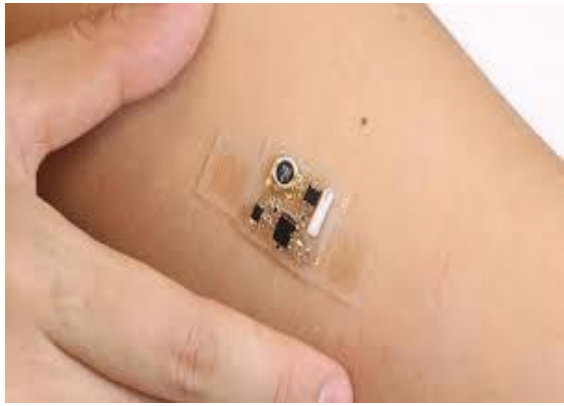
Unit 4

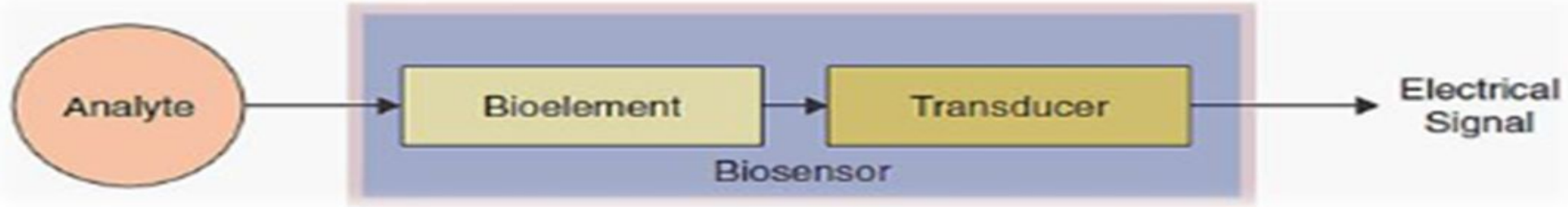
# MOLECULAR MACHINES, BIOSENSOR AND BIOREMEDIATION

## BIOSENSORS



# What is a BIOSENSOR

- These are analytical devices, which measure concentration of an analyte.
- In biosensors, a biological material ( such as enzyme, antibody, whole cell, nucleic acid) is used to interact with the analyte.
- This interaction produces a physical or chemical change, which is detected by the transducer and converted to an electrical signal.
- This signal is interpreted and converted to analyte concentration present in the sample.

