Olfactory System

&

Nano-Bio-Electronic Nose

Five Senses

Chemical Sense

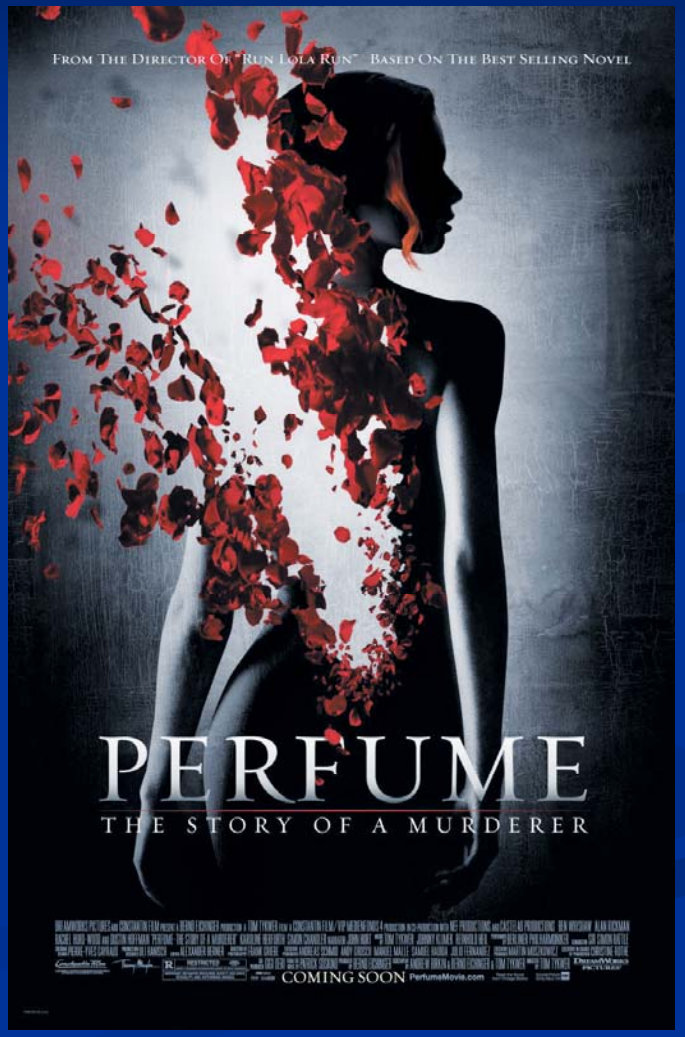
Smell Taste

Physical Sense

Hearing Sight Touch

The Sense of Smell

- The most the most mysterious of our senses.
- Human
  - 10^{-3} ppb
  - 10,000 distinct odors



