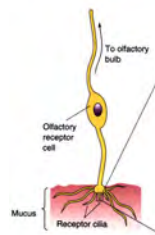
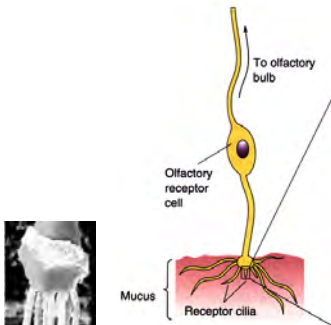
1. Bio-mechanical properties of the nose
2. **Olfactory epithelium**  
 Contains receptor neurons that detect odors
3. Olfactory bulb
4. Olfactory cortex

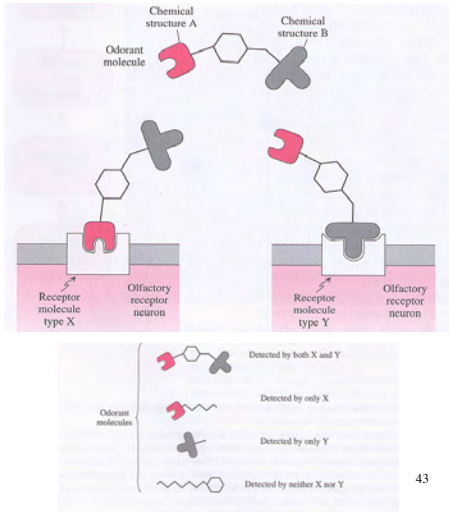
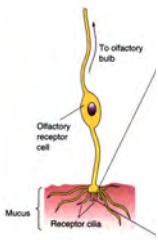


## Olfactory Epithelium



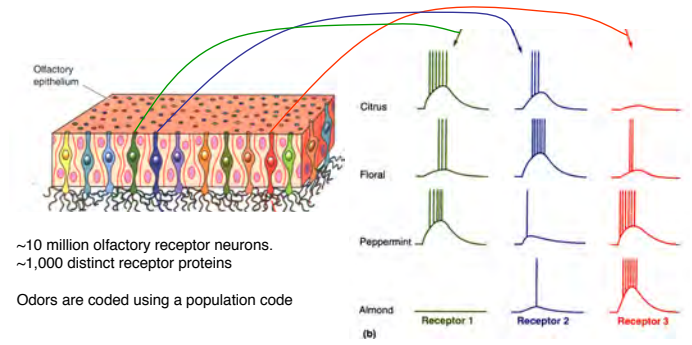
## Olfactory Epithelium





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## Olfactory Coding



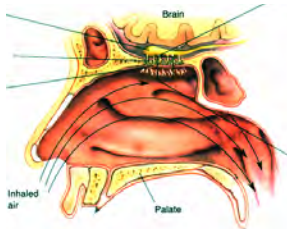
~10 million olfactory receptor neurons.  
~1,000 distinct receptor proteins

Odors are coded using a population code

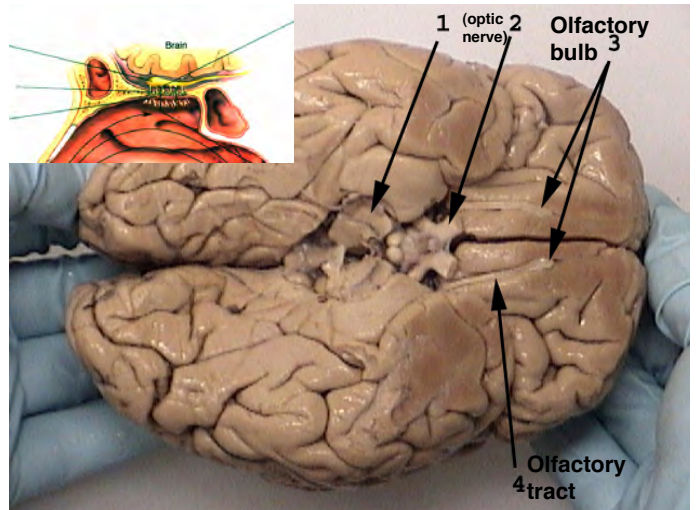
44

## Brain mechanisms of olfaction

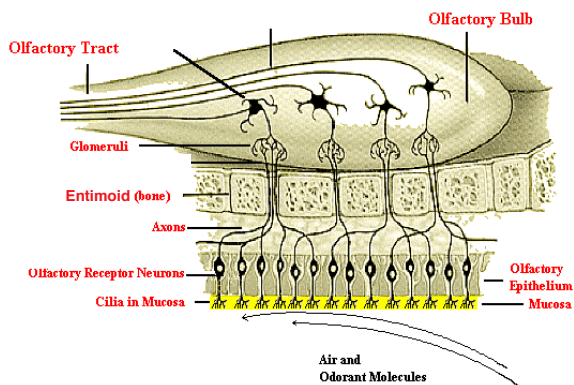
1. Bio-mechanical properties of the nose
2. Olfactory epithelium
3. **Olfactory bulb**  
Collects and encodes odor signals from neurons  
Send processed odor signal to cortex
4. Olfactory cortex



