

# THE ELECTRONIC NOSE AND TONGUE



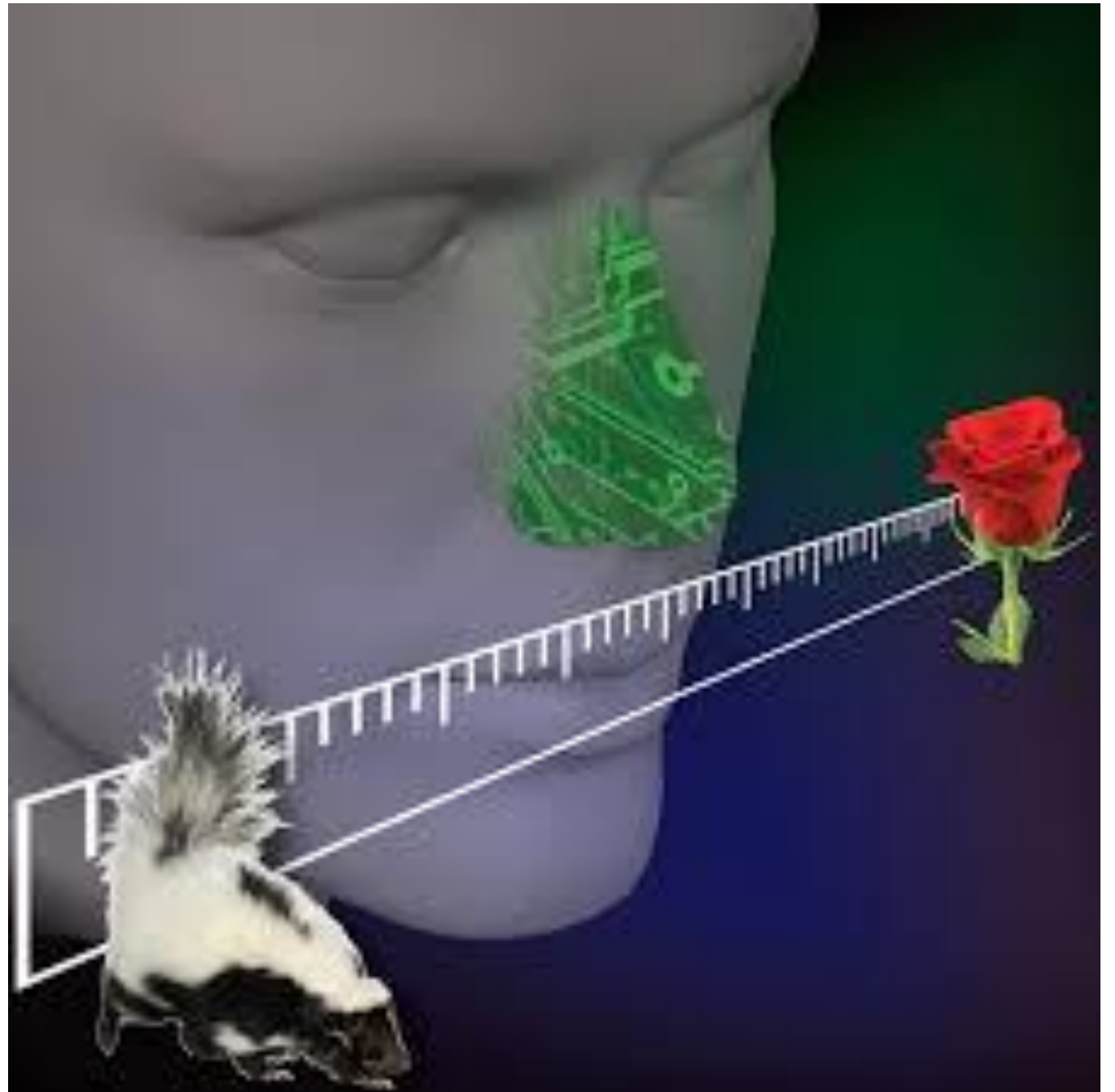
COMPILED BY HOWIE BAUM

# AN ELECTRONIC NOSE IS A DEVICE INTENDED TO DETECT ODORS OR FLAVORS.

Over the last decades, "electronic sensing" or "e-sensing" technologies have undergone important developments from a technical and commercial point of view.

The expression "electronic sensing" refers to the capability of reproducing human senses using sensor arrays and pattern recognition systems.

Since 1982, research has been conducted to develop technologies, commonly referred to as electronic noses, that could detect and recognize odors and flavors.



ALEXANDER GRAHAM BELL, IN 1914

**"Did you ever measure a smell?**

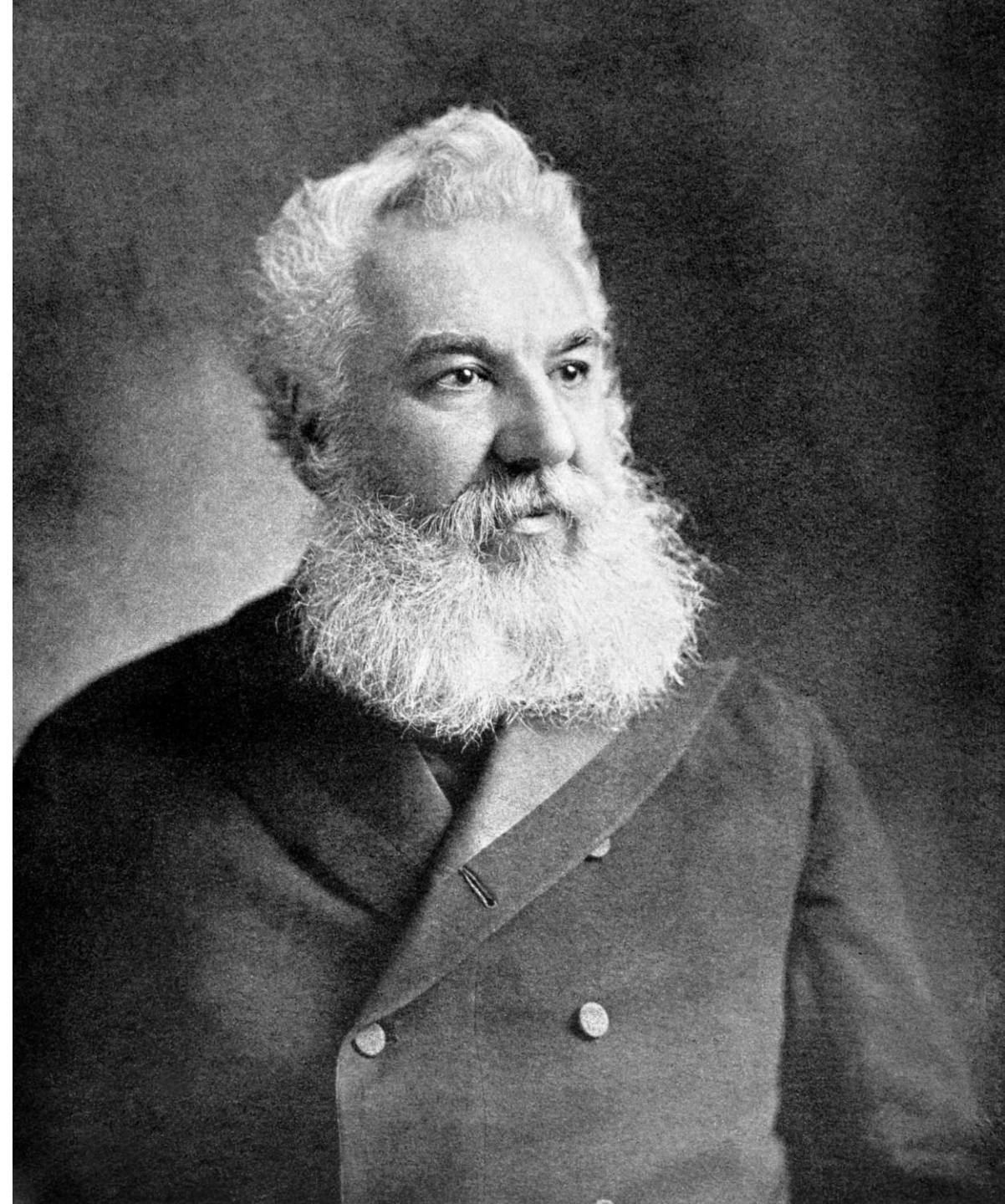
Can you tell whether one smell is just twice strong as another?

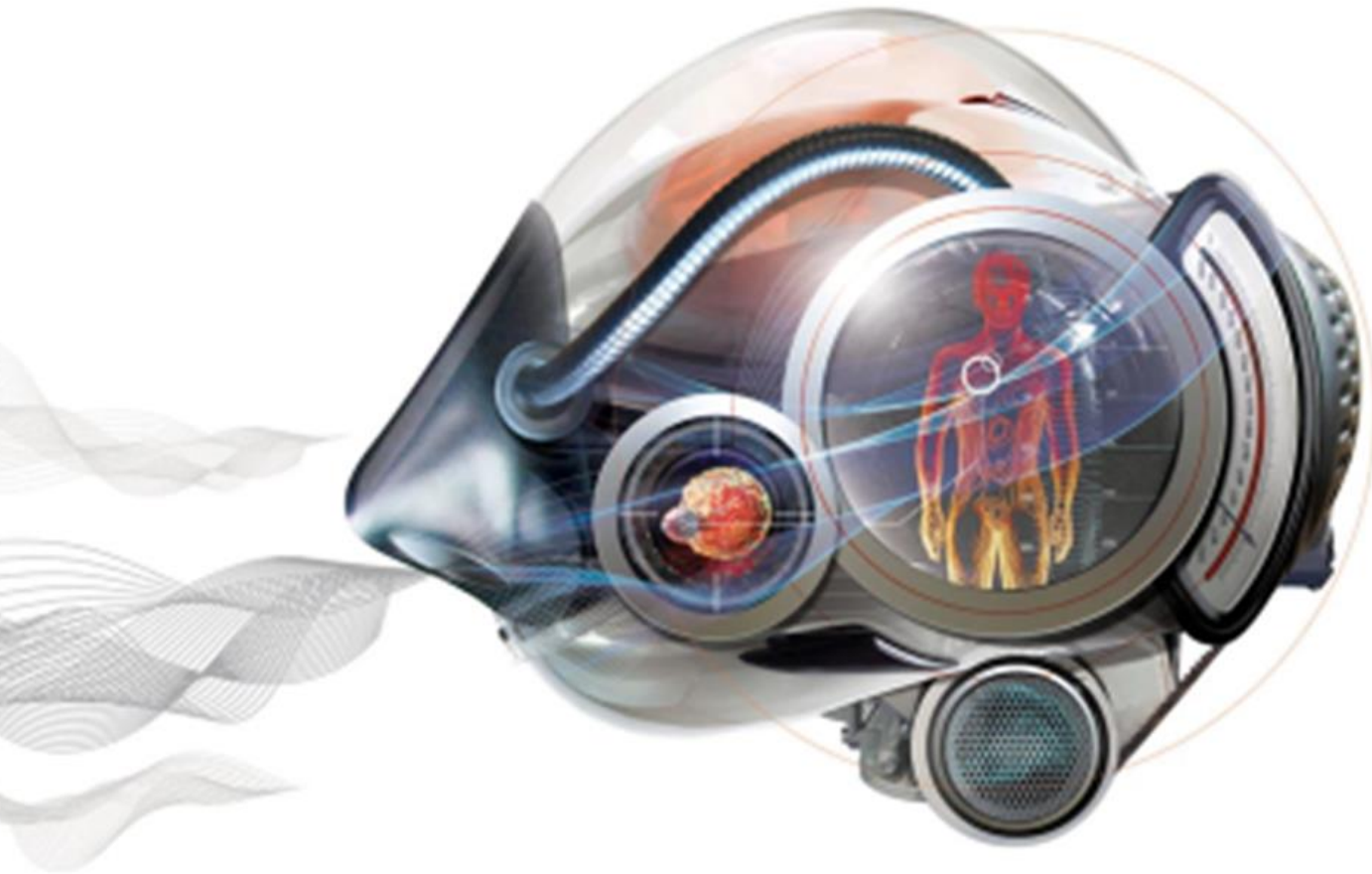
Can you measure the difference between two kinds of smell and another?

It is very obvious that we have very many different kinds of smells, all the way from the odor of violets and roses up to asafetida.

But until you can measure their likeness and differences, you can have no science of odor.

If you are ambitious to find a new science, **measure a smell."**





<https://www.youtube.com/watch?v=3-IHCkK5faM>

## WHAT IS AN ELECTRONIC NOSE ?

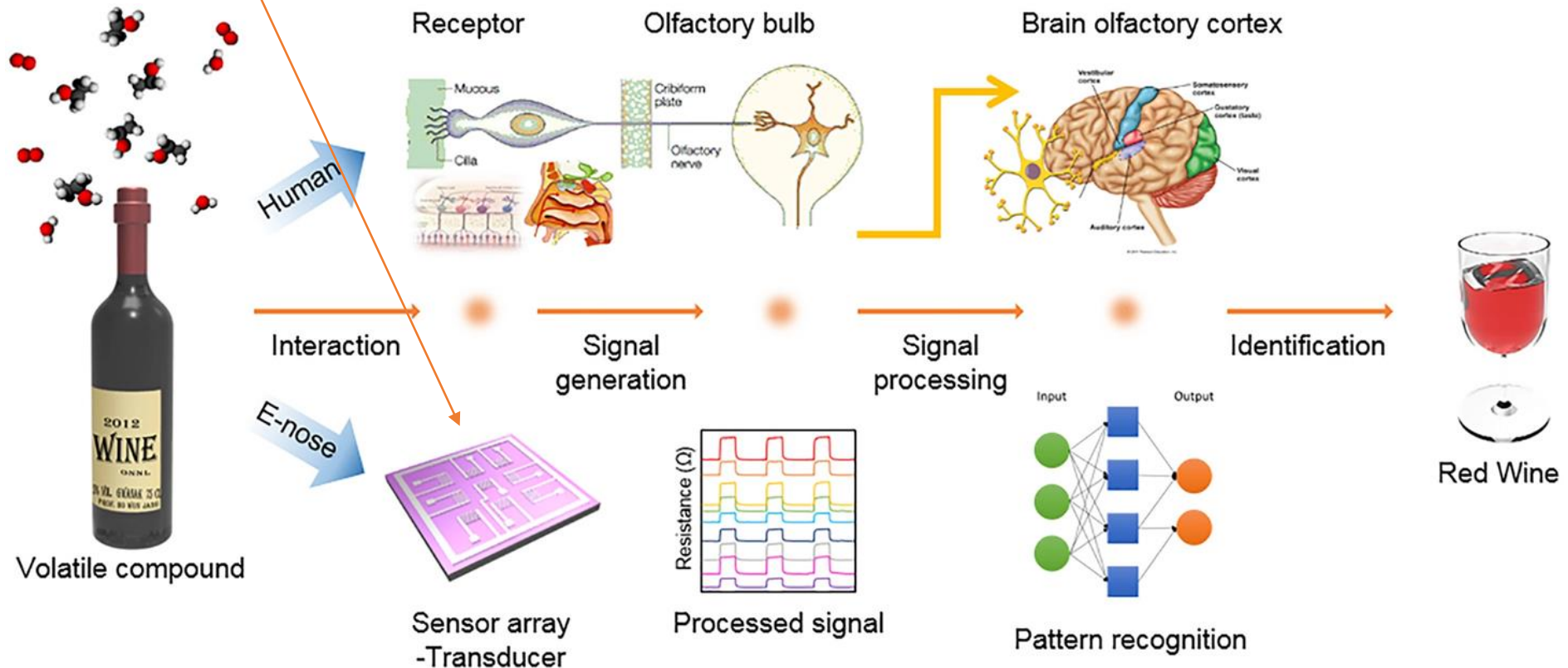
- ❖ E-noses have a series of sensors that correspond to components of an odor and analyzes its chemical makeup to identify it.
- ❖ They are much more sensitive than human noses as they have a greater number of receptor sensors with higher sensitivity.
- ❖ Our human nose is elegant, sensitive, and self-repairing, but the E-nose sensors do not fatigue or get the "flu".
- ❖ Further, the E-nose can be sent to detect toxic and otherwise hazardous situations that humans may wish to avoid.

