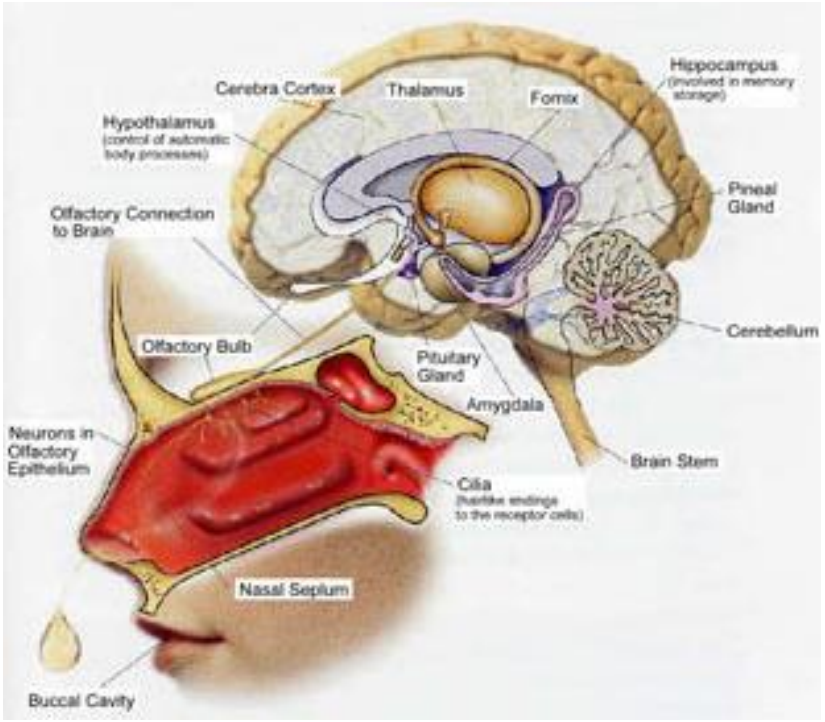
Olfactory processing of odor objects



Joël Sandé

Outline

- Introduction
- Evolution of olfactive receptor
- Effect of concentration
- Architecture of olfactory bulbe
- Signaling pathway
  - ✓ Olfactory cortex
  - ✓ Puriform cortex (some features)
- Paper : Bio-hybrid sensory system
- Brain signal images
- State of the art
- Conclusion

- Question

Introduction

- The sense of smell allows terrestrial organisms to detect and distinguish a large number of volatile substances in the environment
- Essential for the survival of any living being

edibility of food

potential hasard

Body odour

Food acceptation

Reconnaissance of the environment

Introduction

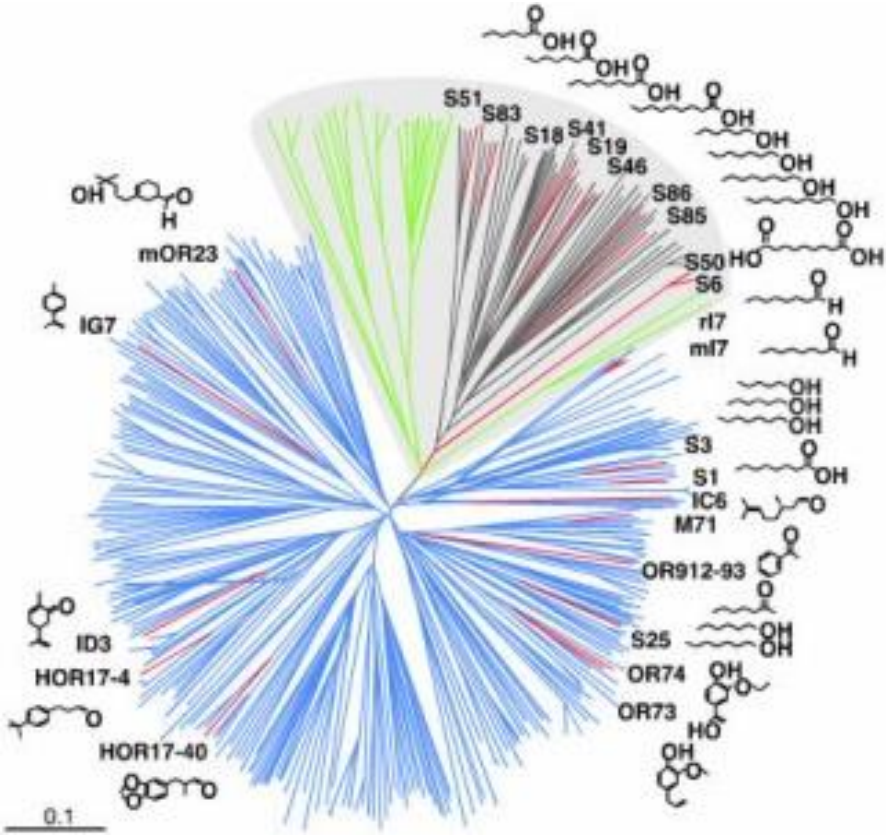
Although considered less efficient compared to other mammals such as dog and rat

Able to distinguish 1000 of different odorants

Evolution of olfactive receptors

2 groups of OR :

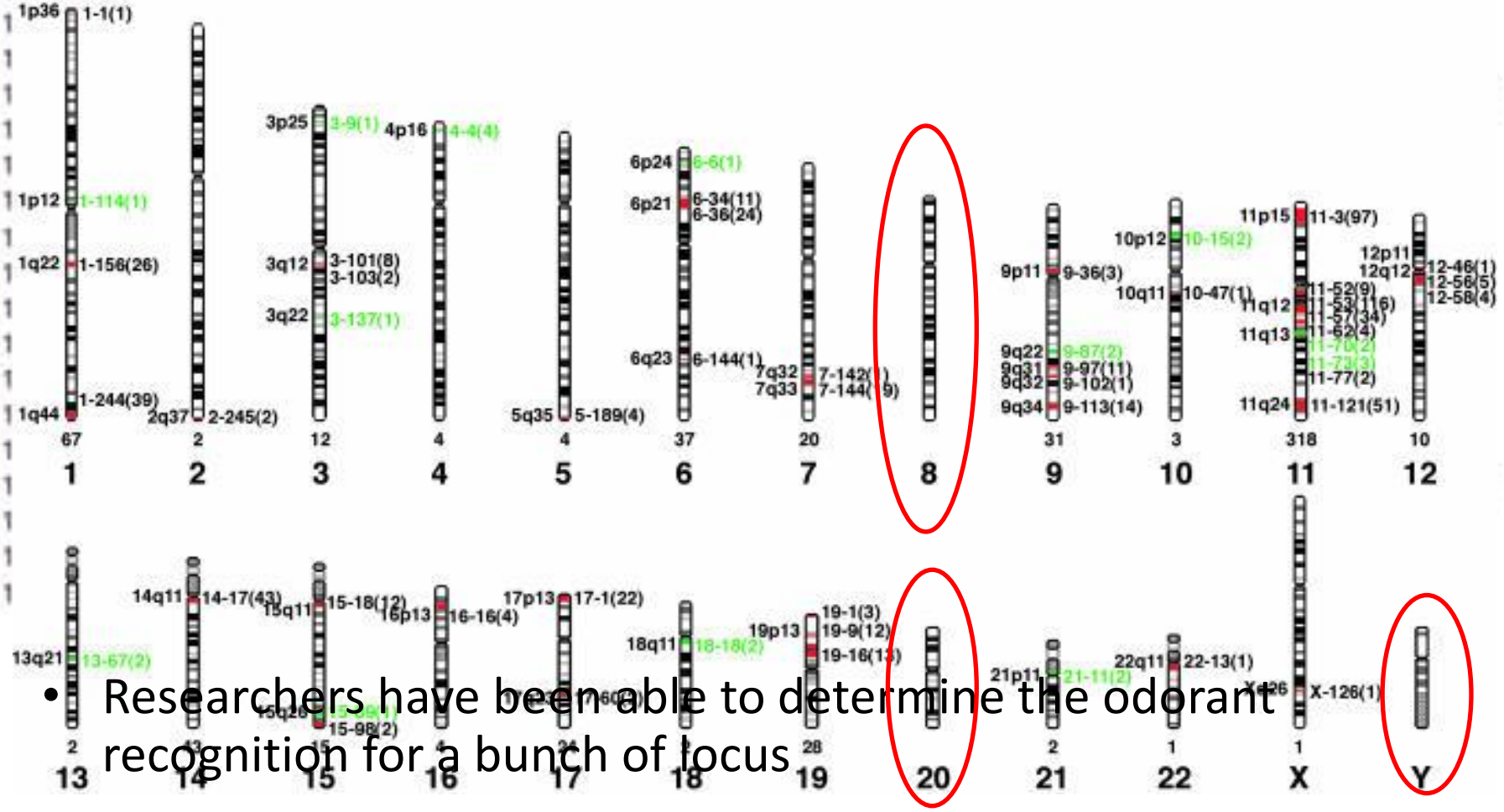
- First group includes the OR related to those of Fish (class I). *green*
- Second group contains only OR air present in Animals (class II). *red*



Phylogenetic tree of sequence relationships among Ors

Evolution of olfactive receptors

Locus	OR (MOR#)*	Amino acid identity, %	Odorant(s) recognized	Perceived odor
1p22	OR23(267–13)	87	Lyral	Lemony, green
5q35.3	IG7(276–1)	83	Limonene	Lemon
9q34.11	ID3(156–6)	71	l-carvone	Spearmint, caraway
11q12.1	OR73(174–9)†	82	Eugenol	Spicy