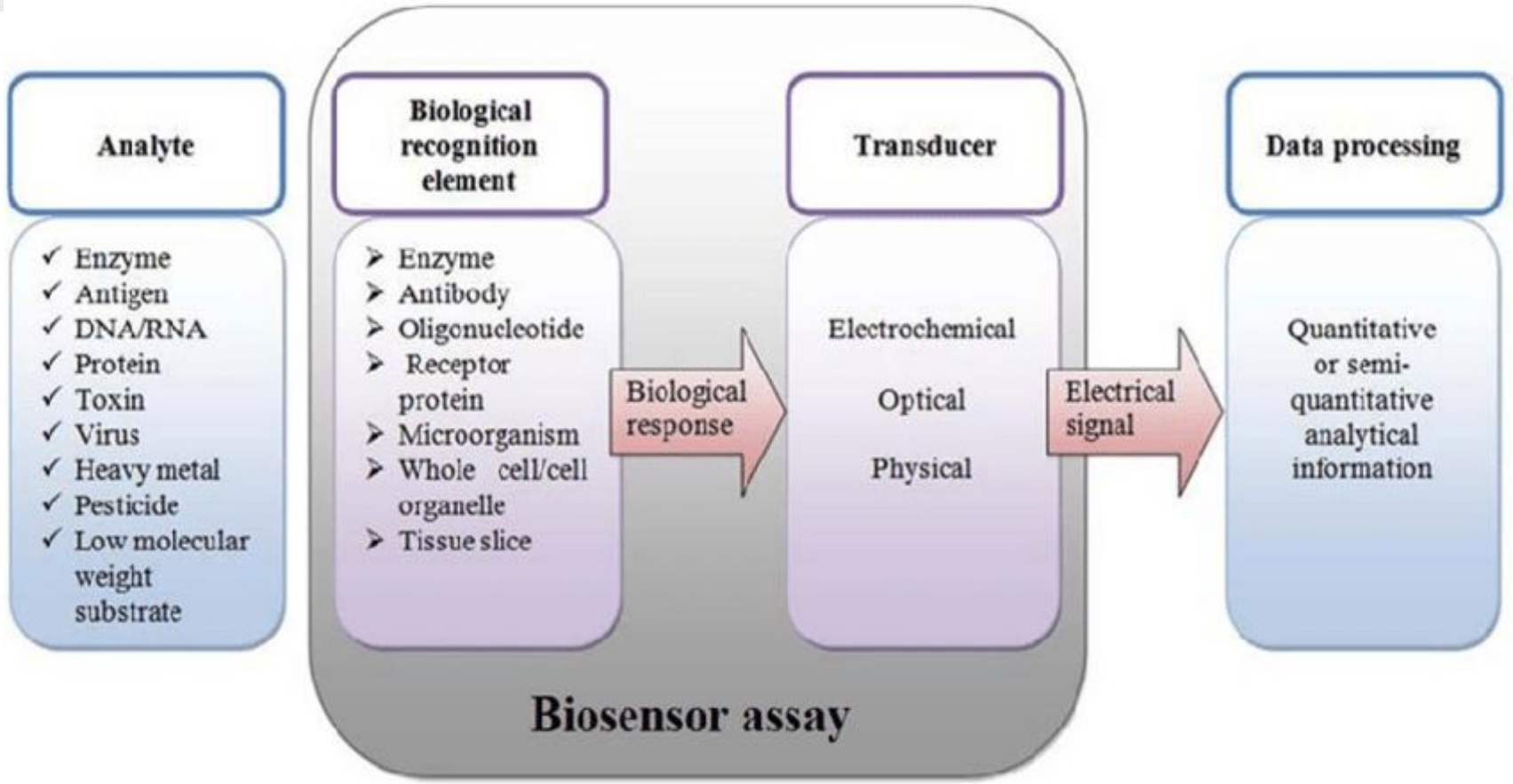


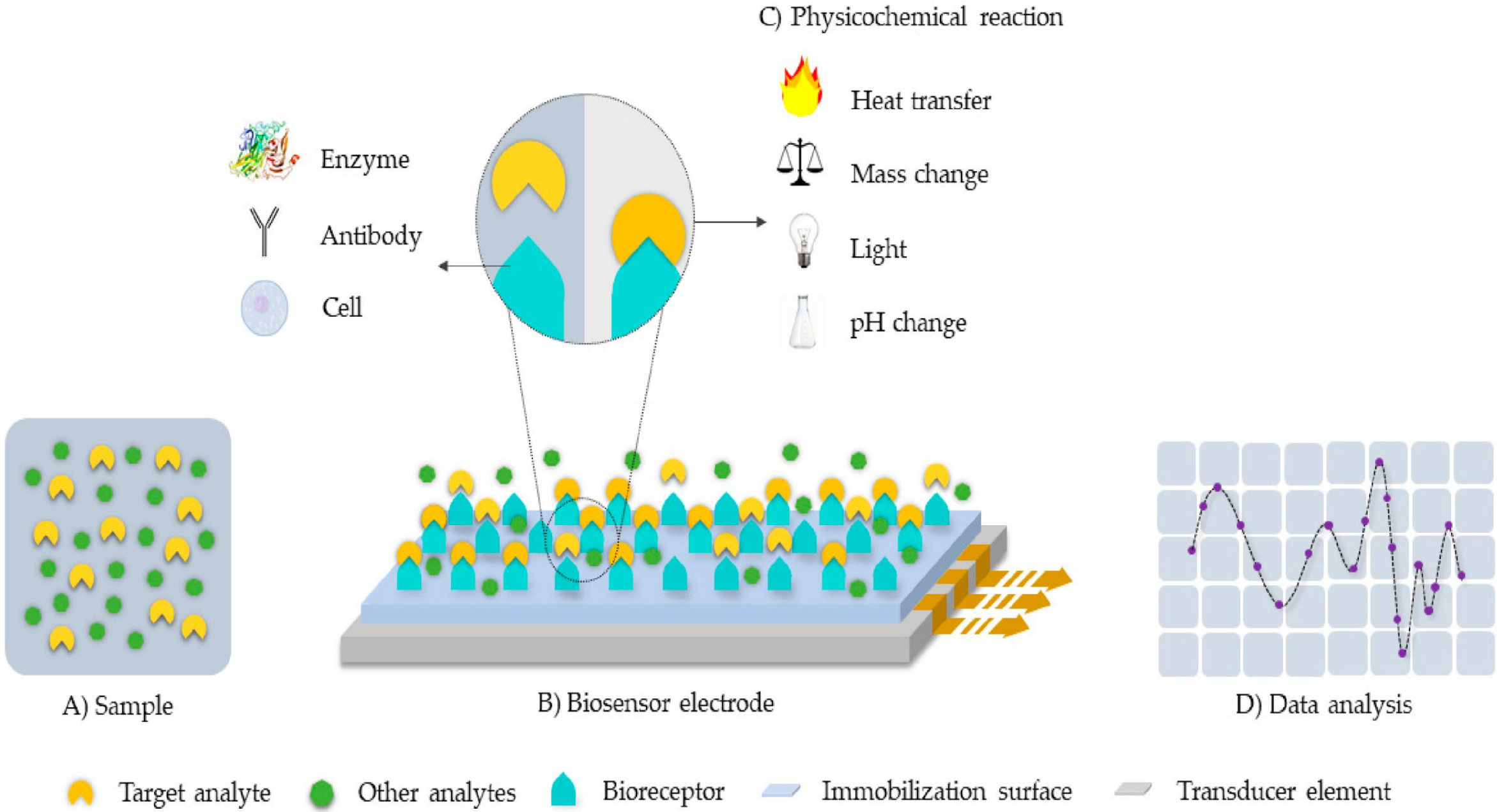
# Father of Biosenser

Father of Biosensors **Leland C. Clark** invented the Clark Oxygen Electrode, a pivotal device that allows real-time monitoring of patient's blood oxygen levels and has made surgery Safer and more successful for millions around the world

# Working principle/ Basic concept

- Basic principle of biosensors involved three elements:
- 1) **biological recognition element** which is highly specific towards biological material analytes, integrated or connected to the physico-chemical transducer
- 2) **transducer** – transduces signal from biological target to electrical signal
- 3) **amplification and detection** - produce discrete or continuous digital electronic signal that is proportional to a specific analyte or group of similar analytes.



