Biosensors

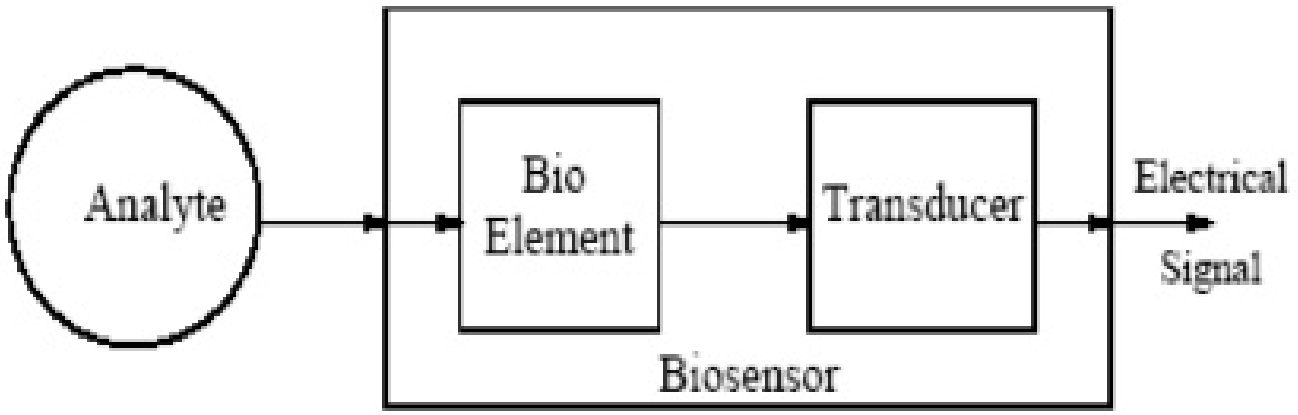
Lecture 24

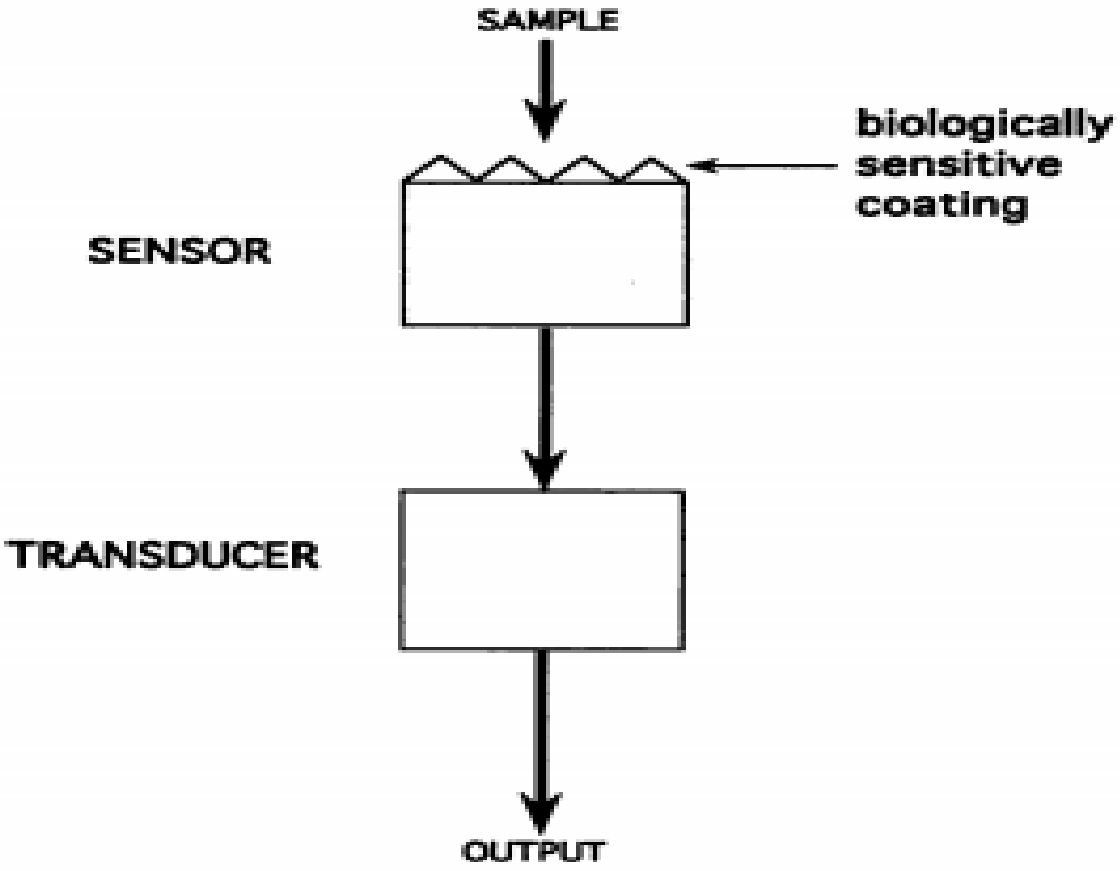
Sensor

- A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer of by an instrument.

Biosensor

- A biosensor is an analytical device, used for the detection of an analyte, that combines a biological component with a physicochemical detector.



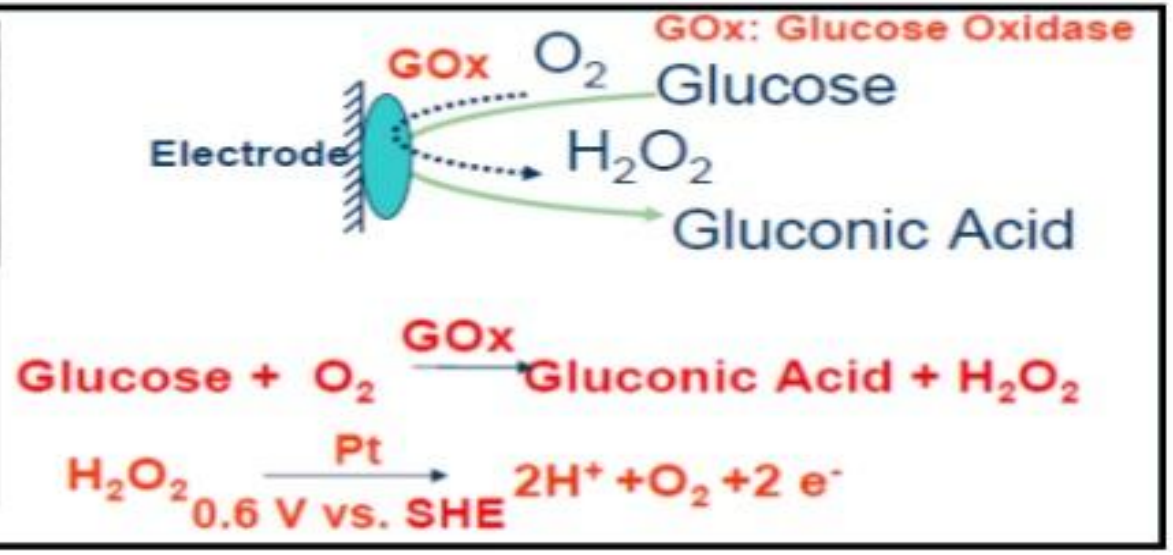


Structure of a biosensor, illustrating its two main components: a sensor and a transducer.