- Researchers have been able to determine the odorant recognition for a bunch of locus

Evolution of olfactive receptors

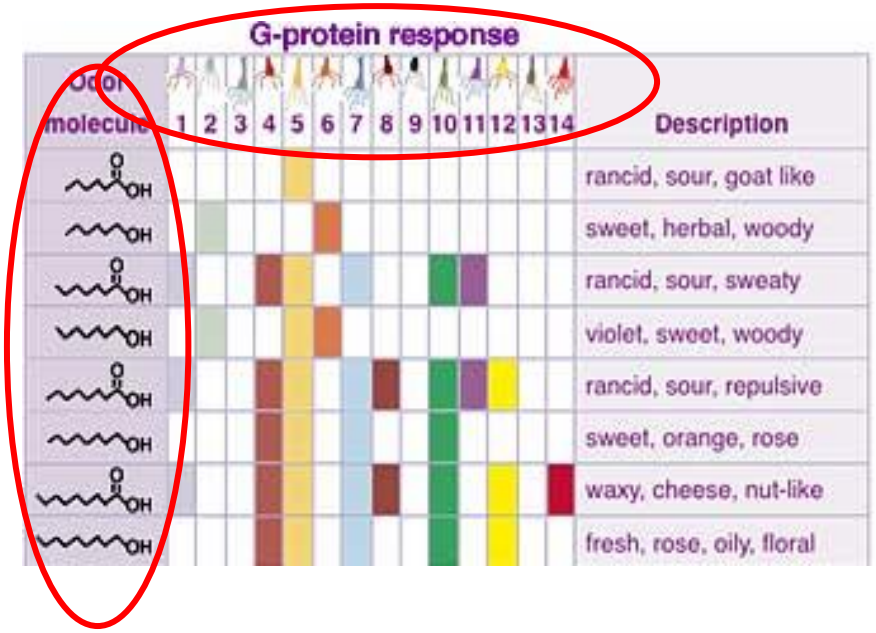
	Poisson-zèbre	Xénope	Poulet	Souris	Rat	Chien	Chimpanzé	Homme
Gènes intacts	102	410	82	1 037	1 201	872	411	339
Pseudogènes	35	478	476	354	292	222	430	297
Nombre total de gènes	137	888	558	1 391	1 493	1 094	841	636

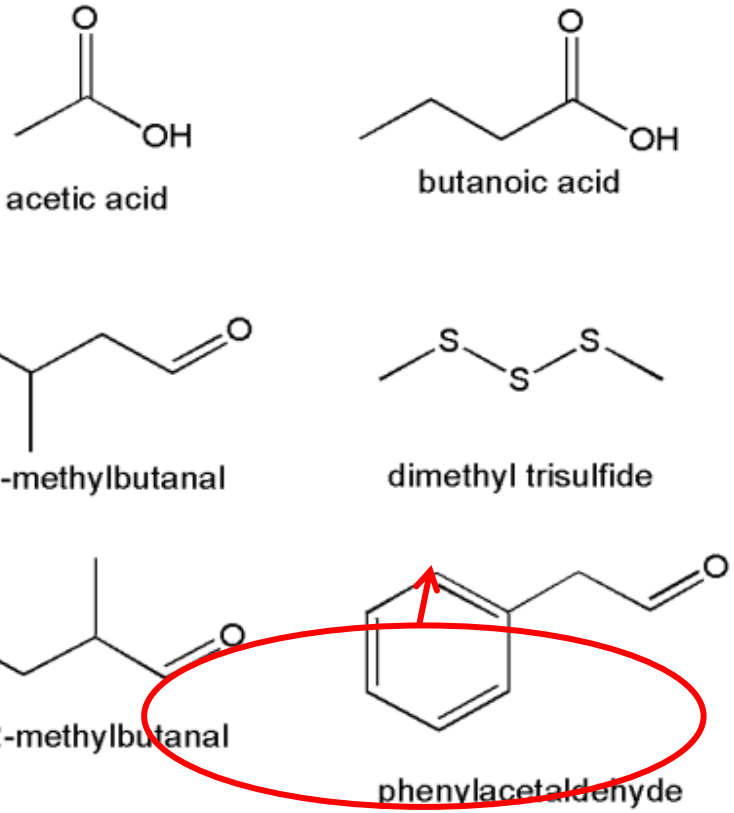
Functional genes

Remark: When primates raised, many olfactory genes have gradually lost their function. It is likely the distance from the ground, the source of many odors, has lost importance to smell the benefit of the vision.

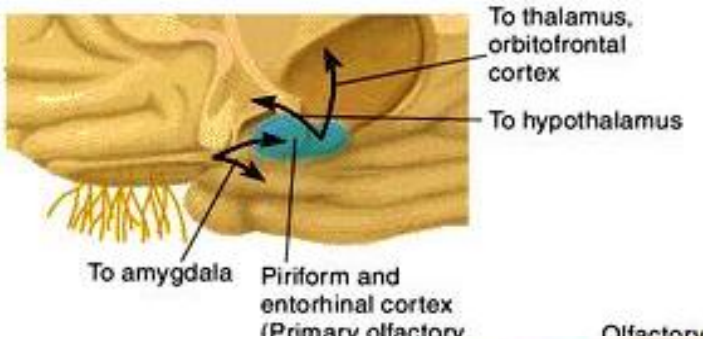
Olfactory sensory

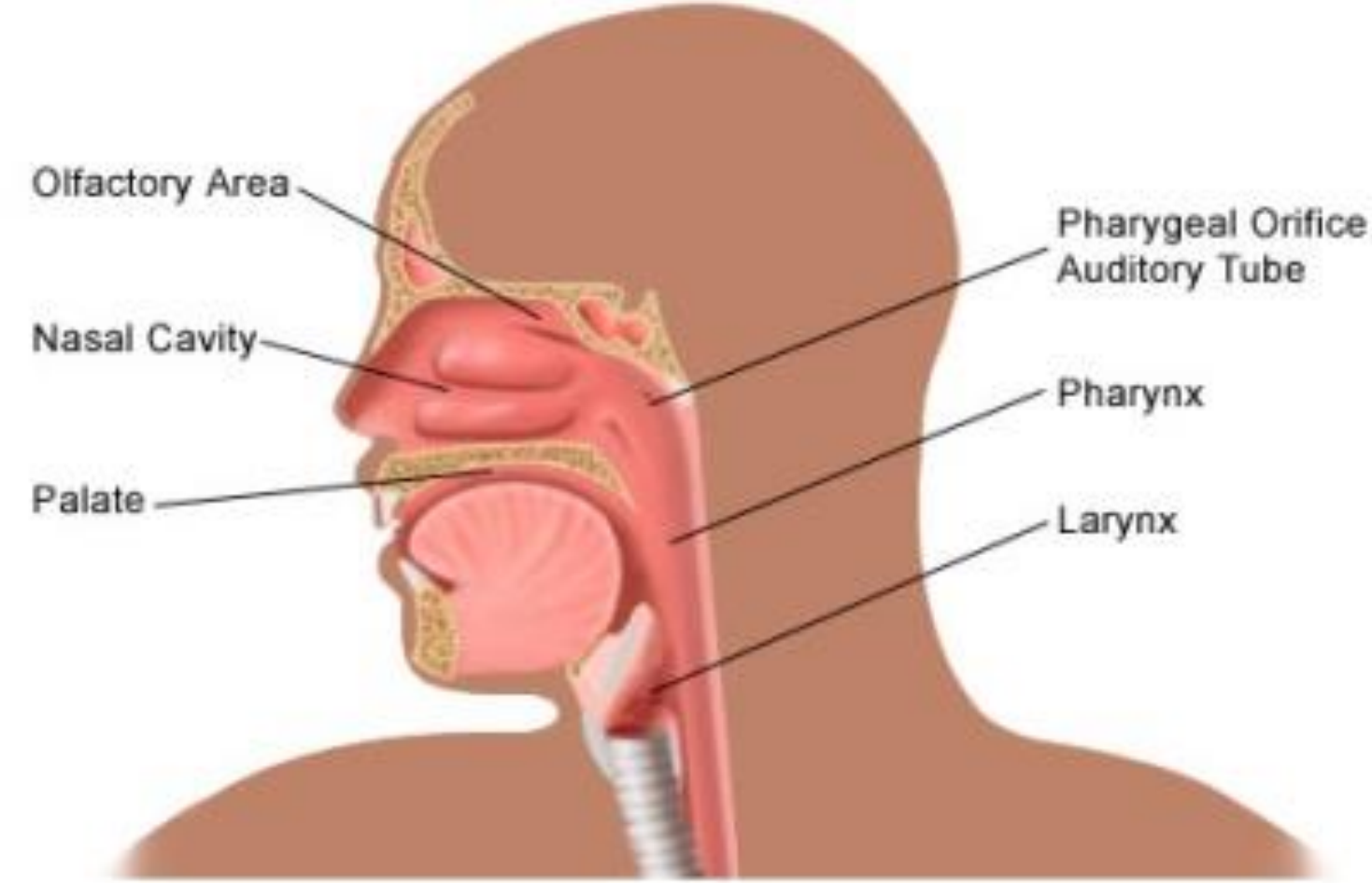
- Binding of odorant molecules to specialized receptors