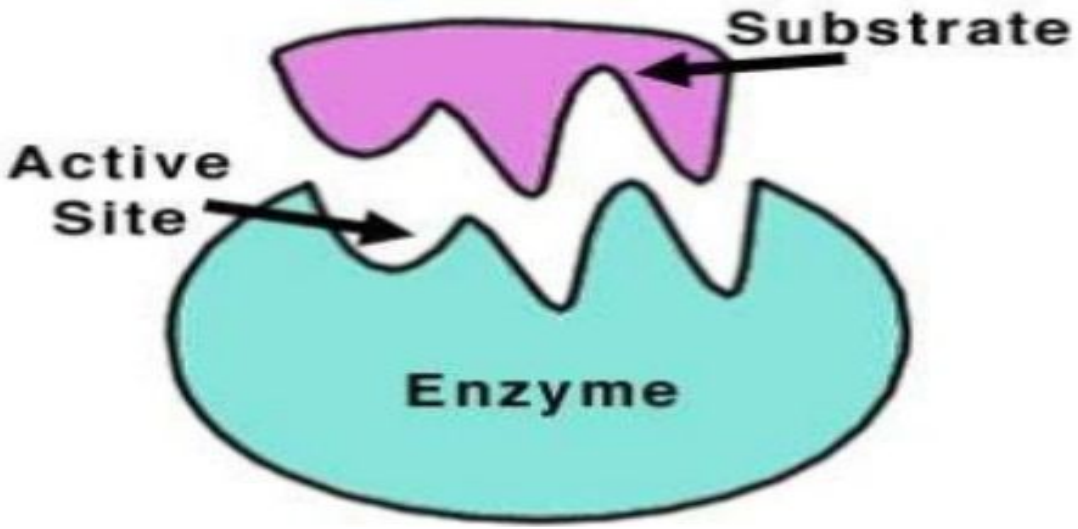

C) Physicochemical reaction
Heat transfer
Mass change
Light
pH change
Enzyme
Antibody
Cell
A) Sample
B) Biosensor electrode
D) Data analysis
Target analyte
Other analytes
Bioreceptor
Immobilization surface
Transducer element

# Components of Biosensor

## 1ST Component: Biological Element

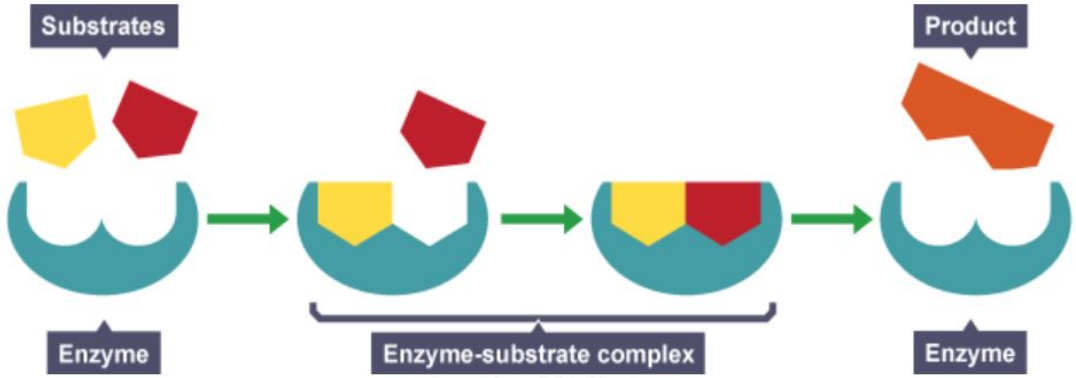
- The component used to bind the target molecule.
- Must be highly specific, stable under storage conditions, and immobilized.

Microorganism
Tissue
Cell
Organelle
Nucleic Acid
Enzyme
Enzyme Component
Receptor
Antibody



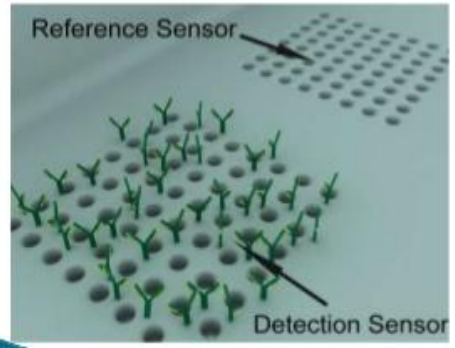
# Mode of action of the Biological Element

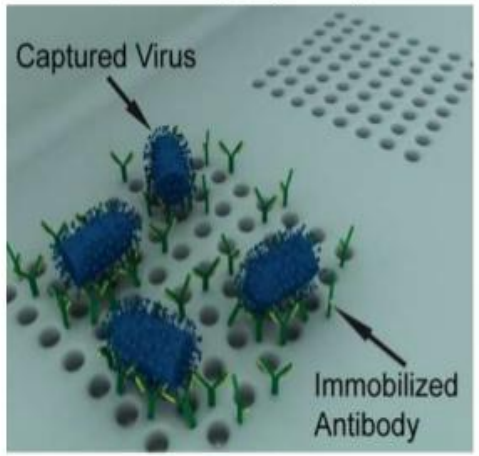
**Enzymes**




## Antibodies

Antibodies are proteins that show outstanding selectivity. Molecules larger than about 10kDa can stimulate an immune response. Many antibodies are commercially available and commonly used in immunoassays. Antibodies are usually immobilized on the surface of the transducer by covalent attachment by conjugation of amino, carboxyl, aldehyde, or sulfhydryl groups. The surface of the transducer must be previously functionalized with an amino, carboxyl, hydroxyl, or other group.