History

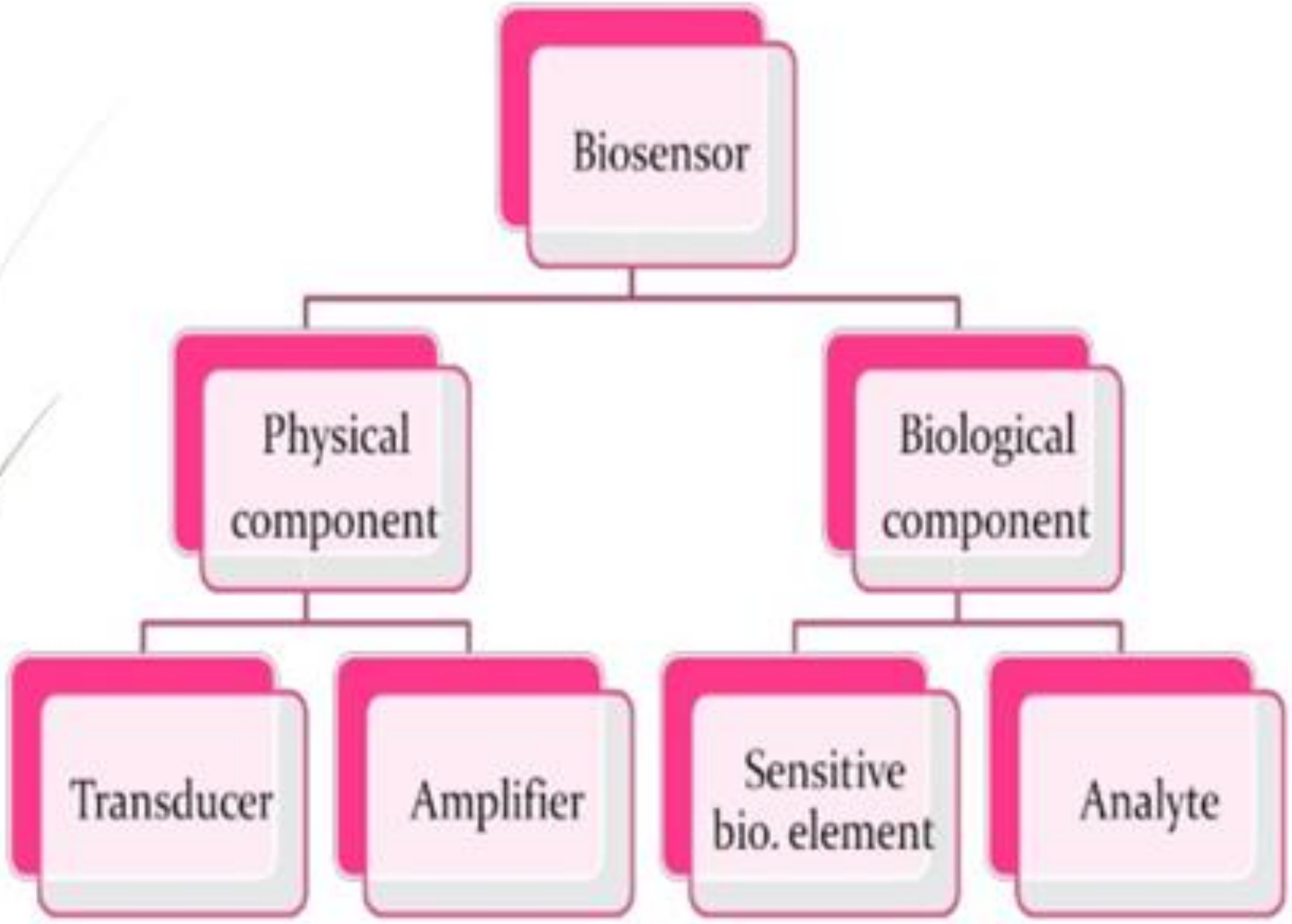
FATHER OF BIOSENSORS

Professor Leland C Clark (1918–2005)