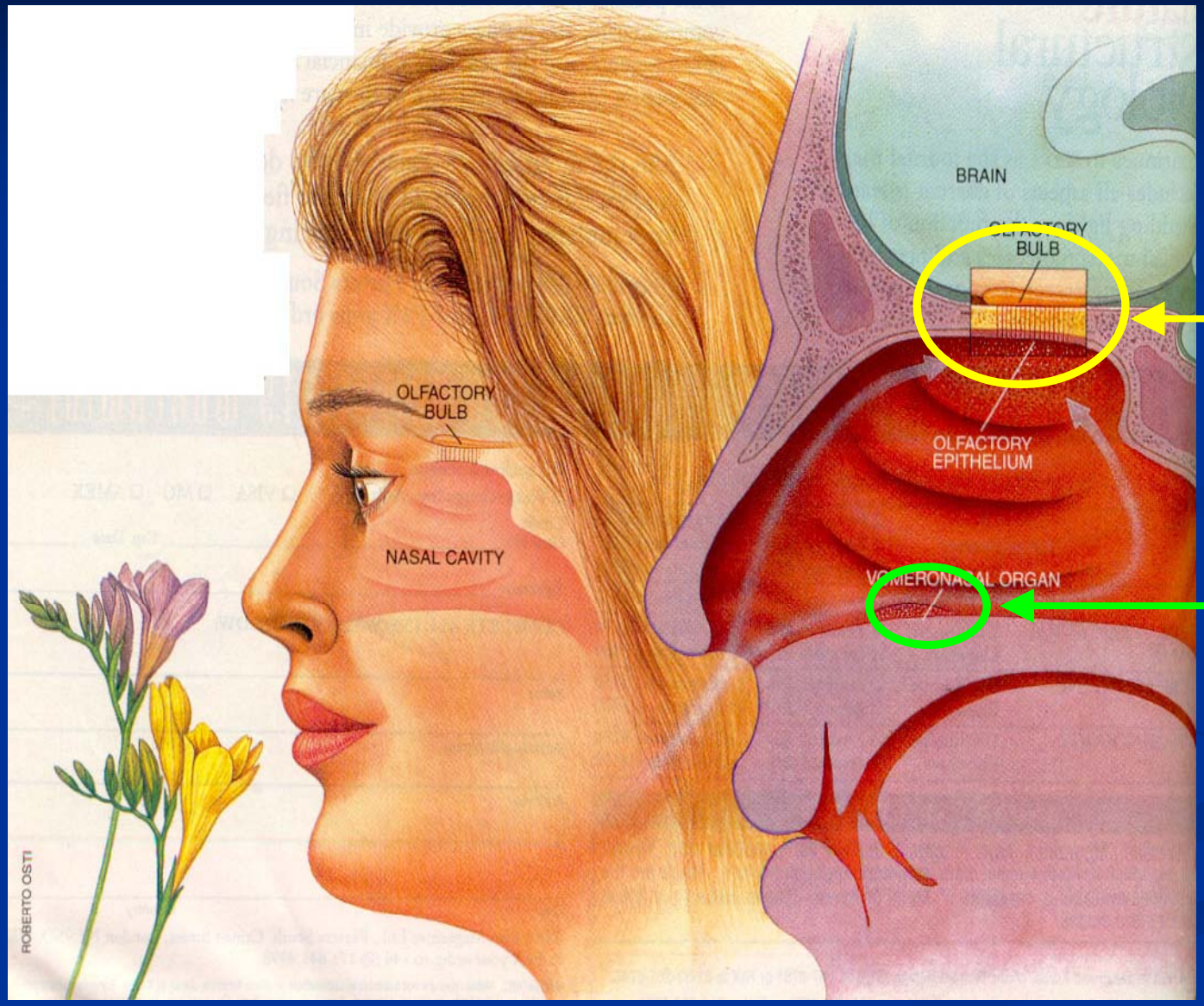
2004 Nobel Prize

in Physiology or Medicine

Discovery of

Smell Sensing Mechanism

Olfactory System



General Smell

Sexual Information

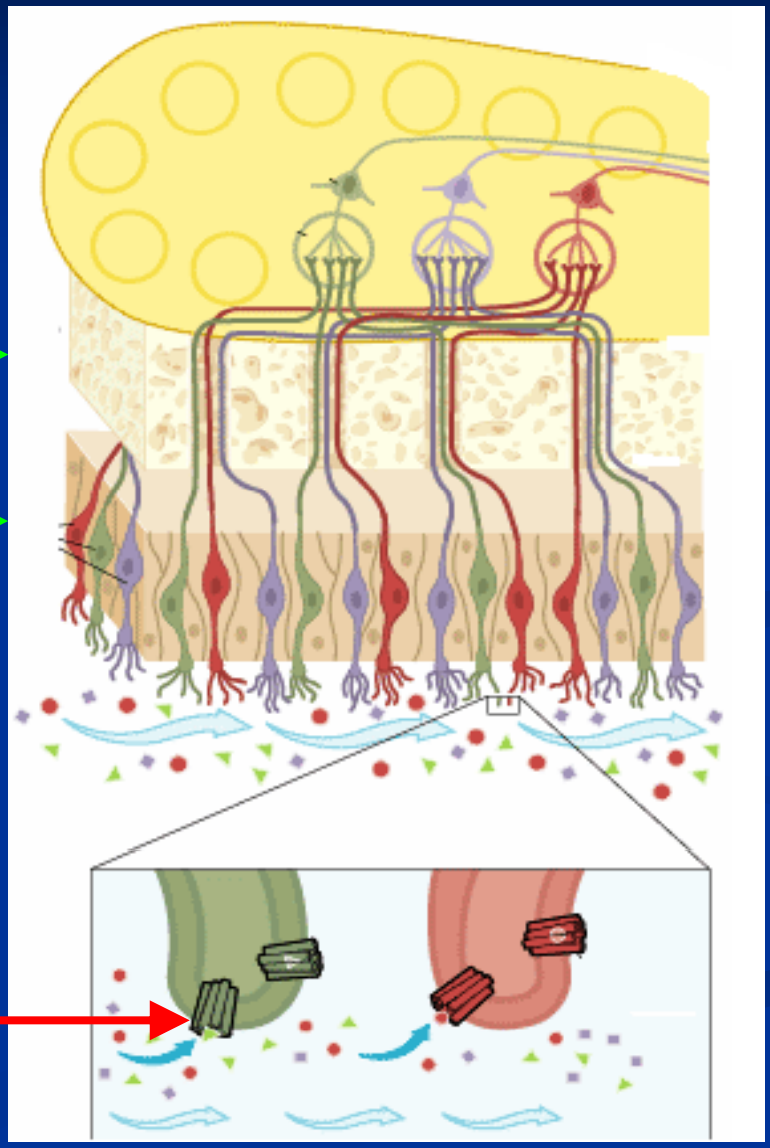
Olfactory Receptor

Brain

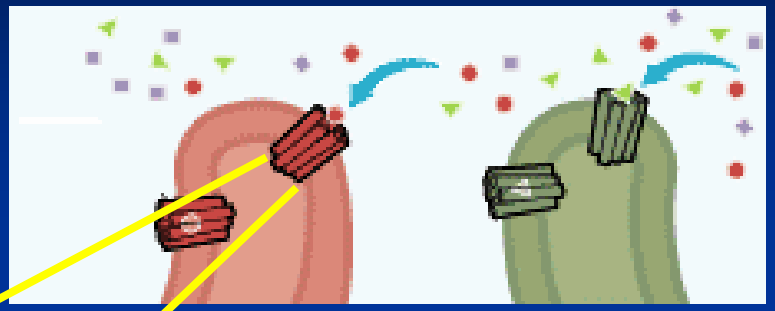
Bone

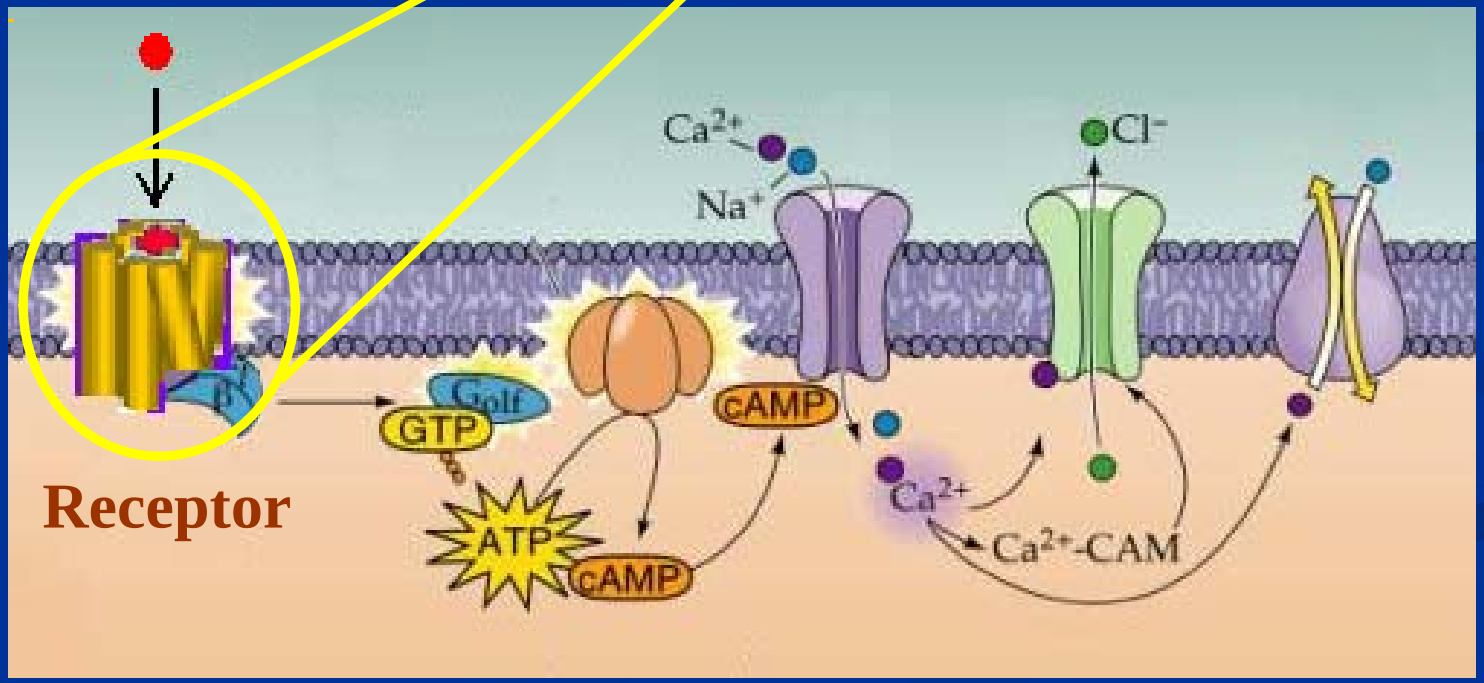
Olfactory Epithelium

Olfactory Receptor

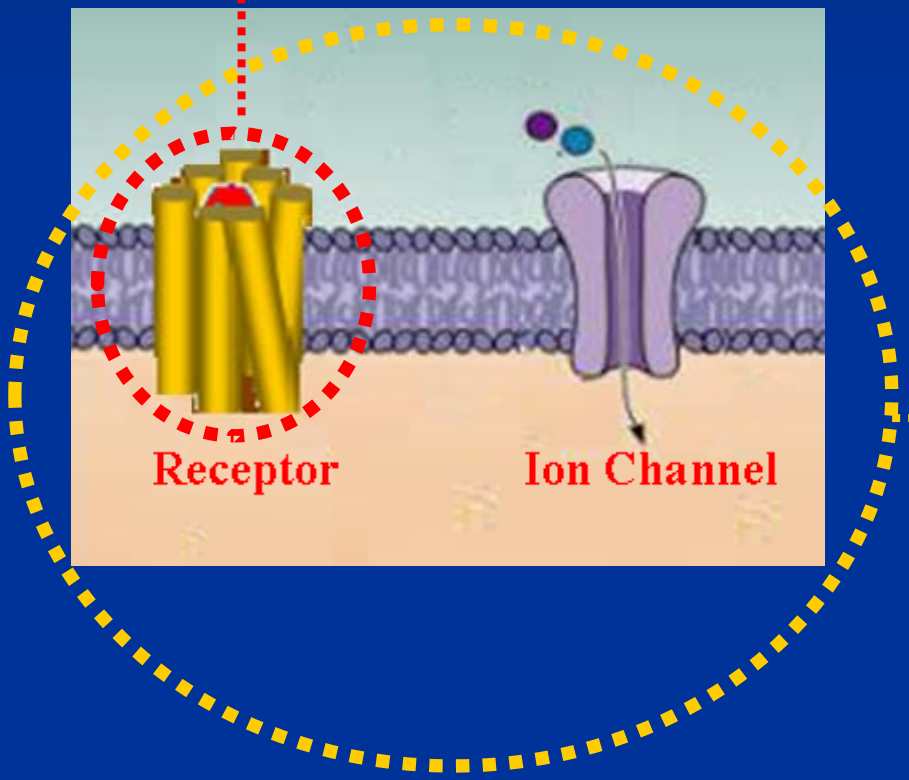


Olfactory Signal Transduction





Receptor and Cell for Biosensor



Receptor-Based Biosensor

- *E. coli*
- **HEK-293 (Human Cell)**

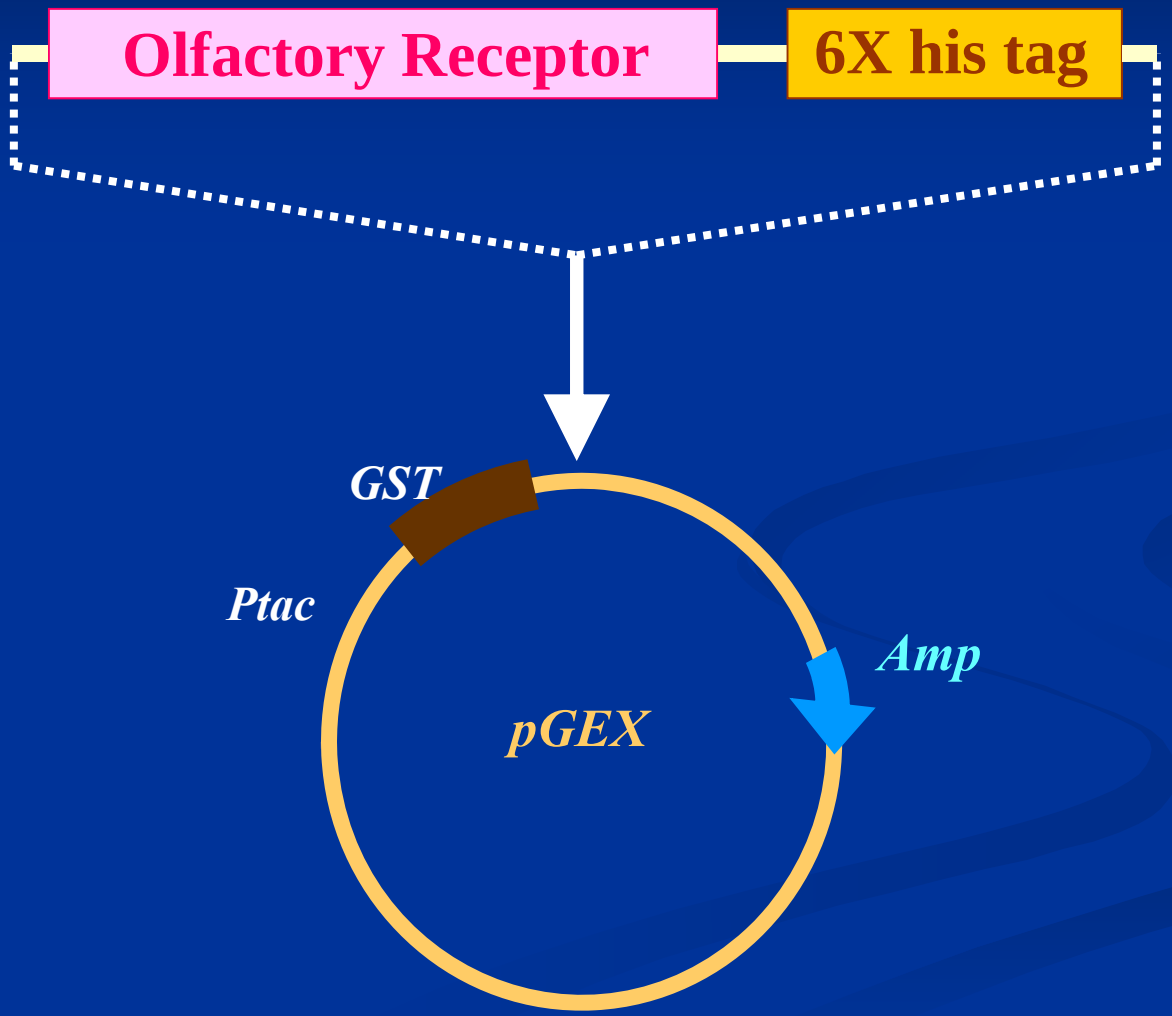
Cell-Based Biosensor

- **HEK-293 (Human Cell)**

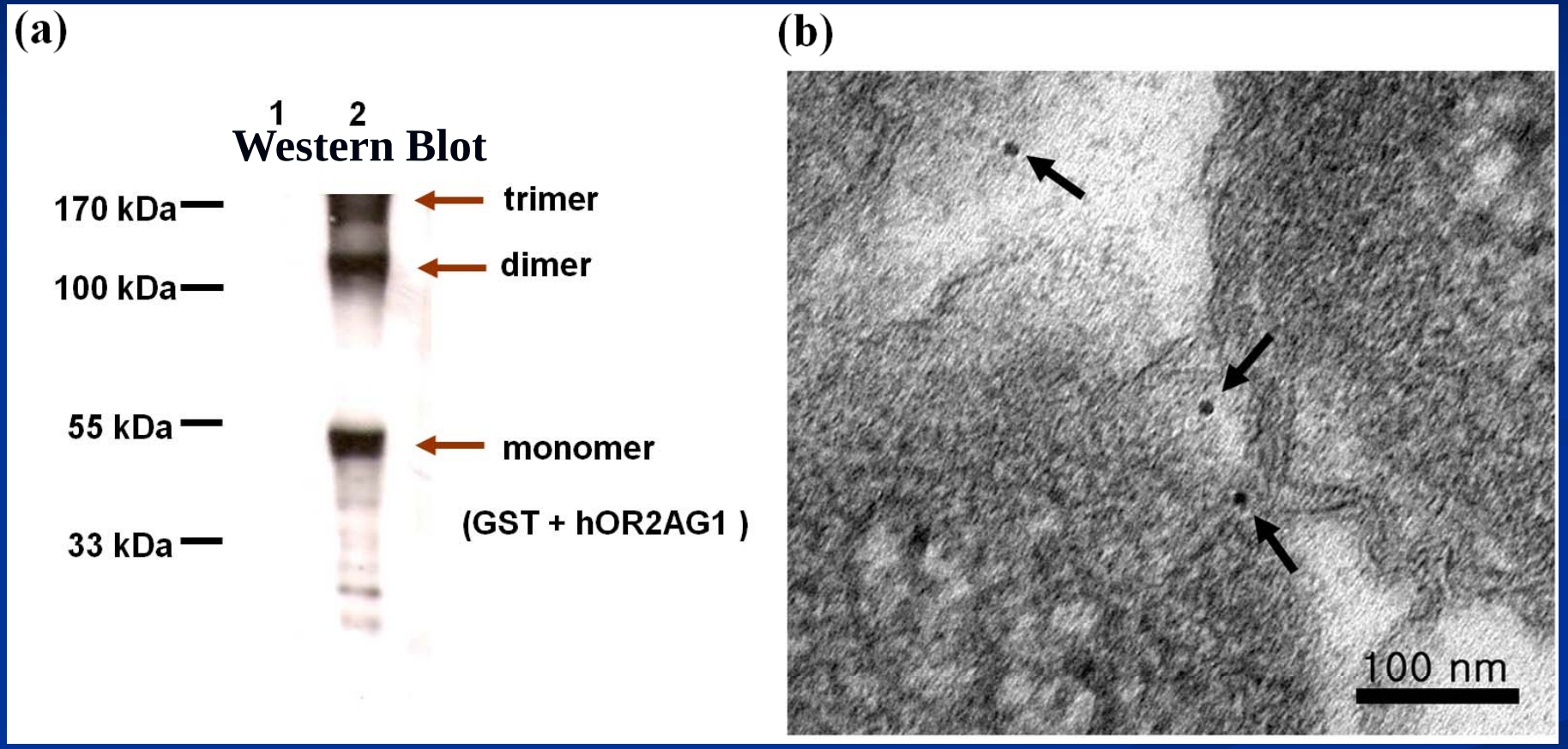
Receptor Expression

in *E. coli*

Cloning of Receptor Gene in *E. coli*



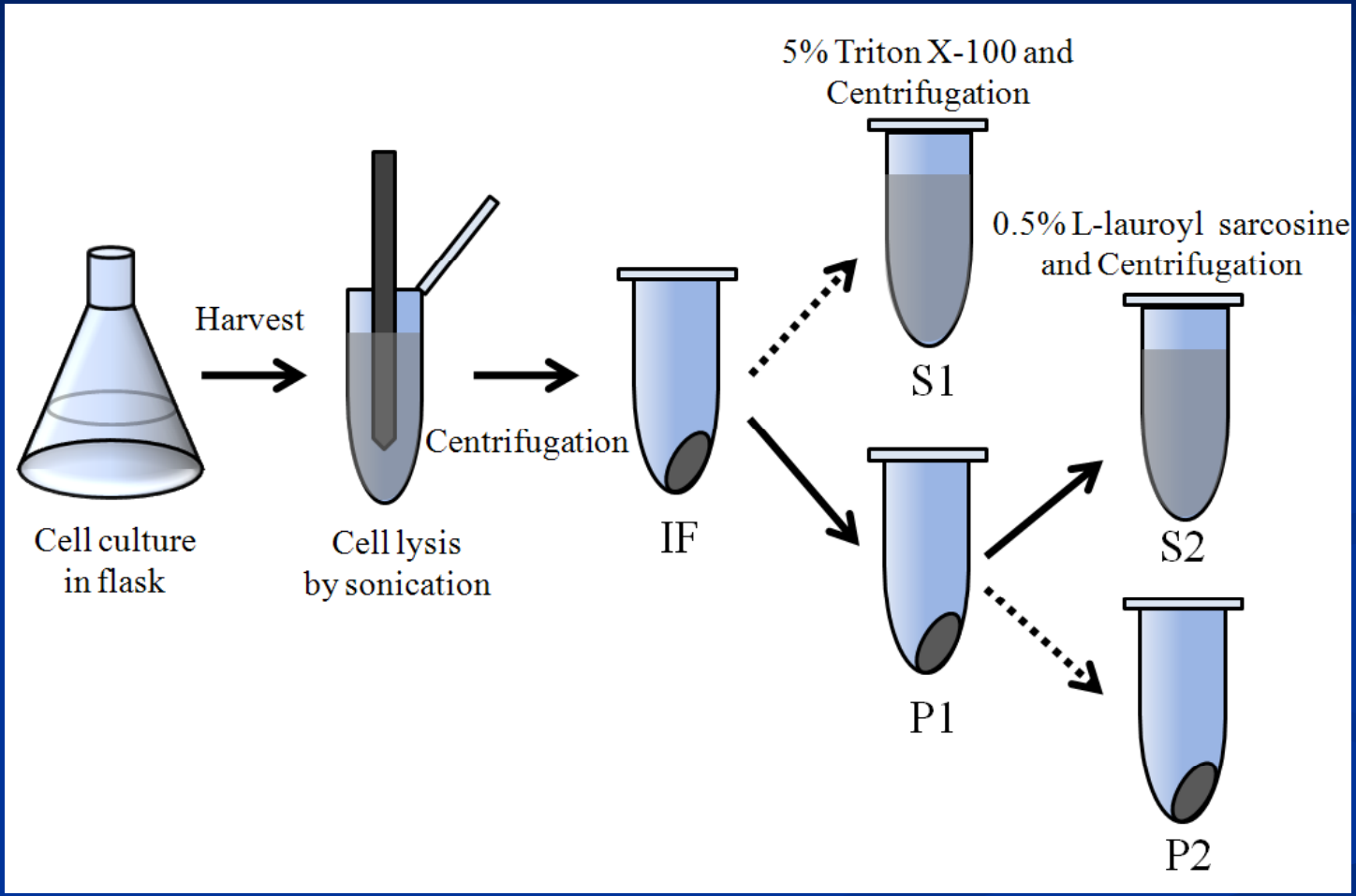
Expression of Receptor in *E. coli*



Sung, Ko, and Park, *Biosensors and Bioelectronics*, 21, 1981-1986 (2006)

Kim *et al.*, *Advanced Materials*, 21, 91-94 (2009)

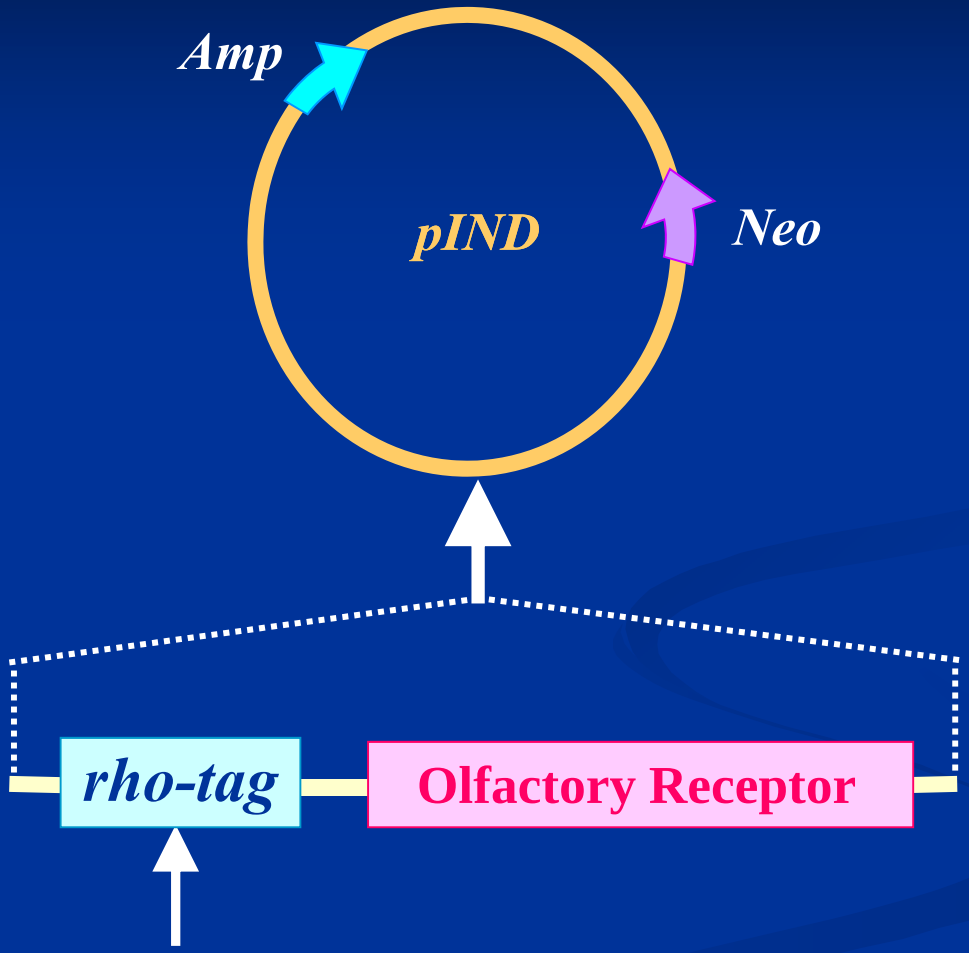
Purification of Receptor



Song, Lee, Oh, and Park, *Current Microbiol.*, 21, 91-94 (2009)

