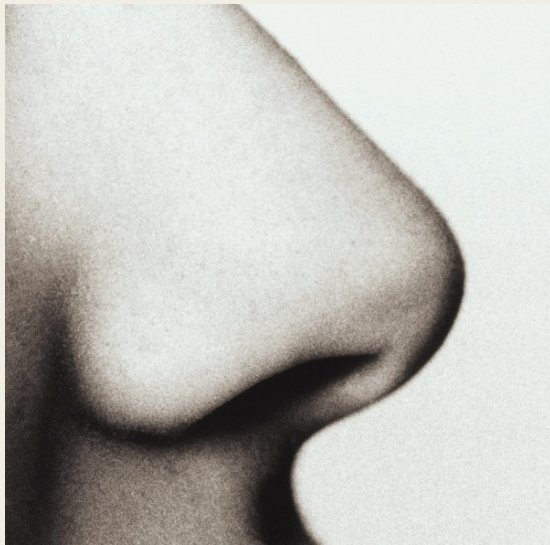


# University of Rome 'Tor Vergata'

## Bachelor Degree's in Engineering Sciences 'Sensors array for clinical diagnosis'



Student:  
Gaia Cavallo



Supervisor:  
Professor R. Paolesse  
Department of Chemical Science and Technology

# VOLATILE ORGANIC COMPOUNDS (VOCs)

Volatile Organic Compounds are carbon based chemicals that easily evaporate at room temperature

We release VOCs from our body into the atmosphere

VOCs reflect the composition of the inside chemistry of the body

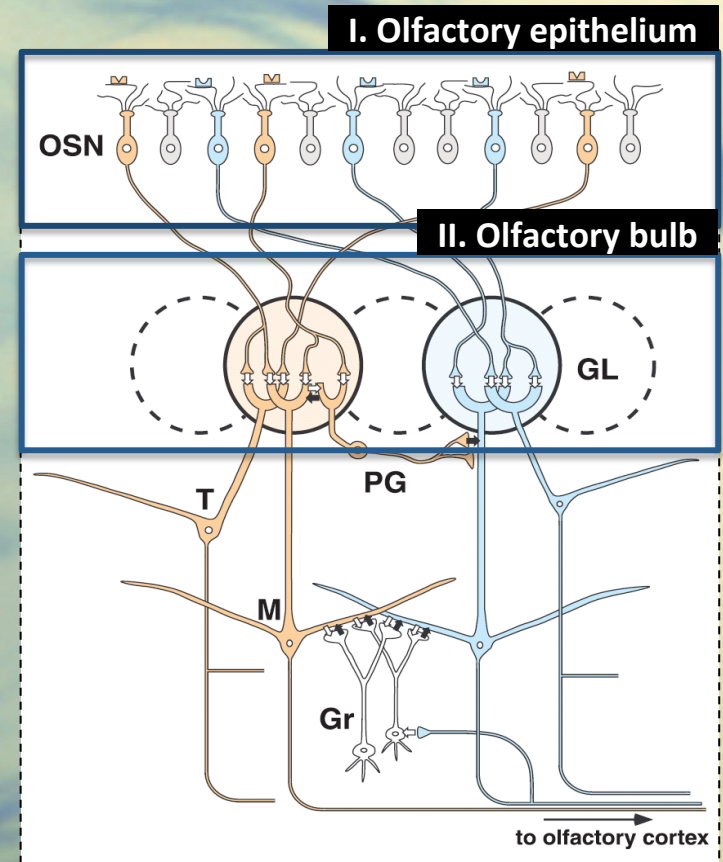
Pathologies produce VOCs that quantitatively and qualitatively different from those released by healthy subject

Organic Volatile Constituents of biological bodies contain clinically meaningful information for the recognition of metabolic disorders in individuals

# OLFACTION/ODOUR

Odour is the human perception, through olfaction sense, of volatile compounds

- Odour is the labelling that human gives to molecules producing stimuli in the olfactory bulb.
- Odorous compounds are very different at molecular level