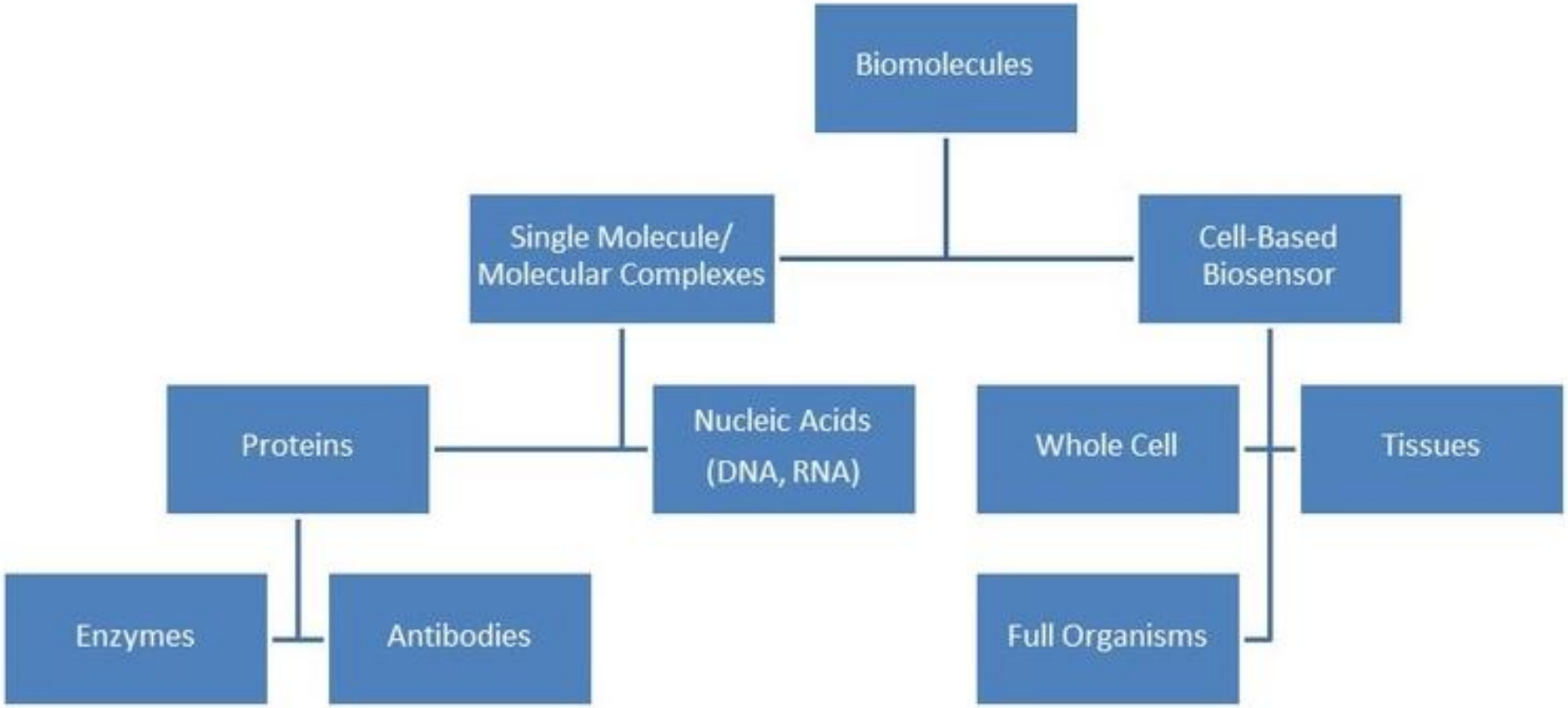


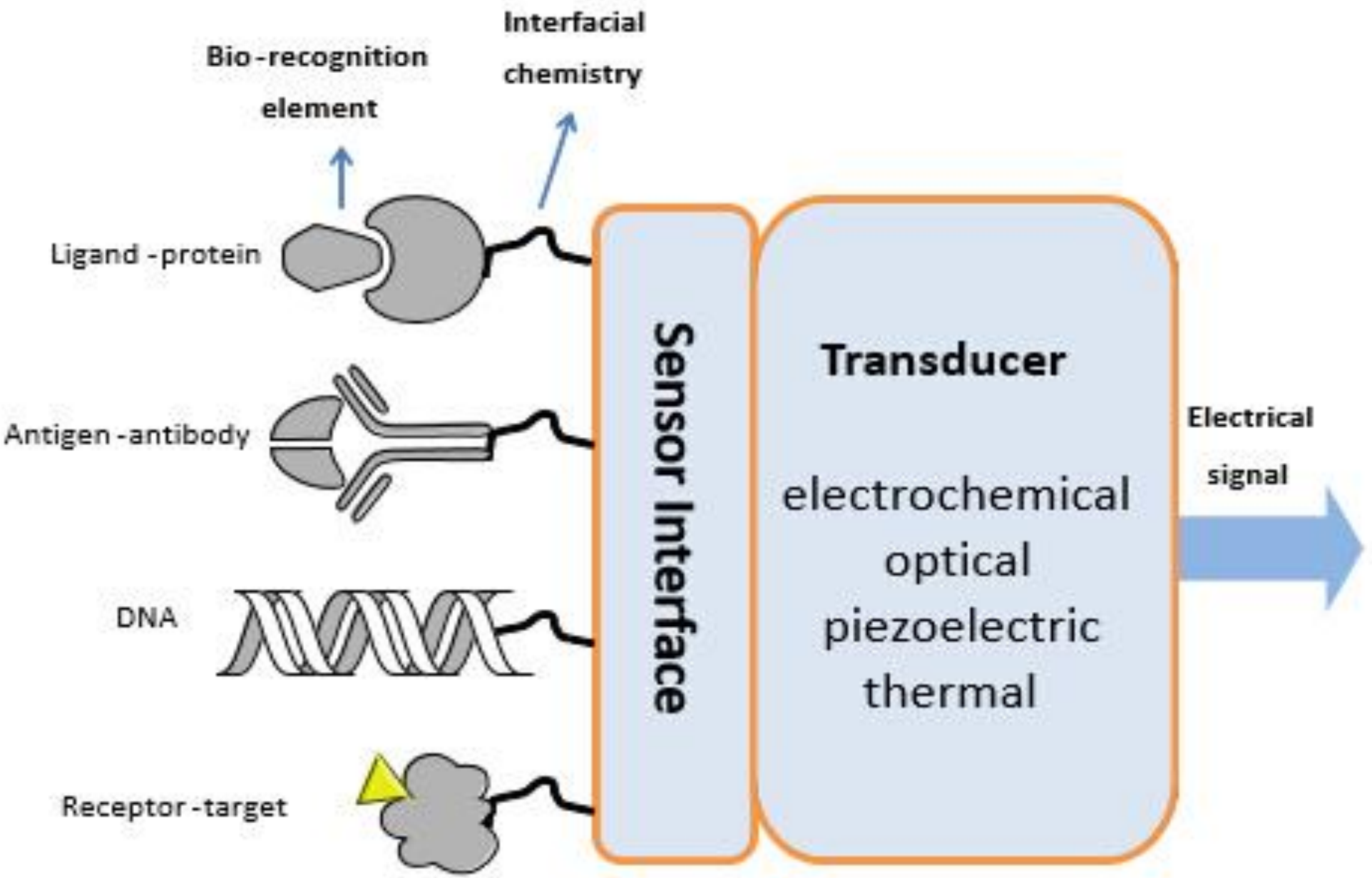
The first and the most widespreadly used commercial biosensor: the blood glucose biosensor – developed by *Leland C. Clark in 1962*