Receptor Expression on Surface of HEK-293 Cell

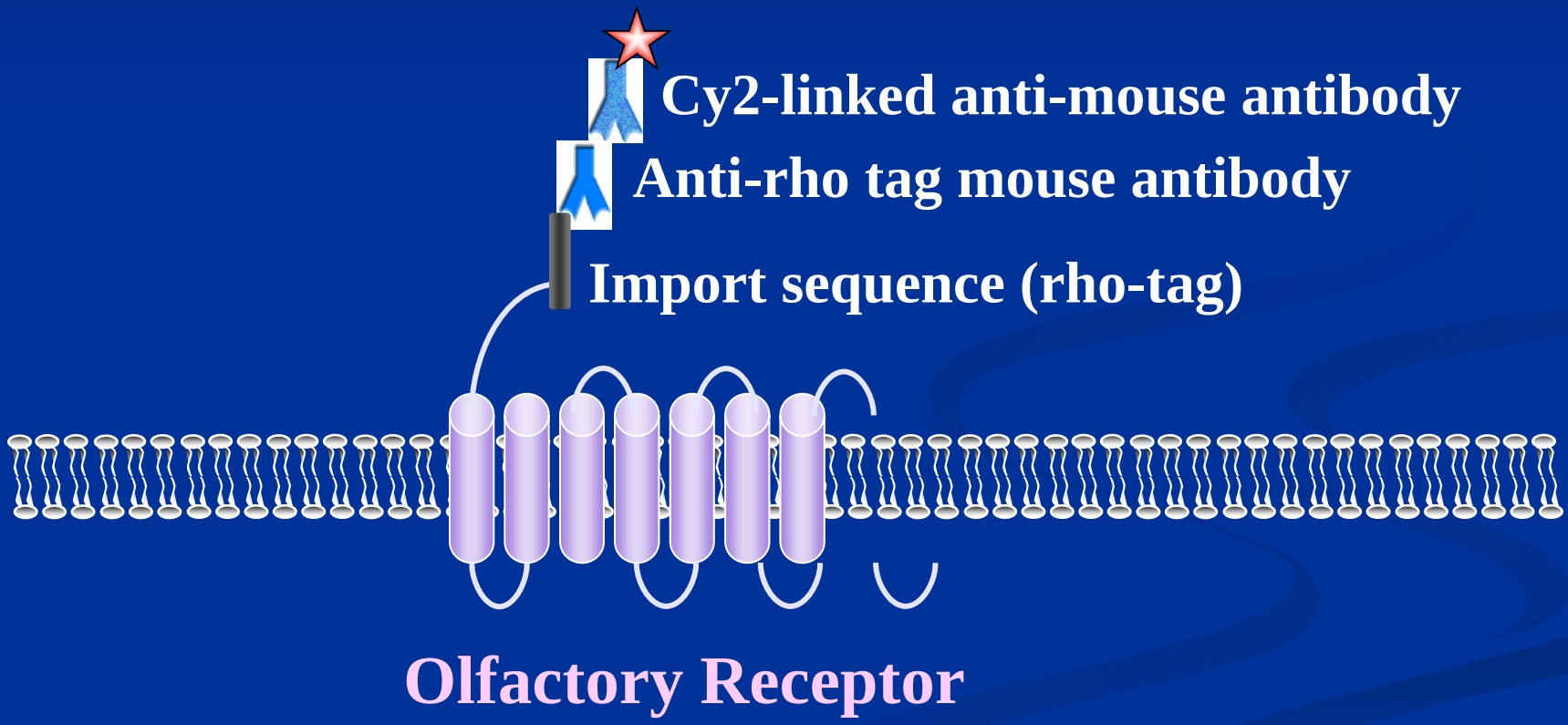
Cloning of Receptor Gene in HEK-293 Cell



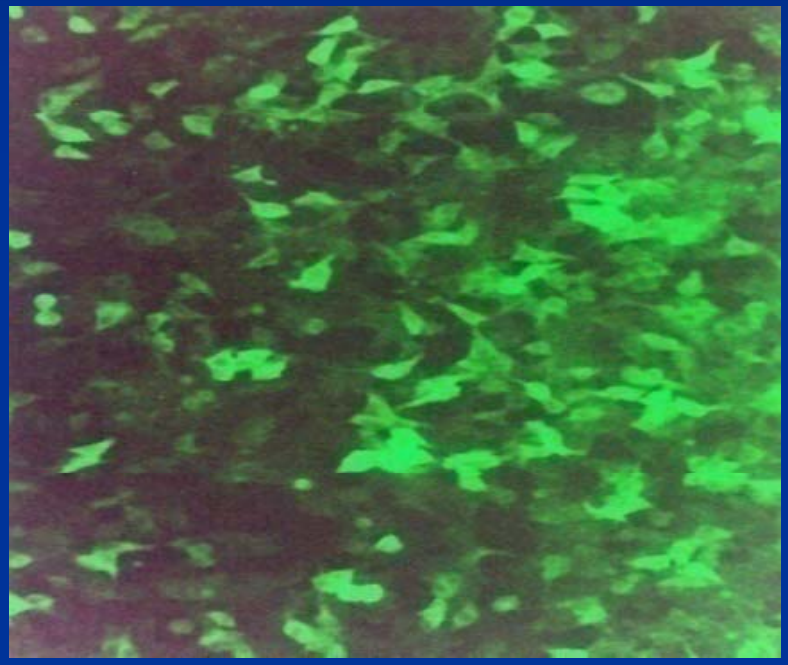
For targeting to cell surface

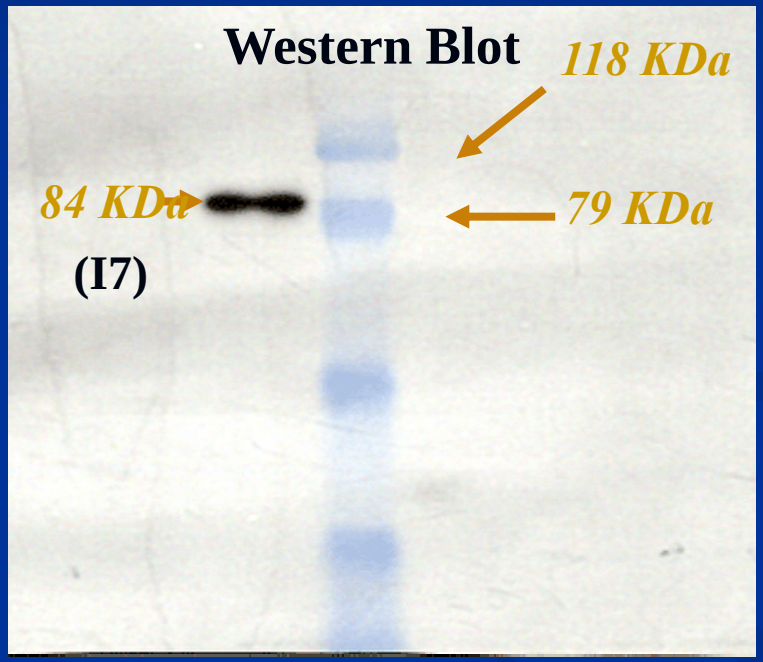
Detection of Surface Expression

(Immunocytochemical method)



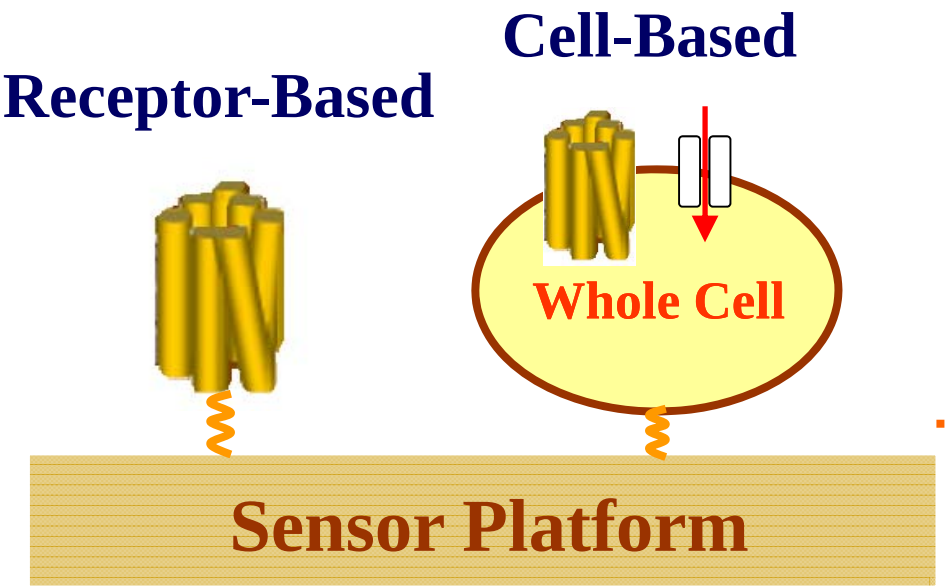
Expression of Receptor on Surface of HEK-293 Cell





Ko, and Park, *Biological Chemistry,* 387, 59-68 (2006)

Development of Biosensor



Biological Recognition Element
(Primary Transducer)

Biochip Hardware Platform
(Secondary Transducer)

Primary Transducer

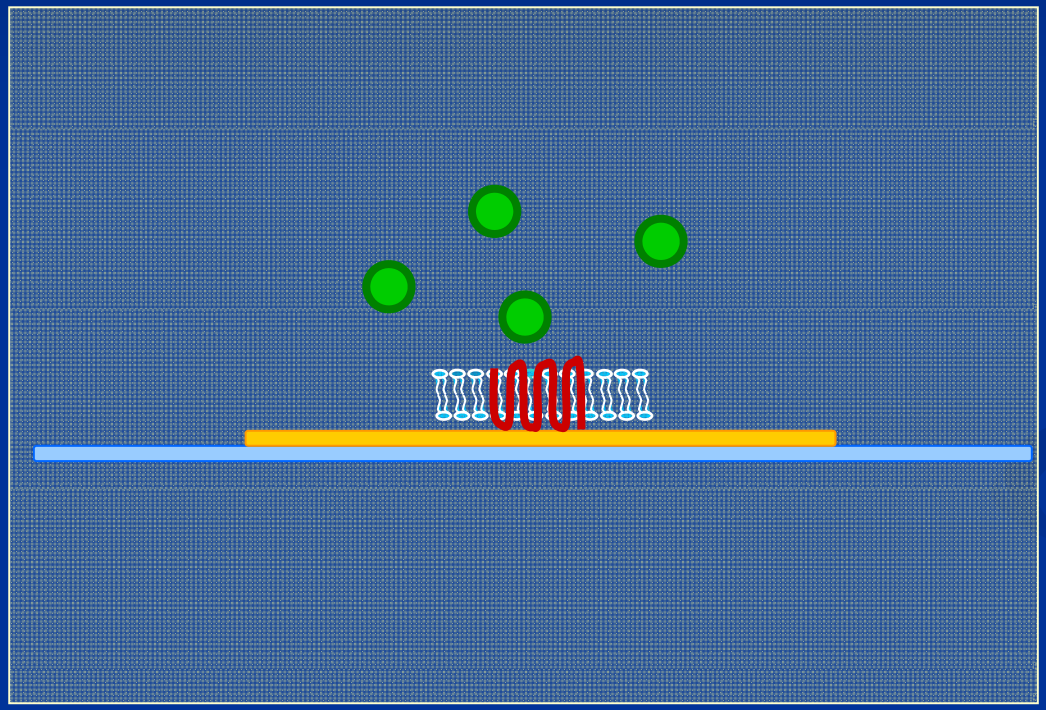
- **Receptor-Based**
  - **Receptor expressed in *E. coli***
  - **Receptor expressed on HEK-293 cell surface**
- **Cell-Based**
  - **HEK-293 cell with receptor expressed on the cell surface**

Secondary Transducer

- QCM (Quartz Crystal Microbalance)
- SPR (Surface Plasmon Resonance)
- Microelectrode
- Nanotube
  - Carbon Nanotube
  - Conducting Polymer Nanotube

QCM

Receptor & QCM



: Odorant (Diacetyl)

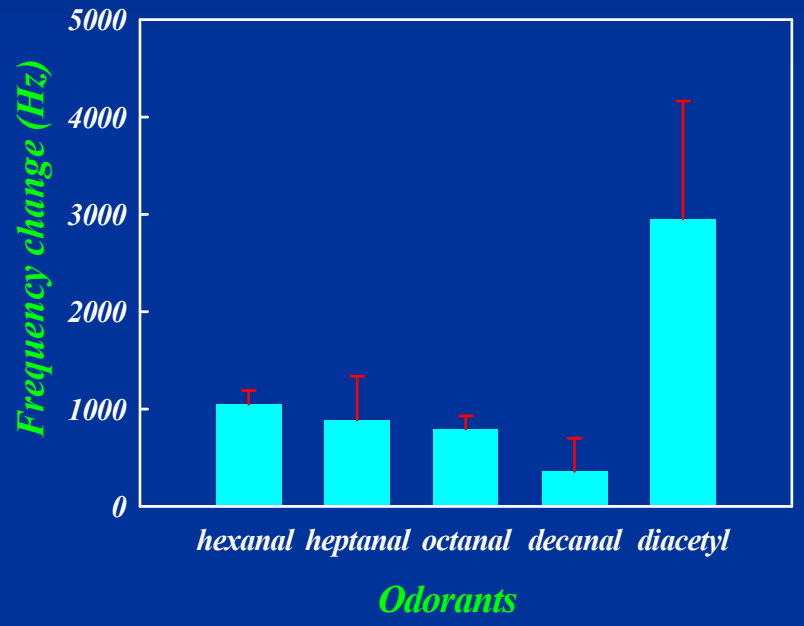
: Receptor (ODR10) expressed in *E. coli*

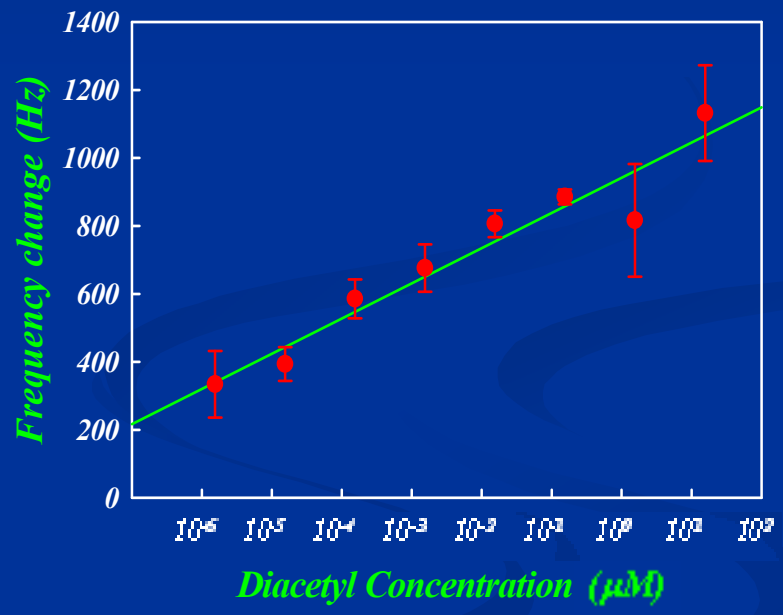
: Gold layer

: Quartz crystal

$$\Delta F = -F \Delta m / (A r t)$$

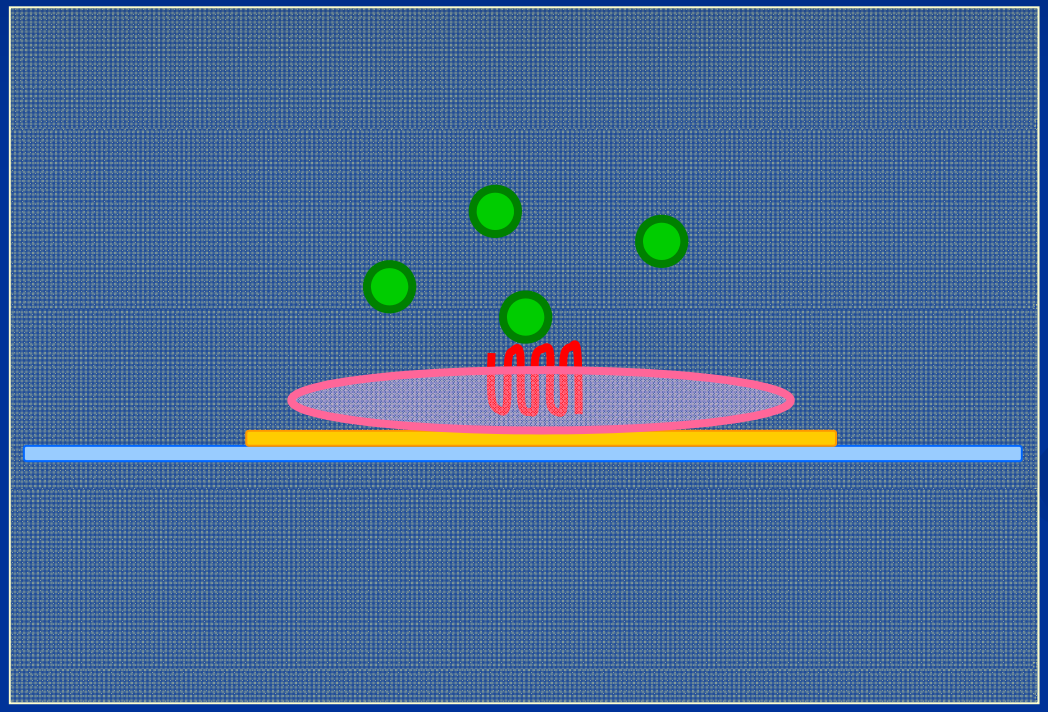
Odor Specificity & Dose-Dependent Relationship