# HOW DOES IT WORK?

Using a sensor array (an electronic chip) and onboard pattern recognition algorithms, the lightweight, portable device works by exposing an array of plastic composite sensors to the chemical components in a vapor.

When the sensors come in contact with the vapor, the polymer expands like a sponge, changing the resistance of the composites.

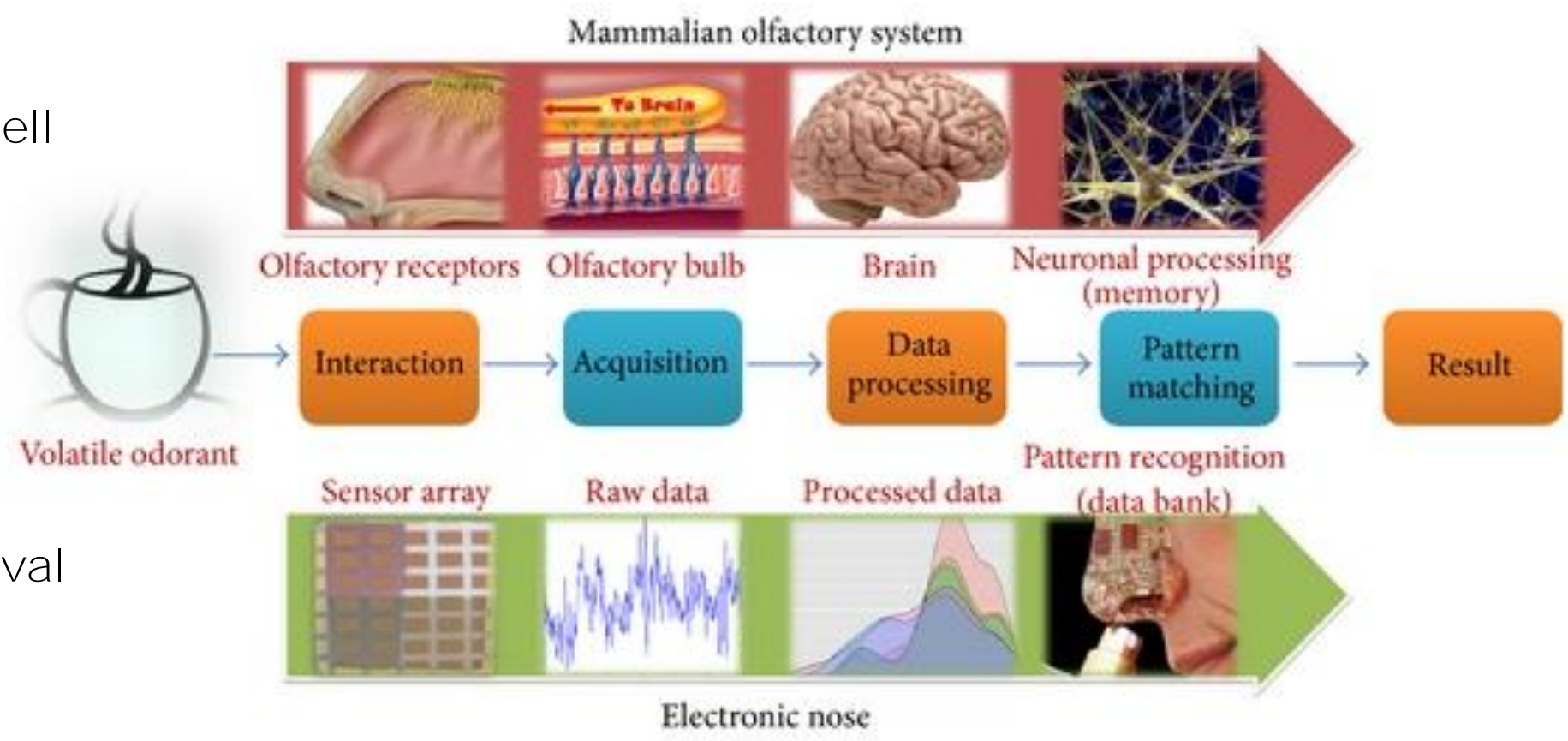
The change in resistance is measured, and from that measurement, the presence of a pre-trained substance is determined with a quick and accurate diagnosis.



The stages of the recognition process are similar to human olfaction and are performed for:

- ❖ Interaction with the smell
- ❖ Sample acquisition
- ❖ Data Processing
- ❖ Pattern Matching
- ❖ Data storage and retrieval

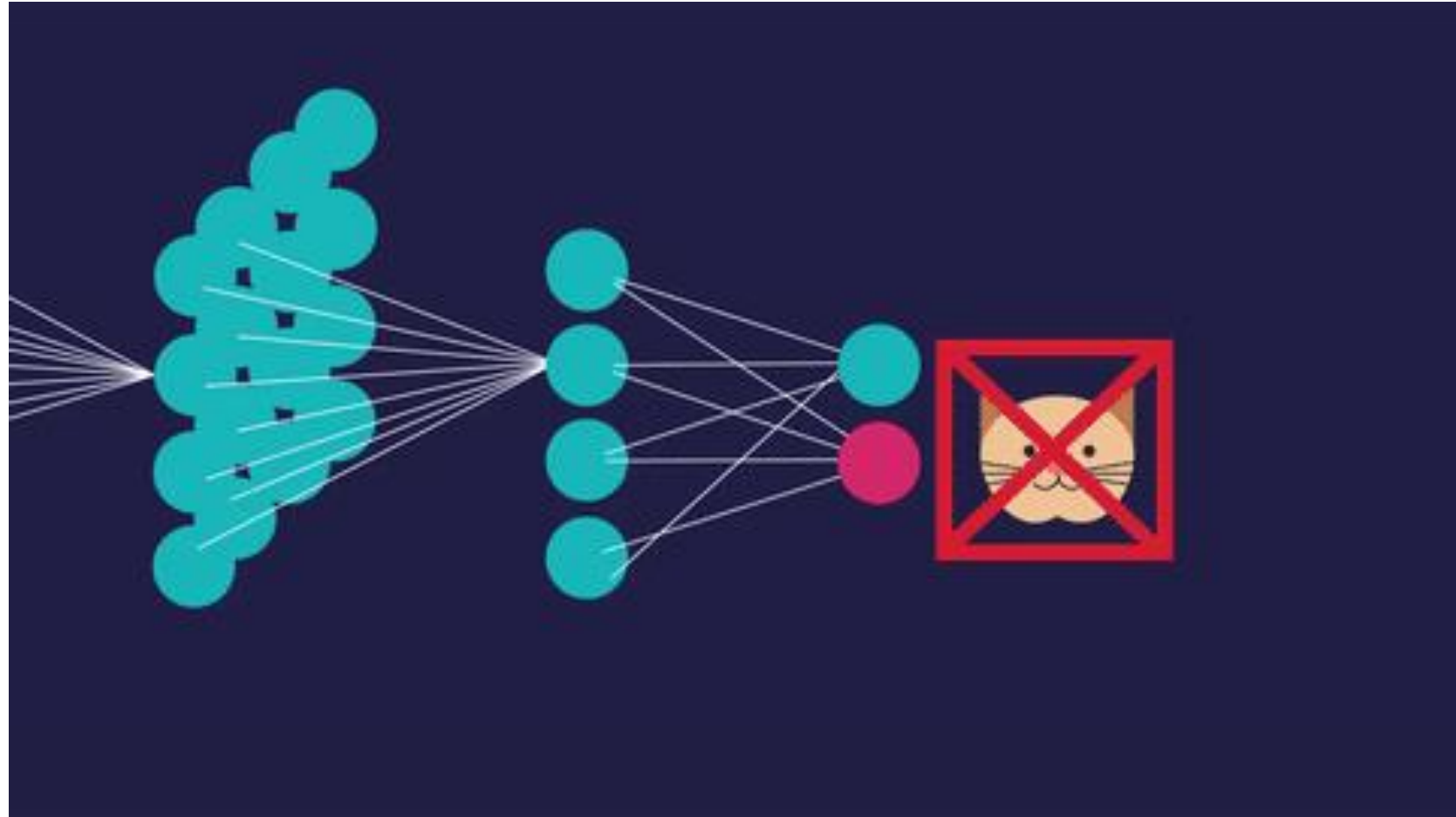
Their design is based on scientific research and principles which is more **accurate**, since a person's smell can be very subjective.



Electronic noses include three major parts:

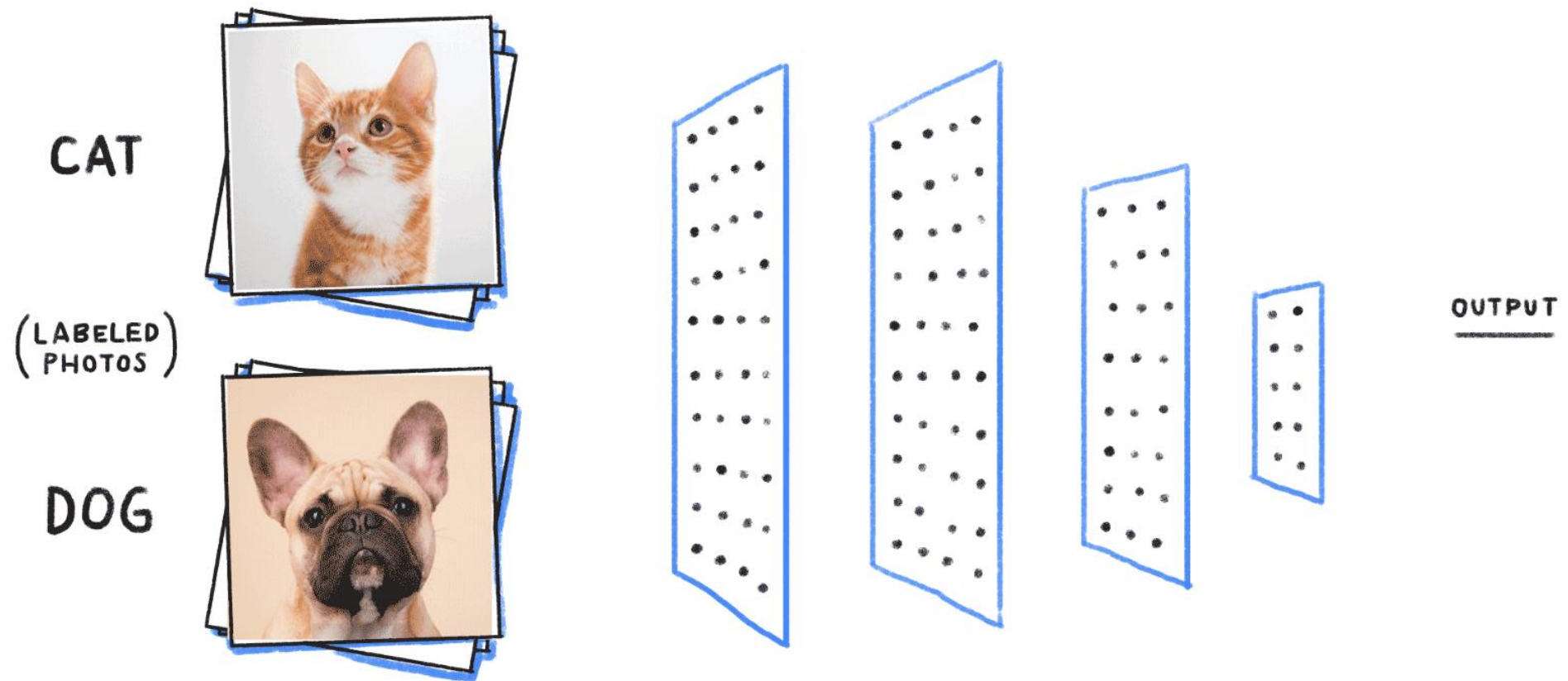
- 1) A sample delivery system
- 2) A detection system - the **adsorption** of volatile compounds on the sensor surface causes a physical change of the sensor
- 3) A computing system to analyze information from the detection system and provide a pattern recognition output that describes the odor or aroma.

Many of the devices use Artificial Intelligence to evaluate the signal from the Detection System and put it through an Artificial Neural Network (ANN), that simulates how the human brain works.



An ANN is based on a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain.

Each connection, like the synapses in a biological brain, can transmit a signal from one artificial neuron to another. An artificial neuron that receives a signal can process it and then signal additional artificial neurons connected to it.





## BREATH ANALYZER



The best-known electronic nose is the breath analyzer.

As drivers breathe into the device, a chemical sensor measures the amount of alcohol in their breath.

This chemical reaction is then converted into an electronic signal, allowing the police officer to read off the result.

Alcohol is easy to detect, because the chemical reaction is specific and the concentration of the measured gas is fairly high.

## CYRANO DE BERGERAC

Cyrano de Bergerac, a cadet (nobleman serving as a soldier) in the French Army, was a brash, strong-willed man of many talents.

In addition to being a remarkable duelist, he was a gifted, joyful poet and a musical artist.

However, he had a very large nose, which caused him to doubt himself.

His name is used for one of the main brands of the electronic nose !