# 2ND Component: Physiochemical Transducer

- Acts as an interface, measuring the physical change that occurs with the reaction at the bioreceptor then transforming that energy into measurable electrical output.

Principle of detection

| | |
|---|---|
| **PIEZOELECTRIC** | **Measures change in mass** |
| **ELECTRO-MECHANICAL** | **Measures change in electric distribution** |
| **OPTICAL** | **Measures change in light intensity** |
| **CALORIMETRIC** | **Measures change in heat** |

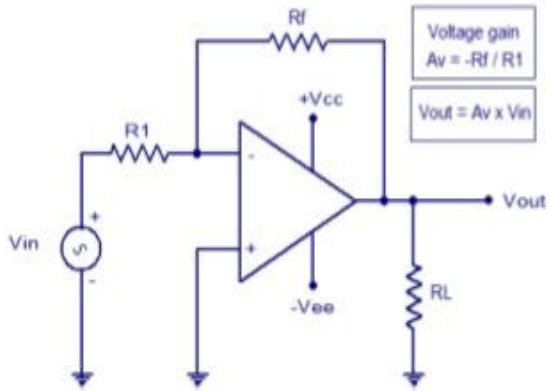
# 3 rd Component: Amplification and detection

## AMPLIFIER

An **amplifier**, is an electronic device that increases the power of a signal

- Power amplifier
- Transistors amplifier
- Operational amplifier etc

OP-AMP



opamp inverting amplifier

## A/D CONVERTER

- Counter controlled A/D converter
- Successive approximation A/D converter
- Flash/parallel A/D converter
- Dual slope A/D converter

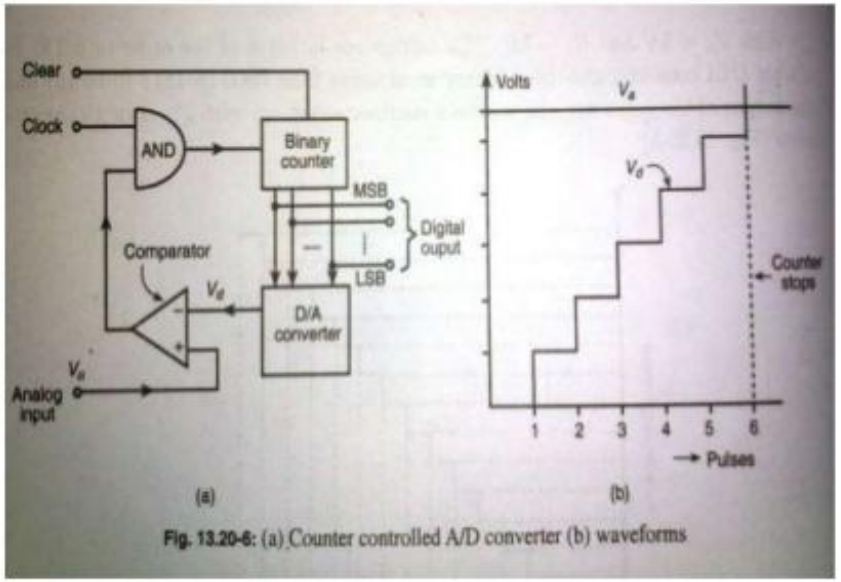
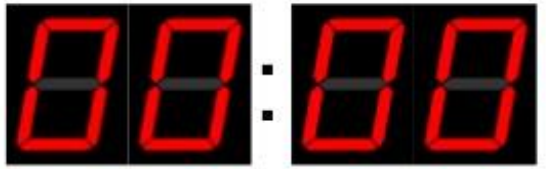
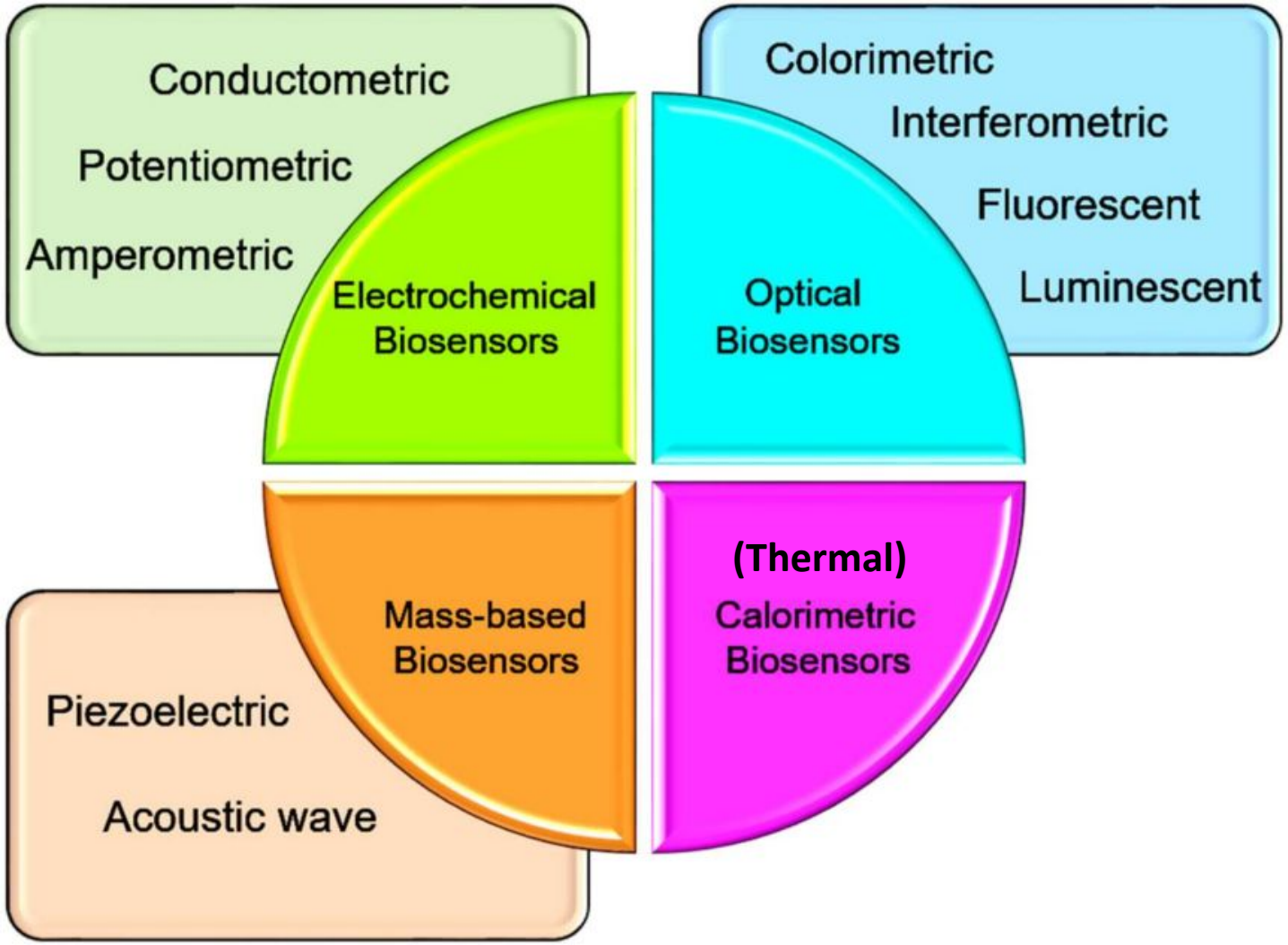