# ELECTRONIC NOSE



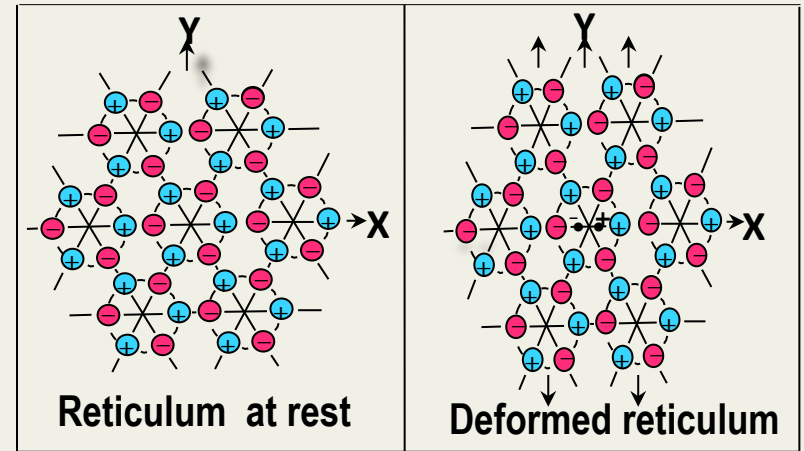
- Array of chemical sensors for VOCs detection and an algorithm for pattern recognition
- Each sensor senses more compounds and each compound is sensed by more sensors.

## COMPOSITION:

8 **QUARTZ** microbalance sensors

Thin layer of **METALLOPORPHYRINS** for chemical sensitivity

# WHY QUARTZ?



Quartz is a **PIEZOELECTRIC MATERIAL**:

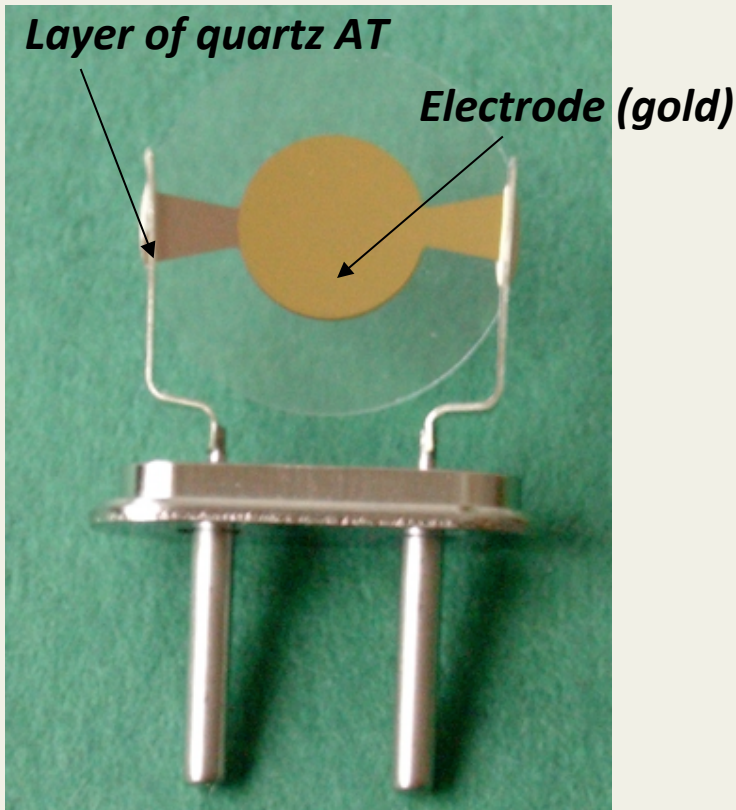
- if an electric potential difference is applied it changes dimensions
- conversely, a deformation of its structure (applied pressure) will generate a measurable voltage

Quartz oscillation frequency is extremely sensible toward mass changes.

Through piezoelectric effect the property of a crystalline quartz can be interfaced with an electric circuit

# QUARTZ MICRO BALANCE

## FOUNDAMENTAL FREQUENCY



$$f_0 = \frac{v_s}{\lambda_0} \quad \frac{\lambda_0}{2} = d$$

$$\Rightarrow f_0 = \frac{v_s}{2 \cdot d}$$

$d$ : thickness of the layer  
 $v_s$ : speed of sound  
(3750 m/s in quartz)