Sung, Ko, and Park, *Biosensors and Bioelectronics*, 21, 1981-1986 (2006)

Receptor & QCM



: Odorant (Octanal)

: Receptor (I7)

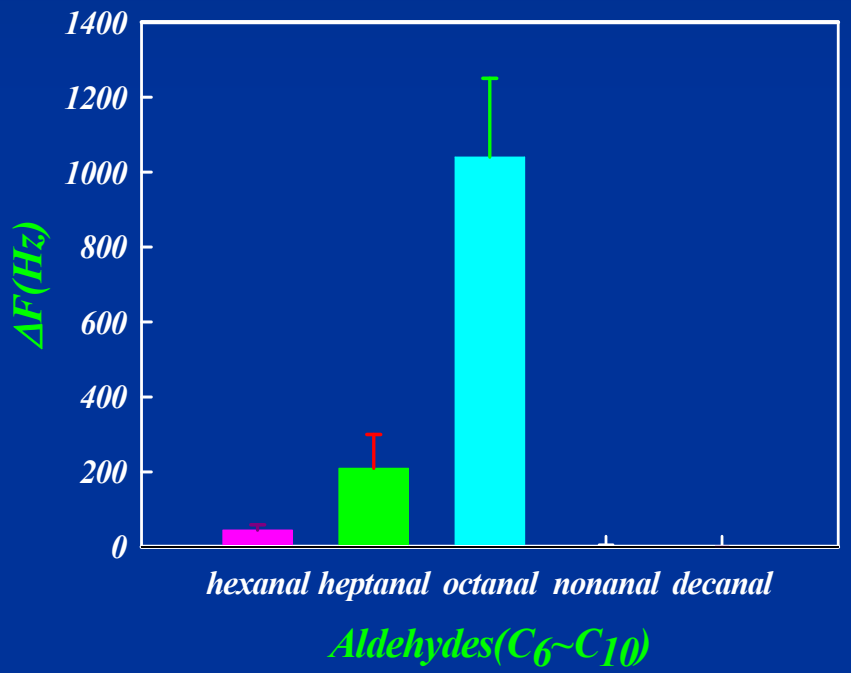
: Dried HEK cell

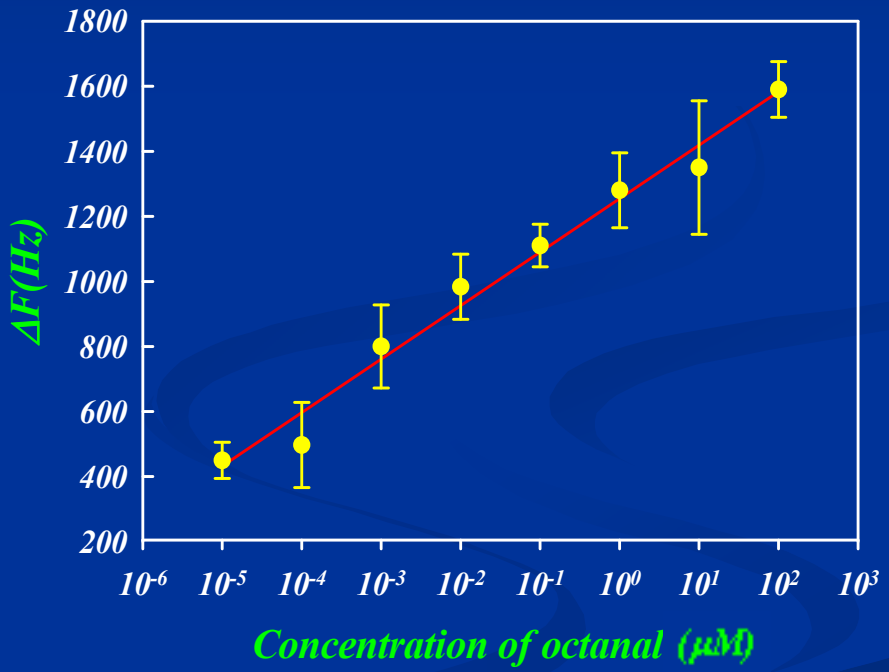
: Gold layer

: Quartz crystal

$$\Delta F = -F \Delta m / (A r t)$$

Odor Specificity & Dose-Dependent Relationship

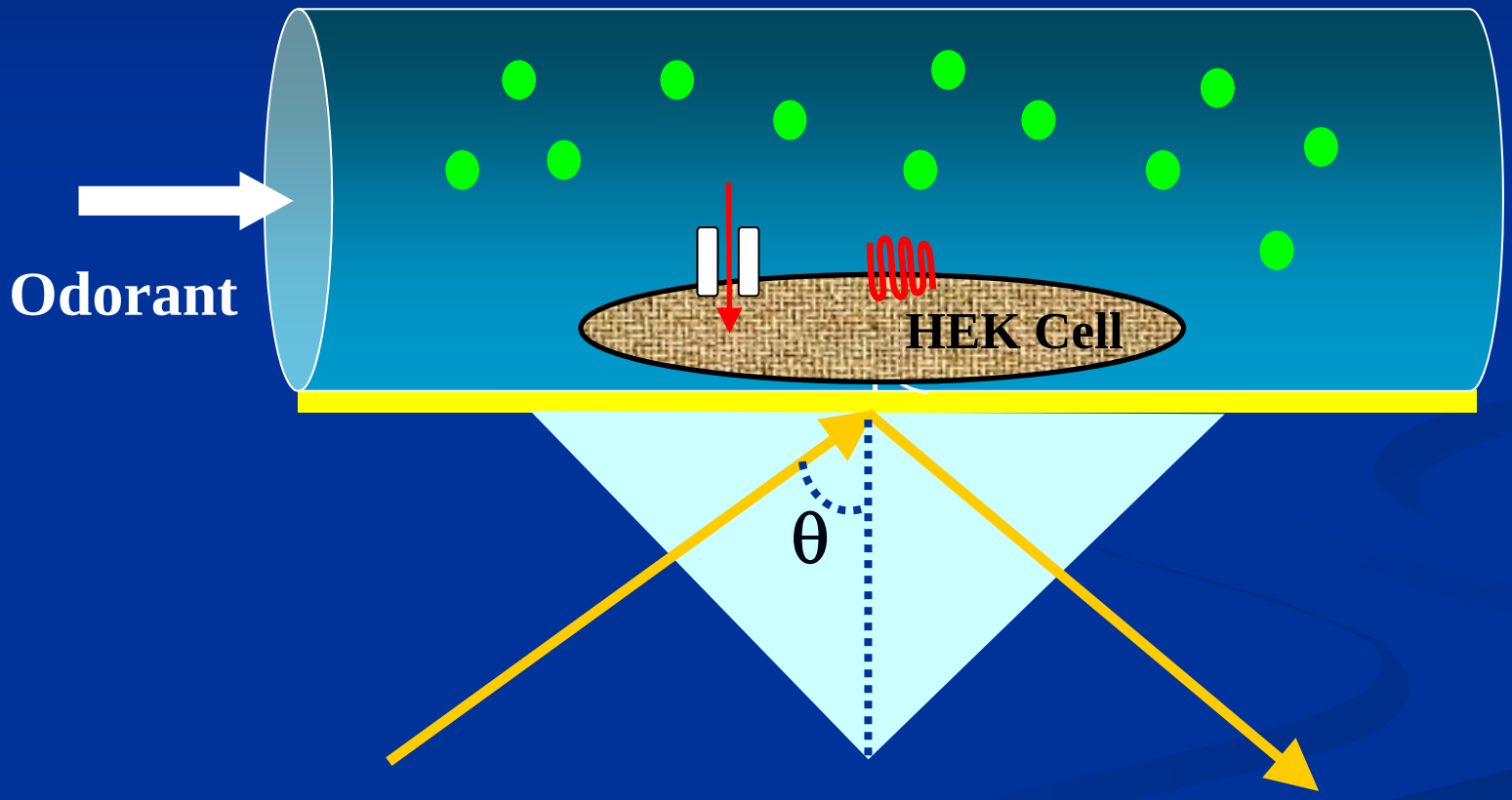




Ko, and Park, *Biosensors and Bioelectronics*, 20, 1327-1332 (2005)
Ko, and Park, *Biosensors and Bioelectronics*, 23, 1017-1023 (2008)

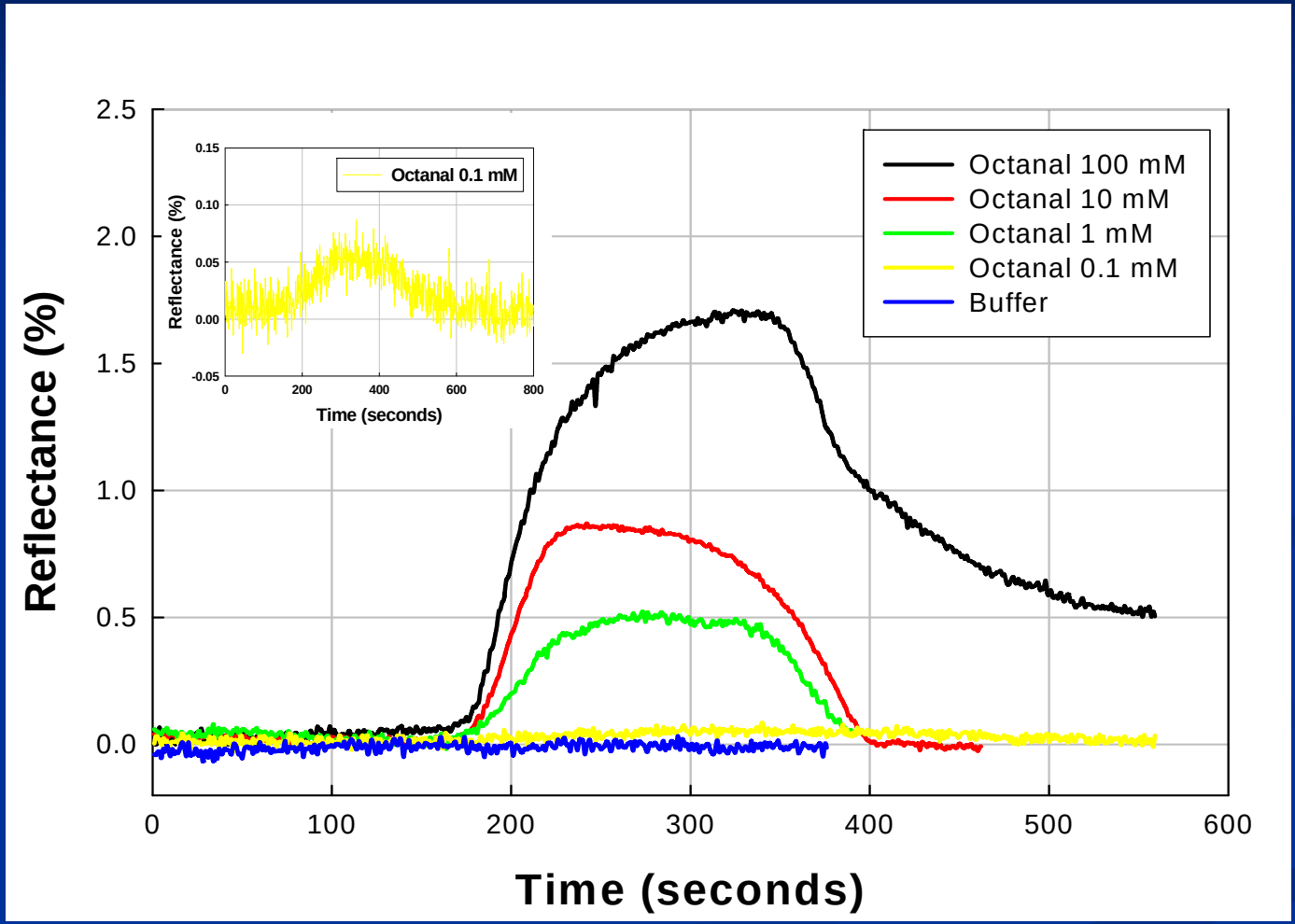
SPR

Cell & SPR



Lee et al., *Enz and Microb Technol.*, 39, 375-380 (2006)