Components of Biosensor



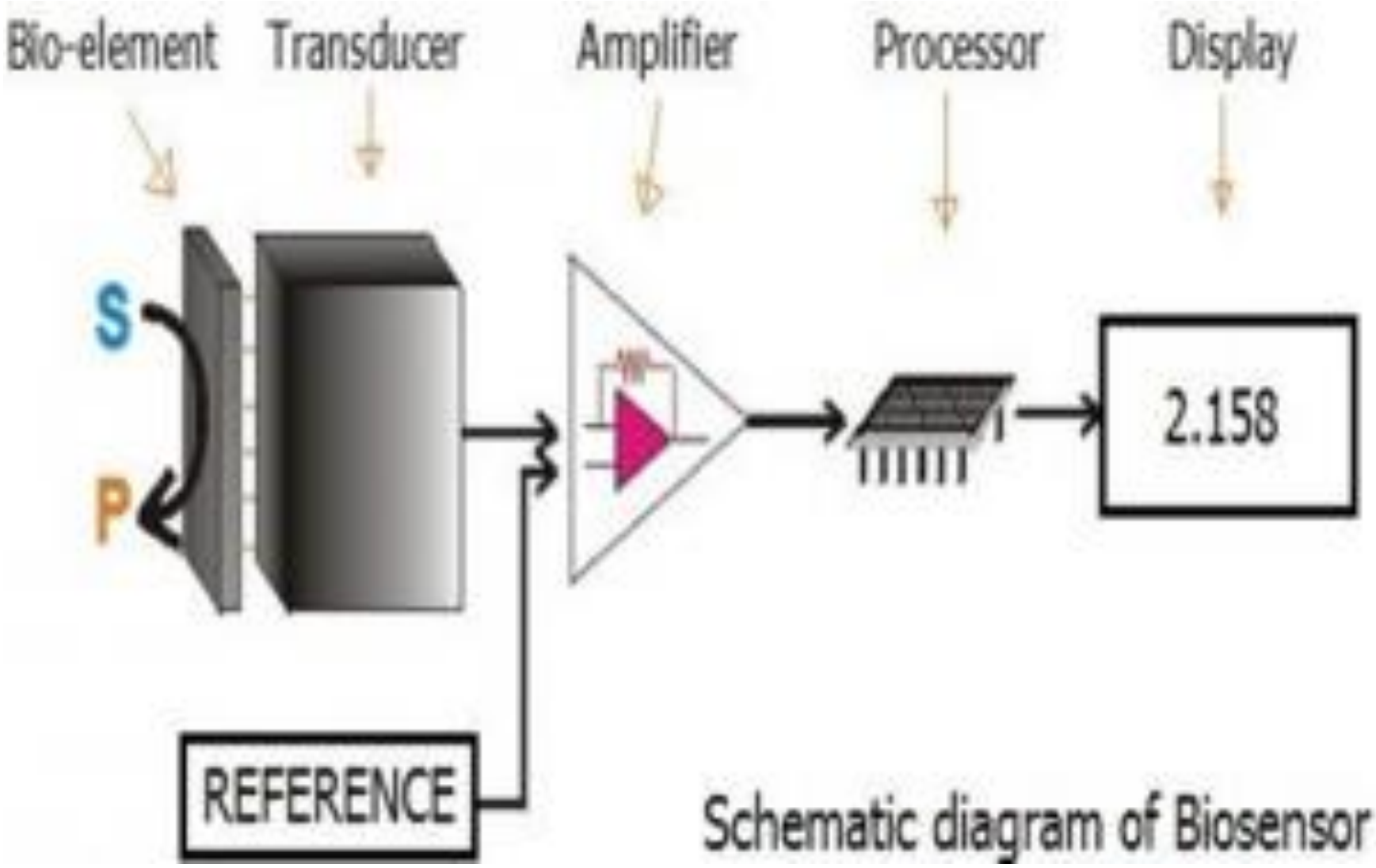
Common Analytes




Bio-recognition element
Interfacial chemistry
Ligand -protein
Antigen -antibody
DNA
Receptor -target
Sensor Interface
Transducer
electrochemical
optical
piezoelectric
thermal
Electrical signal

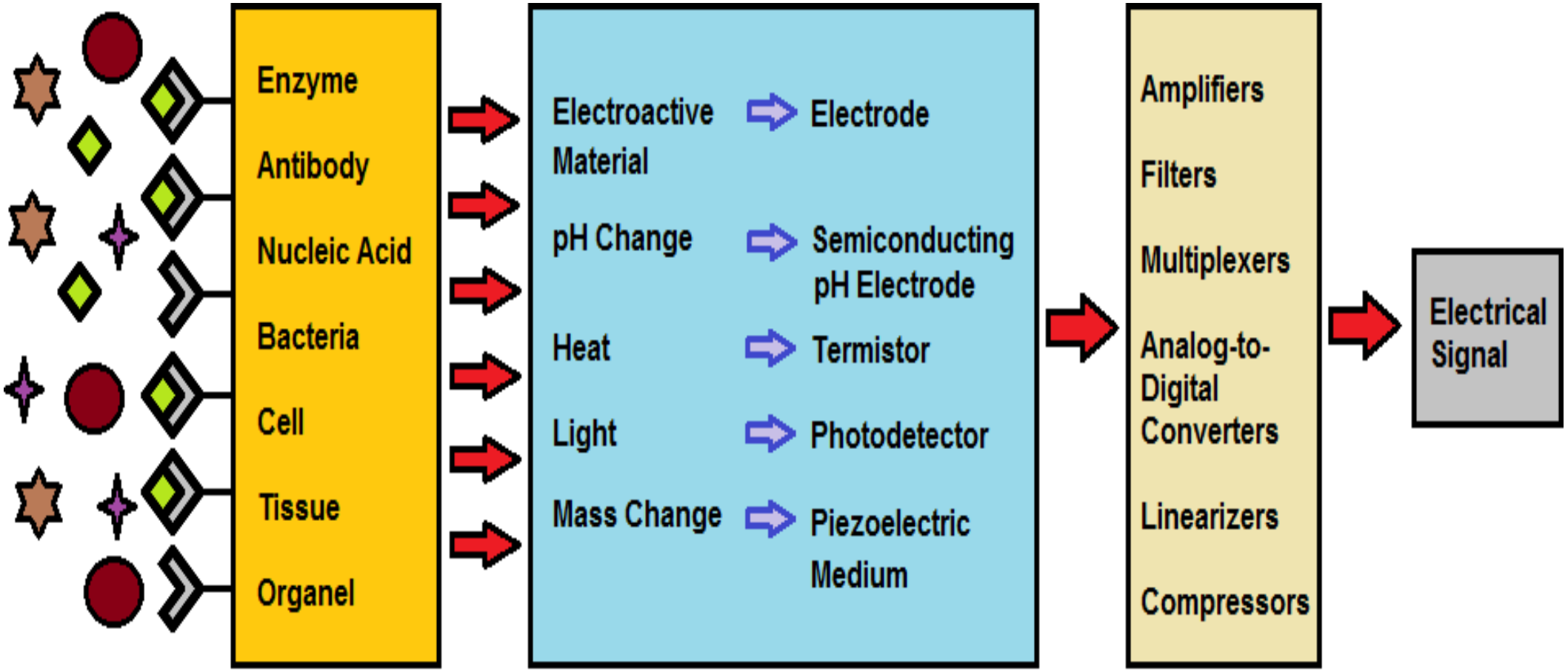
Elements

- **Sample**: The biological component of analyte which is under study
- **Transducer**: a device which converts energy from one form to the other. It is a combination of :
  - **Bioreceptor**: the sensitive biological element
  - **Electrical interface**: The detector which works in a physicochemical way: optical, piezoelectric, electrochemical etc.) that transforms the signal to electric form
- **Electronic system**: Combination of electronic devices ie., amplifier, signal processer and display