45



## From Olfactory Receptors to Olfactory Bulb



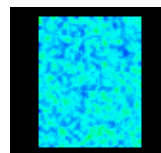
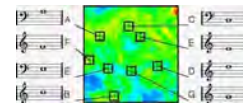
7

## Neural code of Odor:

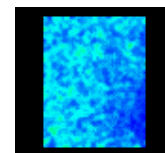
Odors are coded using a population code



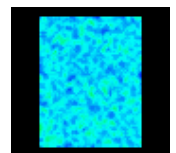
Thus the smells we perceive arise from patterns of activity distributed throughout the olfactory bulb.  
Think of the olfactory bulb as a large "map" whose coordinates specify chemical dimensions (not spatial distances).  
When you smell, say, a rose, a characteristic group of olfactory bulb glomeruli will become active.



Eugenol:  
spicy fragrance of cloves



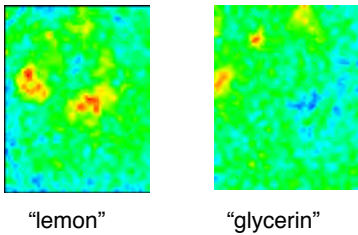
Octanol:  
oily rotten orange mixed with cheap detergent



Queen substance

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**Neural code of Odor:**  
Odors are coded using a population code



Distributed neural representation (population code)

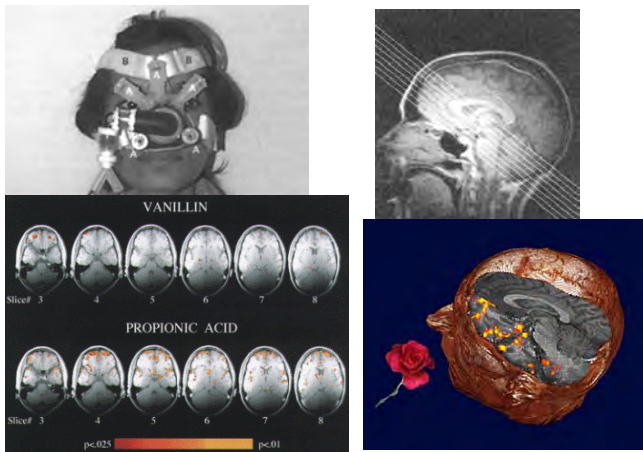
**Brain mechanisms of olfaction**

1. Bio-mechanical properties of the nose
2. Olfactory epithelium
3. Olfactory bulb
4. **Olfactory cortex**  
Complex processing of odors, interactions with other sense and brain systems

Hard to study - stimulus presentation is difficult



**Brain areas activated by odors**



**Odor Identification: Hemispheric differences**

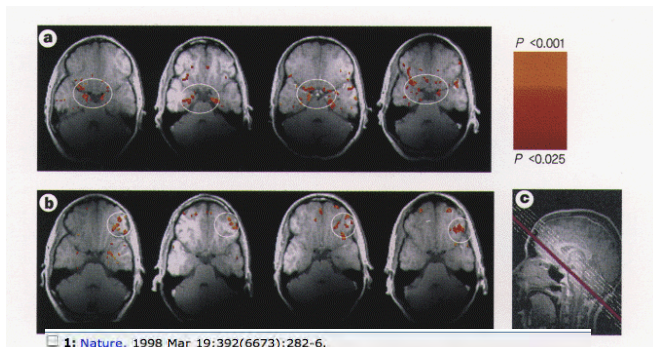
Biol Psychol. 2001 Sep;58(1):65-73.