Fig. 13.20-6: (a) Counter controlled A/D converter (b) waveforms


4DIGIT 7 SEGMENT DISPLAY

# Types of Biosensor

Depending on transducing mechanism used, the Biosensors can be of many types such as:



# Resonant Biosensor

❑ **Resonant Biosensors.**

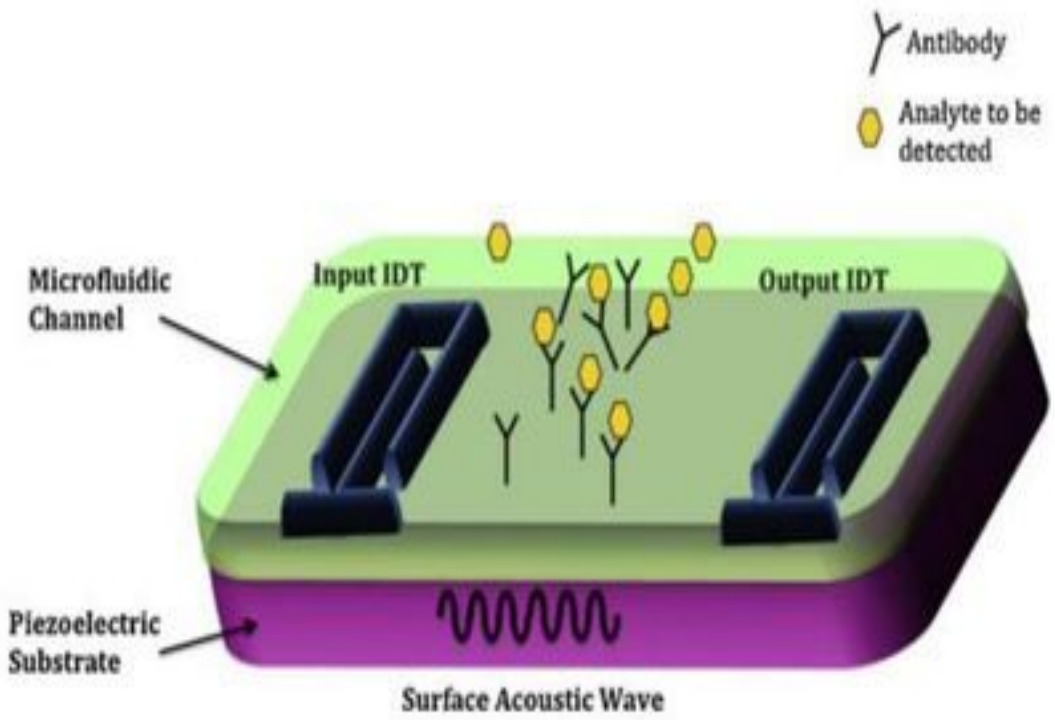
- An Acoustic Wave Transducer is coupled with Bioelement.
- Measures the change in Resonant Frequency.