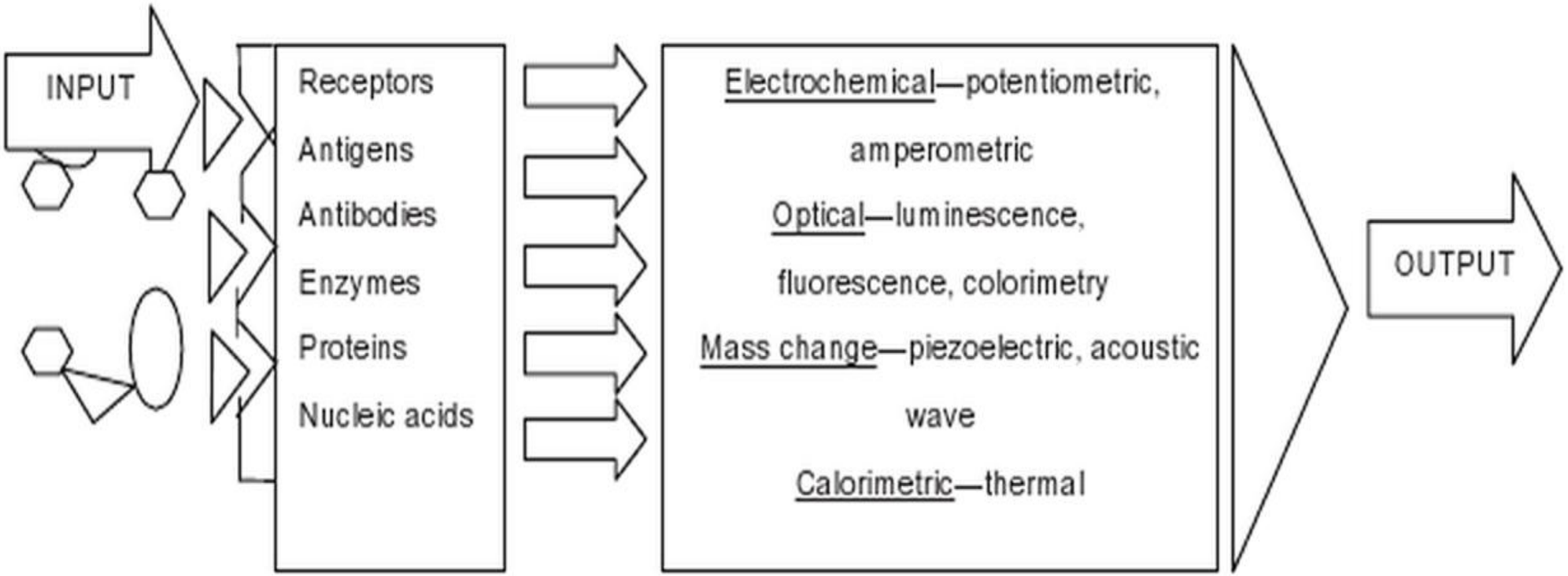


Schematic diagram of Biosensor

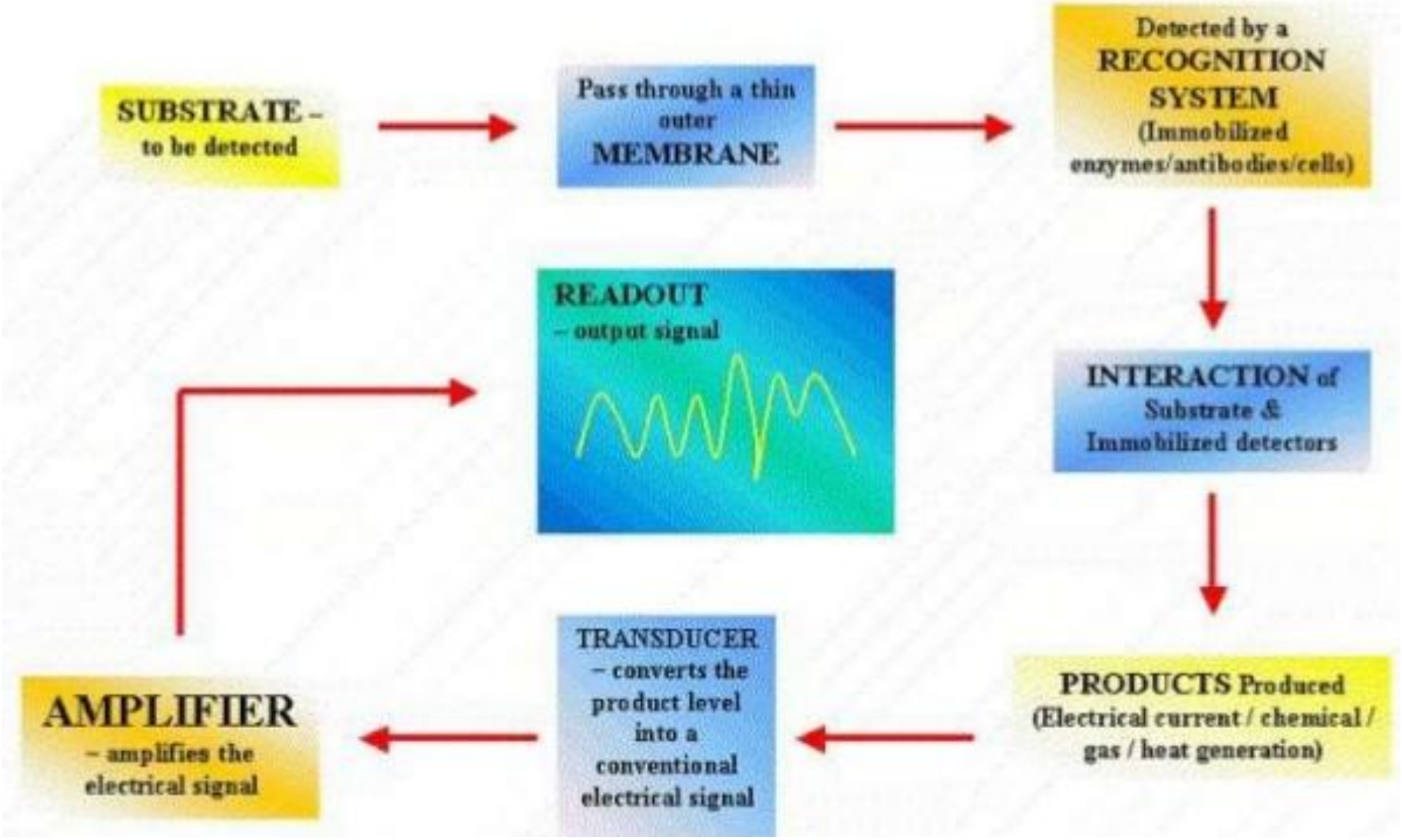
Elements of biosensor



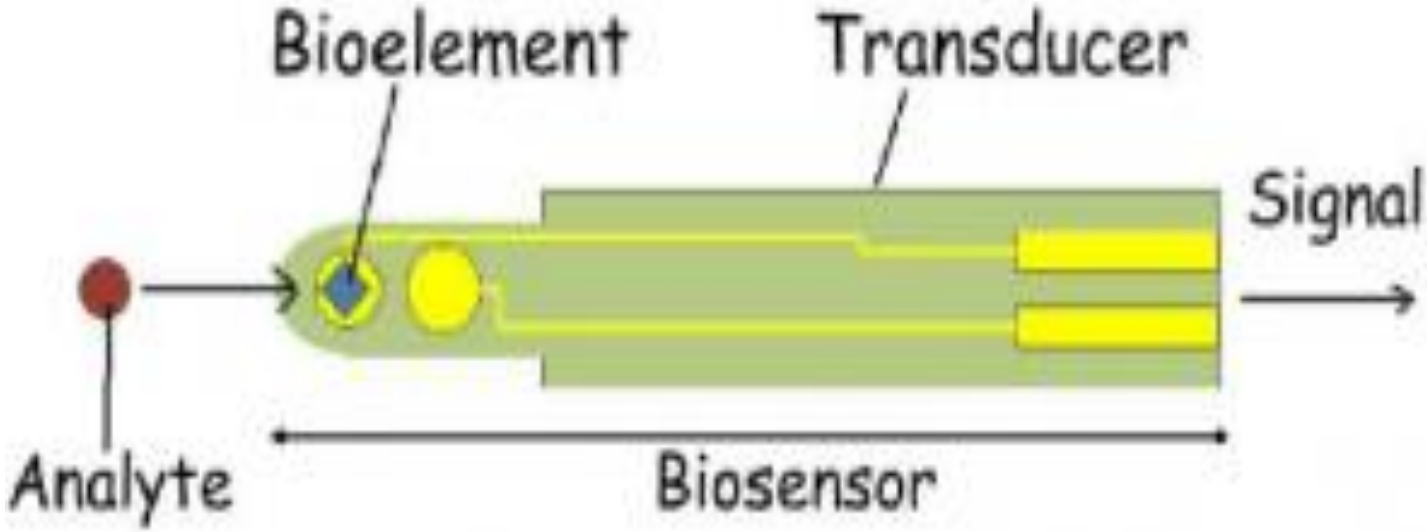
Elements of biosensor



How biosensors work

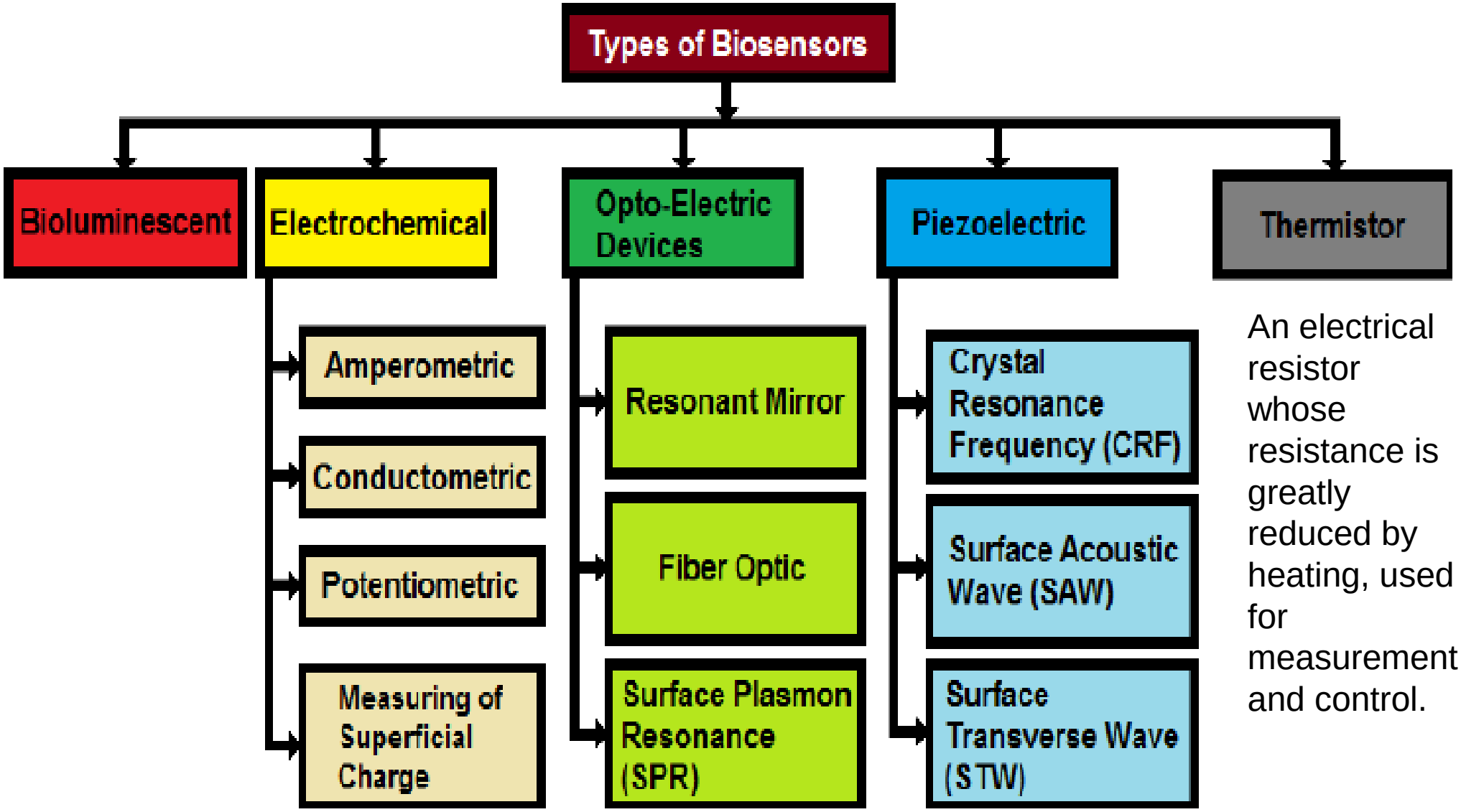


Blood glucose testing



Basic characteristics of a biosensor

- **Linearity**: Linearity of the sensor should be high for the detection of high substrate concentration.
- **Sensitivity**: Value of the electrode response per substrate concentration
- **Selectivity**: Chemical interference must be minimized for obtaining correct result
- **Response time**: Time necessary for having 95% of the response



An electrical resistor whose resistance is greatly reduced by heating, used for measurement and control.