*SAVINIANVS DE CYRANO de Bergerac Nobilis  
Gallus ex Icone apud Nobiles D. Domin. Le BRET  
et DE PRADE Amicos ipsius antiquissimos depicto.  
Z.H. pinxit. W. delin. et Sculptor.*

## CYRANOSE 320 UNIT

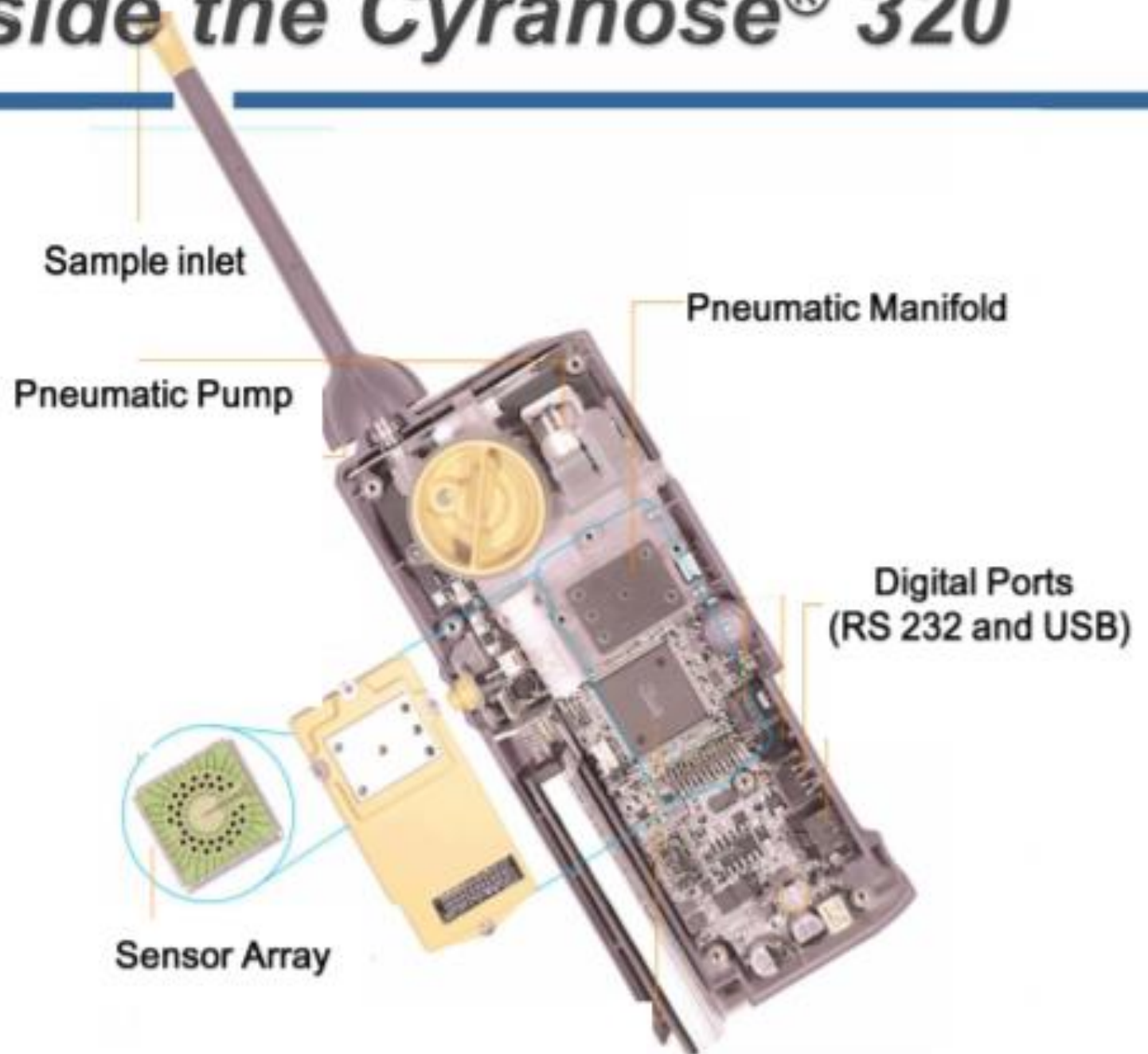
The Cyranose® 320 is a fully-integrated handheld chemical vapor sensing instrument designed specifically to detect and identify complex chemical mixtures that constitute aromas, odors, fragrances, formulations, spills, and leaks.

It uses the NoseChip® array of nano-composite sensors and advanced pattern recognition algorithms to detect and recognize the chemical vapor of **interest, via its "smellprint"**.



# Inside the Cyranose<sup>®</sup> 320

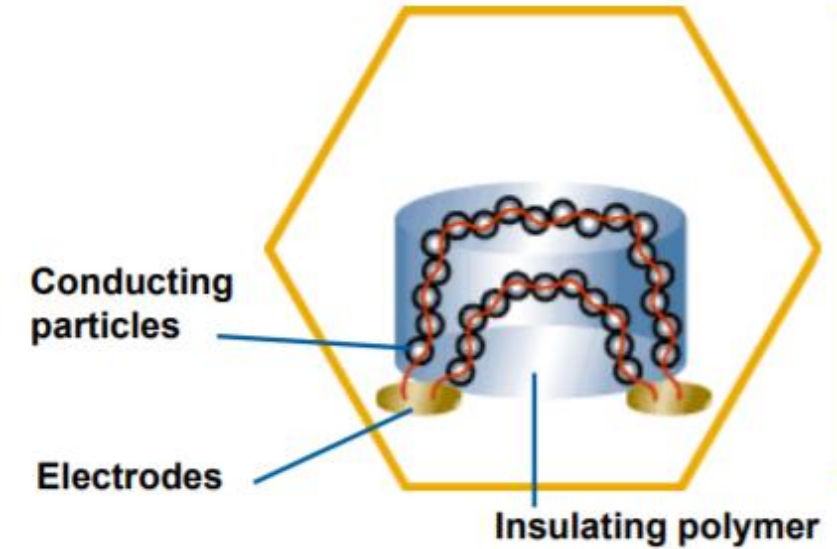
As an example of 1 type of E-Nose product design, the Cyranose is the most widely used, handheld device ever made and has been in production for over 10 years.



There are 32 different electrodes on the Sensor array chip to detect different chemicals, odors, or aromas.

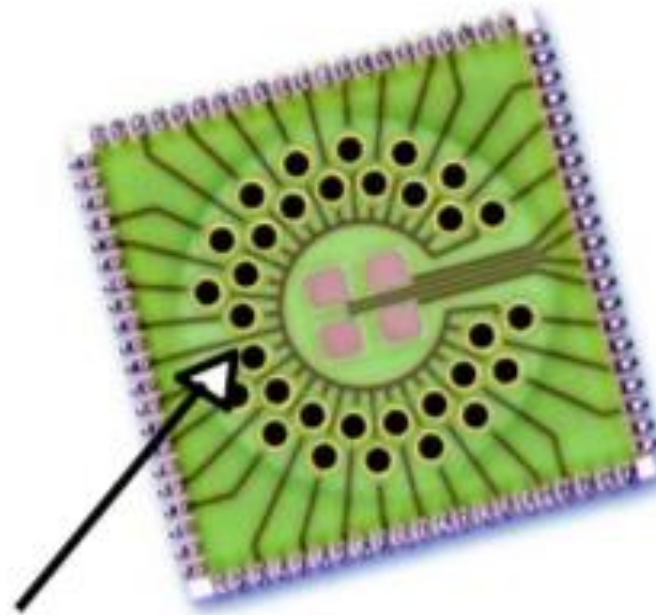
# Nanocomposite Sensor Array

**Composite sensor = polymer + conducting nanoparticles**



The vapor passes over the organic matrix and the swelling produces a change in resistance

**conductive  
polymer  
composite**



“The concentrations that can be measured are extremely low: parts per billion – 1 drop of water in an Olympic swimming pool, down to parts per trillion.

# Sensor Technology

## *Array Based Chemical Sensing*

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Using proprietary pattern matching algorithms, the data is converted into a unique response pattern

# APPLICATIONS

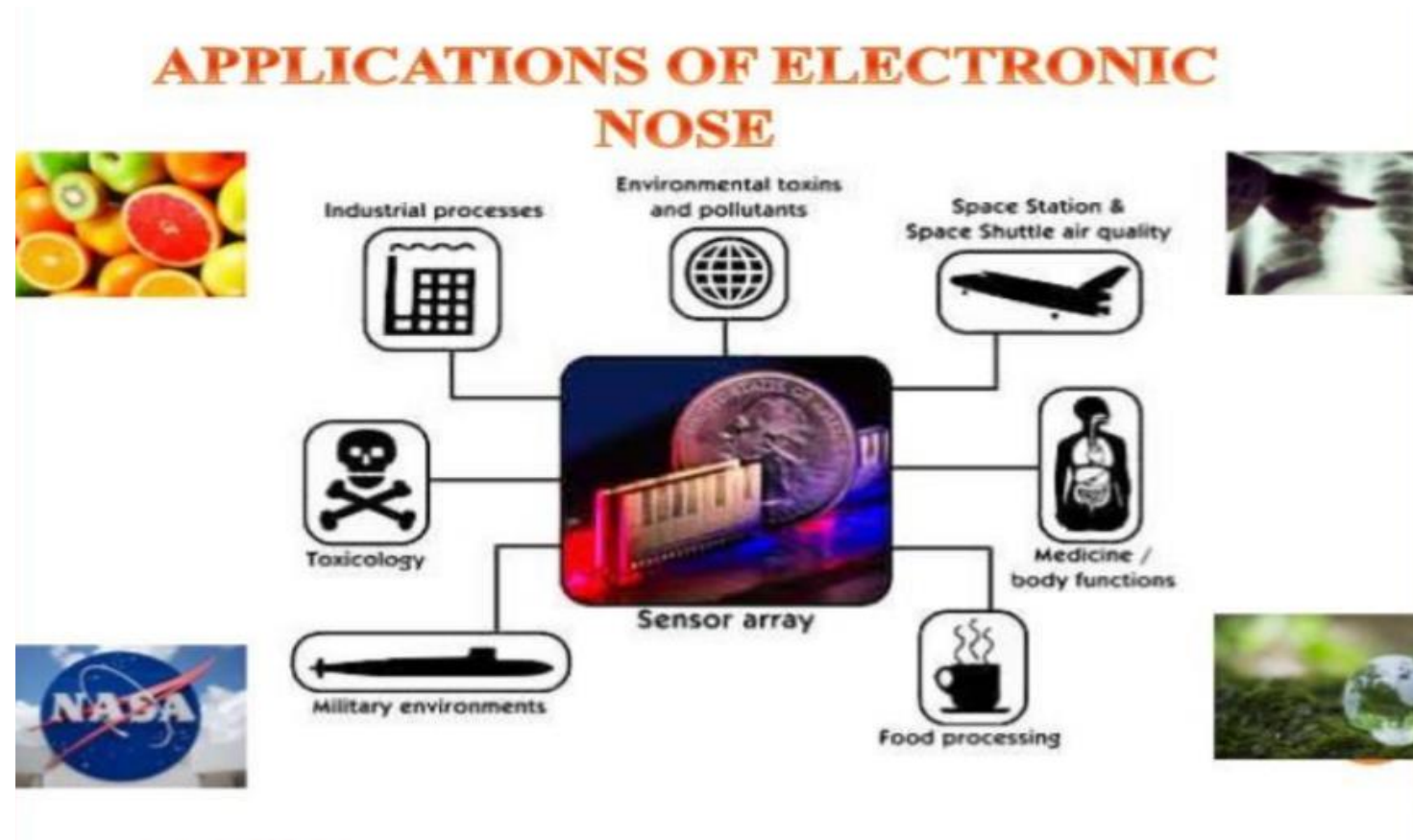
Electronic nose instruments are used by research and development laboratories, and process & production departments for various purposes:

- ❖ Quality control laboratories
- ❖ Conformity of raw materials, intermediate and final products
- ❖ Batch to batch consistency
- ❖ Detection of contamination, spoilage, adulteration
- ❖ Origin or vendor selection
- ❖ Monitoring of storage conditions
- ❖ Meat quality monitoring.



# CURRENT AND FUTURE APPLICATIONS IN THE FIELDS OF HEALTH AND SECURITY

- ❖ Detection of dangerous and harmful bacteria, such as MRSA (Methicillin-resistant Staphylococcus aureus)
- ❖ Detection of lung cancer or other medical conditions
- ❖ Detection of viral and bacterial infections in COPD symptoms
- ❖ Detect odorless smells to for bomb odors
- ❖ Drug detection method in airports
- ❖ Environmental Monitoring
- ❖ Identification of volatile organic compounds in air, water and soil samples





The E-Nose devices are used in these Industries:

Agricultural

Petrochemical

Chemical

Food and beverage

Packaging materials

Plastics

Pet food

Pulp and paper

Medical research

Military

# APPLICATIONS OF E-NOSE

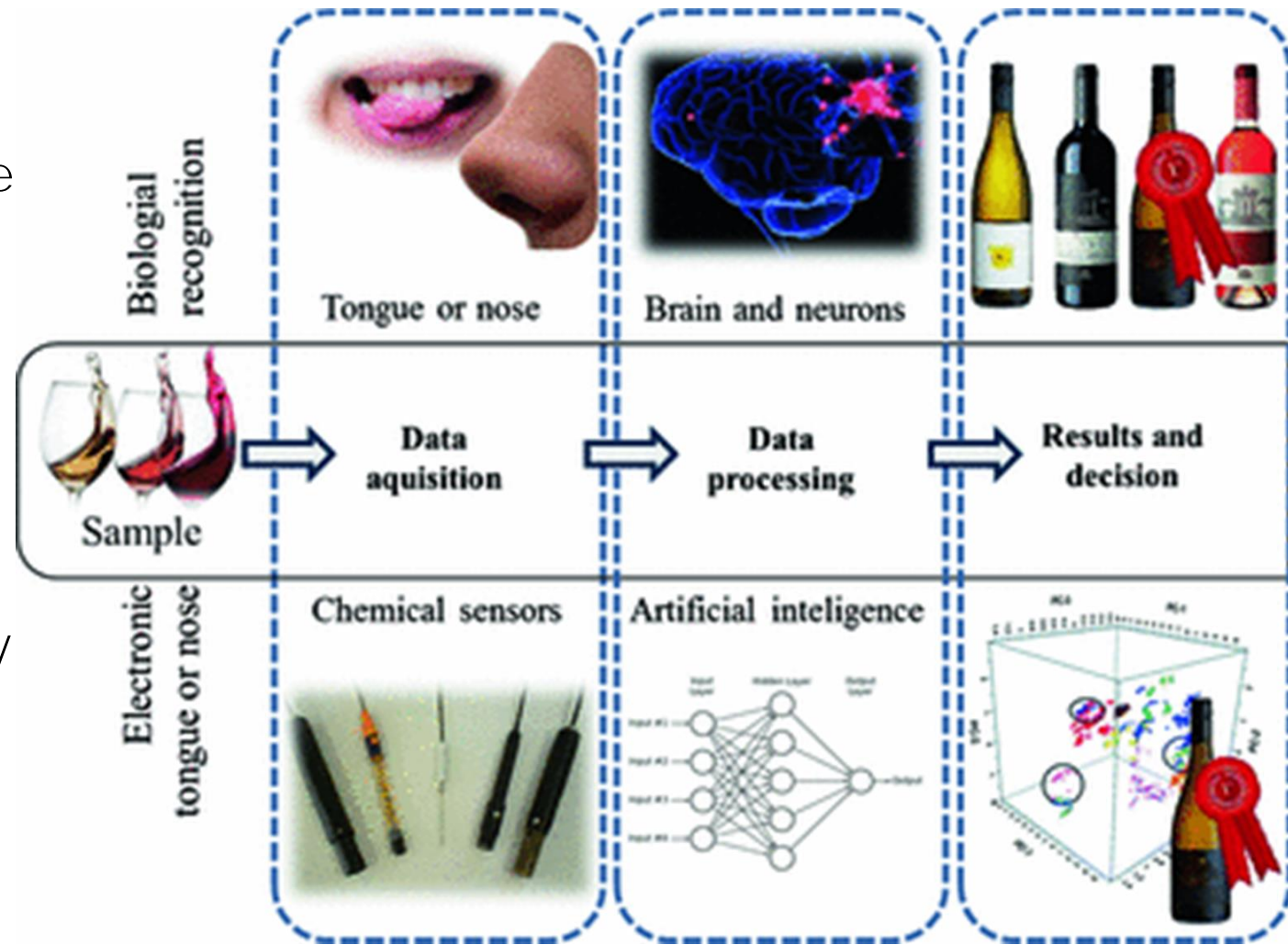


# E-NOSE DEVICES FOR EVALUATING THE AROMA AND FLAVOR CHARACTERISTICS OF WINES AND FOOD GRAINS

Besides the use of E-nose devices in the areas of automobile, packaging, food & beverage, cosmetic, drug, analytical chemistry, and biomedical industries, 2 other important uses are for analyzing **wines** and **food grains**.

1) They are used for the classification and quality assurance of wines. Sensory and chemical properties of wine, especially color, aroma, and taste, are important aspects of their quality.