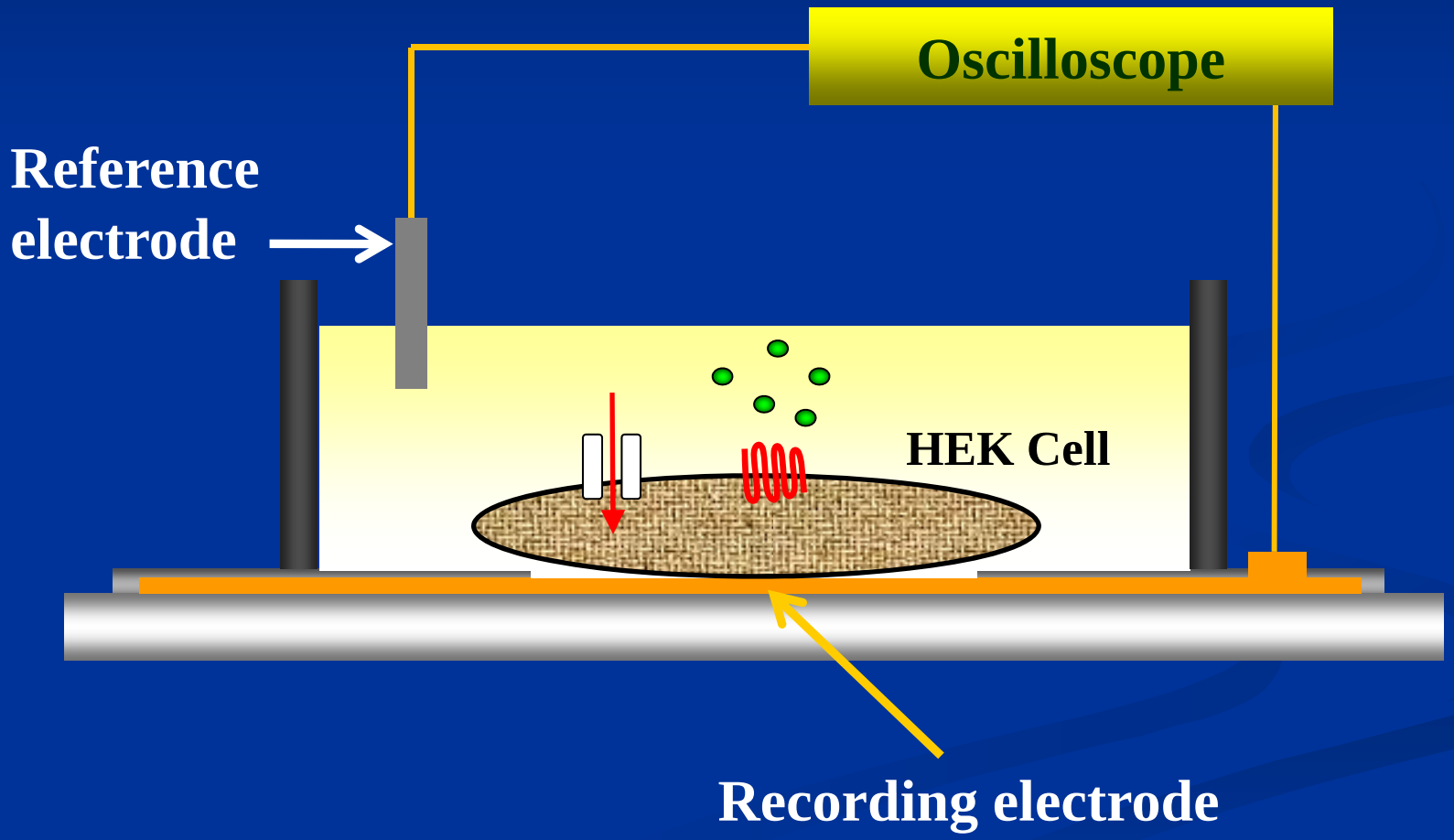
Dose-Dependent SPR Response



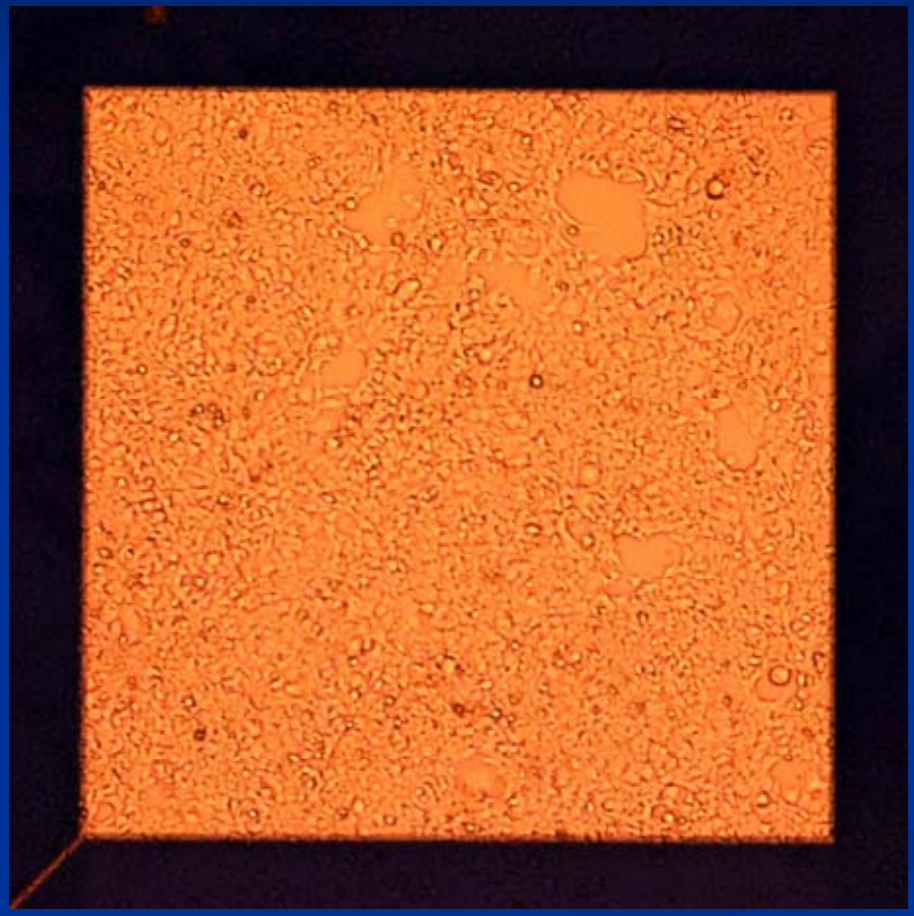
Lee, Ko, and Park, *Biosensors and Bioelectronics*, 25, 55-60 (2009)

Microelectrode

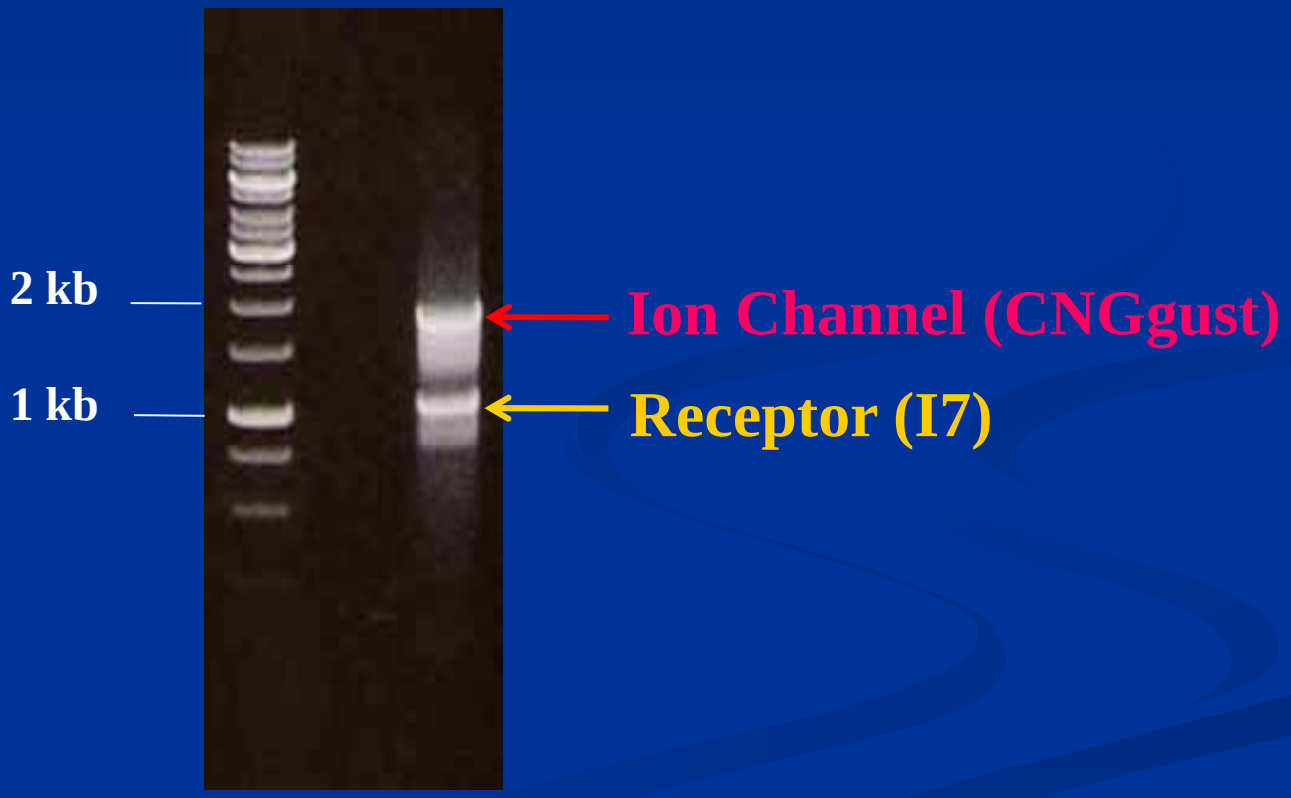
Cell & Planar Microelectrode



Cells on Planar Electrode

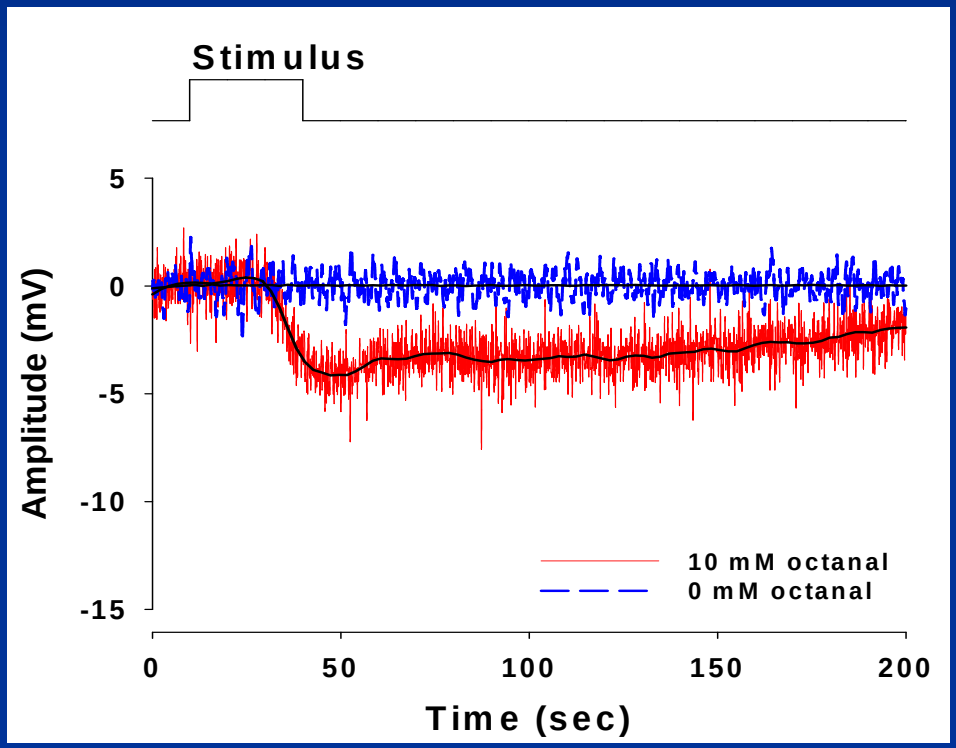


RT-PCR
of Receptor & CNGgust

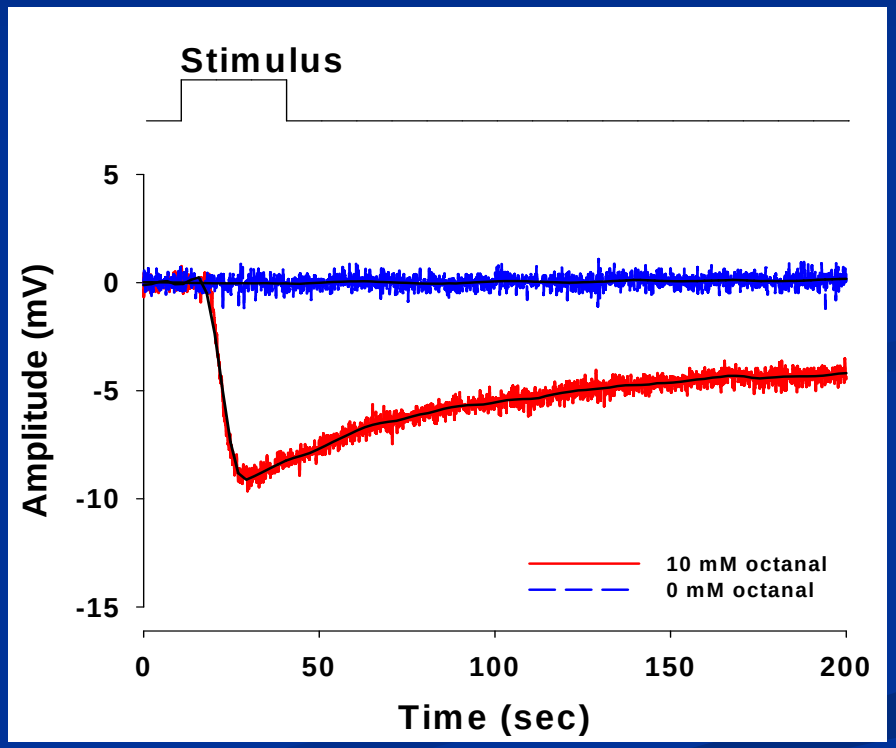


Field Potential Profile

Without CNGgust

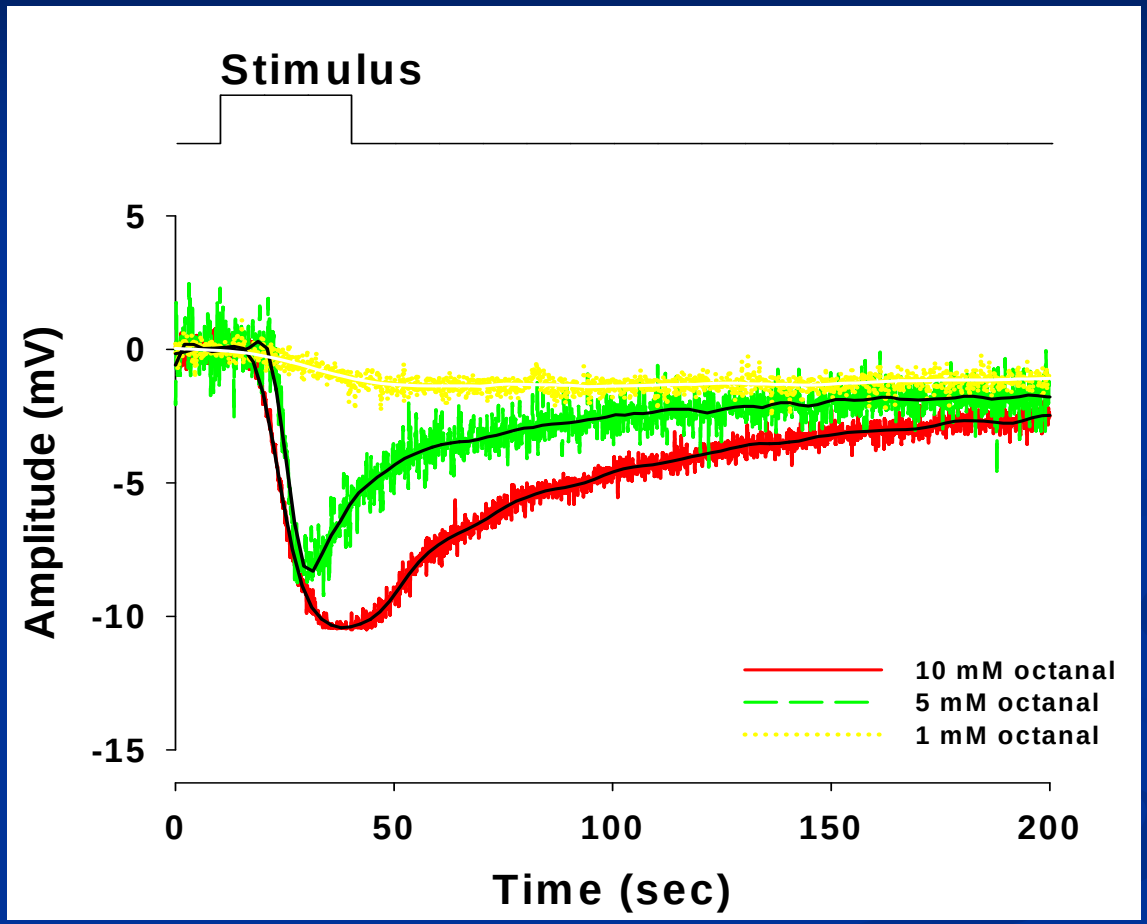


With CNGgust



Lee et al., *Biosensors and Bioelectronics*, 24, 2659-2664 (2009)