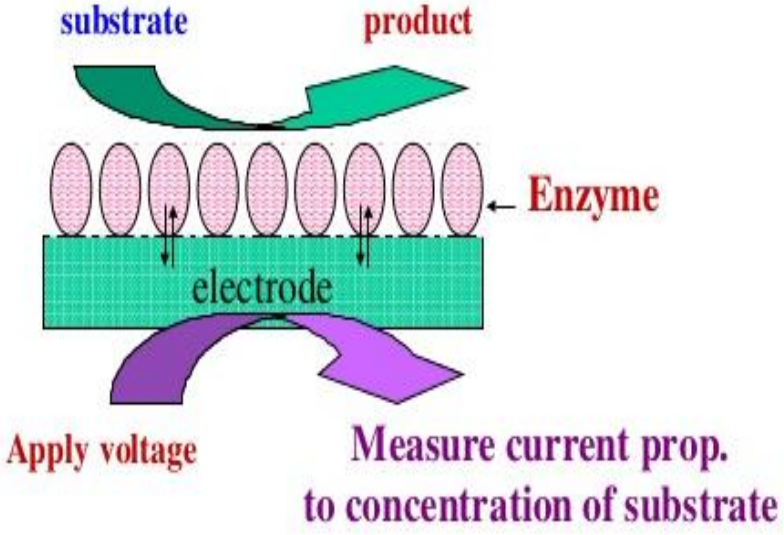
Electrochemical transducers

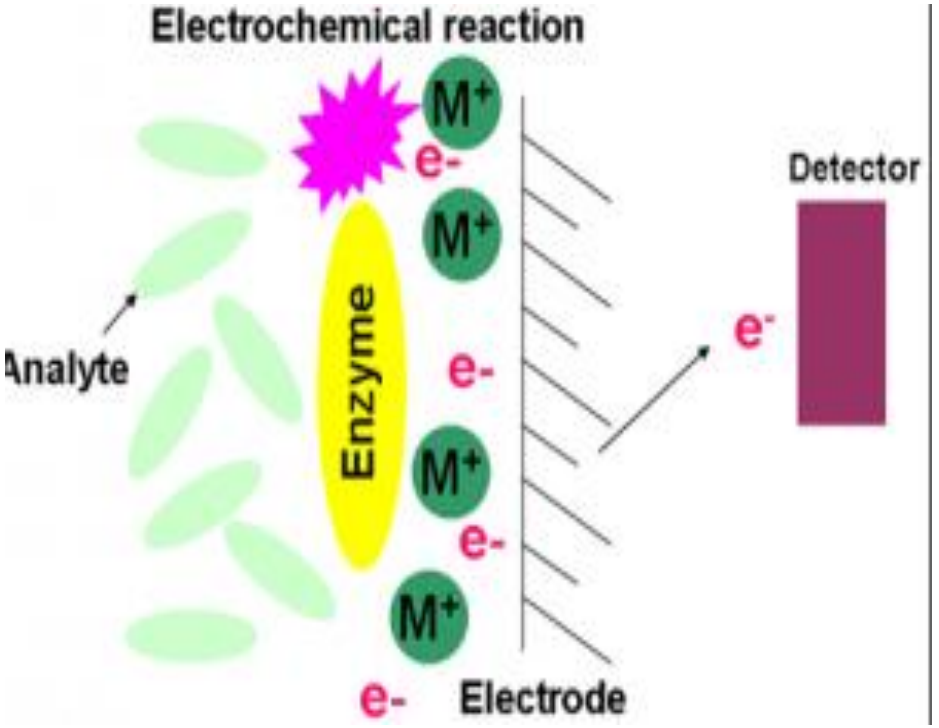
- **Principle**: Many chemical reactions produce or consume ions or electrons which in term cause some change in the electrical properties of the solution which can be measured out and used as measuring parameter.

Electrochemical transducers

- In this case, an electrical signal is measured, which shows significant differences in magnitude if antigen-antibody complex are formed.
- The main electrochemical transducers are:
  - **amperometric** (measuring of current),
  - **potentiometric** (measuring of electrode potential or voltage differences)
  - **conductimetric** (measuring of conductivity or resistance).