➢ Analyte - Antigen

➢ Bioelement – Antibody

➢ Transducer – Acoustic wave transducer

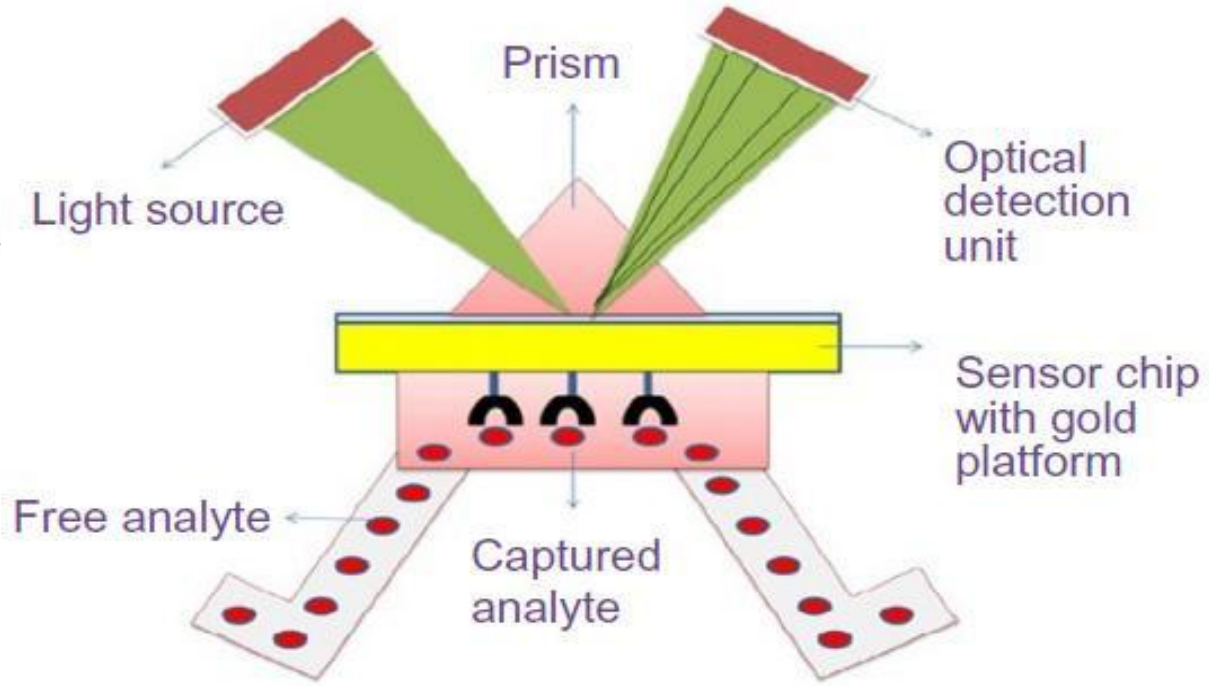
➢ Signal – Change in frequency/mass measured



# Optical detection Biosensor

The output transduced signal that is measured is light for this type of biosensor.

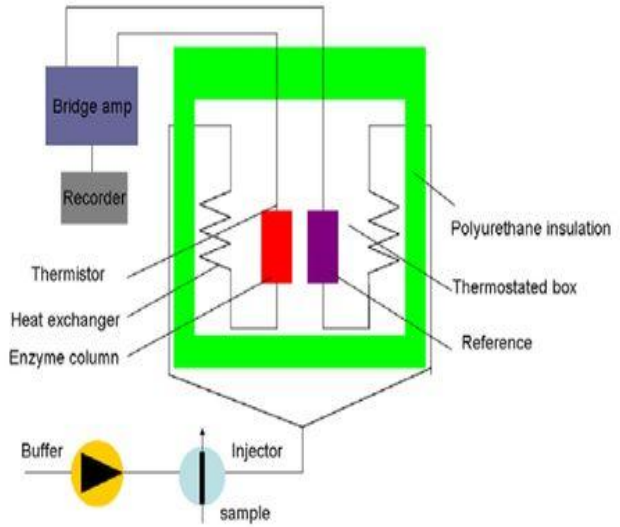
The biosensor can be made based on optical diffraction. In optical diffraction based devices, a silicon wafer is coated with a protein via covalent bonds. The wafer is exposed to UV light through a photo-mask and the antibodies become inactive in the exposed regions. When the diced wafer chips are incubated in an analyte, antigen-antibody bindings are formed in the active regions, thus creating a diffraction grating. This grating produces a diffraction signal when illuminated with a light source such as laser. The resulting signal can be measured.



# Thermal detection Biosensor

- This type of biosensor work on the fundamental properties of biological reactions, namely absorption or production of heat, which in turn changes the temperature of the medium in which the reaction takes place.
- They are constructed by combining immobilized enzyme molecules with temperature sensors. When the analyte comes in contact with the enzyme, the heat reaction of the enzyme is measured and is calibrated against the analyte concentration.
- The total heat produced or absorbed is proportional to the molar enthalpy and the total number of molecules in the reaction.

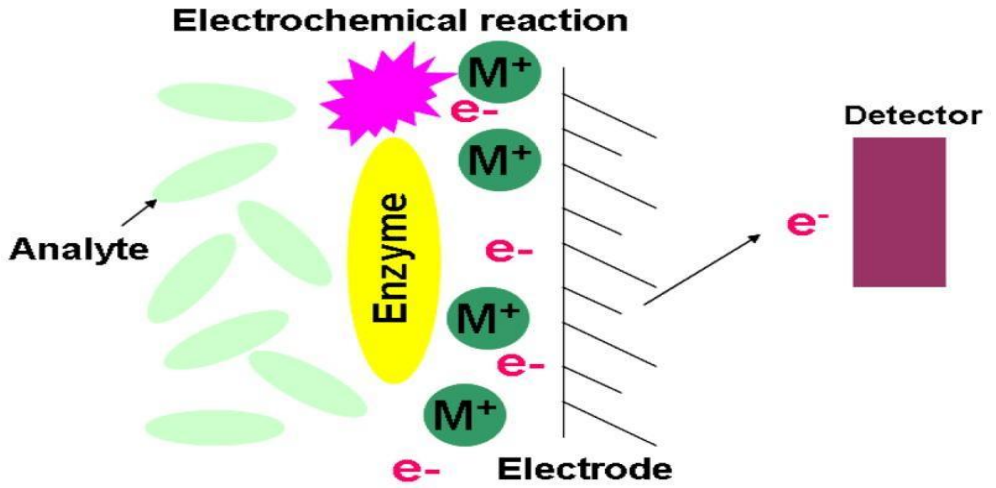
- Analyte - Antigen
- Bioelement – Immobilized enzyme
- Transducer – Thermistor
- Signal – Heat measured




- Common applications of this type of biosensor include the detection of pesticides and pathogenic bacteria.