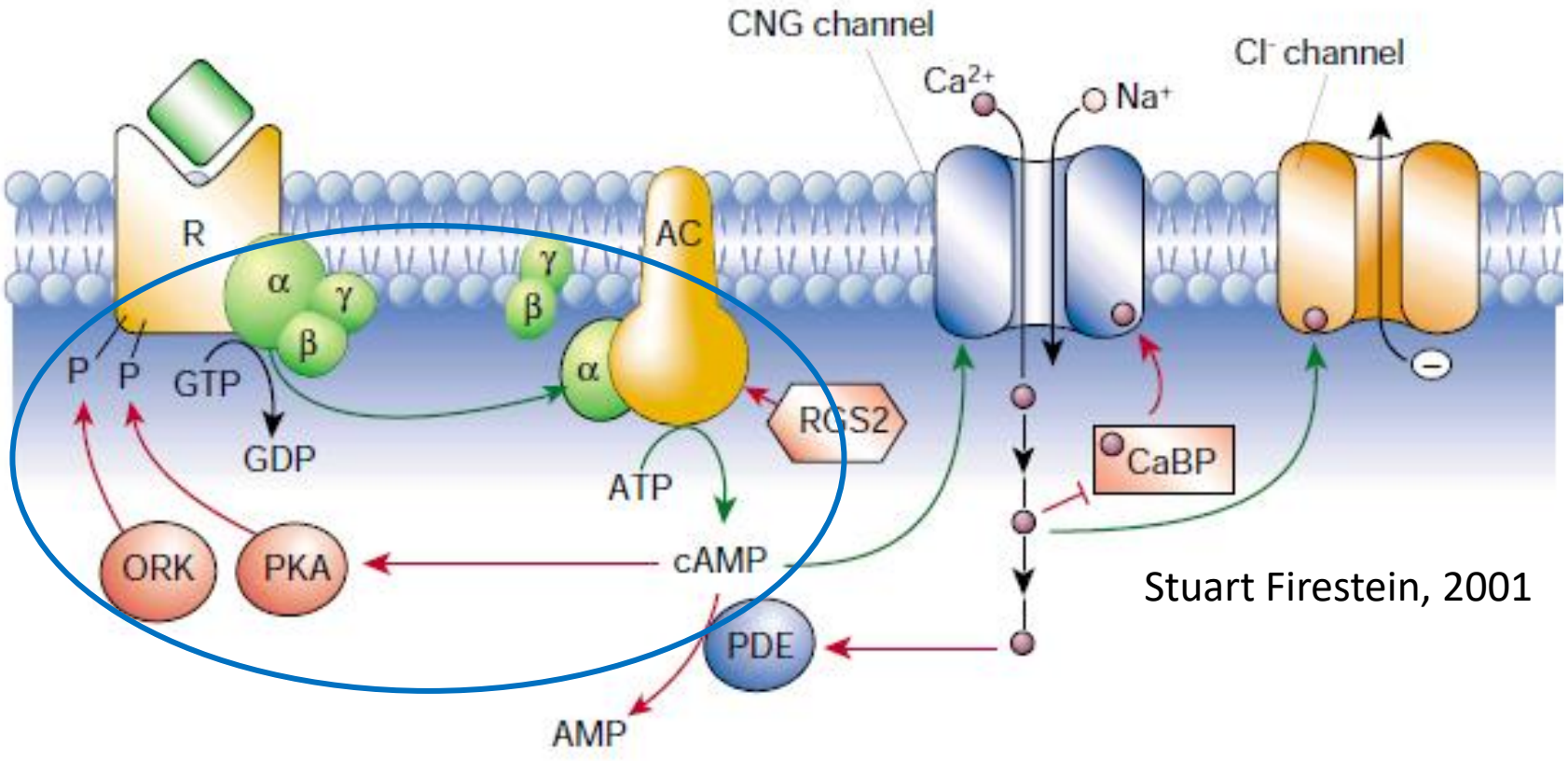


- This interaction Triggers complex cellular reaction cascades
  -> transduction of chemical signals into a pattern of electrical activity conveyed to the brain for further processing


To thalamus, orbitofrontal cortex
To hypothalamus
To amygdala
Piriform and entorhinal cortex


Olfactory Area
Nasal Cavity
Palate
Pharygeal Orifice Auditory Tube
Pharynx
Larynx

Olfactory receptor



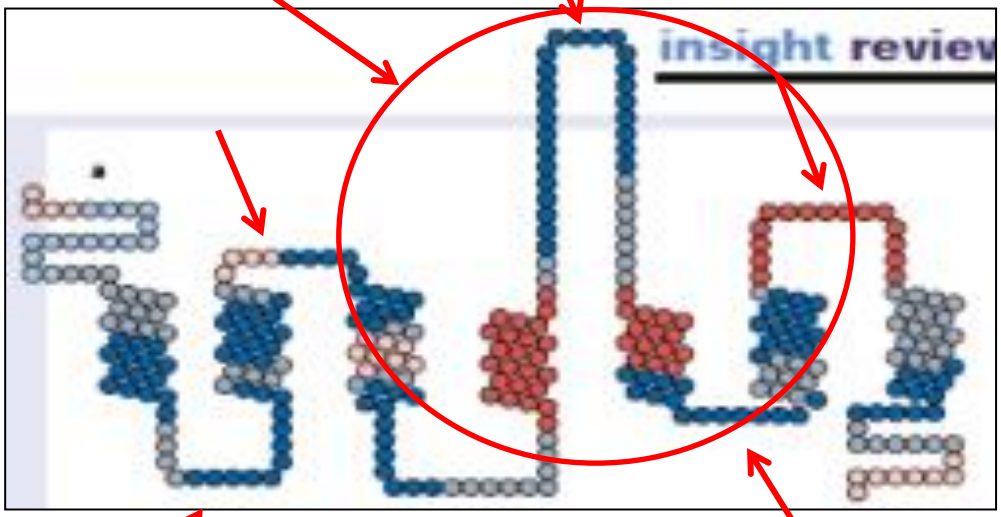
Neurons can follow repeated odor pulses at frequencies of up to 10 Hz ⟶ odour must be rapidly inactived

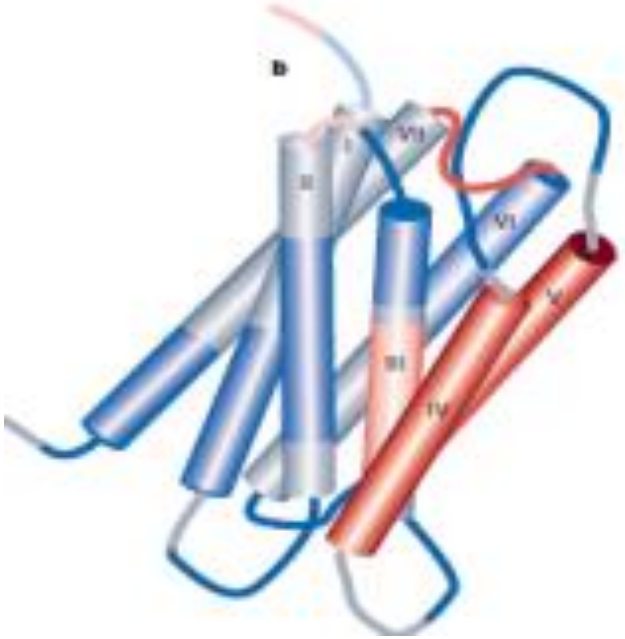
⟶ Prerequisite for high sensitivity

Olfactory receptor

- RO are equipped with:

7 transmembrane domains connected by 3 external loops, 3 cytoplasmic loops. The RO consists of 300 to 350 amino acids.





- Oriented face extracellular binding site that corresponds to regions hypervariables sequences located in the helices transmembrane III to VI

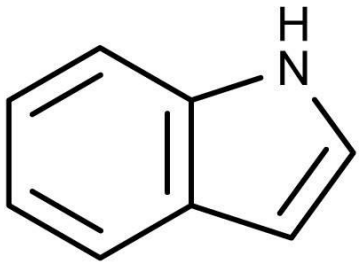
Olfactory receptor

- Qst : Is there a limited number of receiver that proceed by combining or an unlimited number of receivers each specific odor ?

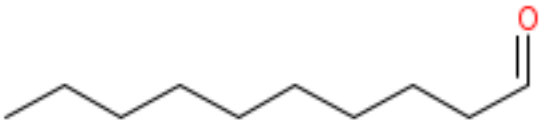
- Findings suggest that the mammalian olfactory system uses a combinatorial coding system to discriminate between odors.

Effect of concentration

- the same molecule can have pure olfactory notes differ depending on the concentration



- fecal ← high — indole — low → Jasmine



- candle ← high — Decanal — low → lemon

→ notion of odotope: different affinity with 2 receptors.