Fundamental frequency of a system is the lowest frequency of a periodic waveform

## SAUERBREY EQUATION

$$\Delta f = - \frac{2f_0^2}{A\sqrt{\mu_q\rho_q}} m_s$$

$A$ : Area between electrodes

$\mu_q$ : Shear modulus for quartz

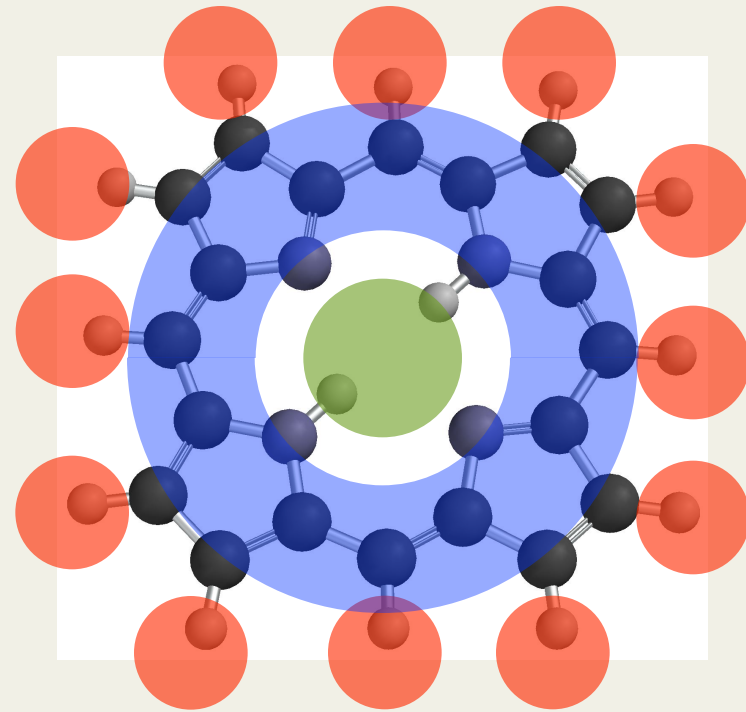
$\rho_q$ : Density of quartz

QUARTZ MICROBALANCE SENSORS (QMB) have a resonant frequency of 20 MHz

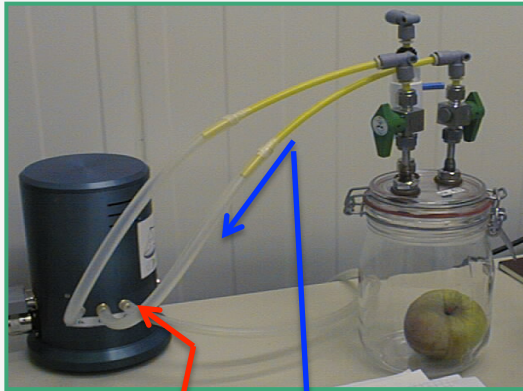
# PORPHYRINS SENSITIVITY

*Porphyryns can interact with volatile molecules via several interaction mechanisms including coordination, hydrogen bond and polarization.*

- The basic structure can be modified complexing a **metal** at the center of the macrocycle, adding **peripheral groups** or even modifying the **molecular framework**.
- The modification results in a variation of the sensing properties

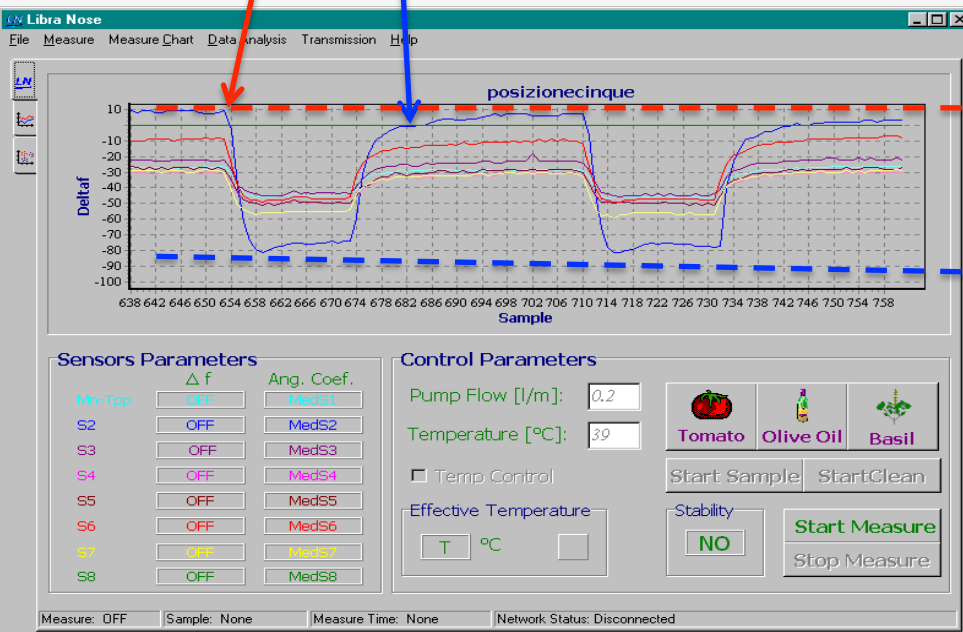
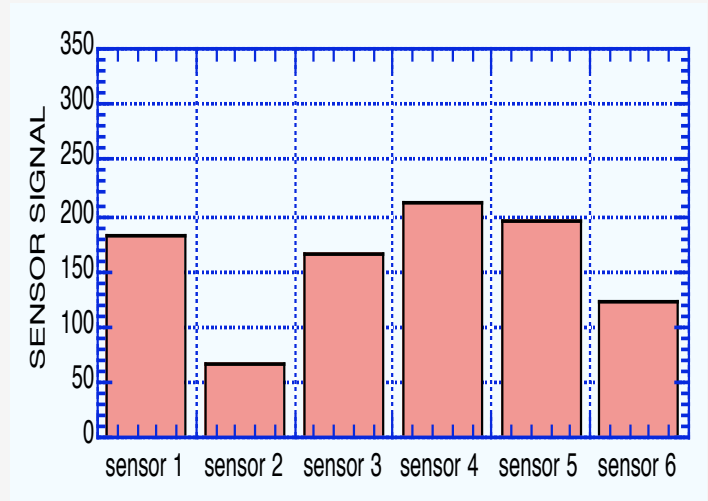