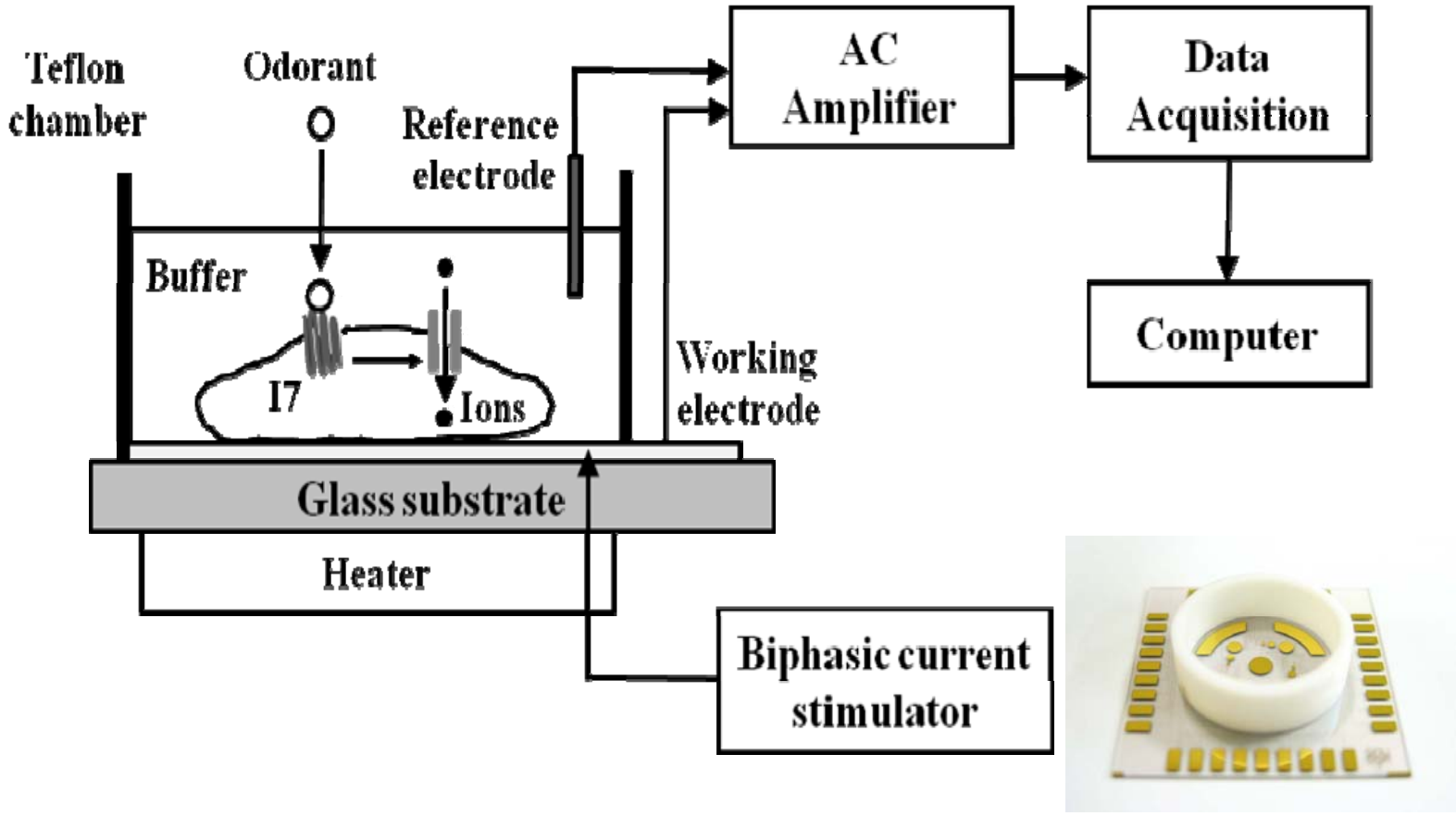
Dose-Dependent Response



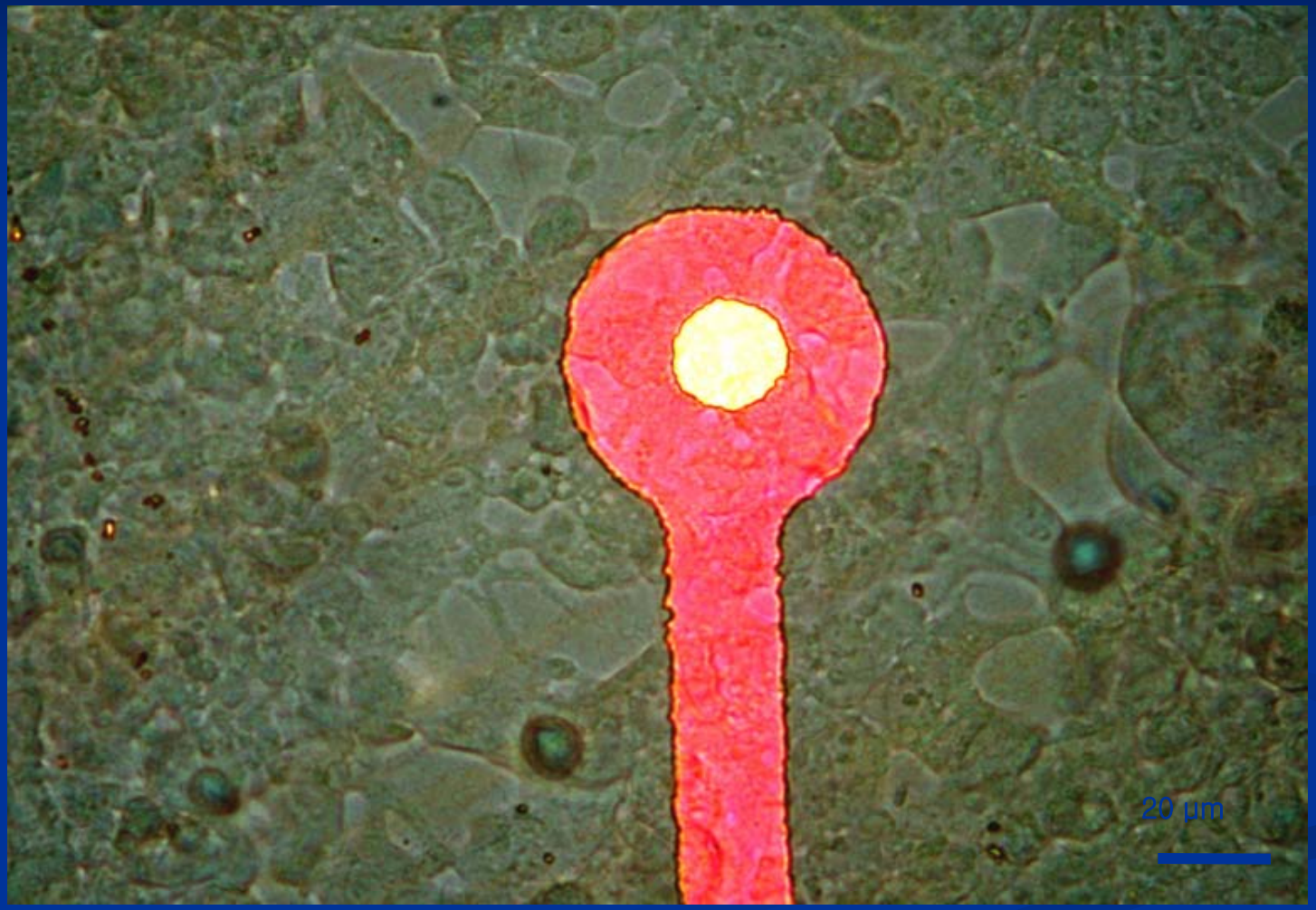
Lee et al., *Biosensors and Bioelectronics*, 24, 2659-2664 (2009)

Signal Enhancement by Electrical Stimulation

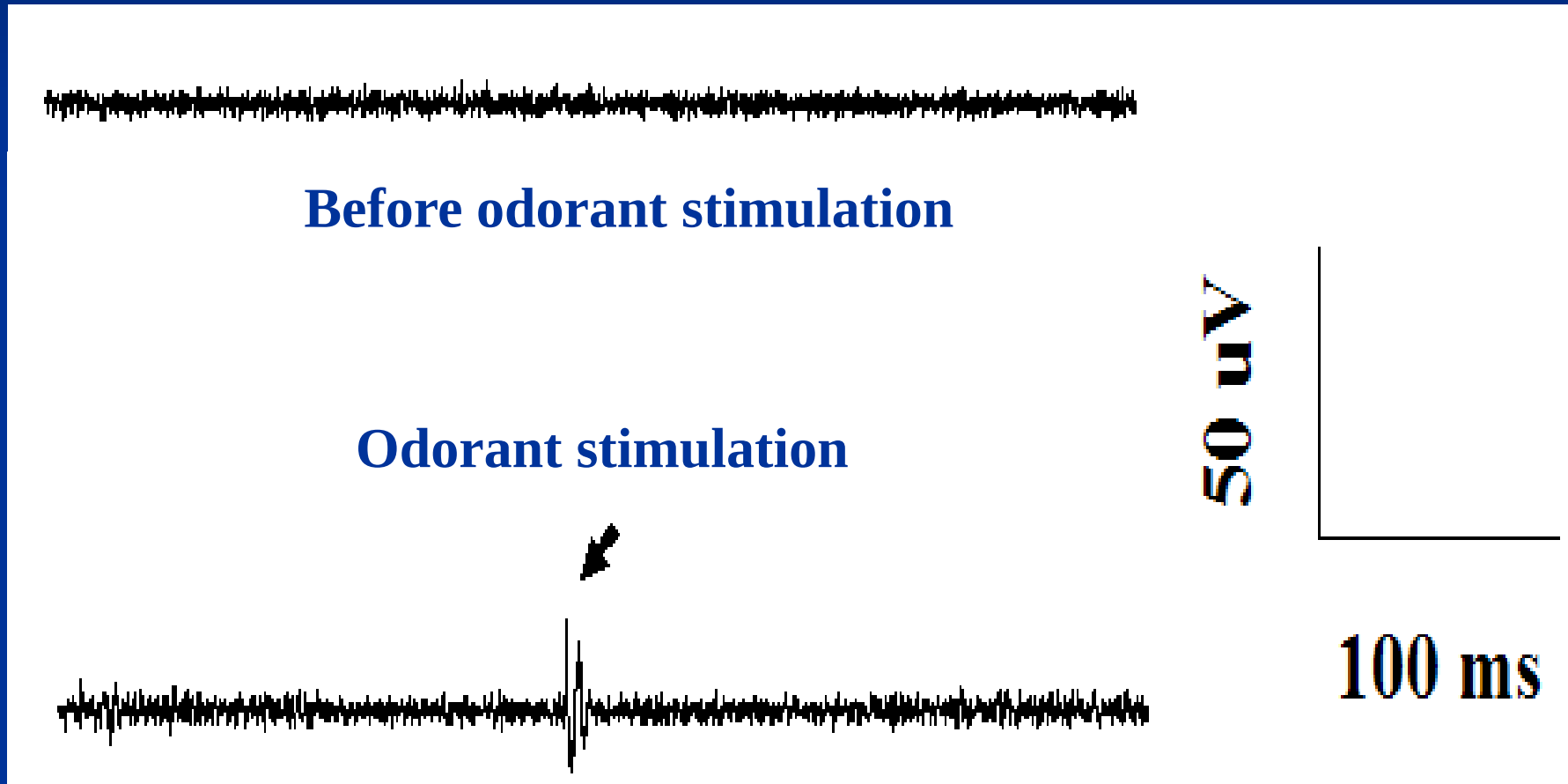
Electrophysiological Set-up



Cells on Planar Electrode

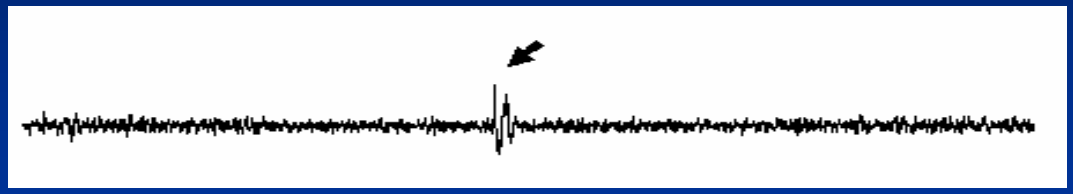


Electrical Response

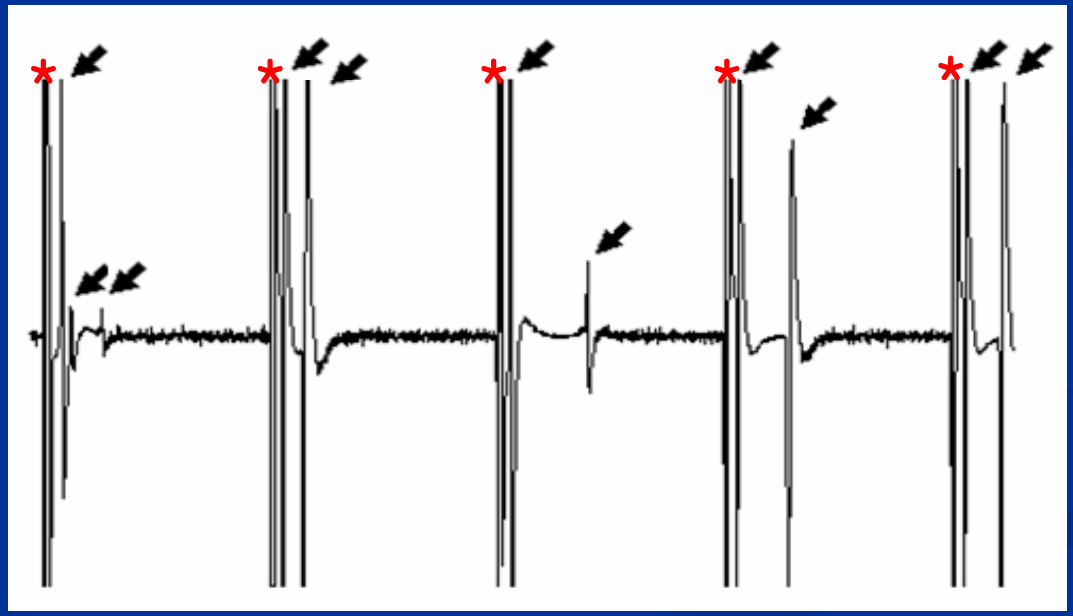


Electrical Response

Odorant stimulation

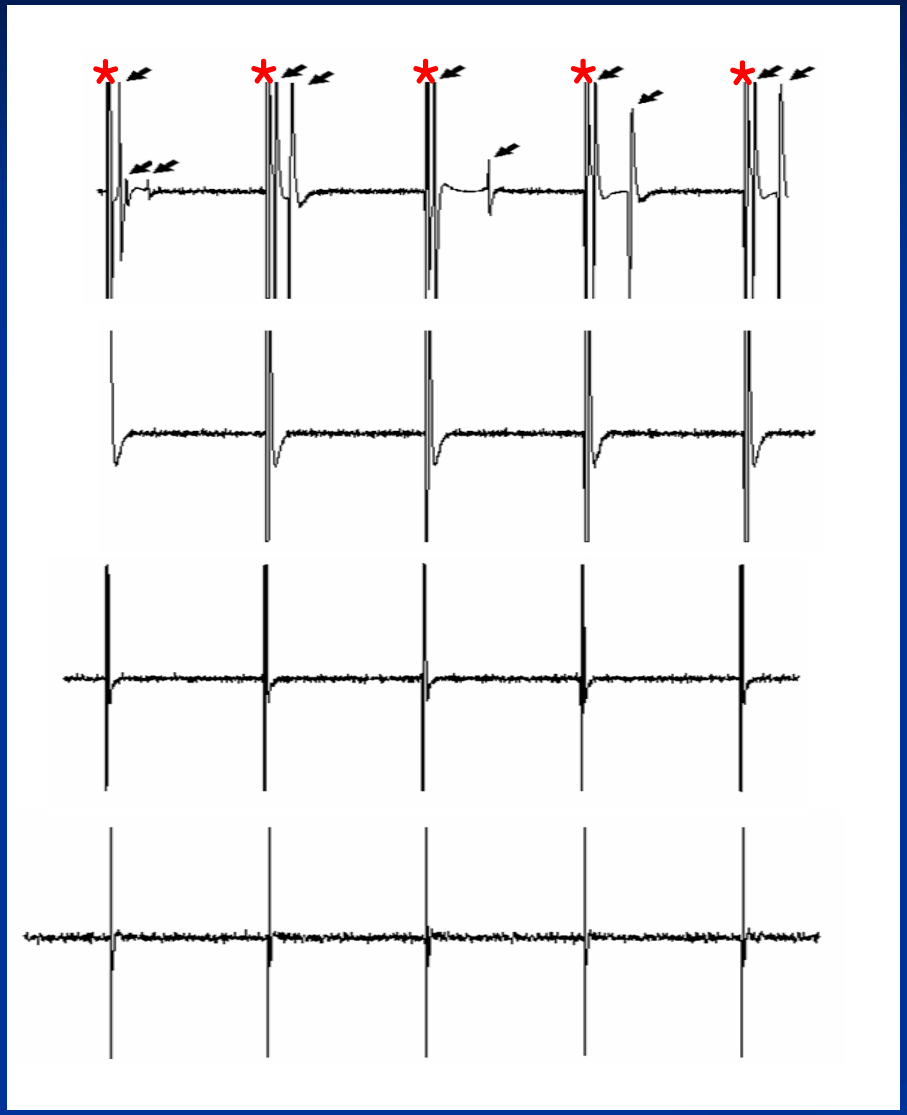


Odorant stimulation with electrical stimulation



Lee et al., *Electrophoresis*, 30, 1-6 (2009)