2) The aroma of grains is the primary criterion of fitness for consumption in many countries.



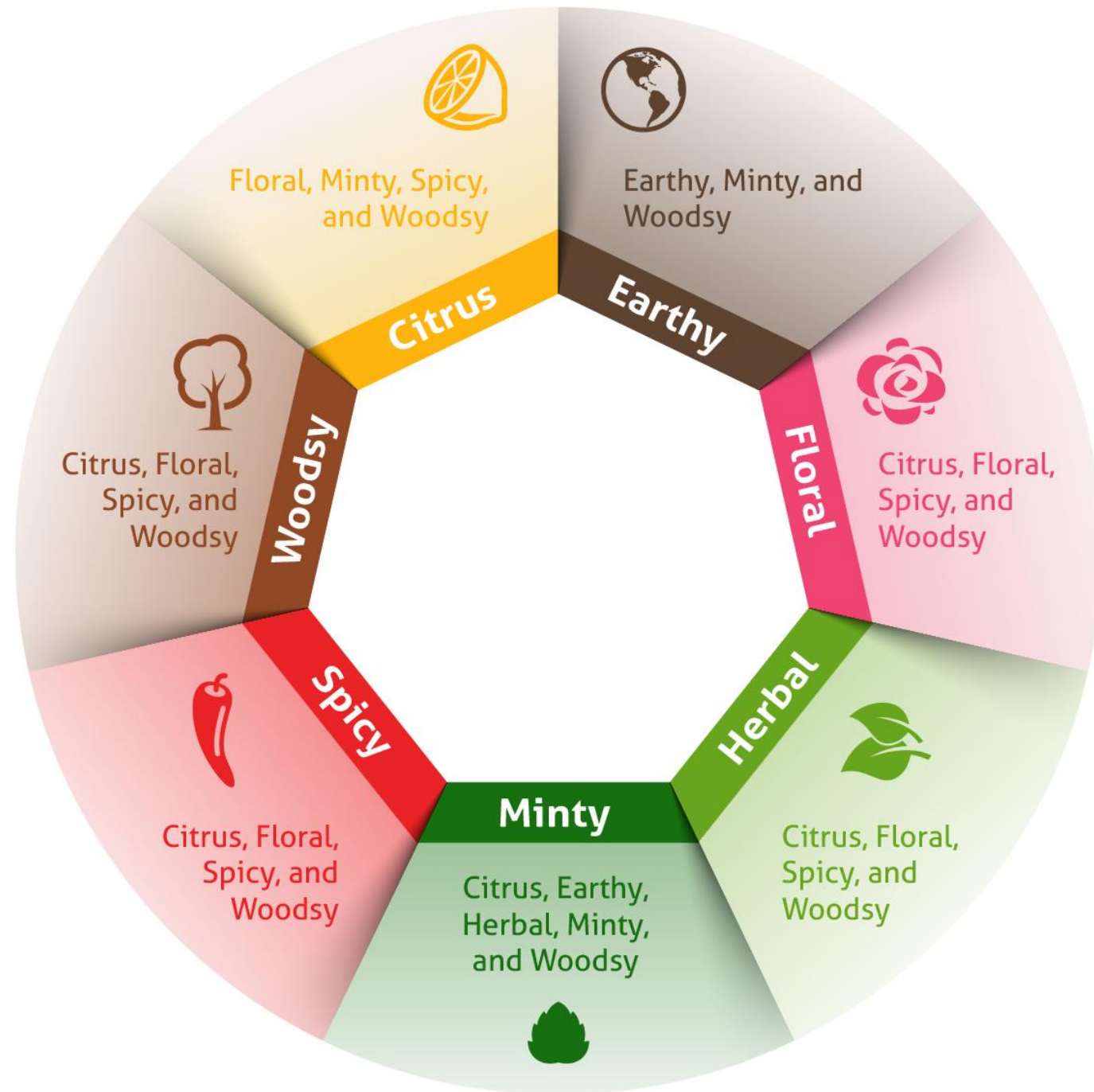
# THERE ARE EIGHT AROMA GROUPS

(1) Earthy aromas (musty, moldy, musk, stale, grassy, herbal, woody)

(2) Floral aromas (fragrant, flowery, perfume, eucalyptus, lavender)

(3) Fruity aromas (citrus, orange, lemon, apple, pear, pineapple, strawberry)

(4) Spicy aromas (cinnamon, mint, peppermint, onion, dill, garlic, pepper, cloves, vanilla, almond, pine)



5) Fishy aromas (fishy, prawns, amine)

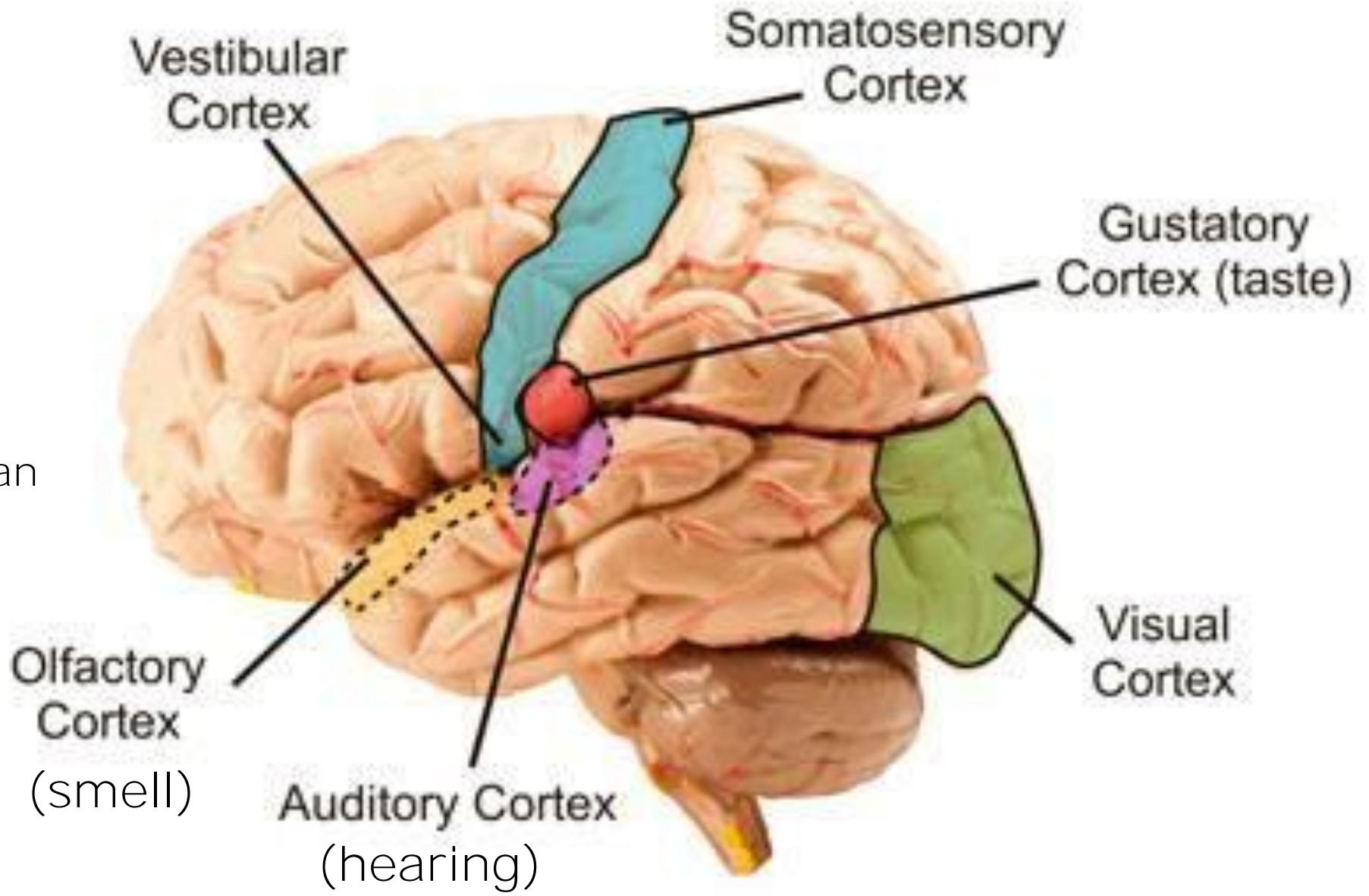
6) Sewage aromas (septic, putrid, rancid, sulfurous, rotten, decayed, cadaverous, foul, sour, pungent, burnt, swampy)

7) Medicinal aromas (disinfectant, phenol, camphor, soapy, ammonia, alcohol, ether, anesthetic, menthol)

8) Chemical aromas (solvent, aromatic, varnish, turpentine, petroleum, creosote, tar, oily, plastic).



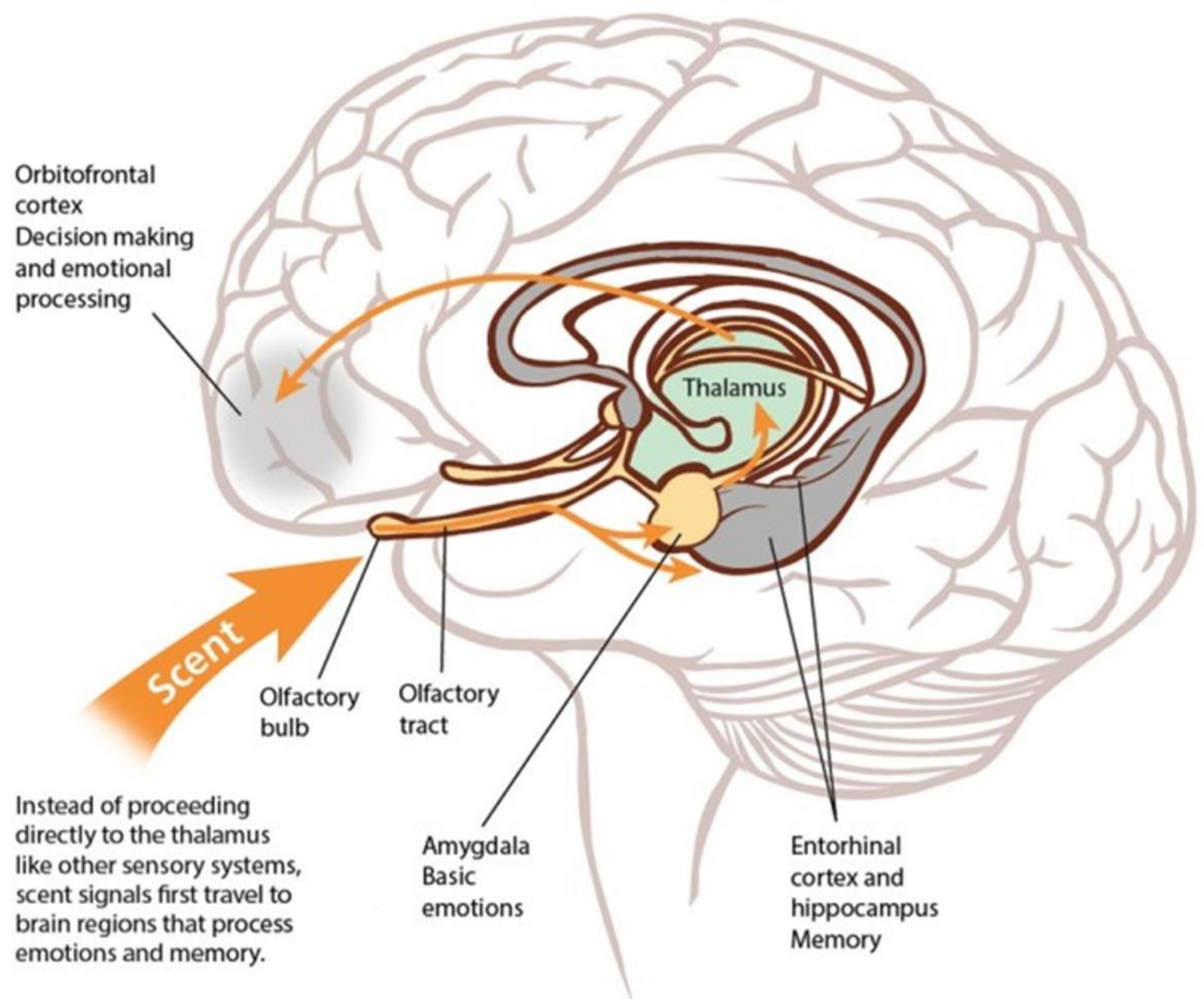
Of all the five senses, olfaction uses a lot of our brain area and is an essential part of our daily lives.



**Human Brain**

A 2014 study showed that we can distinguish at least 1 trillion different odors.

When it comes to smells, people can be influenced emotionally and not realize it.



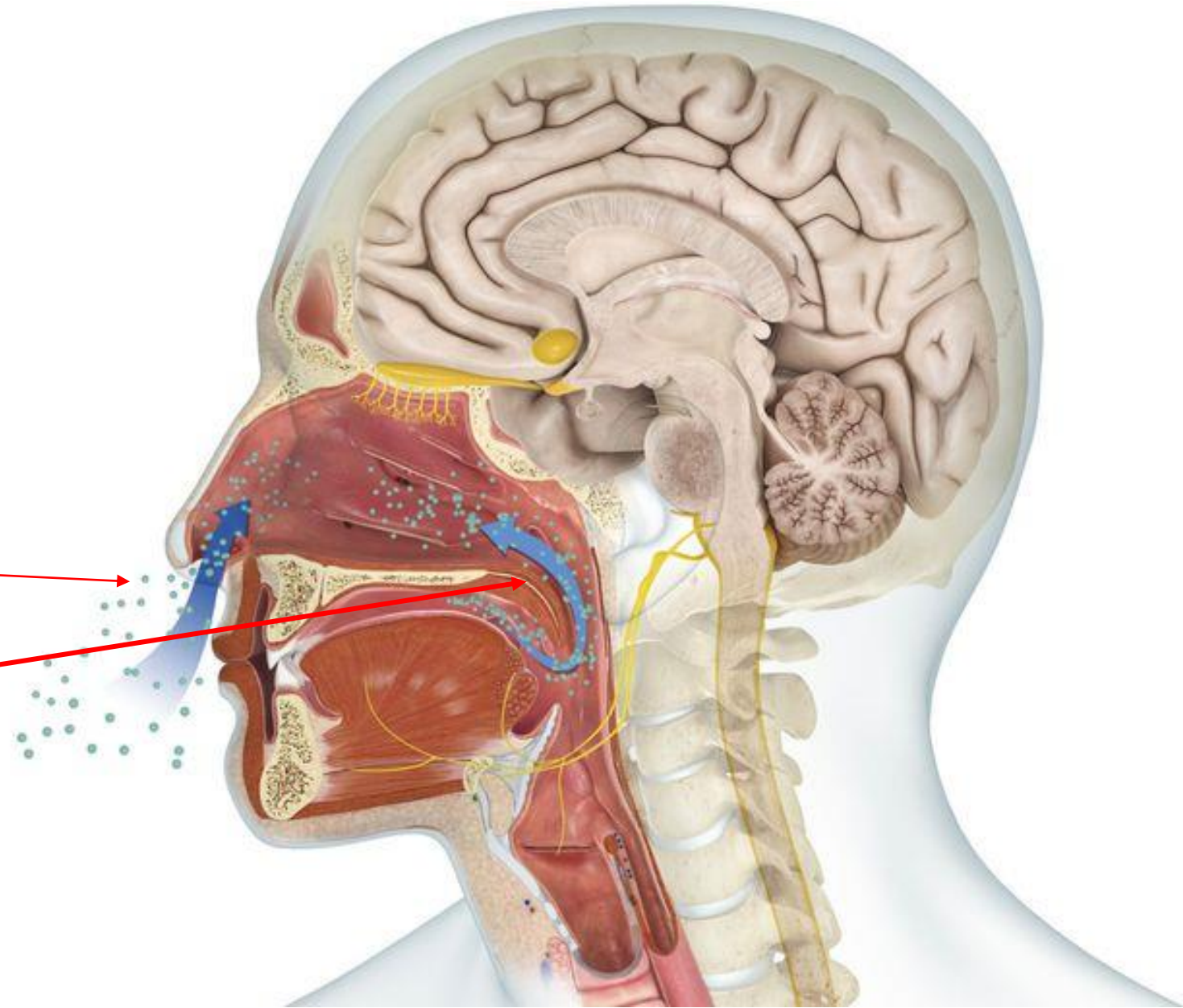
Instead of proceeding directly to the thalamus like other sensory systems, scent signals first travel to brain regions that process emotions and memory.