**Differences in naming accuracy of odors presented to the left and right nostrils.**  
Homewood J, Stevenson RJ.

Two interlinked areas of debate within psychology are the existence of hemispheric specialization for olfactory processing and whether odors are processed primarily as perceptual codes or as a set of semantic features. This study compared accuracy in naming and judgments of familiarity by right handed subjects to common odors that were presented to the left or right nostrils. **There was significantly better production of the correct name of the odor after left side presentation, than after right. Familiarity ratings were identical.**



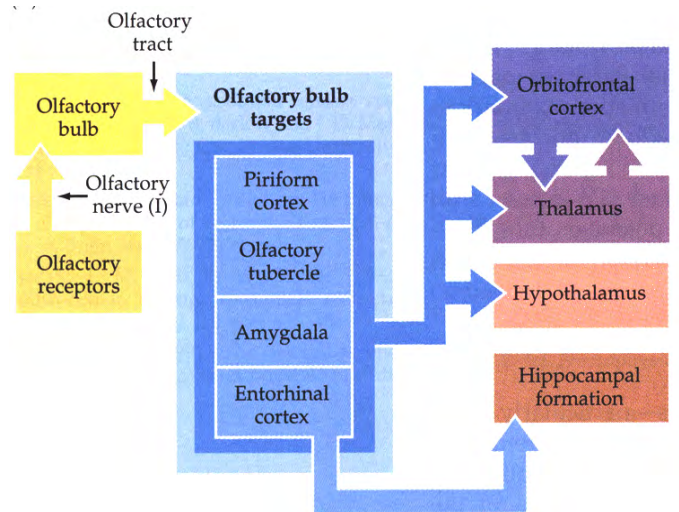
**Brain activity: sniffing vs smelling**

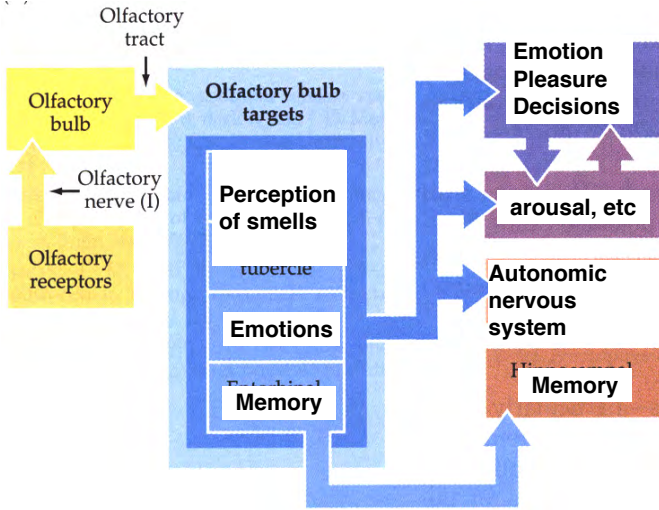


Sniffing and smelling: separate subsystems in the human olfactory cortex.

Sobel N, Prabhakaran V, Desmond JE, Glover GH, Goode RL, Sullivan EV, Gabrieli JD.

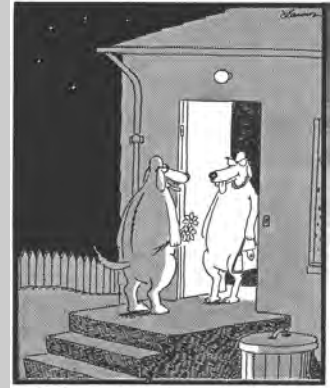
Program in Neuroscience, Stanford University, California 94305, USA.  
nsobel@leland.stanford.edu





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## What are Pheromones?

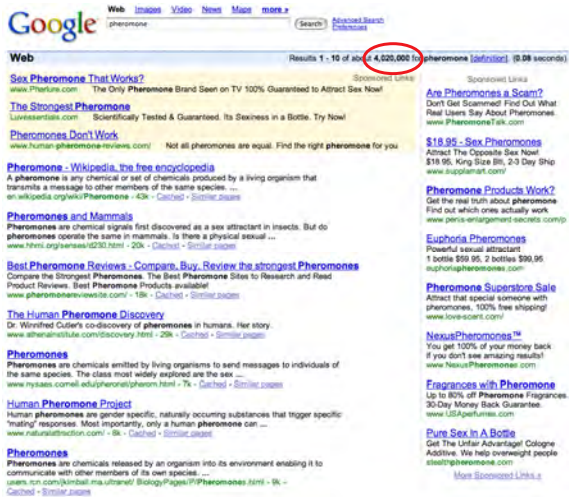
- "A chemical signal released to the outside of the body of the producer that affects the physiology or behavior of a receiving individual of the 'same' species."
- From the Greek *pherein* (to carry) + *hormon* (to excite)

- First isolated by a team of German scientists working with silkworm moths.
- Females appeared to spray a substance into the air—downwind males would immediately come to her.
- It was hypothesized that the released chemical attracted male moths.