# MEASUREMENT SEQUENCE



Reference

Sample

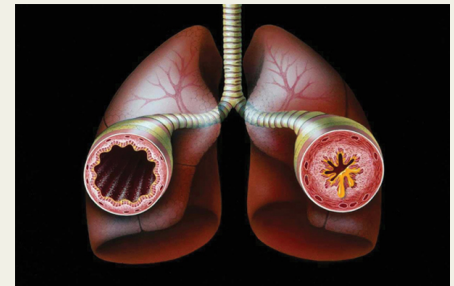
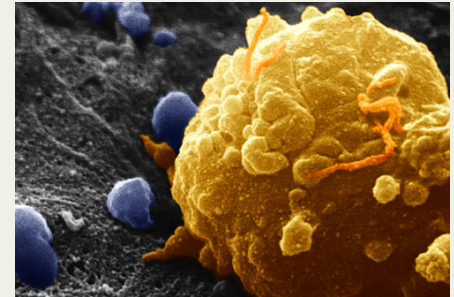


Pattern Recognition



# MEDICAL APPLICATIONS OF ELECTRONIC NOSE

- Monitoring of melanoma
- Diagnosis of asthma
- Detection of cancer



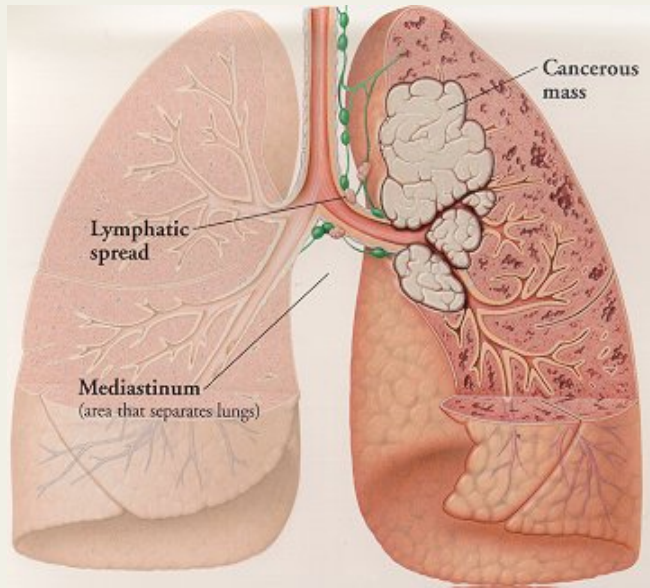
# APPLICATION ON LUNG CANCER

Lung cancer is a disease characterised by uncontrolled cell growth in tissues of the lungs

Several GC/MS studies evidenced about 20 different compounds at anomalous concentration in the breath of lung cancer affected individuals.

None of them can be considered a specific marker...