(Credit: corbac40/Shutterstock)

The two pathways of odor detection:

Orthonasal smell

Retronasal smell  
(Through the back of the mouth  
and up into the nasal passage)



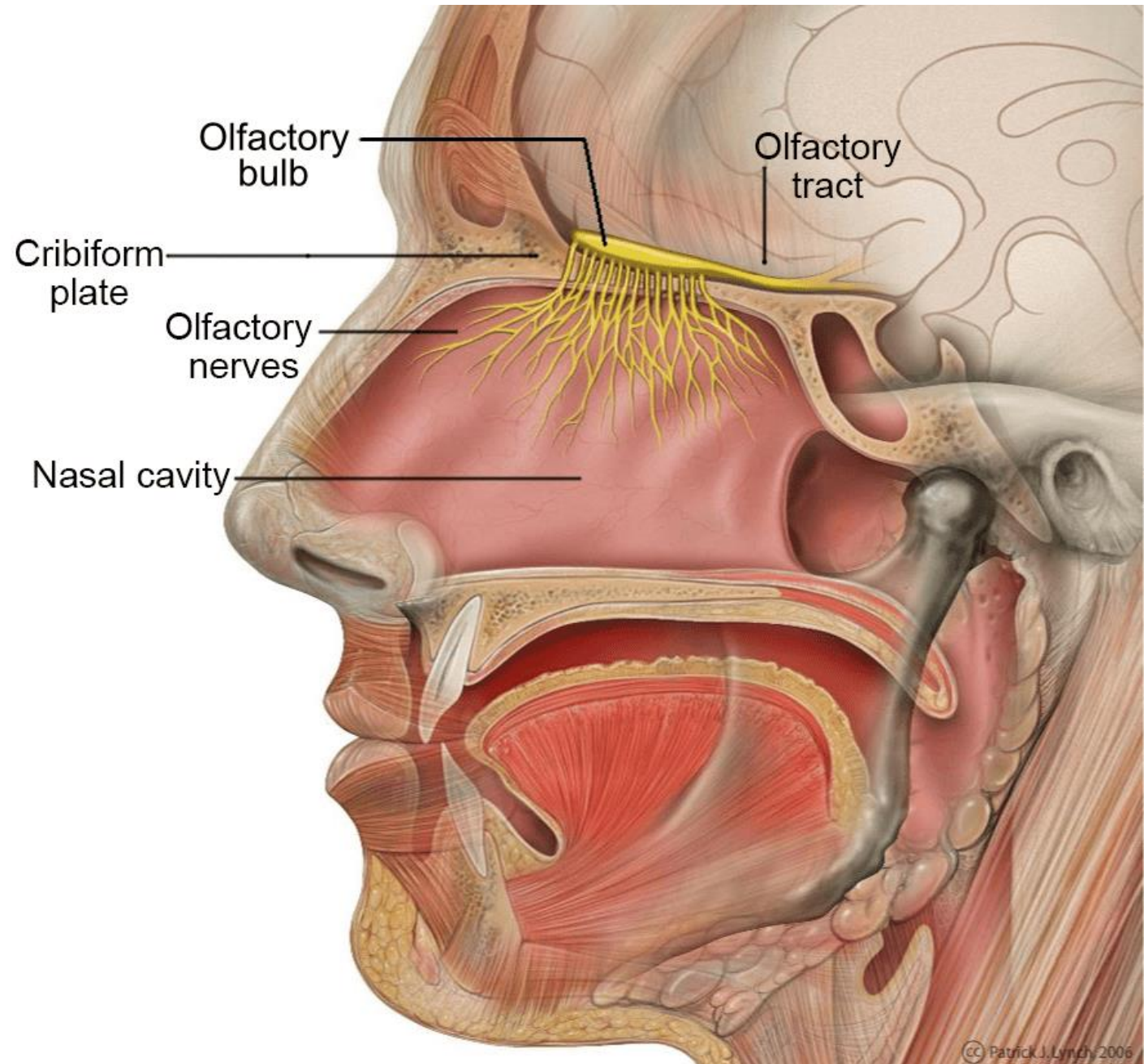
The olfactory cortex is vital for the processing and perception of odor.

It is located in the temporal lobe of the brain, which is involved in organizing sensory input.

The olfactory cortex is also a component of the limbic system.

This system is involved in the processing of our emotions, survival instincts, and memory formation.

It is the limbic system that connects senses, such as odors, to our memories and emotions.



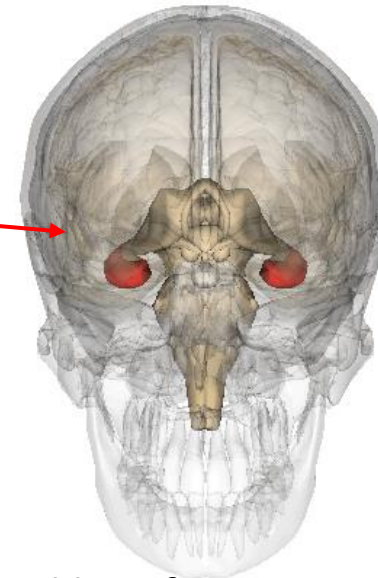
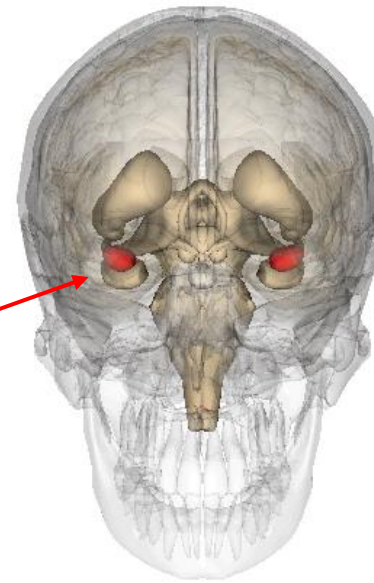


## EMOTIONAL FEELINGS FROM SMELLS

We know that the neurological substrates of smelling are especially geared for associative learning and emotional processing.

The olfactory bulbs are part of the limbic system and directly connect with limbic structures that process emotion (the amygdala) and associative learning (the hippocampus).

No other sensory system has this type of intimate link with the neural areas of emotion and associative learning, therefore there is a strong neurological basis for why odors trigger emotional connections.



Images are generated by Life Science Databases(LSDB). - from Anatomography, website maintained by Life Science Databases

## AFTER YOU EAT ASPARAGUS, DOES YOUR URINE SMELL DIFFERENT ?

**When we eat almost all foods, we don't** have a distinct odor from them, in our urine. But sometimes, asparagus is the exception.

In a study, researchers asked 2,500 men and about 4,400 women — all U.S. citizens of European descent — whether they ever smelled this odor.

In the results, 40 percent of study participants said they could smell the odor in their urine after eating asparagus, and 60 percent said they could not.

More women than men said that they could not smell the odor.



## A NOSE FOR ODORS

### What do dogs have that we don't?

For one thing, they possess up to 300 million olfactory receptors in their noses, compared to about 6 million in us.

The part of a dog's brain that is devoted to analyzing smells is, proportionally speaking, 40 times greater than ours.

When animals want to smell **something, they don't just passively** expose themselves to the chemical.

**They're actively sniffing for it—** sampling the air and moving it around—so the signals that are being received are not static.



As it moves along the ground, the bloodhound's giant, flappy ears help fan up odors to its nose, one reason the breed is the superstar of scent-tracking.

© Luis Santana/iStockphoto

While humans primarily depend on their vision, dogs use both sight *and* smell to assess their surroundings and communicate.

People spend more time interpreting visual data than olfactory information.

Dogs are just the opposite.



- ❖ A drug-sniffing dog "found" a plastic container packed with 35 pounds of marijuana submerged in gasoline within a gas tank.
- ❖ A cancer-sniffing dog "insisted" on melanoma in a spot on a patient's skin that doctors had already pronounced cancer-free; a subsequent biopsy confirmed melanoma in a small fraction of the cells.
- ❖ Research indicates that it's quite likely that a dog's sense of smell can pick up fear, anxiety and even sadness in its owner, and sometimes in others.
- ❖ Trying to mask your strong feelings with a casual smile may fool your **friends, but it's not going to fool a dog's sense of smell.**

A dog's sense of smell is 100,000 times stronger than a human's. Bloodhounds have ~300 million scent receptors while beagles and German shepherds both have ~225 million. In comparison, humans only have about 5 million.





IT'S OKAY BRO

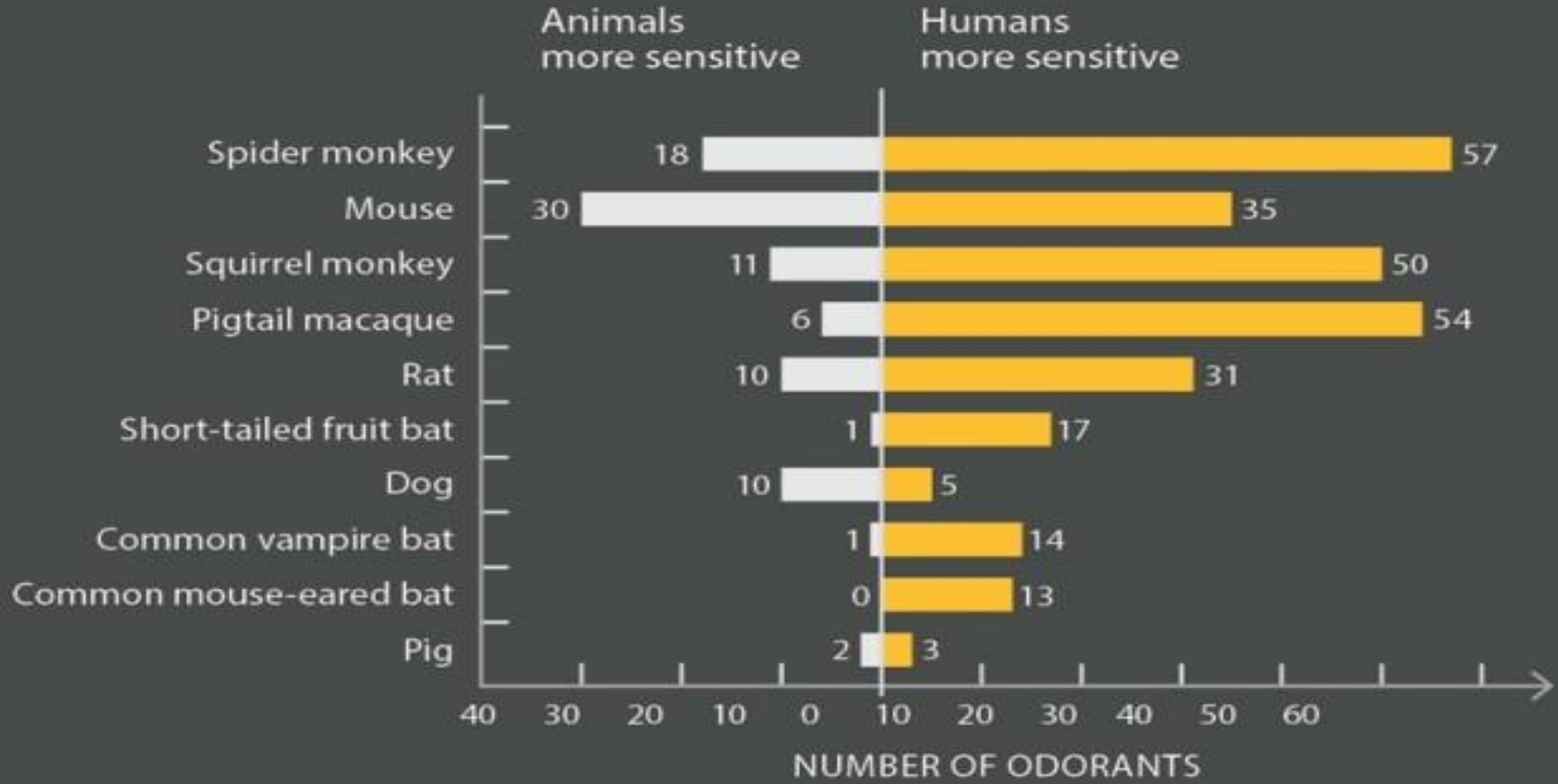
Dogs and Cats also have great sensitivities to know when an Earthquake is coming !



**Cat senses earthquake** 😊



# NOSE TO NOSE: HUMAN VS. ANIMAL





## DOGS BEING ABLE TO DETECT DISEASES FROM OUR BREATH

Each of us has a unique “odorprint” made up of thousands of organic compounds.

These molecules offer a whiff of who we are, revealing age, genetics, lifestyle, hometown — even metabolic processes that underlie our health.

Dogs can be trained to smell if a person has **cancer** of the colon, prostate, breast, or melanoma (skin cancer) by sniffing people's skin, bodily fluids, or breath.

They can also recognize if a person has **Parkinson's disease**.



Dogs can be trained to sense when a person is going to have:

- ❖ A Migraine headache
- ❖ Low Blood sugar
- ❖ A Seizure ----->
- ❖ Narcolepsy (sleeping sickness)
- ❖ Fear and stress

Dogs are smelling the surge of hormones our bodies release to respond to stressful situations, including adrenalin and cortisol

New training allows dogs to sense the Covid-19 virus from the urine of persons who have it.