Response to Electrical Stimulation



(1) Odorant stimulation

(2) Odorant stimulation
in Ca^{++}-free solution

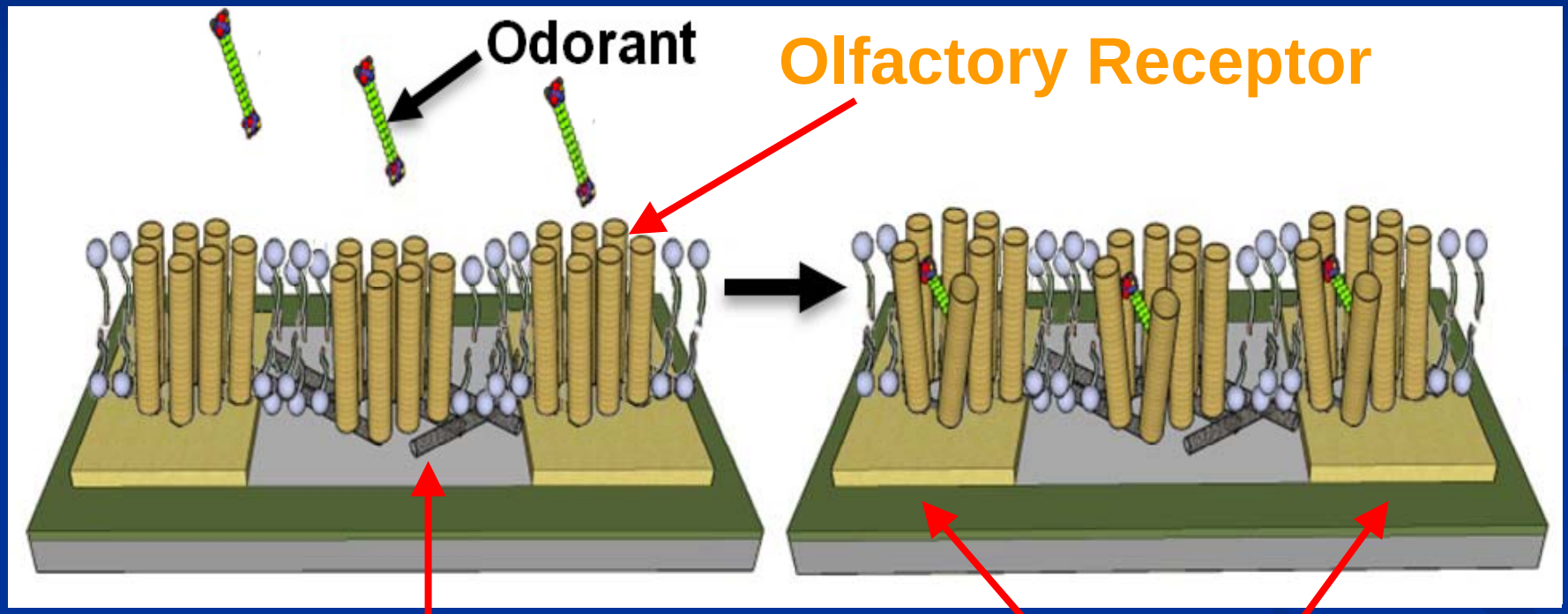
(3) Non-odorant stimulation

(4) Odorant stimulation
without receptor
(Cells with only CNGgust)

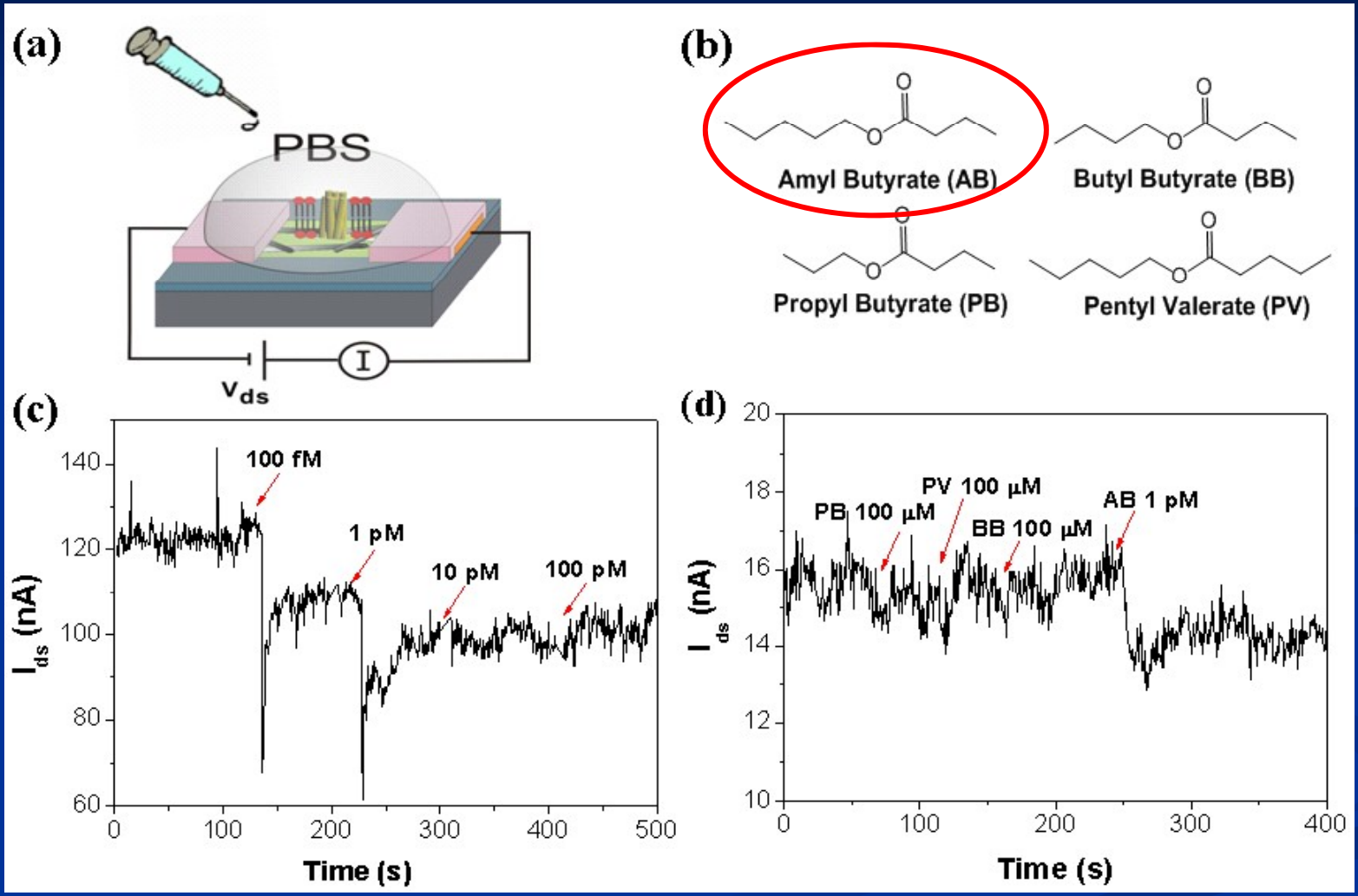
Lee et al., *Electrophoresis*, 30, 3283-3288 (2009)

Carbon Nanotube

Receptor & Carbon Nanotube



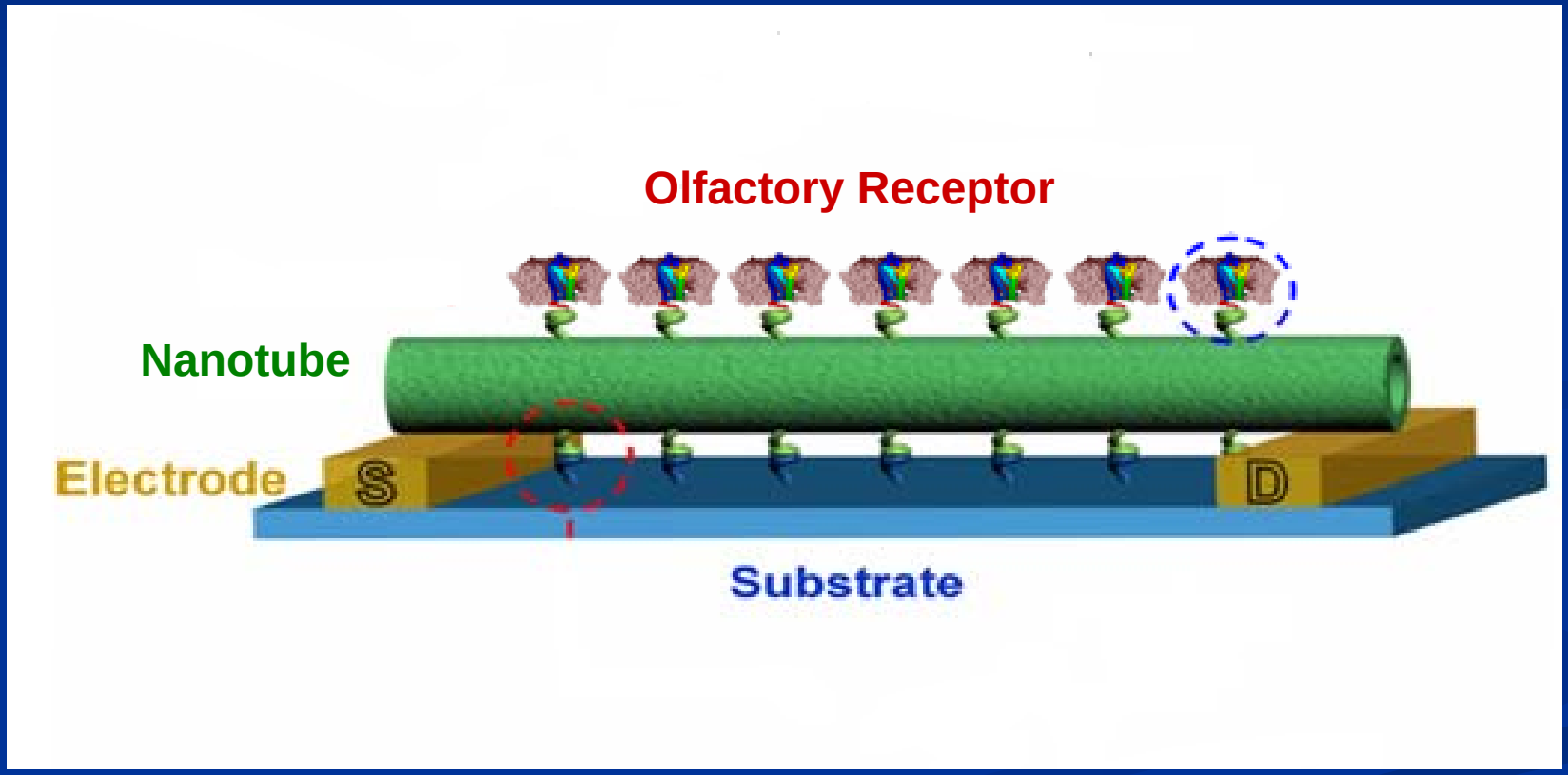
Current Change



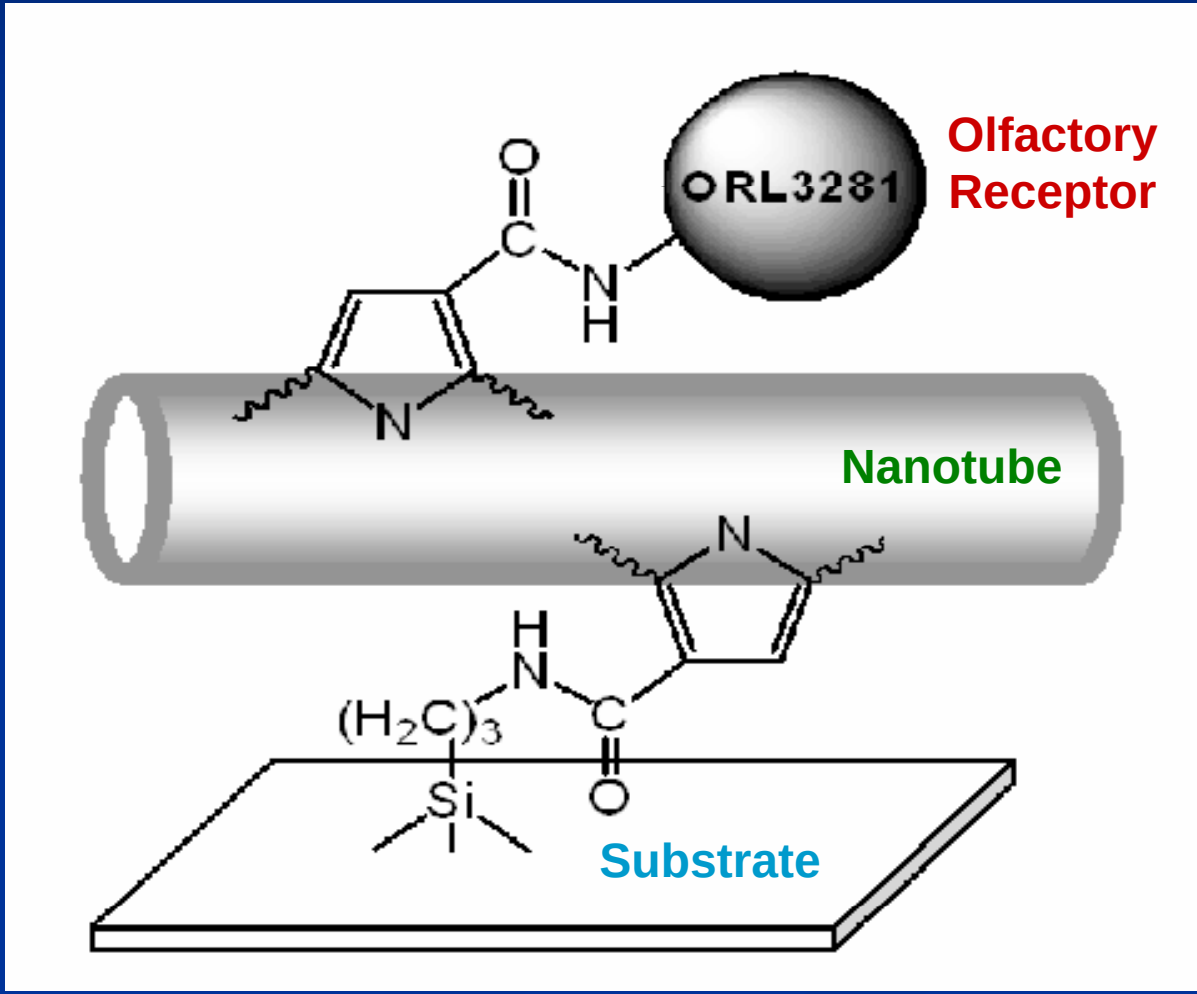
Kim *et al.*, *Advanced Materials*, 21, 91-94 (2009)
Highlighted by Nanowerk (2009)