Architecture of olfactory bulb

A

- Filled circles denote

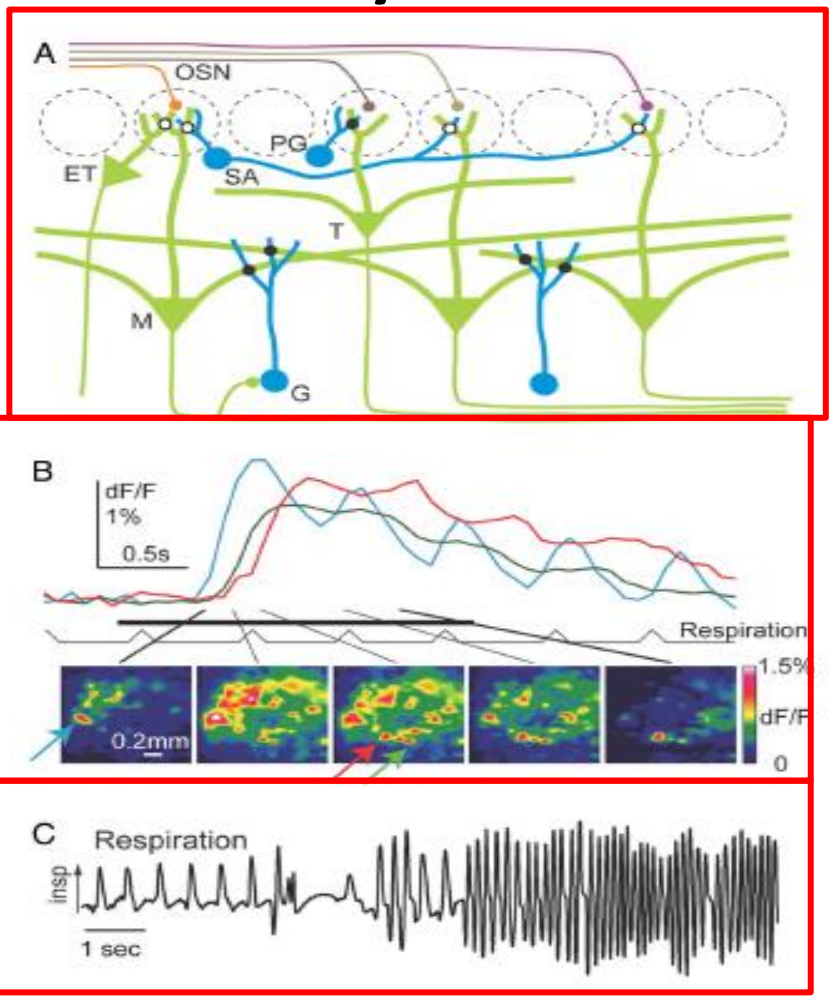
bidirectional synaptic connections

- Open circles

ET = External tufted; G = granule ;

M = mitral; PG = periglomerular;

SA = short-axon; T = tufted.

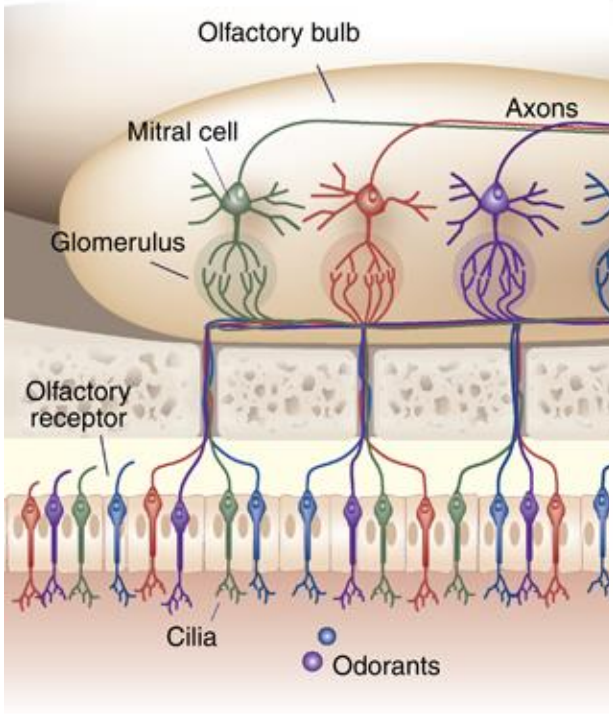


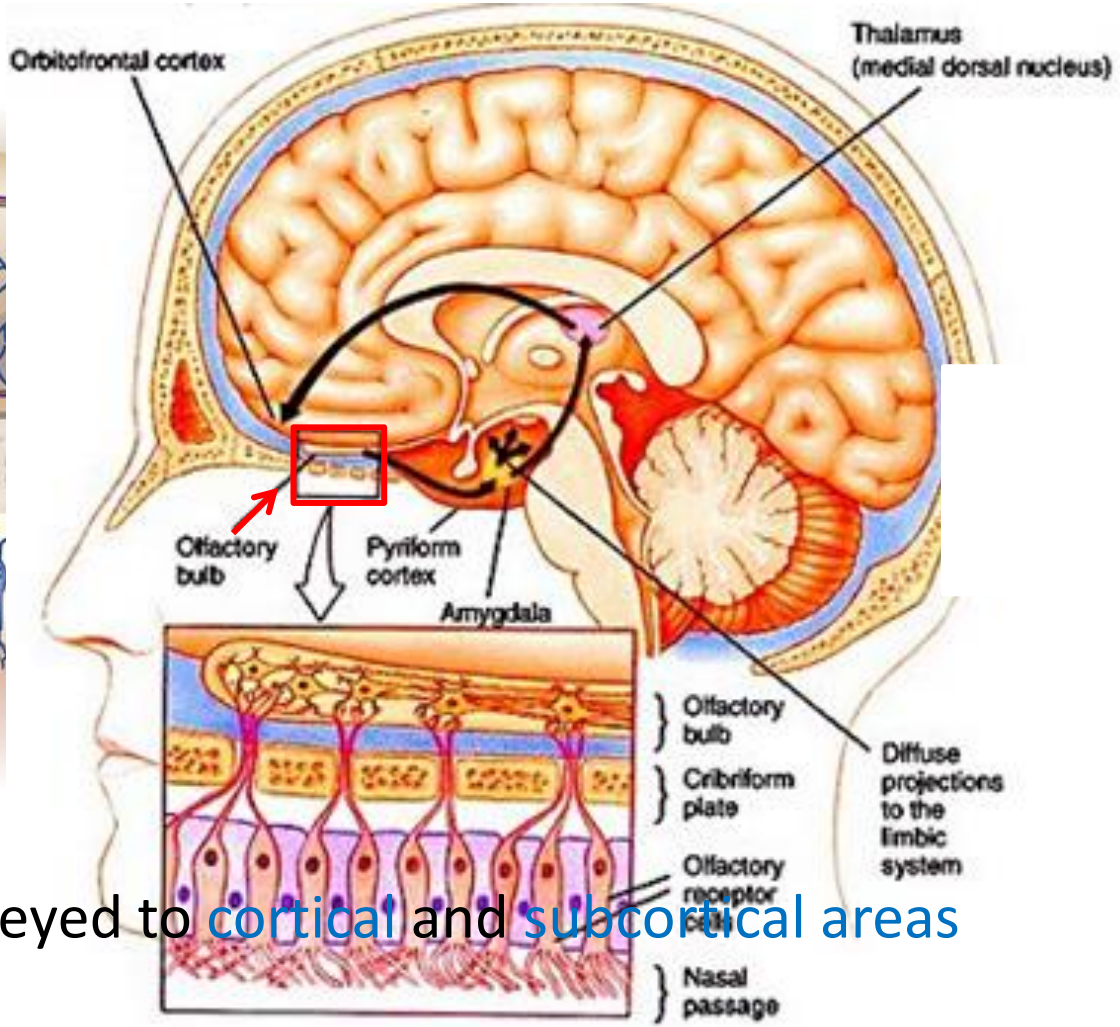
B Response time course of 3 glomeruli to ethyl butyrate.

C Respiration measured in an awake, freely moving rat, showing changes in frequency, amplitude and duration of individual "sniffs"

Signaling pathway

- In vertebrae these input pattern are processed in the olfactory bulb.



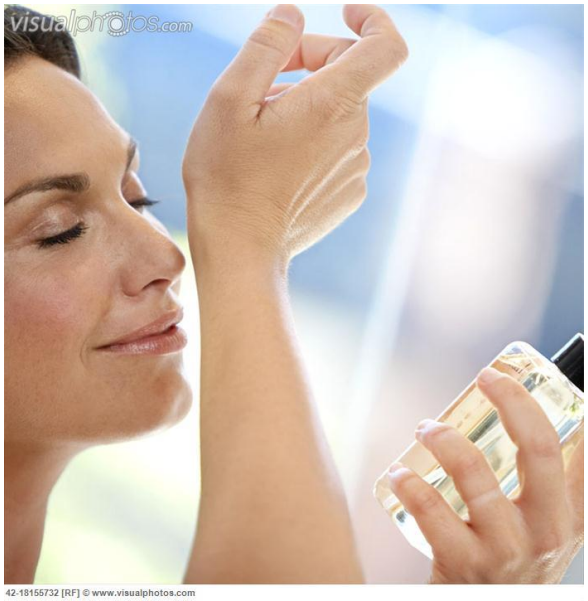


Output of OB is conveyed to cortical and subcortical areas

Signaling pathway

- The activity of neurons in higher brain areas is not only modulated by odors but also by variable behaviors