They can also detect malaria in children

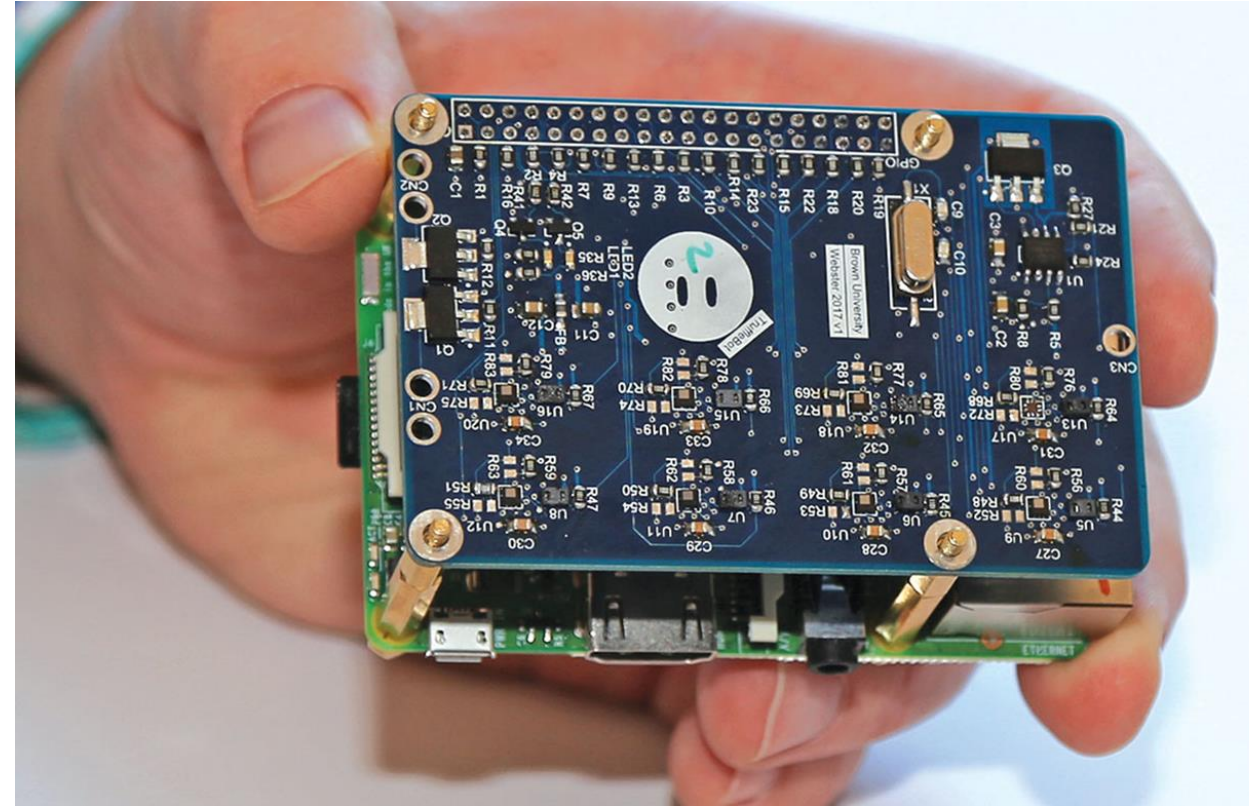


# THE TRUFFLEBOT

Most E-nose devices rely exclusively on chemical sensors, such as metal oxides or conducting polymers.

**The “TruffleBot” actually sniffs odors, sucking up vapors in a premeditated pattern through four pathways.**

It moves those vapors across 8 pair of chemical and mechanical sensors, using a 3.5-inch-by-2-inch circuit board that sits on a Raspberry Pi circuit board.



E-nose sensor that works with readout electronics, used for ethanol and humidity detection.



Sensing chip unit for measuring nitrogen monoxide (NO) and nitrogen dioxide (NO<sub>2</sub>), common air pollutants and chemicals for a range of secondary pollutants.

# Human Nose vs. E-Nose

- Human Nose
  - $>10^8$  receptor cells
  - $>10^3$  types
  - Responds in a few seconds
  - Sensitivity in ppb/ppt
  - Massive neural processing in the brain
  - Receptors regenerated every few weeks (~30 days)
- Electronic Nose
  - 5-32 sensors
  - 5-32 types
  - Responds in tens of seconds to a few minutes
  - Sensitivity in ppm/ppb
  - Pattern recognition, AI, artificial neural nets
  - Sensors replaced on a maintenance schedule (depends on application)

# THE USE OF E-NOSE DEVICES FOR SMELLING A **PERSON'S BREATH, TO LOOK FOR DISEASES**

The U.K. company Owlstone Medical is developing a testing platform called Breath Biopsy as a **non-invasive** diagnostic method which all sorts of volatile organic compounds that are produced in our bodies.

They are collaborating with clinicians, researchers, and other biomedical companies around the world on its potential application for early detection of various cancers, respiratory illnesses, and immune diseases.



A patient places the mask over her or his nose and mouth and breathes normally for a few minutes.

The device delivers a controlled supply of air, and the exhaled breath is captured and stabilized on specially designed cartridges for later analysis.  
(Photo courtesy of Owlstone Medical.)

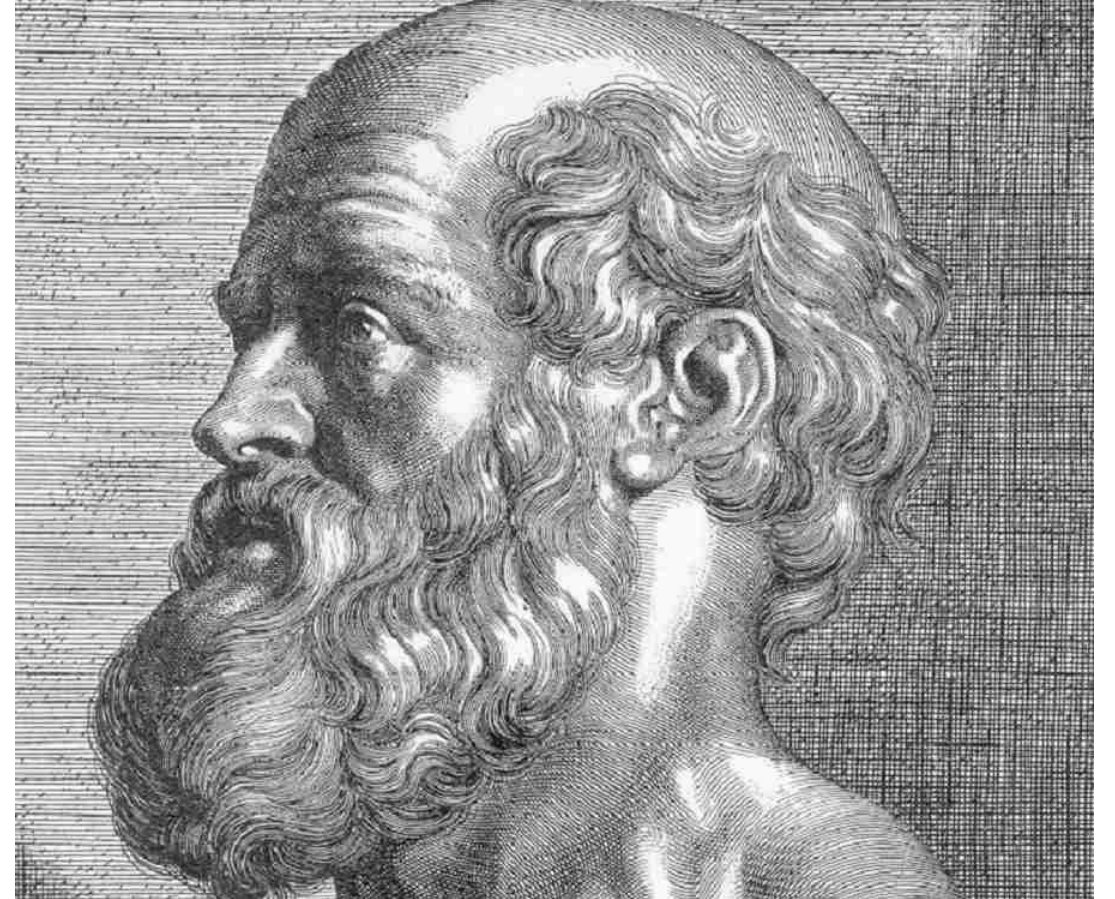
# THE HISTORY OF BODY AND BREATH SMELLS FOR DIAGNOSING DISEASES AND MEDICAL CONDITIONS

The sense of smell has been used as a medical diagnostic tool for thousands of years

Ancient medical practitioners plied their trade by trusting their noses.

Around 400 BCE, Hippocrates recognized the diagnostic usefulness of body odors and reported on several disease-specific odors emanated from urine or spit.

They knew that diabetes could make a patient's breath smell sweet and that a wound emitting a foul odor was infected.



Hippocrates – 400 BCE - treatise on breath  
aroma and disease

Lavoisier and Laplace (1784) - showed  
that respiration consumes oxygen and  
eliminates carbon dioxide

Nebelthau (mid 1800s) - showed that  
diabetics emit breath that smells like the  
solvent acetone

Anstie (1874) - Isolated ethanol from breath

Pauling (1971) - used Gas Chromatography  
**to detect 250 compounds in person's breath**

Phillips (1999) - used Gas  
Chromatography/Mass Spectrometry to detect  
3000 compounds in breath

2000 - present - new advances in breath  
analysis each year through laser  
spectroscopy, mass spectrometry and E-Nose  
analysis





# VOLATILE ORGANIC COMPOUNDS FROM OUR BREATH

Up to 3,000 different volatile organic compounds (VOCs) are emitted from the human body, and the components of VOCs usually reflect the metabolic condition of an individual.

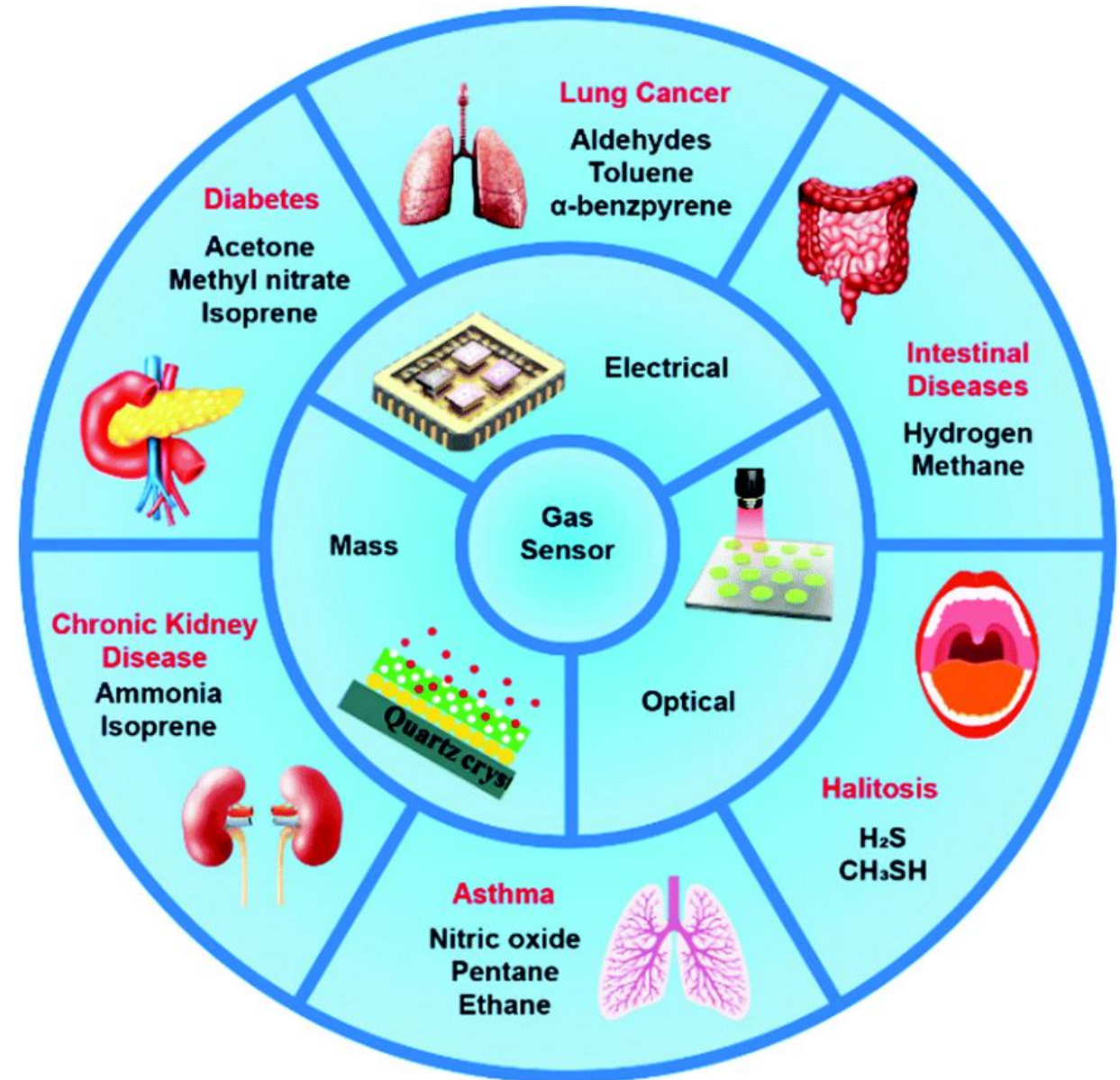
Recent progresses in analytical techniques allow rapid analyses of VOCs derived from breath, blood, skin and urine.

Disease-specific VOCs can be used as biomarkers of:

infectious diseases

Metabolic diseases

Genetic disorders



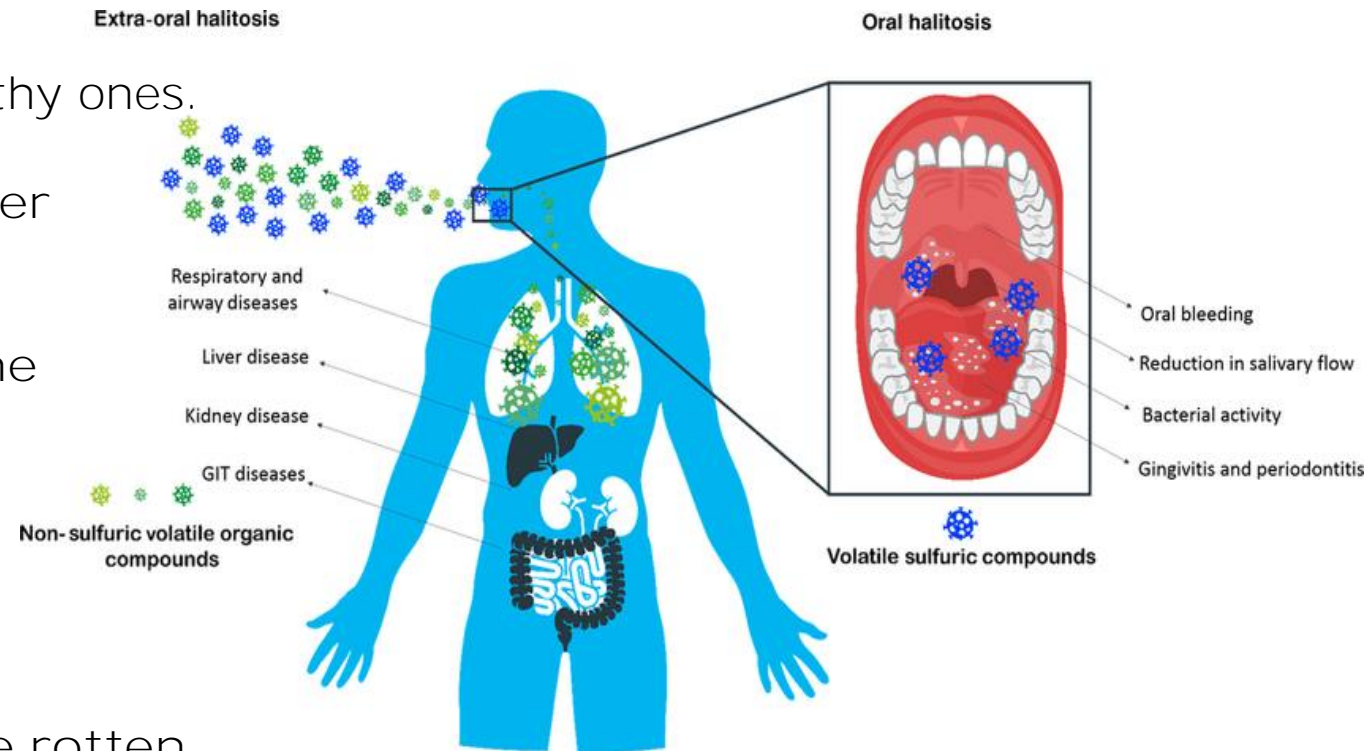
# **ANALYZING A PERSON'S BREATH TO DETERMINE IF THEY HAVE ANY MEDICAL CONDITIONS**

- ❖ Many diseases produce a measurable pattern of volatile chemicals (VOC'S) in breath, urine and blood. Research has found over 3,000 of these in our breath !!
- ❖ Non-invasive breath measurement will provide rapid diagnosis and treatment monitoring capability for physicians in emergency and point-of-care applications.
- ❖ Low cost and low power intelligent sensor array devices will enable home health diagnosis and monitoring capability for many individuals.