**It is rather the whole combination of all the compounds that makes possible the disease identification.**



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Styrene (ethenylbenzene)  
Heptane, 2,2,4,6,6-pentamethyl  
Heptane, 2-methyl  
Decane  
Benzene, propyl-  
Undecane  
Cyclopentane, methyl-  
Cyclopropane, 1-methyl-2-pentyl-  
Methane, trichlorofluoro-  
Benzene  
Benzene, 1,2,4-trimethyl-  
1,3-butadiene, 2-methyl- (isoprene)  
Octane, 3-methyl-  
1-hexene  
Nonane, 3-methyl-  
1-heptene  
Benzene, 1,4-dimethyl  
Heptane, 2,4-dimethyl  
Hexanal  
Cyclohexane  
Benzene, 1-methylethenyl-  
Hepatanal

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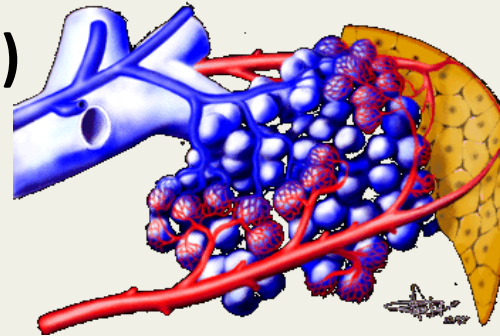
\*Chemical identification was tentative. Listed in descending order of contribution to model.