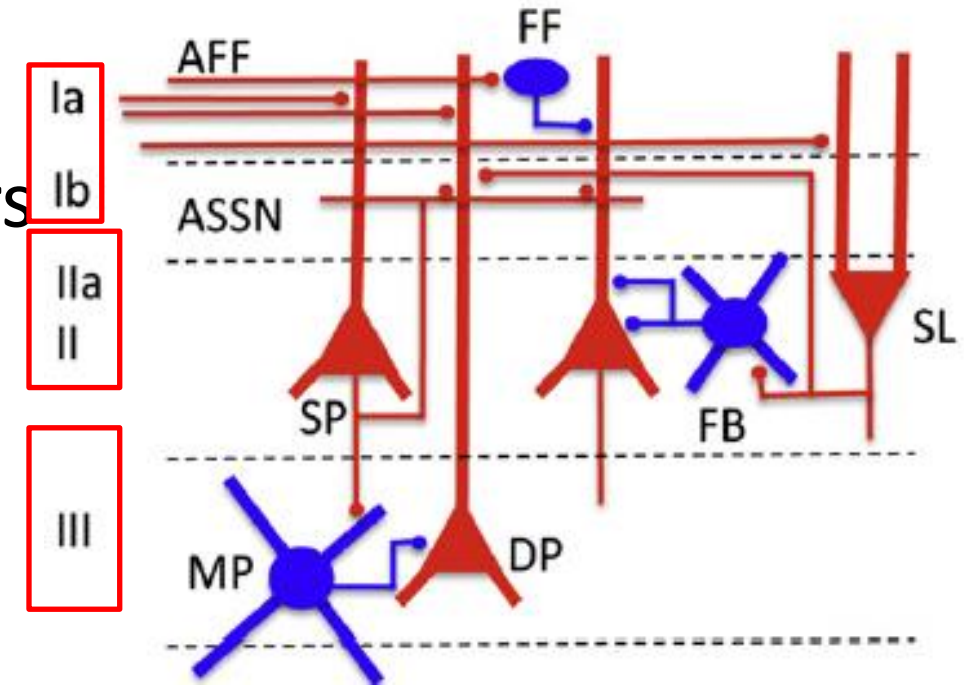
versus



- Converging projection + Diverging projections producing parallel processing to different sub-regions of the OC → thus OC play a crucial role in the translation into emotional and memory perception.

Olfactory cortex

- OC consists in 3 layers

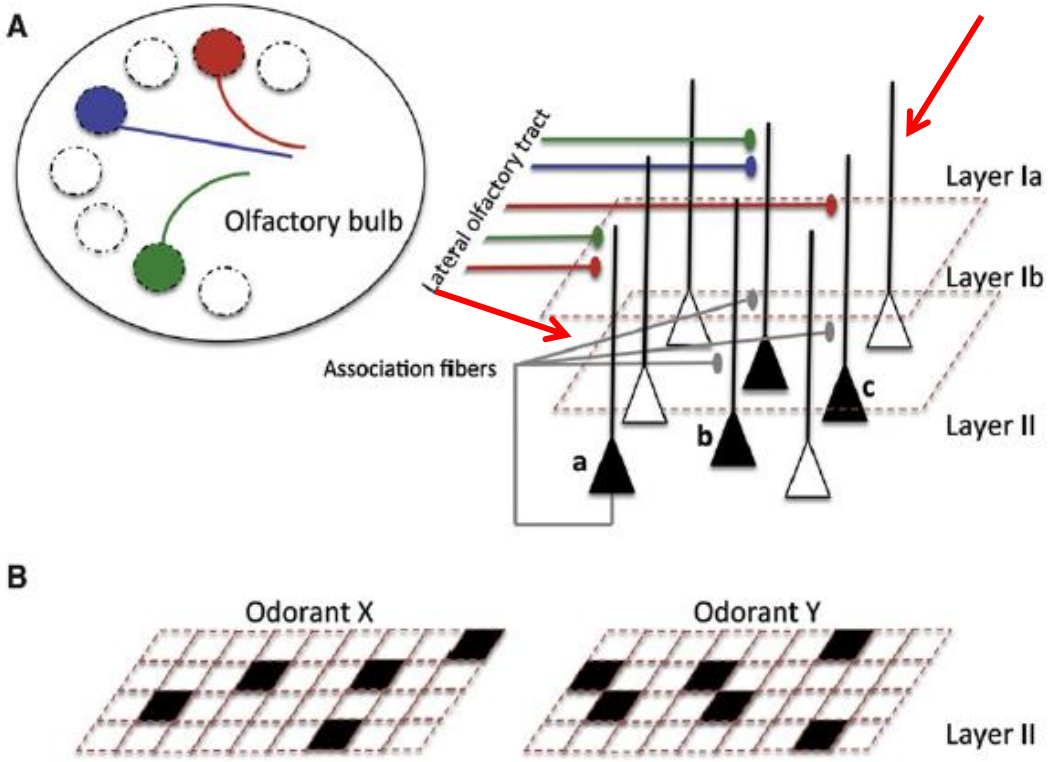


1. plexiform layer
2. Body cell layer
3. Layer of Bodies cell of Deeper pyramidal

The Piriform cortex is the largest sub-region of olfactory cortex

Puriform cortex

Features



- Piriform cortex performs pattern separation and completion
- Pyramidal cells that do not respond directly to stimulation of individual glomeruli, do respond when specific combinations of glomeruli are activated ⟶ Auto associative connection

Puriform cortex

- Piriform cortex is susceptible to run-away excitation and seizure activity $\longrightarrow$ Thus, synaptic inhibition plays the role of managing the sensitivity of the circuit.

- Distributed Afferent Input

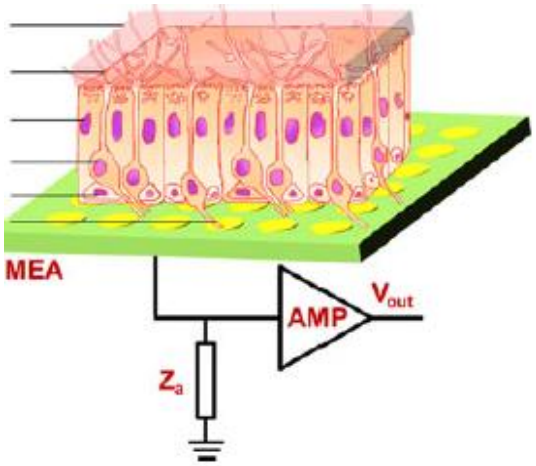
- Evoked Ensemble Activity

- Associative Synaptic Plasticity

- Neuromodulation

Bio-hybrid sensing system

Purpose : combine olfactory epithelium with microelectrode array (MEA) to establish an hybrid system to record the odor-induced electrophysiological activities



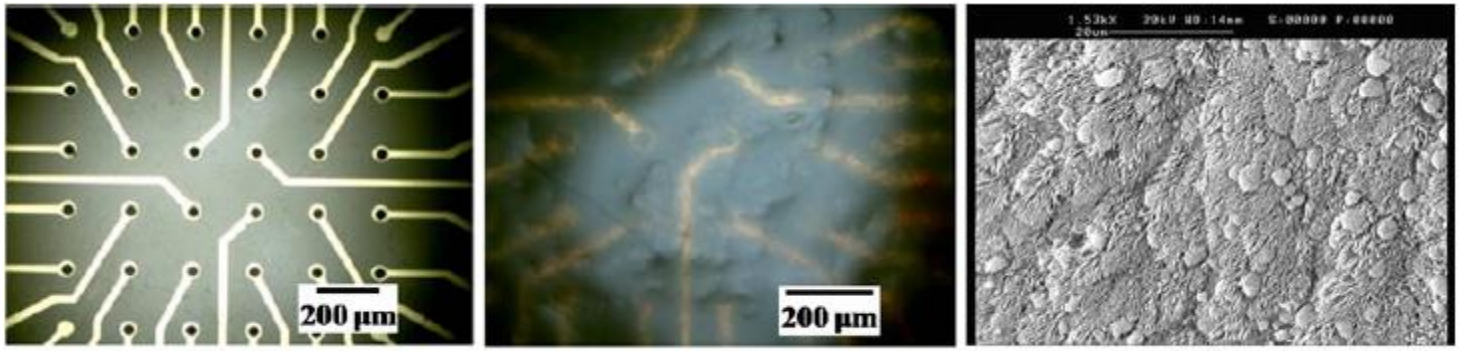
Method : They measured extracellular potential of olfactory receptor neurons in intact epithelium in the presence of ethyl ether, acetic acid, butanedione, and acetone, respectively

Bio-hybrid sensing system

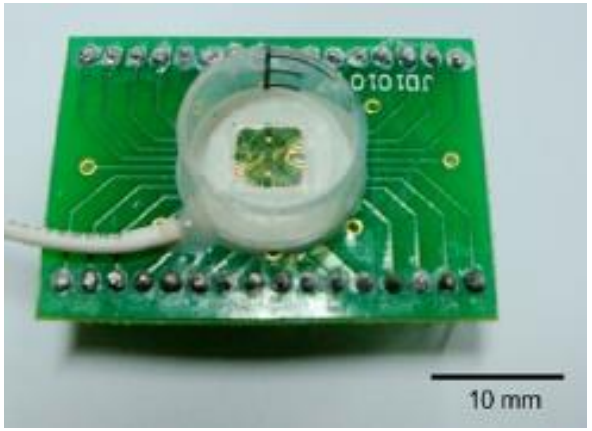
Fabrication of microelectrode array

- MAE is widely applied to detect tissue electro-physiological signals
- Layer of Ti (30 nm) was deposited onto the glass substrate for 30 min
- The photoresist was spin-coated onto the metallic layer
- The metal without protection was removed, while the electrodes and interconnections were left