# BREATH BIOPSY

The E-**Nose technology that analyzes a person's** breath, is called **Breath Biopsy** and is useful for diagnosing:

- ❖ Chronic sinusitis
- ❖ Pneumonia
- ❖ Can distinguish asthmatic patients from healthy ones.
- ❖ Sniff out infections in urine, blood and other body fluids.
- ❖ Pinpoint antibiotic-resistant bacteria in the nasal swabs of hospital patients.
- ❖ Urinary tract infections
- ❖ Liver disease



The breath of **diabetics** sometimes smells like rotten apples or the chemical Isoprene.

The skin of **typhoid** patients, smells like baking bread.

Using a Cyranose unit with a Nasal Breathing Cup, with the patient breathing out of her nose, into the unit.



# METABOLOMICS

There is this whole new field called 'metabolomics' -- how chemical patterns on your breath or off your urine could indicate illness

Published research over the last ten years has shown that diseases such as asthma, chronic obstructive pulmonary disease (COPD), tuberculosis, lung cancer, gastric cancer and colon cancer all have a distinctive "smellprint" -- a pattern of volatile molecules that can't be sensed by a human nose, but can be picked up by AN E-Nose device.

The device to the right was developed by the Israel Institute of Technology, in Haifa, by a team has been working to develop an electronic nose.



## THE ENOSE COMPANY

They currently focus on 2 product-lines containing E-Nose technology:

1) This is the Aeonose smallest unit and is used for exhaled-breath analysis for screening for tuberculosis, asthma, diabetes, and throat cancer.

The patient breathes into the diagnostic unit, and within minutes a proper indication is given whether additional patient examination is required.

From a healthcare point of view, faster and more efficient indication of diseases is desirable, in **order to optimize the patient's treatment or to enable non-invasive diagnostics without the need for highly-trained staff.**



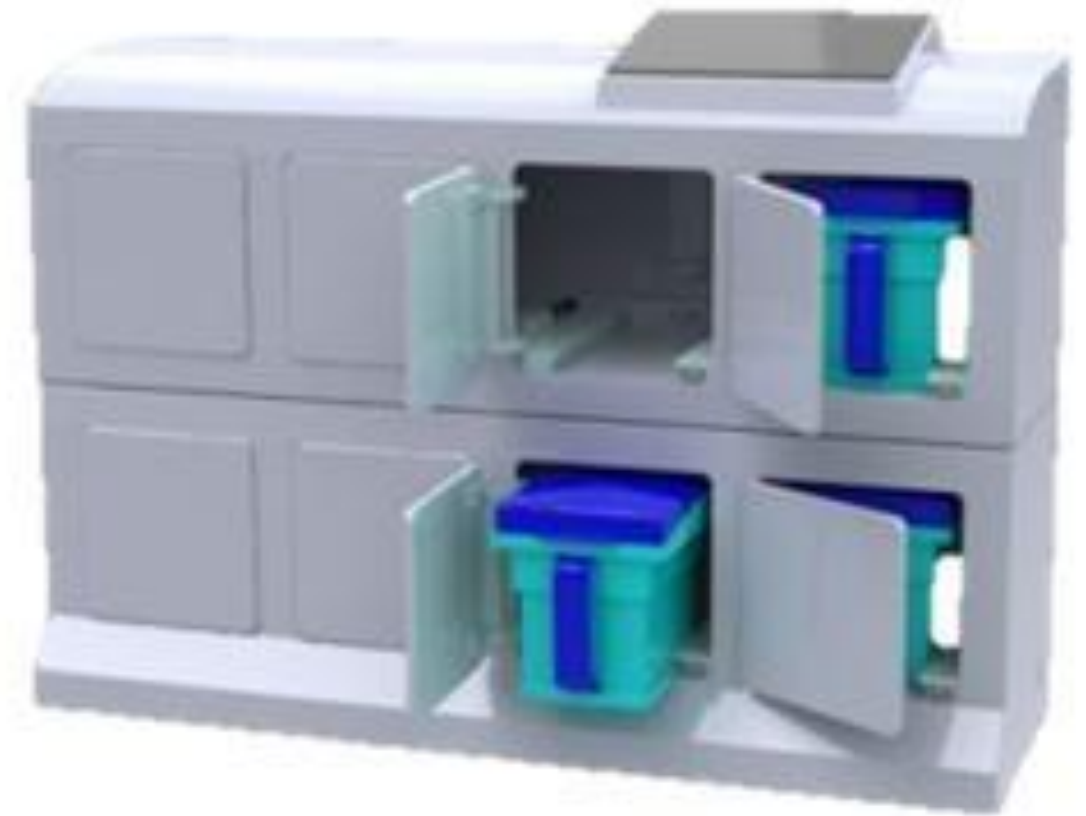
## DETECTING AND IDENTIFYING **PATHOGENIC BACTERIA: AETHOLAB™**

2) The Aetholab™ is a diagnostic unit for detecting and identifying pathogenic bacteria in blood.

The pathogens (present in a blood sample) are cultured in a special medium at 35-37 °C (95 – 98.6 degrees Fahrenheit.)

Metabolizing pathogens produce gases that can be detected and identified.

The process is specific for many bacteria.

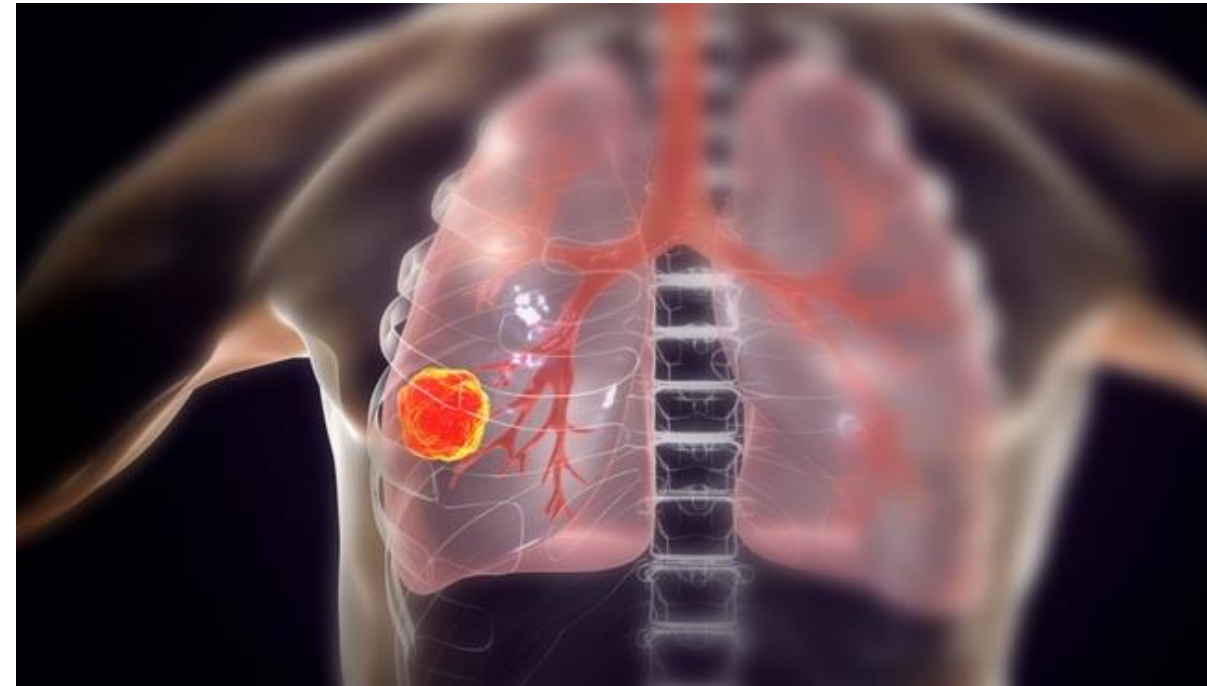


# DIAGNOSING CANCERS WITH AN E-NOSE DEVICE

E-Nose devices can diagnose lung cancer up to 2 years earlier than standard clinical care.

In cancer research and medicine, biomarkers are used in three primary ways:

1. To help diagnose conditions, as in the case of identifying early stage cancers (Diagnostic)
2. To forecast how aggressive a condition is, as in the case of determining a patient's ability to fare in the absence of treatment (Prognostic)
3. To predict how well a patient will respond to treatment (Predictive)

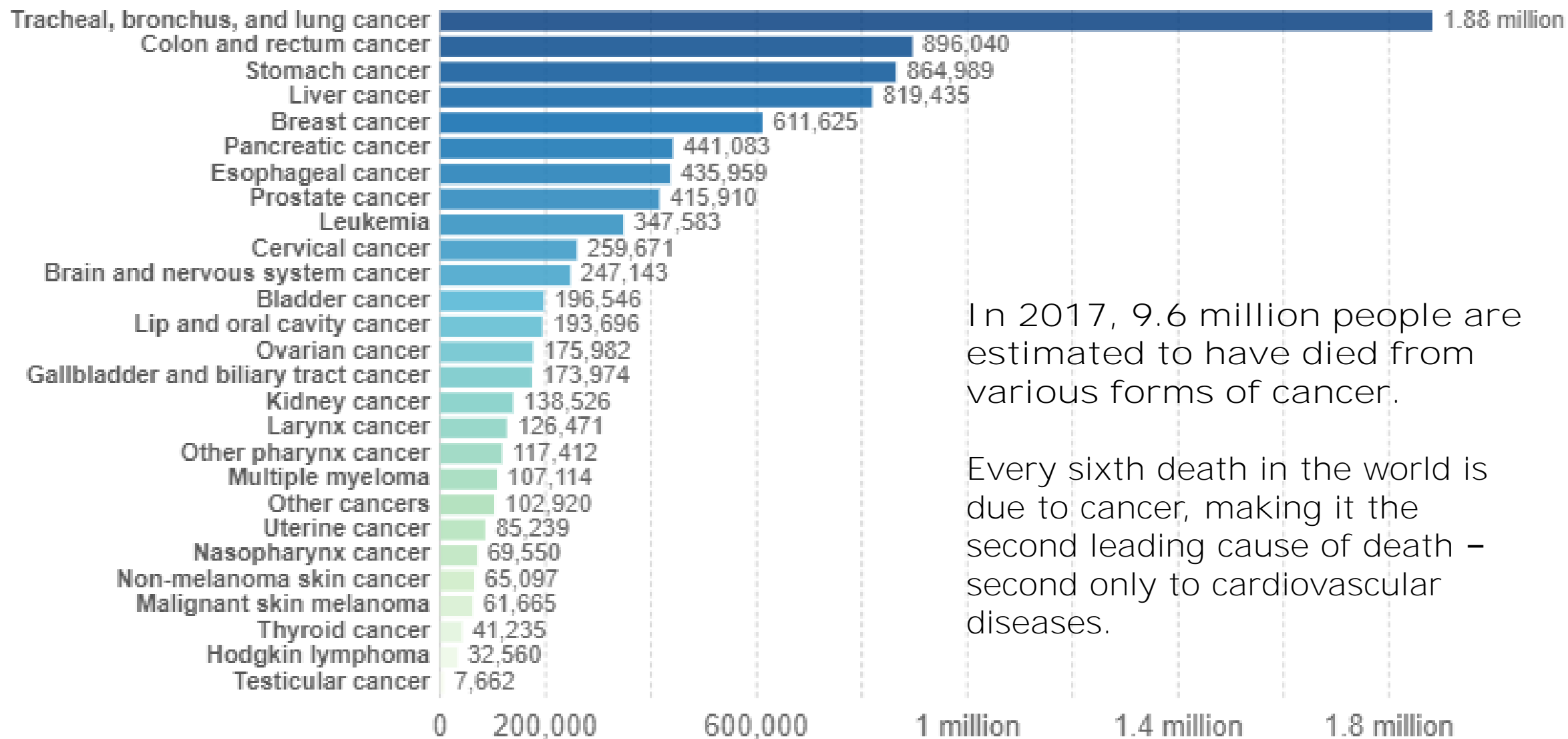




# Cancer deaths by type, World, 2017

Total annual number of deaths from cancers across all ages and both sexes, broken down by cancer type.

[↔ Change country](#)



In 2017, 9.6 million people are estimated to have died from various forms of cancer.

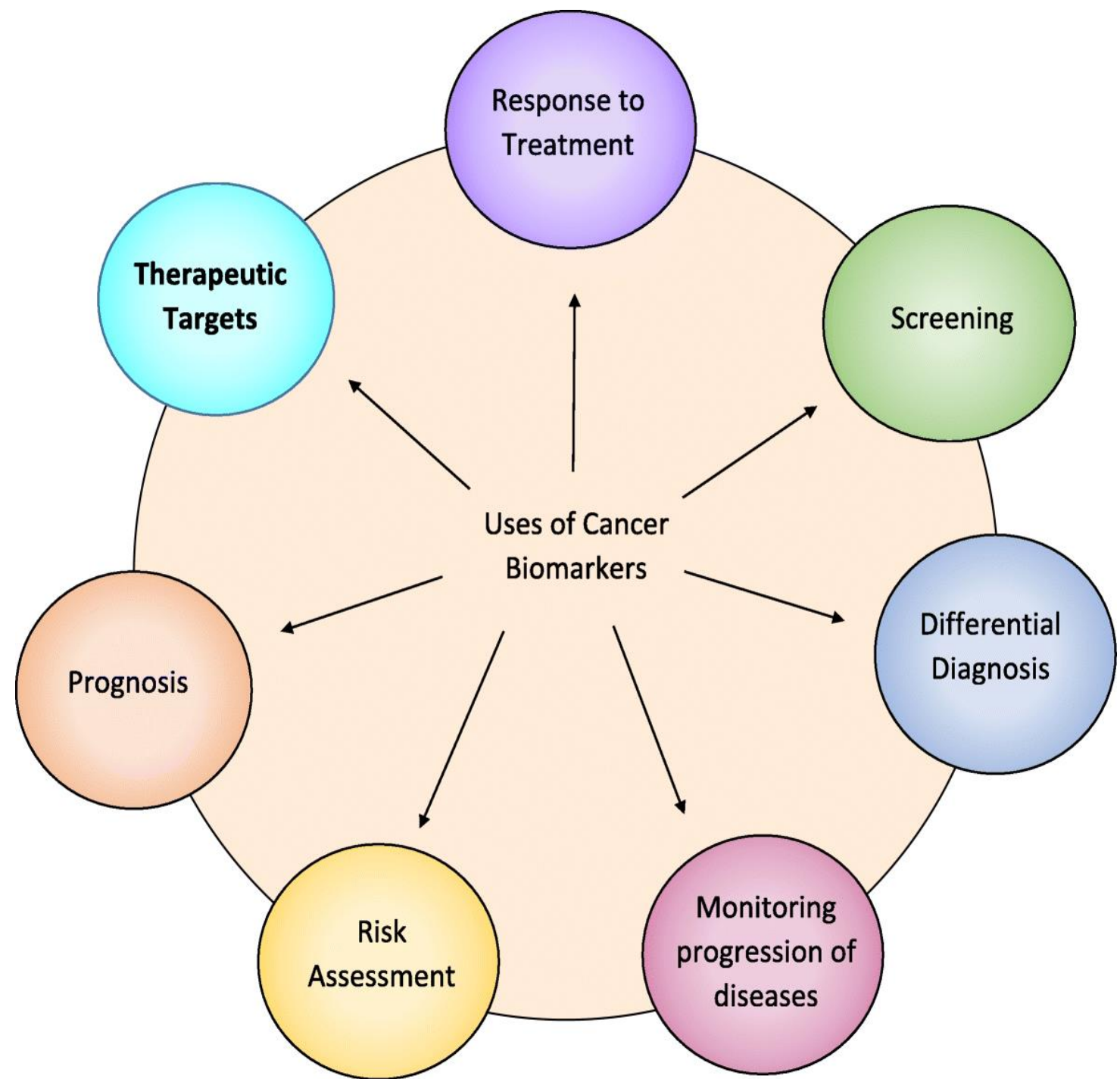
Every sixth death in the world is due to cancer, making it the second leading cause of death – second only to cardiovascular diseases.