**Table 2: 22 breath VOC picked out by discriminant analysis\***

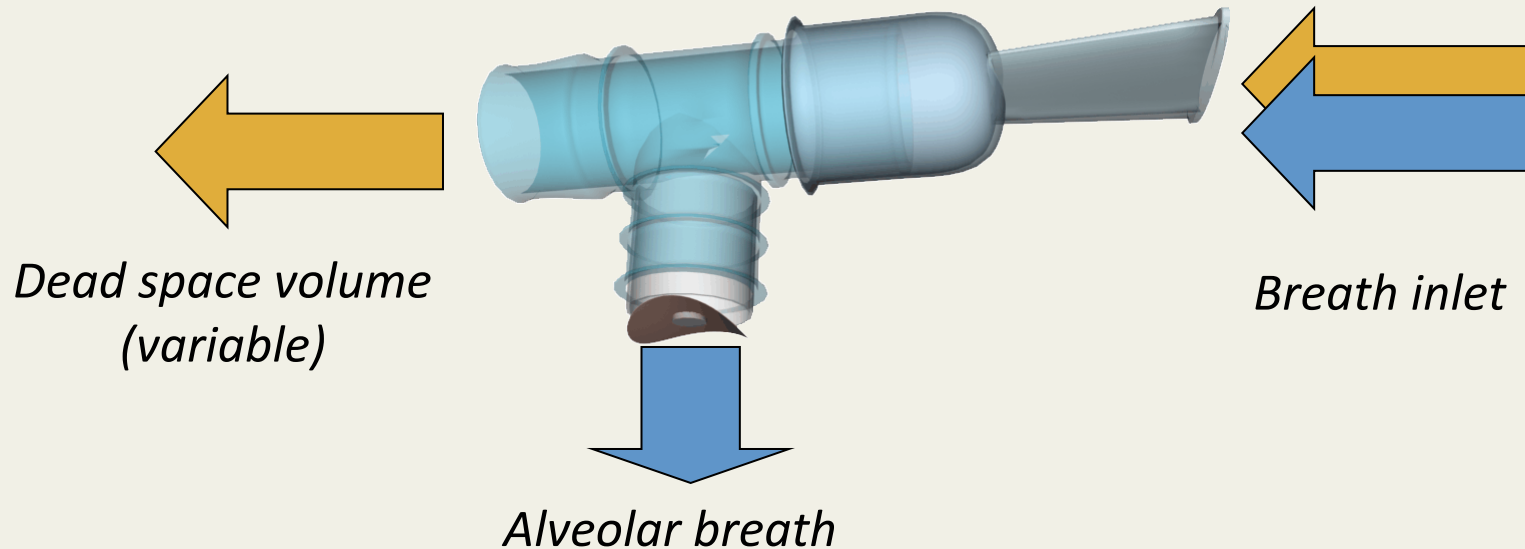
# COLLECTING TECHNIQUES

## 1) BAG BREATH SAMPLING (BBS)

Method for collecting air from alveoli  
Totally non invasive method



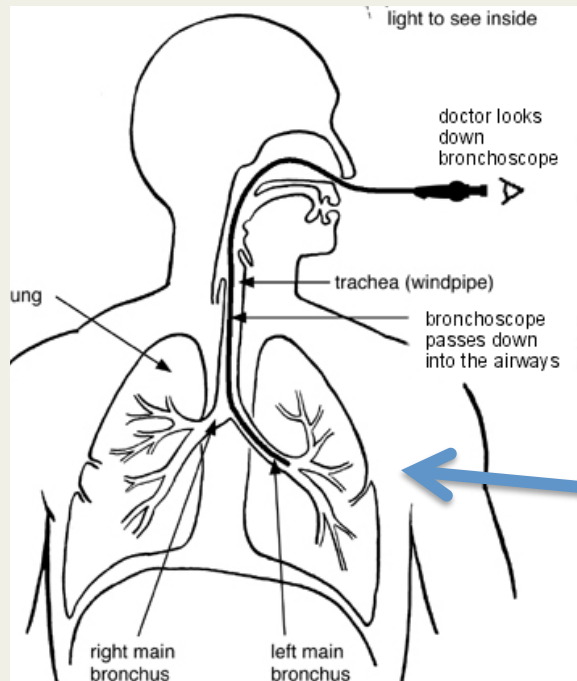
*Alveolar breath  
Source of  
information*



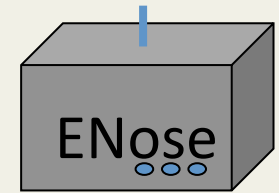
## COLLECTING TECHNIQUES

### 2) ENDOSCOPIC BREATH SAMPLING (EBS)

Method for collecting air from different sites of the lungs  
Invasive method



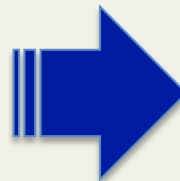
Tedlar bag (3L V), placed inside a rigid box (10L V)



Electronic Nose

Bronchoscope collects air from investigated site

The box is connected to a pump while the bag receive air directly from the bronchoscope



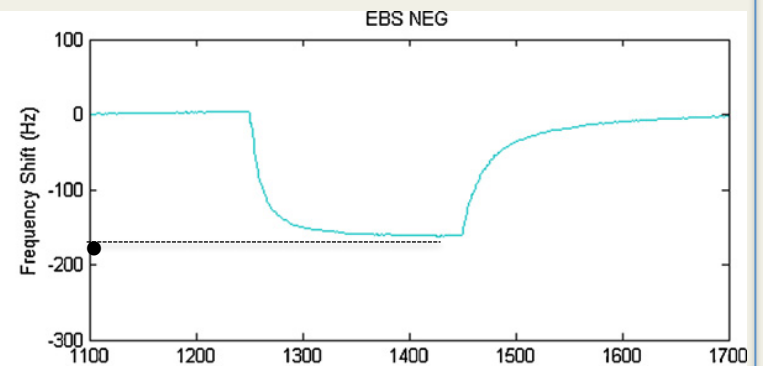
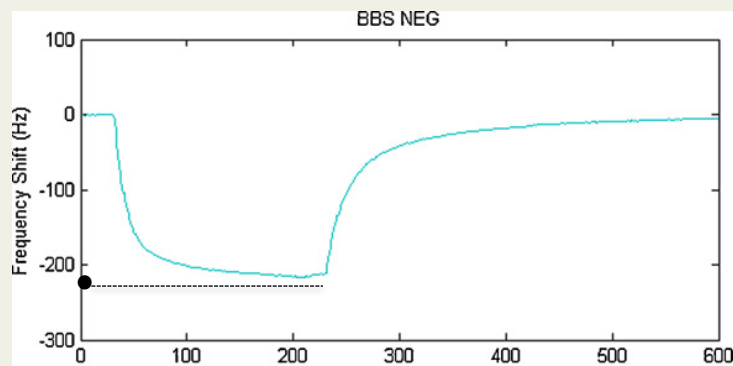
When the pump is turned on, pressure in the the box is decreased and air flows inside the bag