Bio-hybrid sensing system



Micrograph of MEA with a 6×6 array



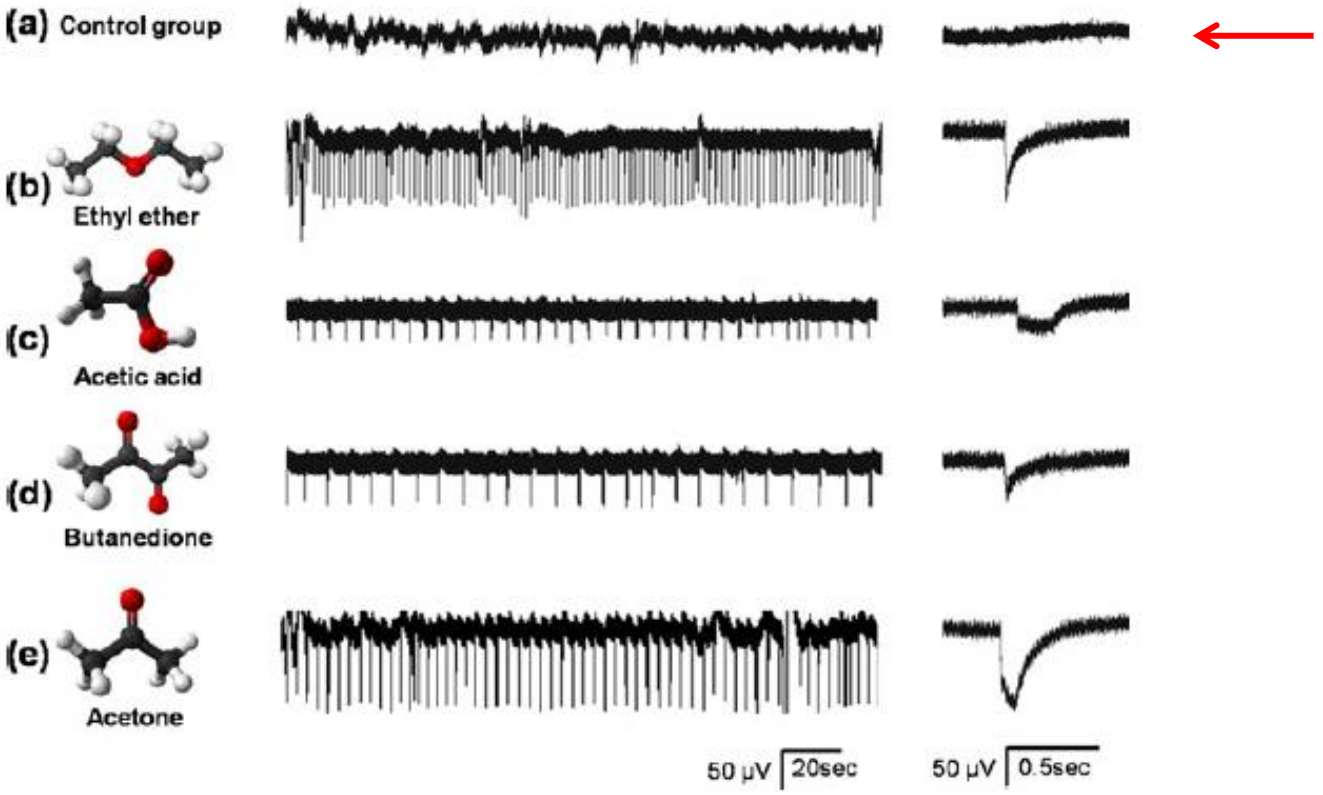
(a) MEA pattern

(b) Microelectrodes distribution under olfactory epithelium

(c) Expanded cilia of the olfactory epithelium under SEM

Bio-hybrid sensing system

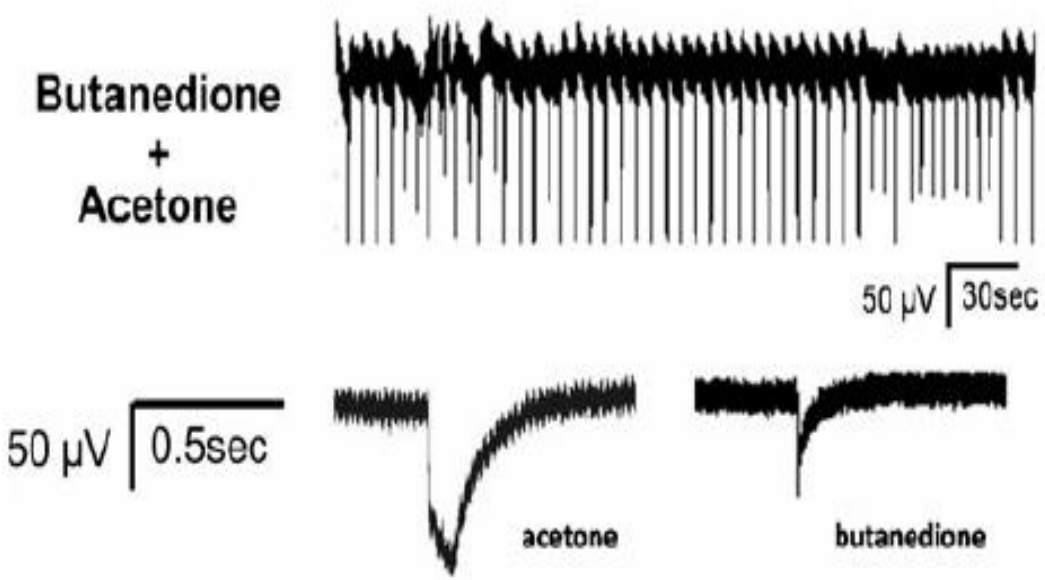
Results

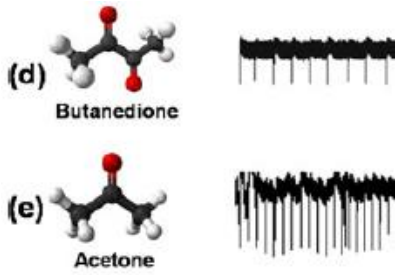


Compared to the control group, signals after odor induced stimulation show evident evoked potentials, with difference in firing rate and amplitude.

Bio-hybrid sensing system

Results





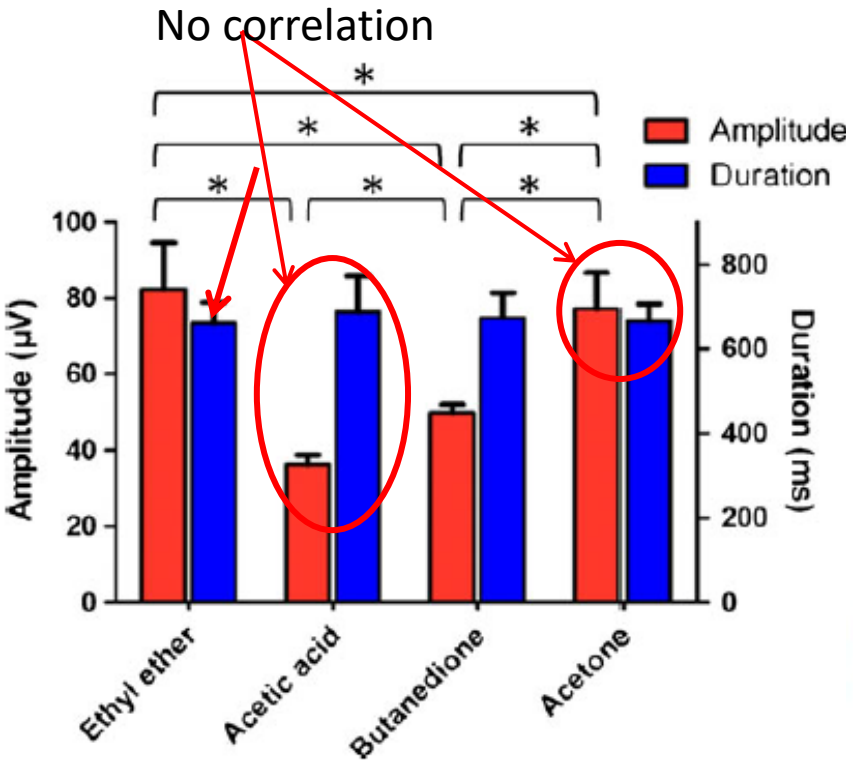
(personally I see only Acetone)

Response signals to the mixture odor stimuli

mixture of acetone and butanedione. Although there is a similar functional group of –C=O in acetone and butanedione, 2 patterns of signal responses can be recognized – able to discriminate