# USING AN E-NOSE DEVICE TO DETECT LUNG AND OTHER CANCERS

A total of 1,806,590 new cancer cases and 606,520 deaths were expected in the US in 2020, which is about 4,950 new cases than last year and more than 1,600 deaths each day.

Most lung cancer patients already have advanced disease at the time of diagnosis.

Biomarkers could lead towards an earlier lung cancer diagnosis and have the potential to improve outcomes and treatment by the use of an electronic nose (e-nose).



**A biomarker is defined as “a**

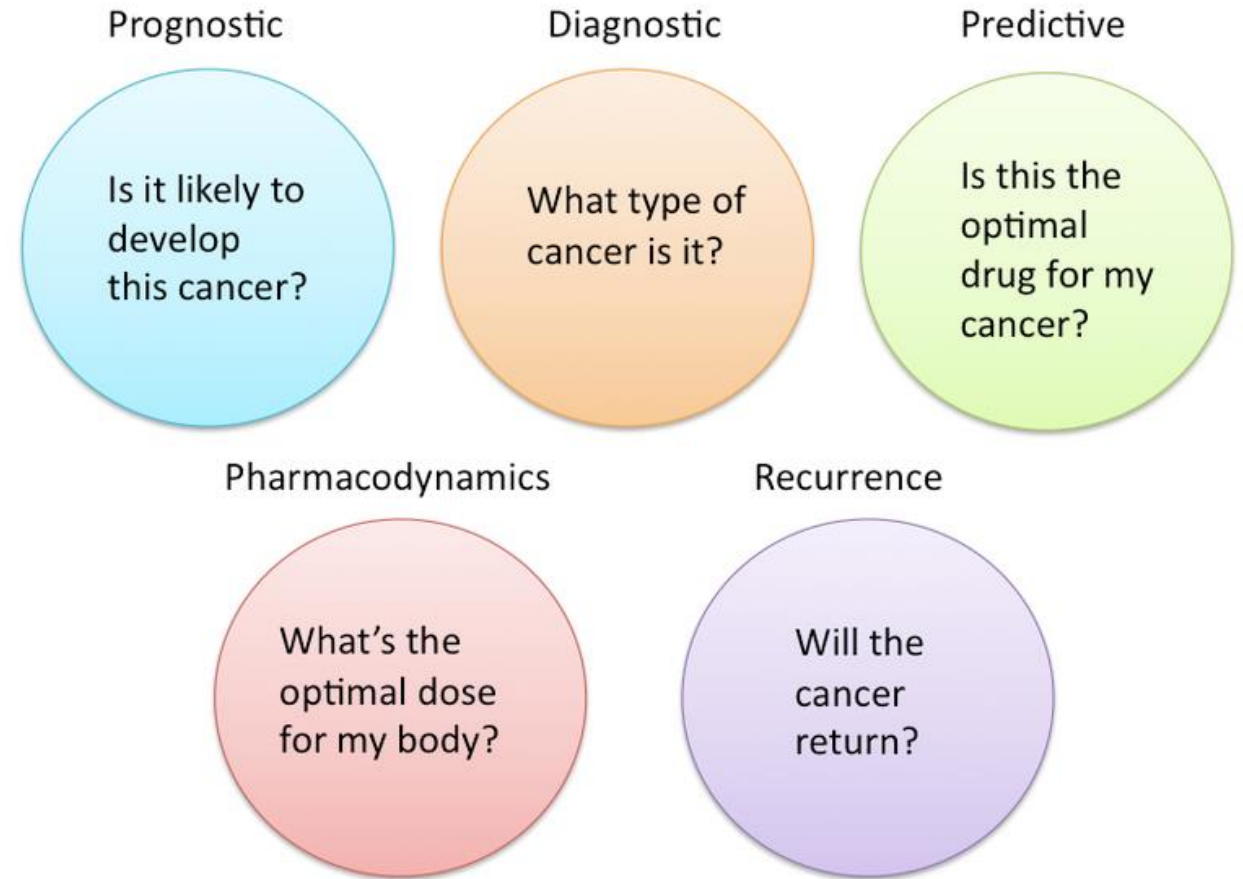
characteristic that is measured as an indicator of normal biological processes, pathogenic processes, or responses to an exposure or intervention, including therapeutic interventions.

A biomarker is not an assessment of how an individual feels, functions, or survives.

Biomarkers are molecules that indicate normal or abnormal process taking place in your body and may be a sign of an underlying condition or disease. Various types of molecules, such as DNA (genes), proteins or hormones, can serve as biomarkers, since they all indicate something about your health.

Biomarkers may be produced by the cancer tissue itself or by other cells in the body in response to cancer.

Questions that can be answered by cancer biomarkers



A biomarker should fulfil criteria such as being detectable at a point where it would change the patient pathway or outcome of the disease or allude to other tests in diagnostic or screening settings.

The Digital nose is popular as an electronic nose or e-sensing.

It compares to the human smelling system using sensor arrays and pattern recognition systems.

It is designed to identify odors and flavors.

Future concepts may have the output of the device, shown on Smart phones



# THE ELECTRONIC TONGUE

The electronic tongue is an instrument that measures and compares tastes.

Chemical compounds responsible for taste are detected by human taste buds and the 7 sensors of electronic instruments detect the same dissolved organic and inorganic compounds.

The types of taste that is generated is divided into five categories:

Sourness

Saltiness

Bitterness

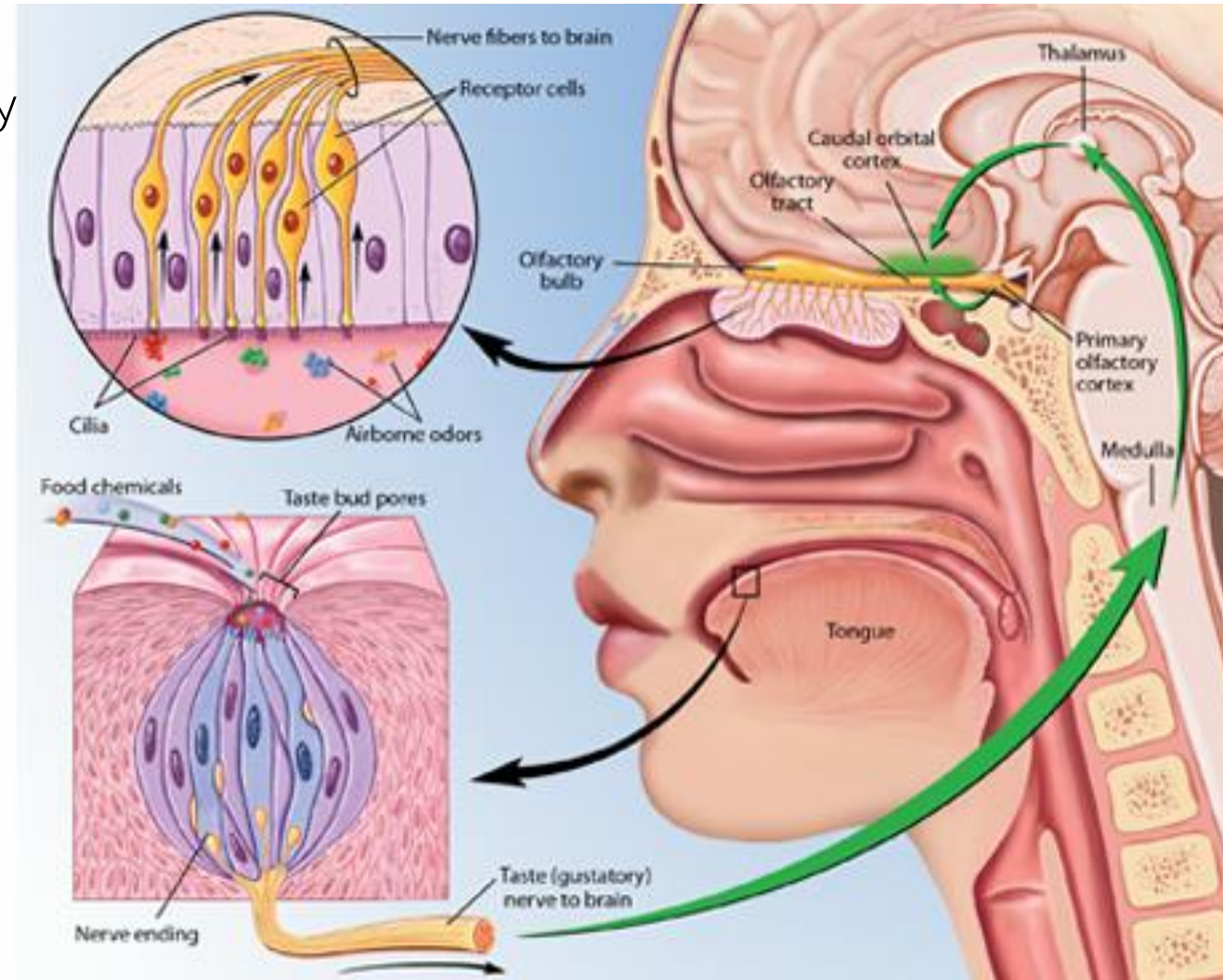
Sweetness

Umami (savoriness)

## TASTE AREAS on the HUMAN TONGUE



- ❖ Taste and smell are separate senses with their own receptor organs, yet they are intimately entwined.
- ❖ Tastants, chemicals in foods, are detected by taste buds, which consist of special sensory cells.
- ❖ When stimulated, these cells send signals to specific areas of the brain, which make us conscious of the perception of taste.
- ❖ Similarly, specialized cells in the nose, pick up odorants - airborne odor molecules.
- ❖ Odorants stimulate receptor proteins found on hair-like cilia at the tips of the sensory cells, a process that initiates a neural response.
- ❖ Ultimately, messages about taste and smell converge, allowing us to detect the flavors of food.



# APPLICATIONS FOR THE ELECTRONIC TONGUE

Electronic tongues have several applications in various industrial areas: the pharmaceutical industry, food and beverage sector, etc. for:

- 1) Analyze flavor ageing in beverages (for instance fruit juice, alcoholic or non-alcoholic drinks, flavored milks...)
- 2) **Quantify bitterness or "spicy level" of drinks or dissolved compounds**
- 3) Quantify taste masking efficiency of formulations (tablets, syrups, powders, capsules, lozenges, etc.)
- 4) Analyze medicines stability in terms of taste
- 5) Benchmark target products
- 6) Monitor environmental parameters
- 7) Monitor biological and biochemical processes



<https://www.youtube.com/watch?v=4gdzxuBWZoM>

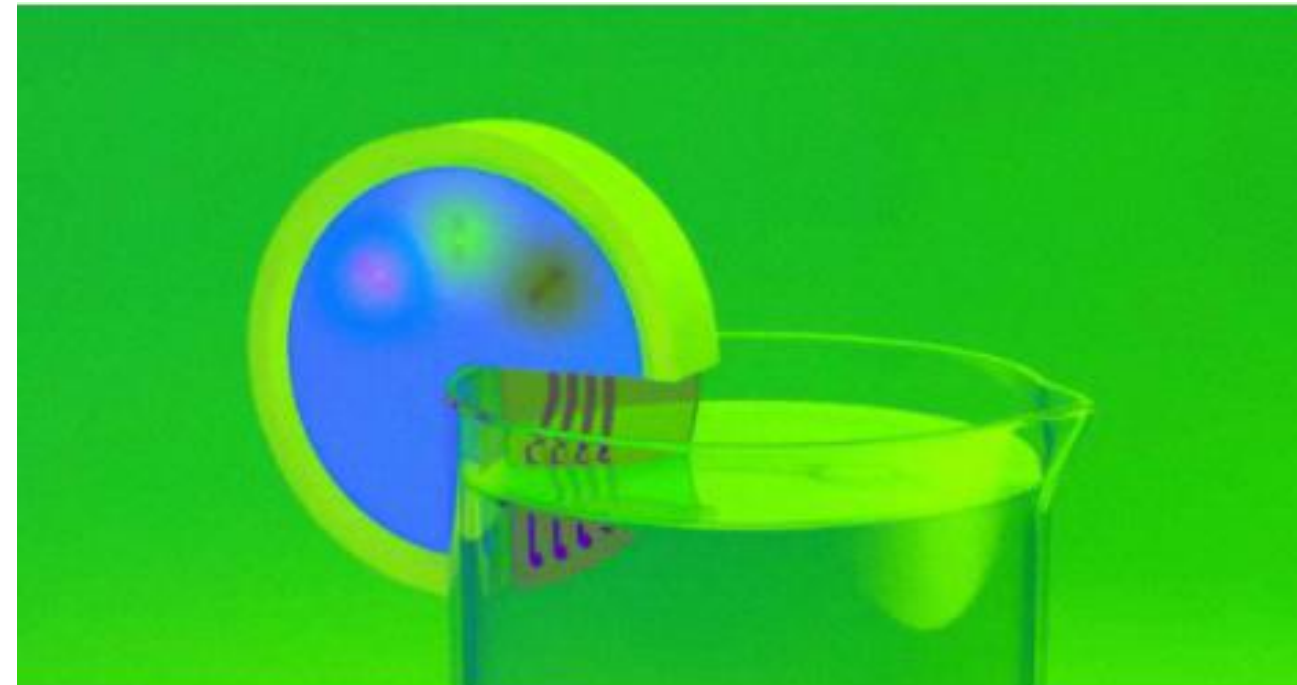
5 minutes

# IBM UNVEILS NEW "ELECTRONIC TONGUE" TO TASTE AND IDENTIFY LIQUIDS

The IBM team calls its electronic tongue Hypertaste, and it looks a bit like a drink coaster with a slit in its side that rests on the edge of a glass of liquid.

Once in this position, an array of electrochemical sensors can sense the presence of molecule combinations in the liquid, analyze them and measure it within a minute.

Once Hypertaste has this fingerprint, it transmits it to a mobile device, which in turn, sends it to a cloud server. There, an Artificial Intelligence software compares that fingerprint to the fingerprints of known liquids and sends the closest match back to the mobile device.









THE END

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