# Electrochemical Biosensor

Many chemical reactions produce or consume ions or electrons which in turn cause some change in the electrical properties of the solution which can be sensed out and used as measuring parameter.




## *Electrochemical Biosensor types:*

- Potentiometric
  : measure E
- Amperometric
  : apply E, measure I
- Conductimetric
  : measure the change in conductance

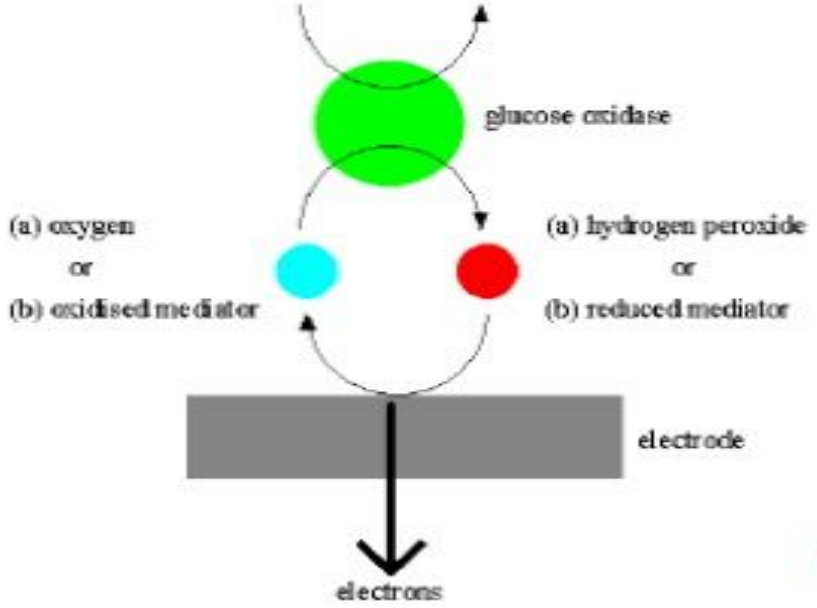
# Application of Biosensor

# Glucose Biosensor

A amperometric glucose biosensor measures the current (electron) arising during the reaction.

**Principle:**

1. Glucose reacts with glucose oxidase (GOD) to form gluconic acid while producing 2 electron and two protons, thus reducing GOD.
2. The reduced GOD with surround oxygen , electron and protons react to produce hydrogen peroxide and oxidised GOD (original form)
3. Consumption of oxygen or production of $H_2O_2$ can be detected with platinum electrode.