- Male moths in captivity immediately flew to vials with the substance
- When the substance was released in nature, it attracted marked moths from 5-7 miles away!

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## What are Pheromones?



- The substance was called "bombykol"—the first isolated pheromone
- The sense organs were found on the antenna of male moths
- The antenna, when removed and attached to a micro-electrode, would send an action potential when bombykol was diluted to one molecule in a  $10^7$  air molecules
- one Gypsy Moth female possesses 0.01 g which hypothetically could incite a response in one billion males.



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## Types of Pheromones

### Communication pheromones

#### Trail pheromones

- Commonly found in numerous social insect species
- Used for orientation to & from the nest for the establishment of foraging trails (highways)

#### Alarm pheromones

- Common in social insects & aggregate feeders
  - wasps, termites, bees, & some aphids
- Function
  - defense
  - Dispersal

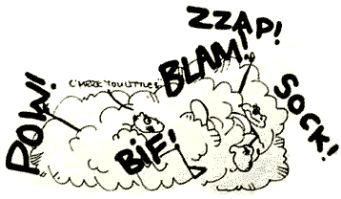
#### Aggregation pheromones

- Signal that recruits conspecifics to a food source.
- Known in bark beetles & certain desert grasshoppers.
- Can also function in an anti-aggregation mode when sufficient individuals are present.



## Types of Pheromones

### Social pheromones



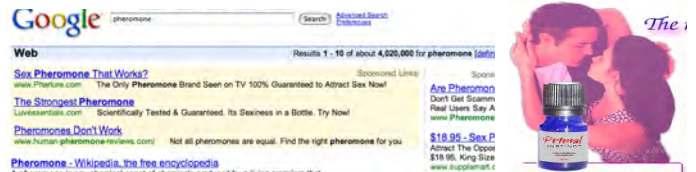
- Pheromones in the urine of male mice determine if others will attack
- A male + a female OR A male + a castrated male = no fight
- A male + a castrated male + other male's urine = FIGHT

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## Types of Pheromones

### Sex pheromones

- **The best known & best studied of all pheromones.**
  - Function: Gender attraction
  - Most frequently females “calling” to males
  - Occasionally males “calling” to females
  - Rarely, sex attractants released by both genders of a species.
- **Also used to regulate the onset of mating behavior**
  - E.g., a male hamster will try to mate with another male hamster “wearing” female vaginal secretions



## Types of Pheromones

### Prey capture



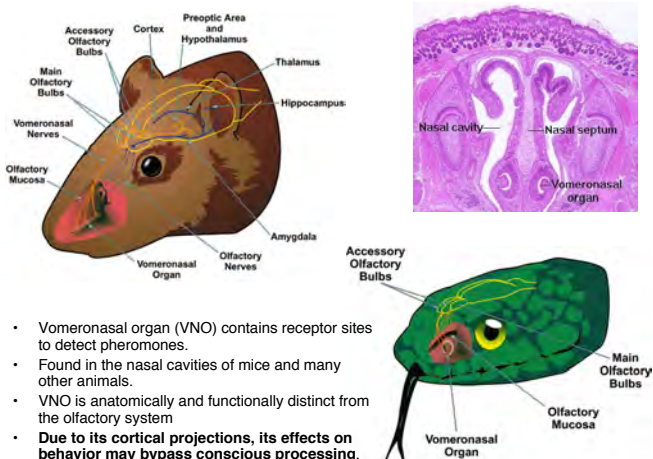
- Some animals mimic pheromones to trick prey
- Bolas Spider (*Mastophora hutchinsoni*) mimics the mating pheromone of the moth
- When the male moth searches for a suitable female...

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## Effects of Pheromones in Mammals

- **Lee-Boot Effect:** When female mice are housed together their estrous cycles stop.
- **Whitten Effect:** When above females are exposed to a male, their estrous cycles re-start in synchrony.
- **Vandenbergh Effect:** The acceleration of puberty onset in a female rodent cause by exposure to a male.
- **The Bruce Effect:** When a recently impregnated mouse encounters a male other than the one with which she mated, the pregnancy will terminate.
- What sensory system mediates these behaviors?