Bio-hybrid sensing system

Signal waveforms are characterised by: amplitude - duration - firing rate



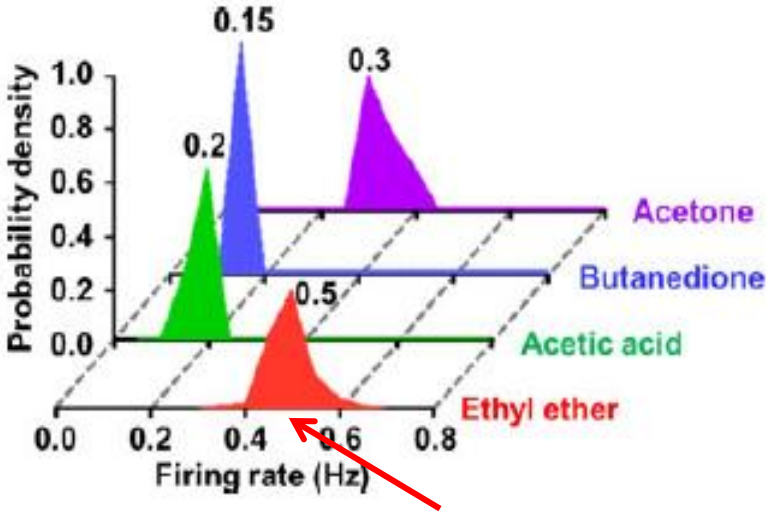
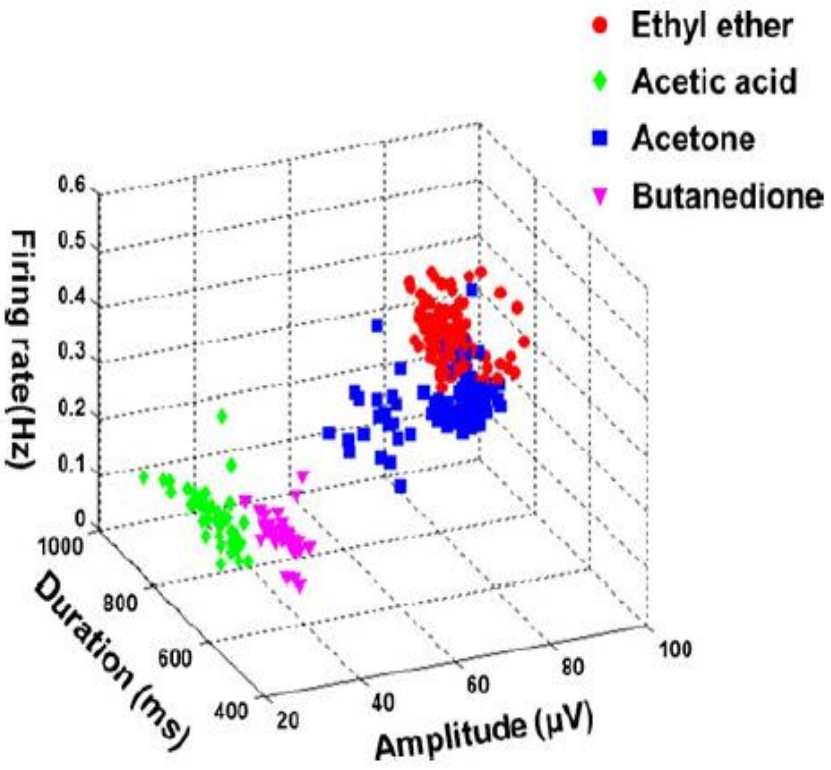


Fig. 6 The probability density distribution of response signals firing rate of olfactory epithelium biosensor exposed to the different odors

Normalized result of basic characteristics of potentials in our experiment. It was evident that the amplitude and duration of signal waveforms vary depending on the odorant category

Bio-hybrid sensing system



All the characteristics can be extracted to analyse the discrimination in 3D recognition pattern

Bio-hybrid sensing system

Conclusion: The bio-hybrid system can reflect the in vitro odor information of different signal characteristics. It provides a reliable and fast platform to odor detection.

Brain signal images

- Analyse of brain activity

Manganese-enhanced MRI. 4 features :

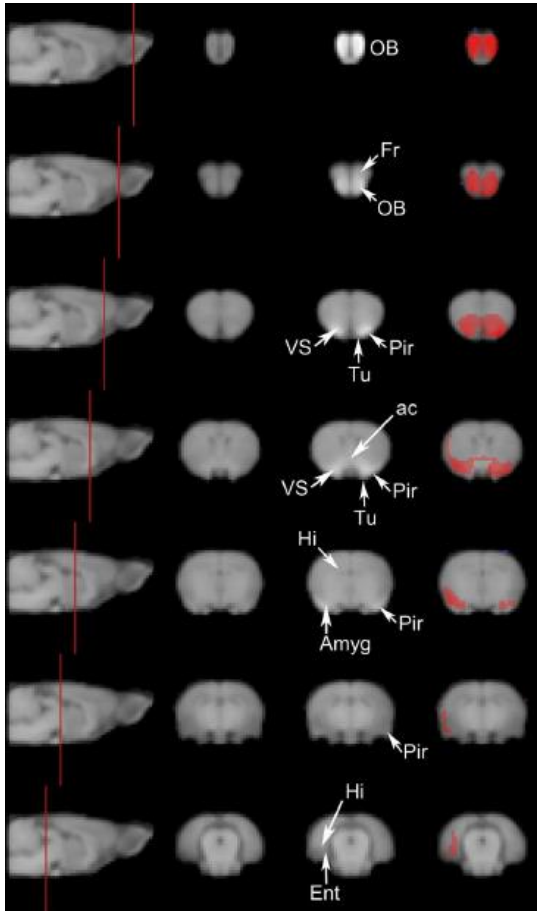
1. Mn has paramagnetic properties that make it detectable by MRI.

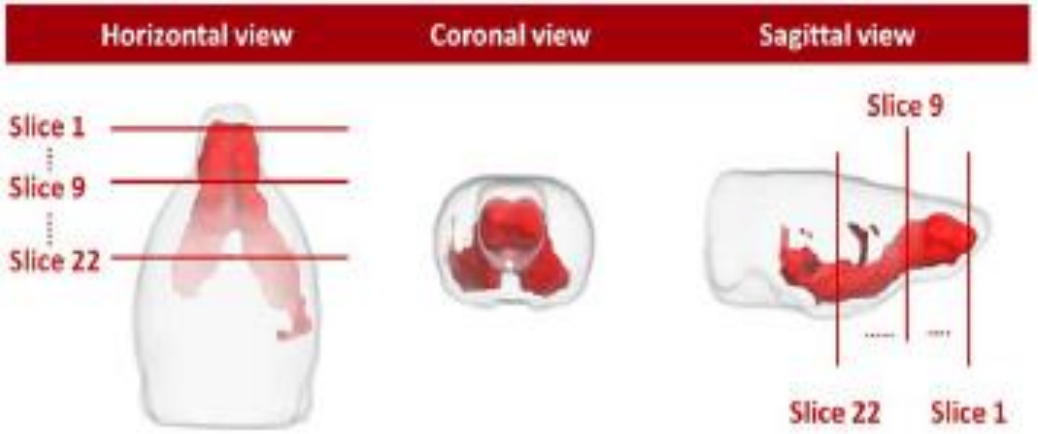
2. Mn is a calcium analogue and, as such, is taken up by activated neurons and migrates along neuronal processes .

3. Mn is slowly eliminated by neurons.

4. MEMRI allows to avoid both anesthesia and restraint during stimulation.

Brain signal images

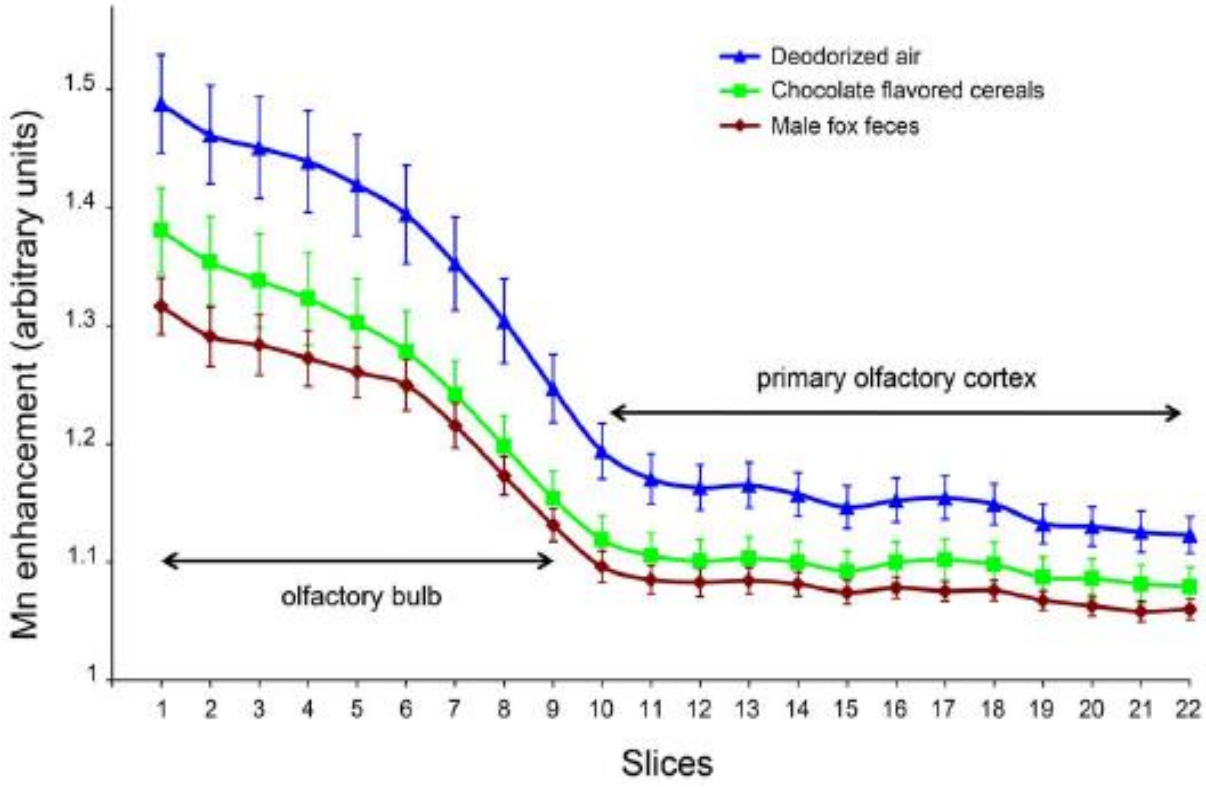




(confirmed by c-Fos immunohistochemistry)