# Example of frequency shift registered by Mn-TTP sensor

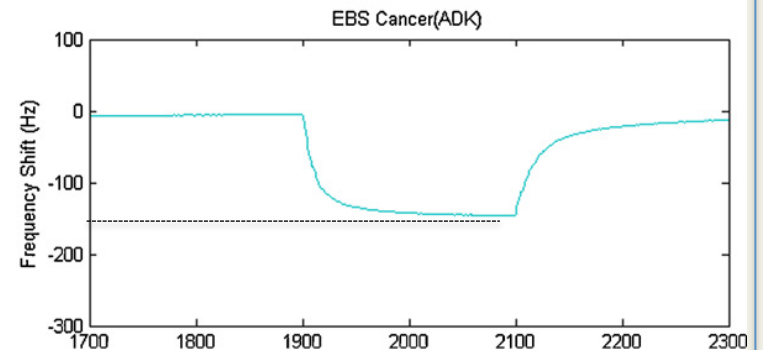
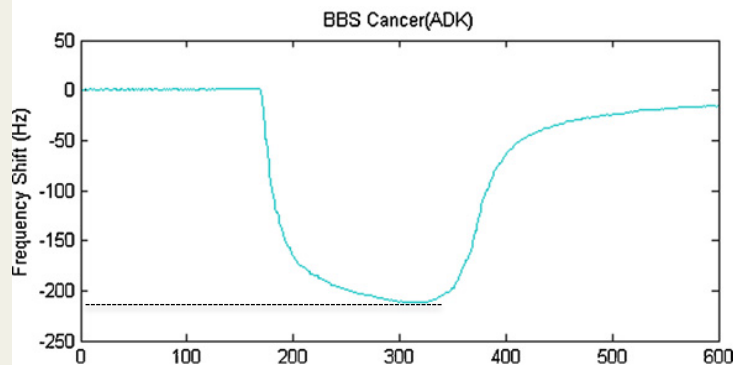
BAG BREATH  
SAMPLING