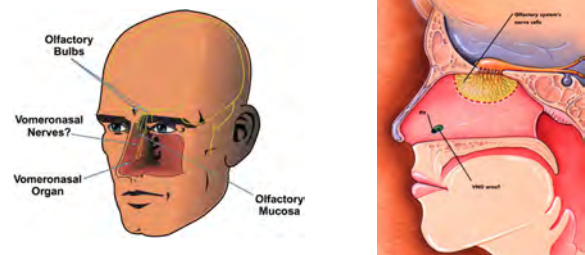
64



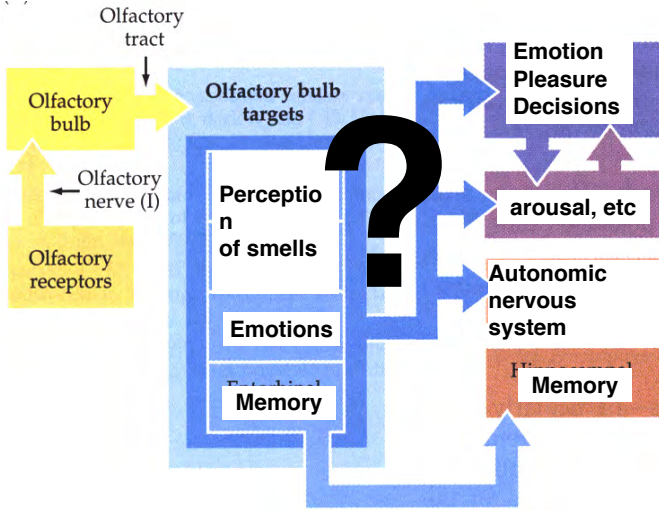
- Vomeronasal organ (VNO) contains receptor sites to detect pheromones.
- Found in the nasal cavities of mice and many other animals.
- VNO is anatomically and functionally distinct from the olfactory system
- **Due to its cortical projections, its effects on behavior may bypass conscious processing.**

## Human Pheromones?

- Human embryos have VNO's similar to other mammalian species.
- Adults were thought to lack a functional VNO.
- However, now we know that there is a small pit about 2 cm in from the nostril that is similar in form to the embryonic VNO. Over 90% adults have this pit.
- In other mammals, the nerves connecting the VNO to the brain are easily defined.
- In humans, there have been no nerves connecting the brain to the CNS found.



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## Human Pheromones?

- In the late 1960's, Martha McClintock, while an undergrad at Radcliffe college, noticed that women on her dorm floor seemed to menstruate on the same schedule
- Showed that effect in her undergrad honors thesis:
  - menstrual synchrony more likely among roommates than among women who lived in the same dorm building.
  - ~7-8 months of cohabitation was required for synchrony.
- What caused this?
- Dr. McClintock (now head of her department at the University of Chicago) suspected exocrine glands in the armpits that produce odorless secretions



## Human Pheromones?

- Sweat from other women applied to upper lip changes cycle in line with women from where sweat came (Stern & McClintock, 1998)
- Collect endocrine secretions from armpits of women about to ovulate
- Expose 1/2 of subjects to these secretions (odorless), and 1/2 to a control
- Experimental subjects had their ovulation occur *earlier* than control subjects
- Perform the same experiment, with secretions from women who had already ovulated
- Experimental subjects had their ovulation *delayed* compared to control subjects
- The ability of an odorless glandular secretion to change reproductive behavior argues for active pheromones**



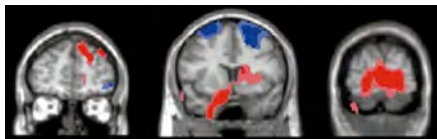
## Does it work on males?

Female body odor as a cue to ovulation (Singh & Bronstad, 2001)

- Women volunteered to wear one t-shirt on three consecutive nights during their ovulatory stage, and then a different t-shirt for three nights during their non-ovulatory stage.
- Males sniffed the t-shirts and rated them on attractiveness and "sexiness".
- Male raters judged the t-shirts worn during the ovulatory stage as being more pleasant and sexy.
- The males olfactory system is tuned to chemical cues released by the female that signal fertility



## Neural activation by pheromones



Sustained human chemosignal unconsciously alters brain function

Silvia Jacob<sup>1</sup>, Leann H. Kirschner<sup>1,2</sup>, John Mezz<sup>1</sup>, Malcolm Cooper<sup>1</sup> and Martha K. McClintock<sup>1,2,3,4</sup>

- showed that **androstadienone** alters brain activity both in subcortical regions and in areas of the neocortex not exclusively associated with olfaction.
- these areas are part of an integrated neural network for regulation of emotional and attentional states.
- provides evidence that a human pheromone has distributed effects on cortical processes and brain metabolism even when it is not detected consciously

*Find your dominant nostril*