Conducting Polymer Nanotube

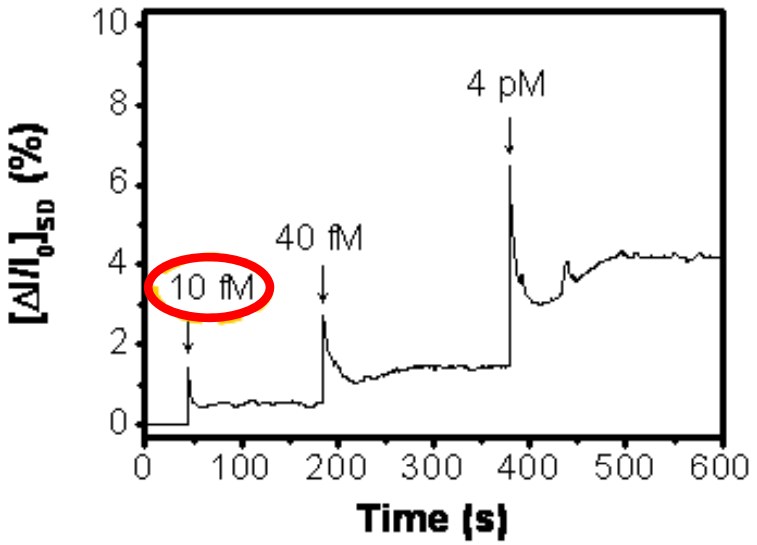
Receptor &Conducting Polymer Nanotube

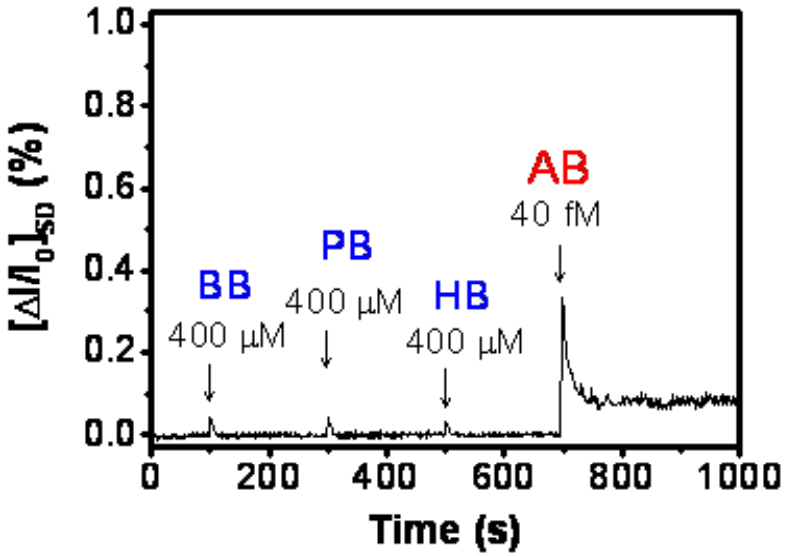


Receptor Covalently Bonded on Nanotube



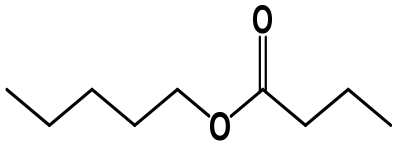
Sensitivity and Selectivity



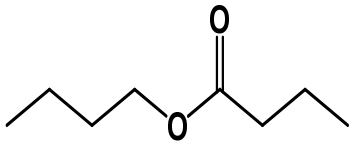


Yoon *et al.*, *Angewantde Chemie*, 48, 2755-2758 (2009)
Featured highlight, npg asia materials, Nature asia-pacific (2009)
Highlighted by Chemistry World, Royal Society of Chemistry, UK (2009)

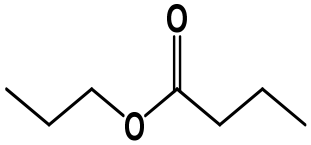
Odorant Molecules



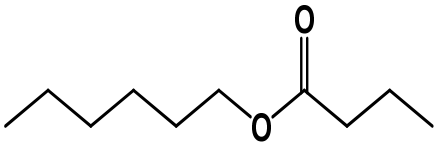
Amyl butyrate (AB)



Butyl butyrate (BB)

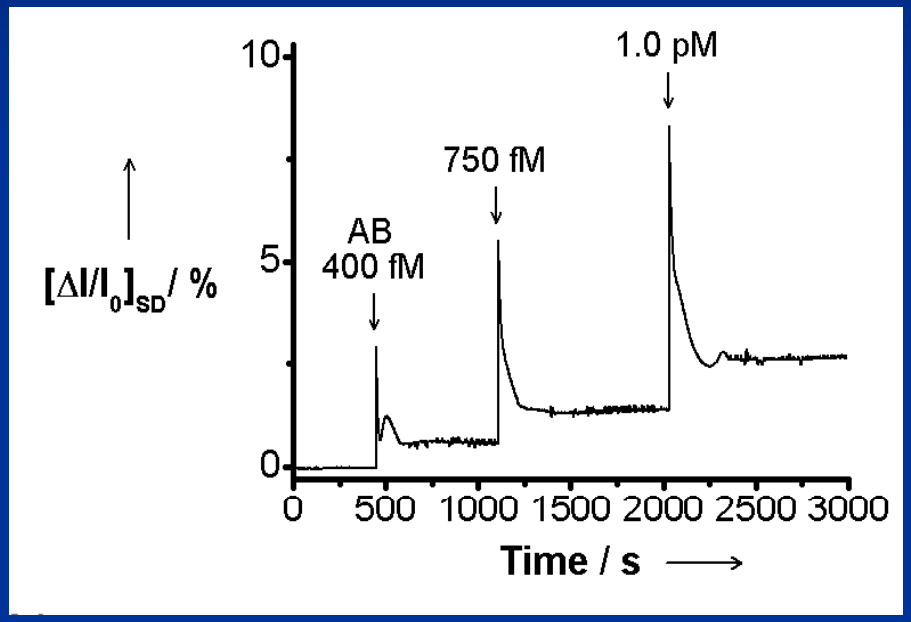


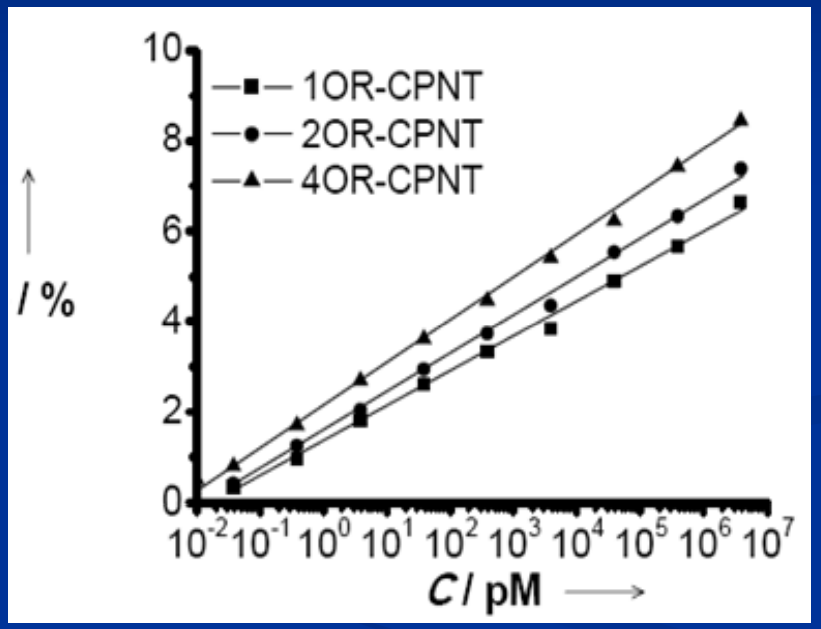
Pentyl butyrate (PB)



Hexyl butyrate (HB)

Dose-Dependent Relationship





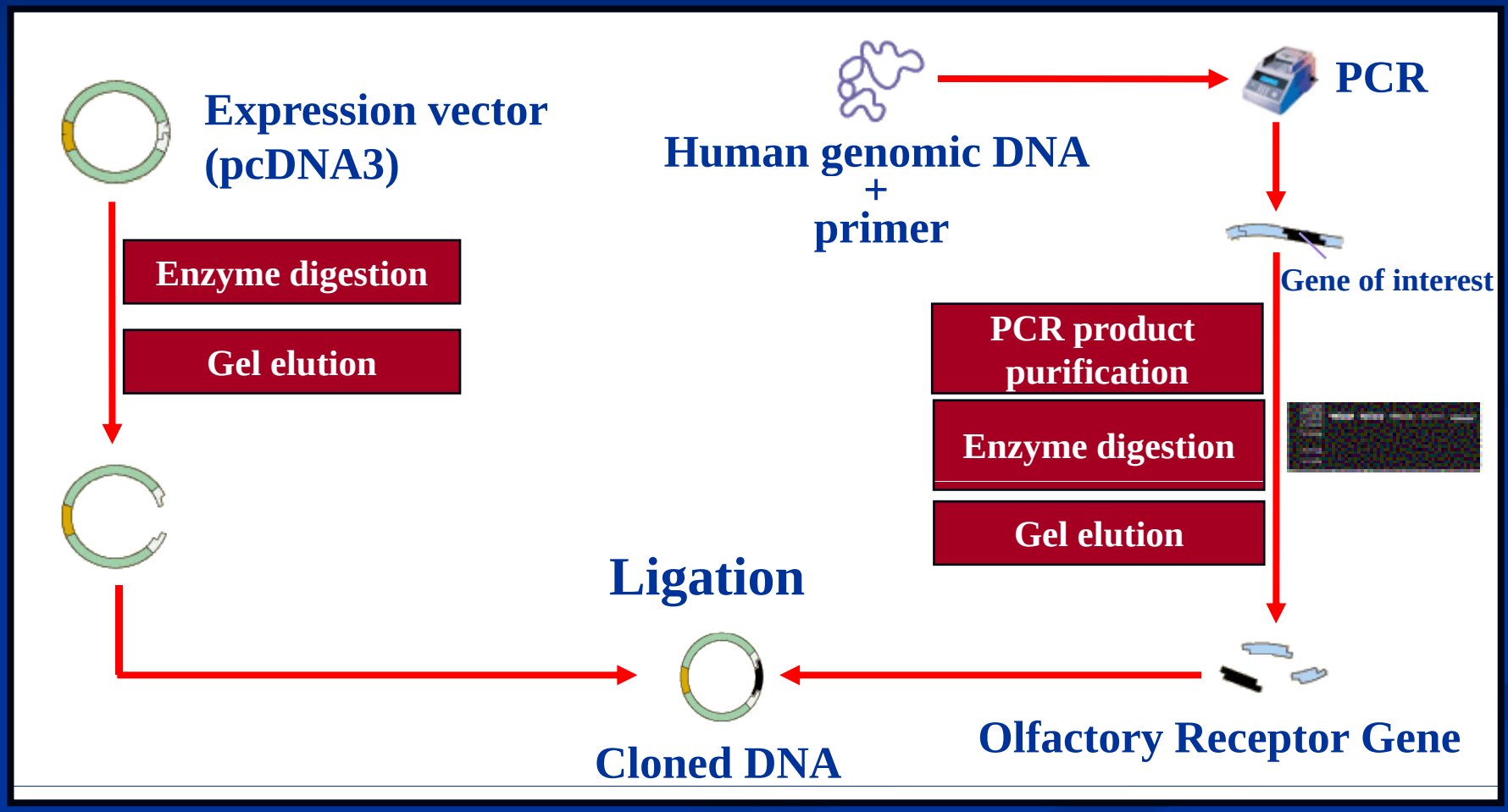
Yoon *et al.*, *Angewantde Chemie*, 48, 2755-2758 (2009)
Featured highlight, npg asia materials, Nature asia-pacific (2009)
Highlighted by Chemistry World, Royal Society of Chemistry, UK (2009)

Cloning
Whole Set of Human Olfactory Receptor Genes

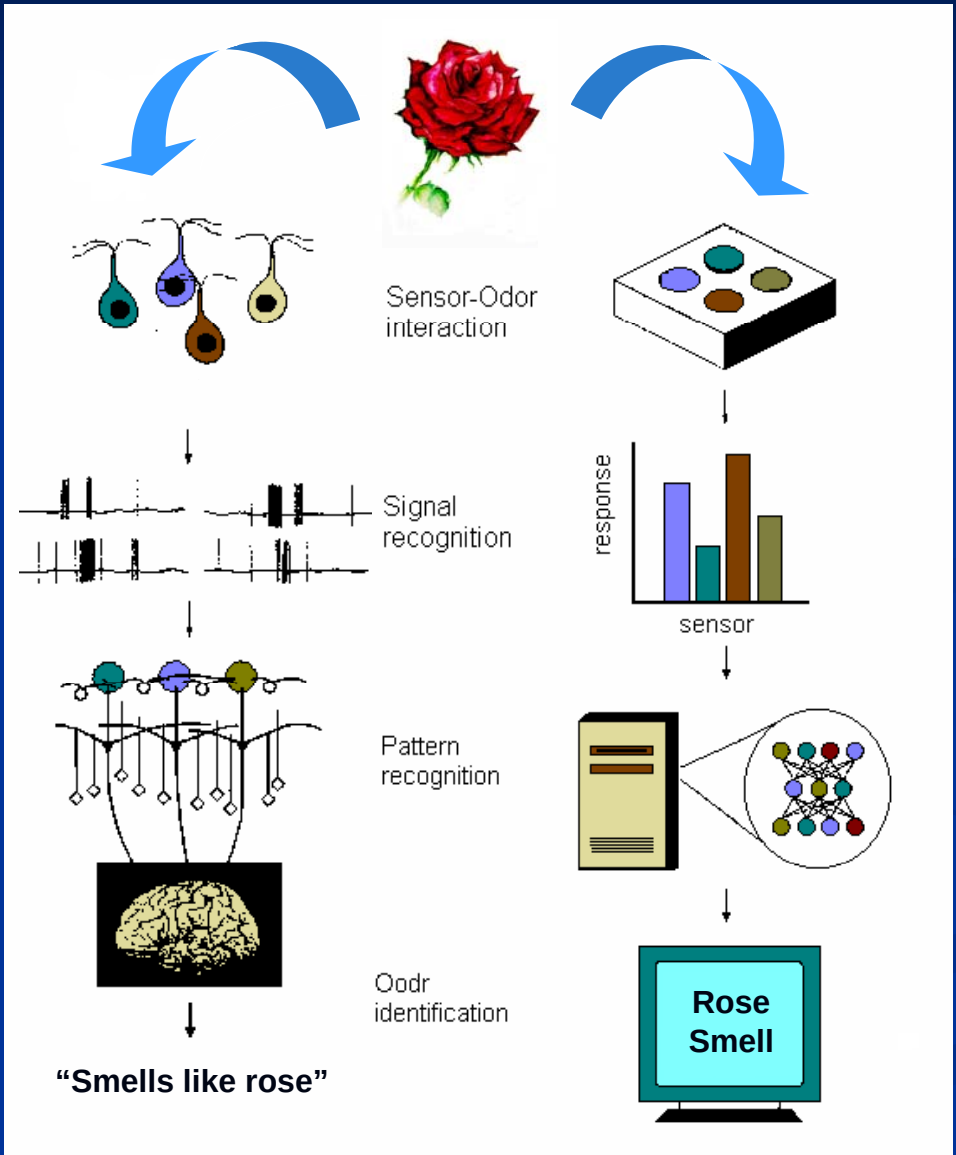
Human Olfactory Receptor

- About 370 genes are potential candidates for full-length human olfactory receptor gene sequences.

Cloning of Human Olfactory Receptor Genes



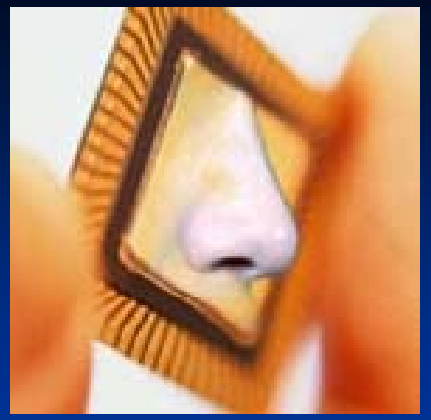
Natural Nose & Artificial Nose



Natural Nose

Artificial Nose

Applications



- Standardization of smell
  (classification, code for each smell …)
- Smell Industry (perfume, cosmetics, wine…)
- Disease diagnosis
- Monitoring of food freshness
- Environment monitoring by smell sensing
- Process monitoring by smell sensing
- Public safety (explosive, toxitant)
- Smuggling (drugs…)
- Security (smell sensing security system)