ENDOSCOPIC BREATH  
SAMPLING

NEGATIVE  
INDIVIDUAL

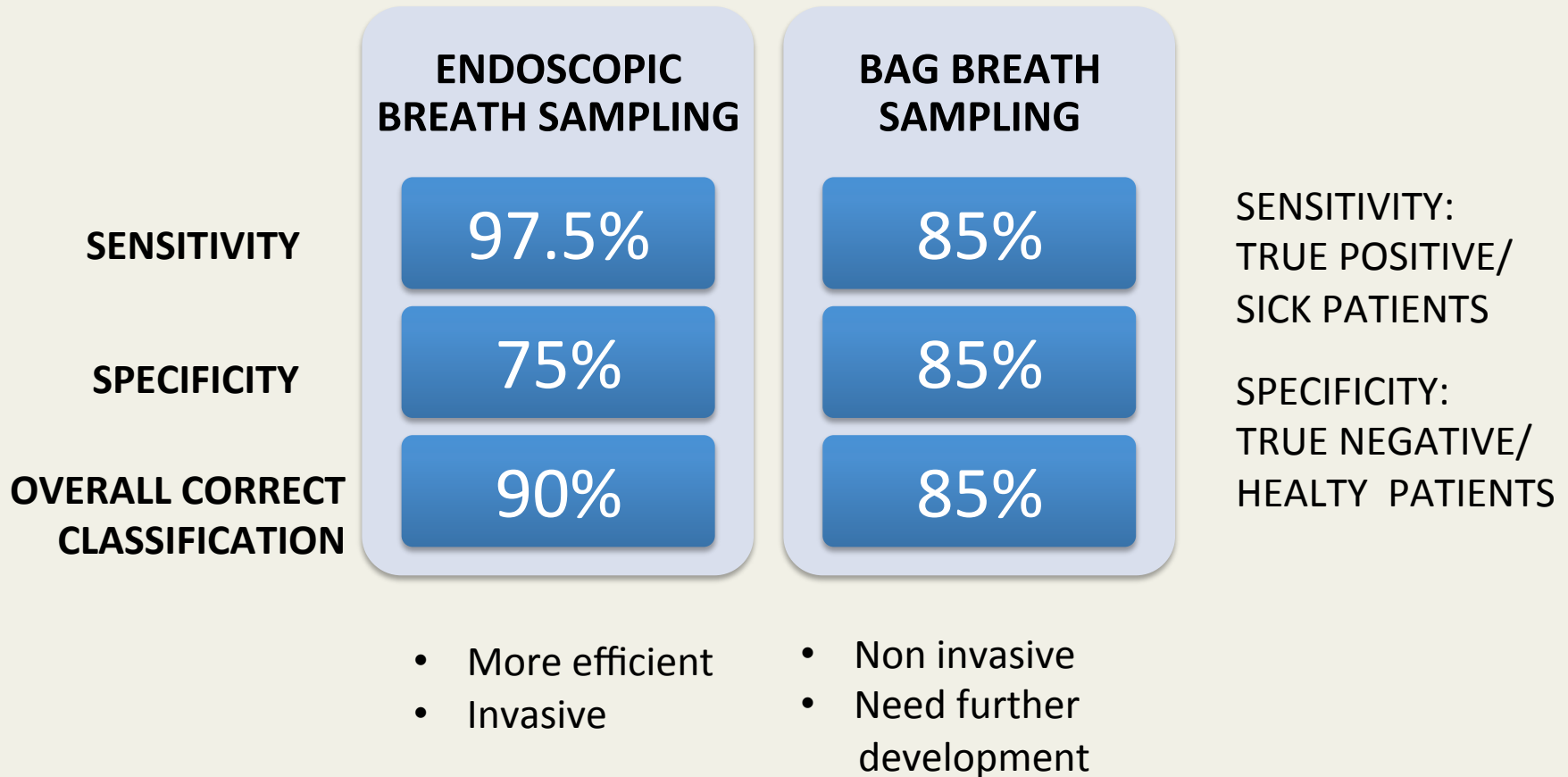


CANCER  
INDIVIDUAL



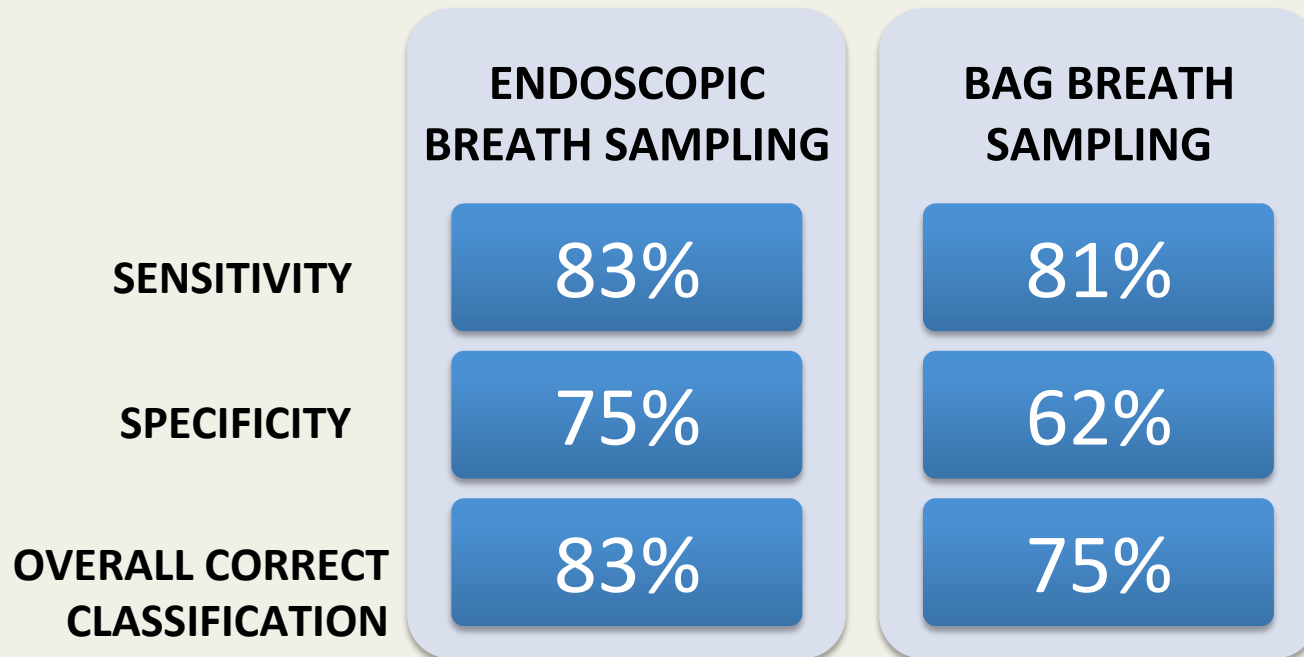
# DIAGNOSTIC DISCRIMINATION CAPACITY

Between affected and not affected by lung cancer



# DIAGNOSTIC DISCRIMINATION CAPACITY

Between different cancer types



Perspective to be able to discriminate between different cancers

# CONCLUSIONS

- Analysis of volatiles secreted outside the human body is able to get information on the health status of the individuals
- The advent of chemical sensors and chemical sensors systems (electronic noses) has opened the way of fast and simple and non invasive diagnostic tools in medicine, and in particular for various forms of cancer and seems to be effective for malignant lesions identifications
- The probability of cancer recognition is rather high but need further improvements to be used as a screening methodology



**Thank you for your attention!!**

I wish to thank all the members of  
'Engineering Sciences'

for the priceless opportunity to be among the pioneers of a course in  
which sciences has no geographical limits.