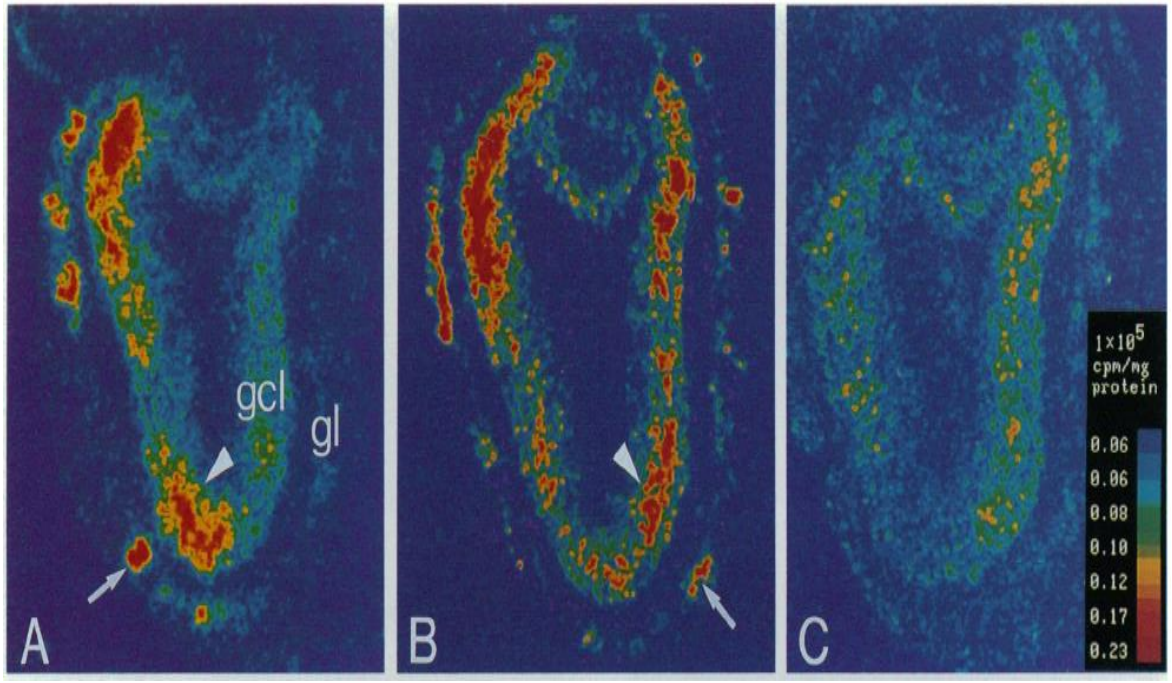
- MEMRI activation maps showed Mn enhancement all along the primary olfactory cortex.

Brain signal images



- Odour stimulants were used to stimulate conscious rats previously treated by intranasal instillation of manganese (Mn)
- Differents natural odour activate differently the central olfactory pathways in the piriform cortex

Brain signal images



(35S-labeled c-fos cRNA (A) or for [14C]dGlc autoradiography)

Pseudocolor images of film autoradiograms of olfactory bulb of rats exposed to

- peppermint (A)
- isoamyl acetate (B)
- clean air (C)

State of the art

Examine the state of the art of instrumental sensing currently used for the detection of odours

Why ? : Air pollution mainly due to industrial and commercial activities; They introduce an enormous and various amount of chemicals into the ambient air.

State of the art

- Based on Gas Chromatography coupled with Mass Spectrometry (GC/MS) widely used to analyse air quality

- They are called Electronic Noses (E-Noses)

- detection threshold = equivalent to 1 m^3 *n*-butanol (reference gas)

- The discovery of materials with chemo-electronic properties has provided the opportunity for the development of artificial olfactory instruments mimicking the biological system

State of the art

- Properties : must themselves be odourless, undergo minimal physical or chemical reactions with the air sample.

- Name:

  Polytetrafluoroethylene <-> Teflon

  Polyvinylfluoride <-> Tedlar

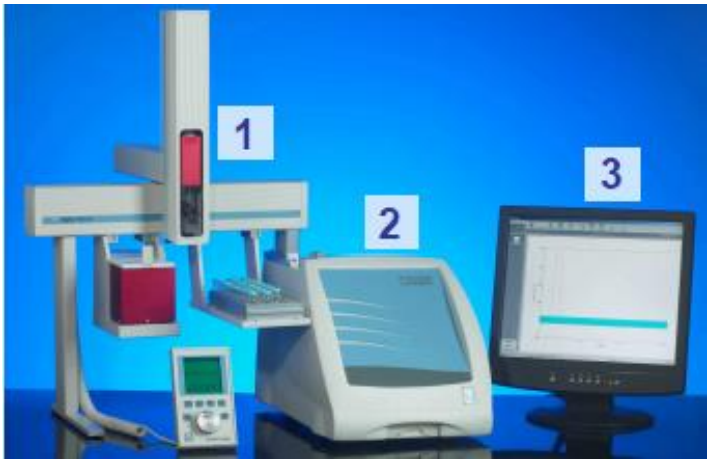
  polyterephtalic ester <-> Nalophan

- Sampling device:

  Canisters – Odourmapper - Aromascan

State of the art

FOX



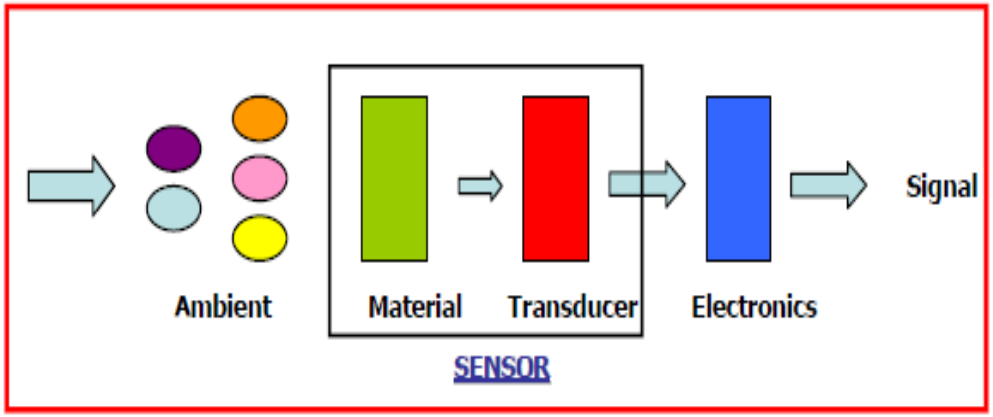
GEMINI

HERACLES

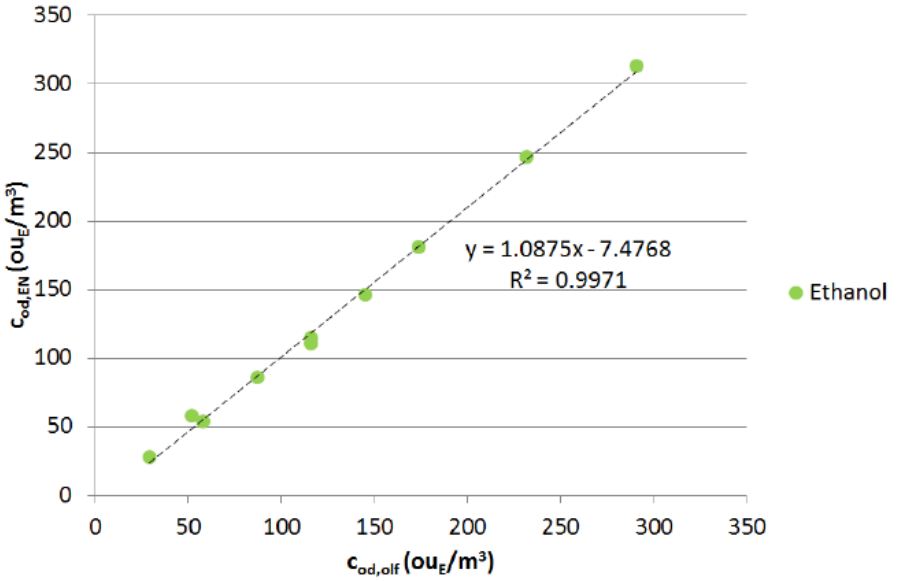
AIRSENSE

State of the art

- Principle



- Laboratory tests



Estimated Vs Real odour concentration of the ethanol sample

Conclusion

The sense of smell is the one that informs us about the volatile molecules in our environment. with a complex system ranging from the receptors to the puriform cortex, it manages not only smells signaling but also emotional behavior associated with it. It’s possible to analyze the afferent activity, as demonstrated in the main article. Moreother, technology has developed E-nose outstanding performance, mimicking the olfactory system in order to monitor the ambient air pollution. One always learn from nature.

Questions