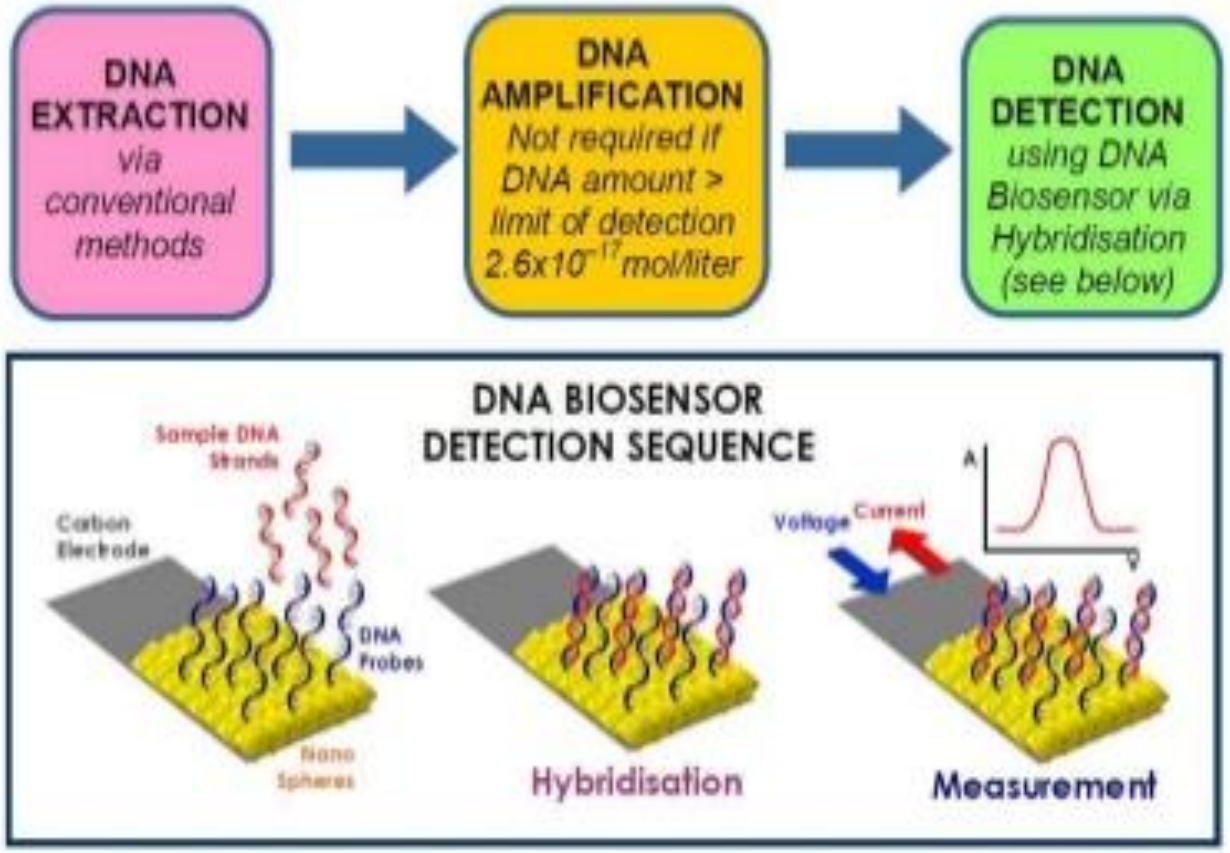
# Biosensors in disease detection

## DNA BIOSENSOR

- Motivated by the application to clinical diagnosis and genome mutation detection

Steps involved in dna recognition layer:

1. Formation of DNA recognition layer
2. Actual hybridization event
3. Transformation of hybridization event into an electrical signal

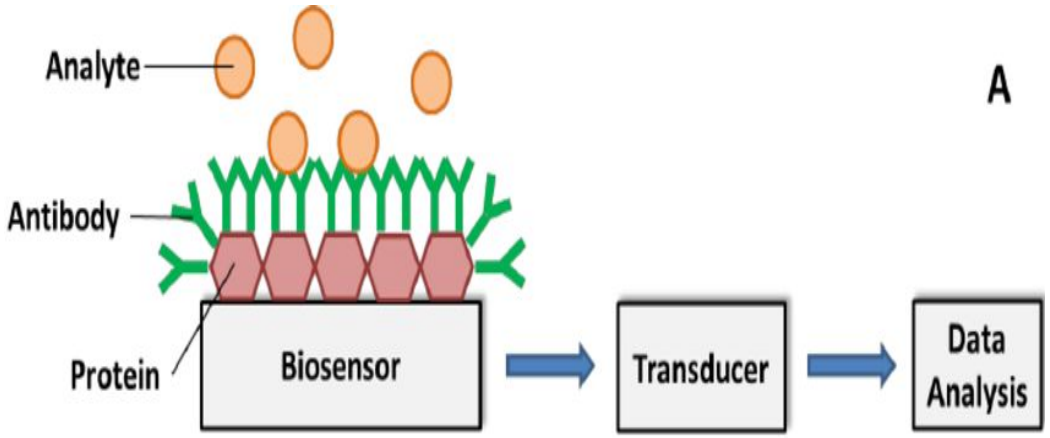


# Detection of pollutants

## Methods

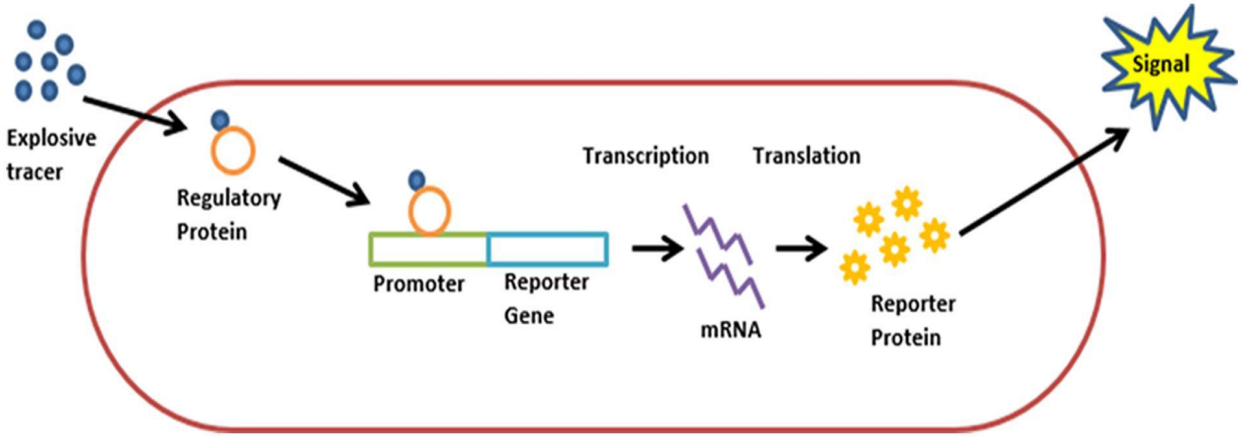
### Immunoassay

- Biosensors has developed to detect various organic molecule including benzopyrene and parathion
- Based on immunological reaction.
- Here antibodies employed to detect specific environmental pollutant.
- Antibodies coupled with transducer, which convert binding event to a signal that can be analysed.




### Reporter gene

- Reporter gene of a cell can detect the external pollutants.
- This gene code for light, such as lux gene.
- When light is emitted indicating, pathway induced in the presence of specific pollutant.



# Questions

1. What are biosensors? Elaborate on the components of a biosensor?
2. Write short notes on (1) Resonant (2) Optical (3) Thermal (4) Ion Selective (5) Electrochemical biosensors.
3. Explain the working of glucose biosensor?
4. What is the application of biosensors in (1) Detection of diseases (2) detection of pollutants (3) ?