Principle of Electrochemical Biosensors



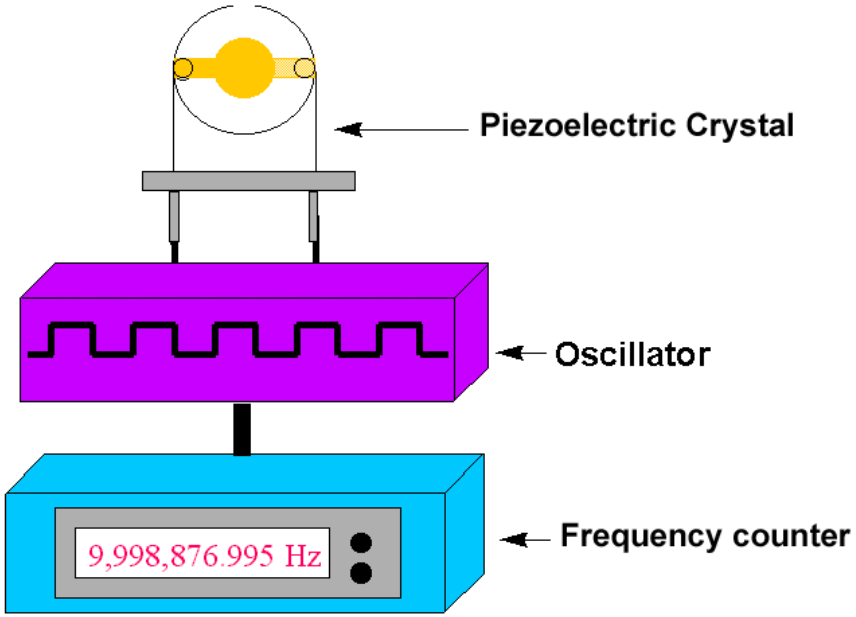


Blood Glucose Biosensor

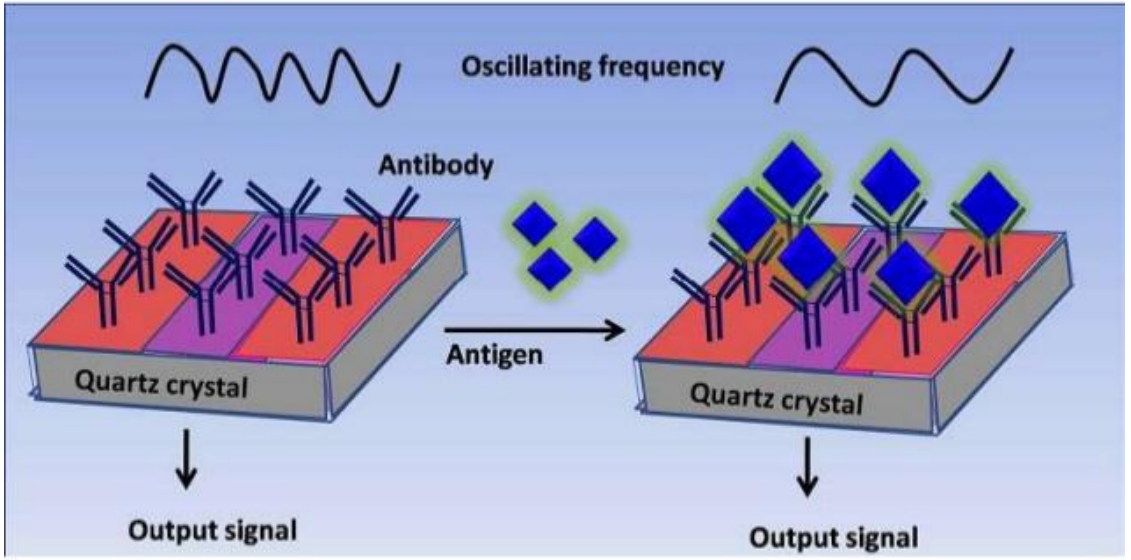
- Amperometric Biosensor
- Enzyme **Glucose oxidase** (GOx) catalyzes the oxidation of **glucose** by molecular oxygen producing **glucolactone** and **hydrogen peroxide**.
- In order to work as a catalyst, GOx requires a redox cofactor –flavin adenine dinucleotide (FAD), works as an initial electron acceptor and is reduced to FADH2.
- Glucose + GOx –FAD^{+} Glucolactone + GOx – FADH2

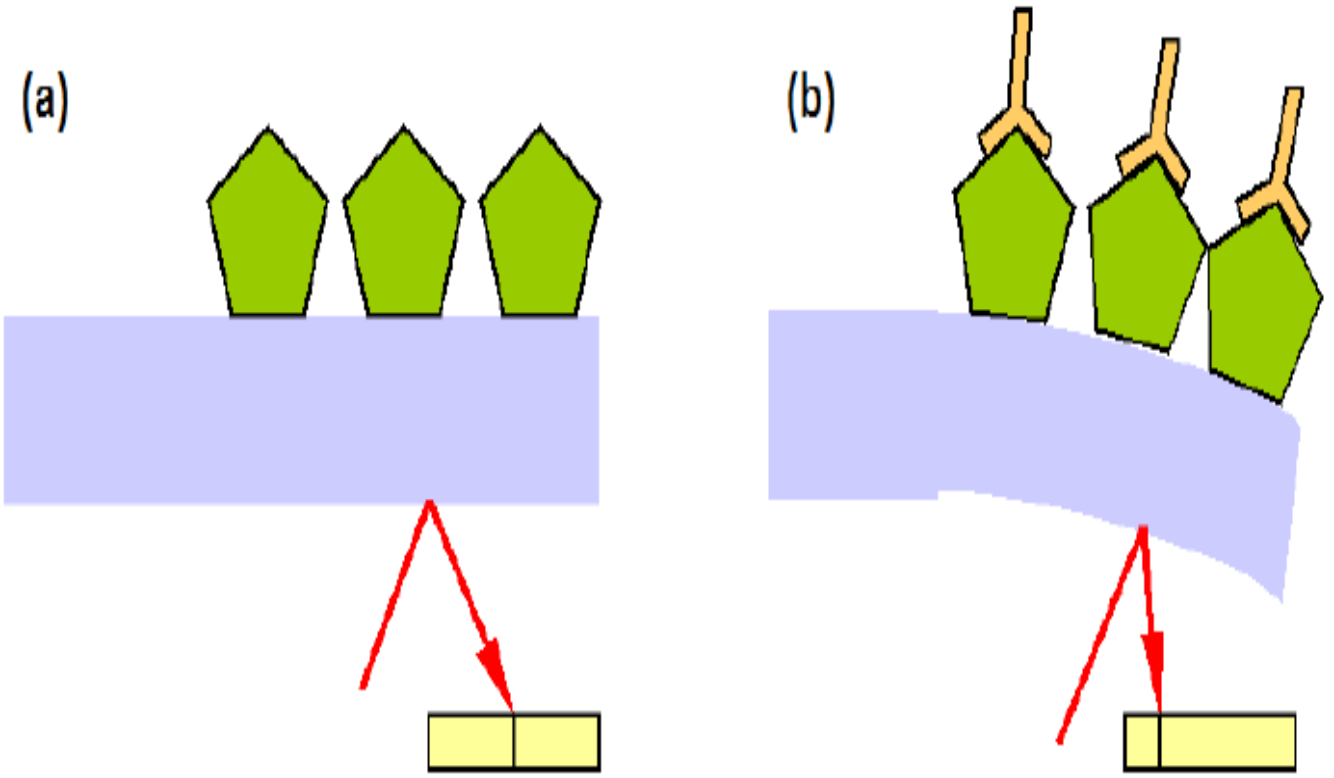
$\rightarrow$

Piezo-electric – measures quartz vibrations under the influence of an electric field



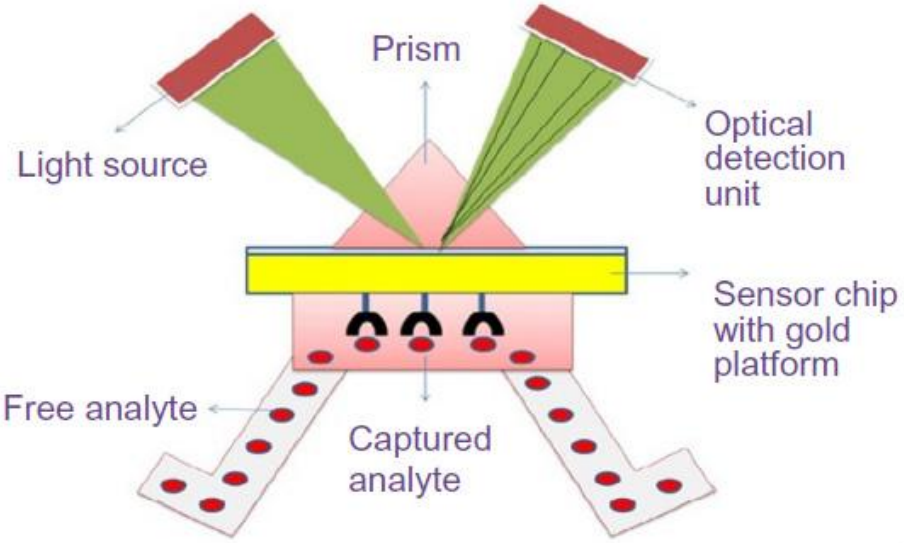
piezoelectric immunosensor



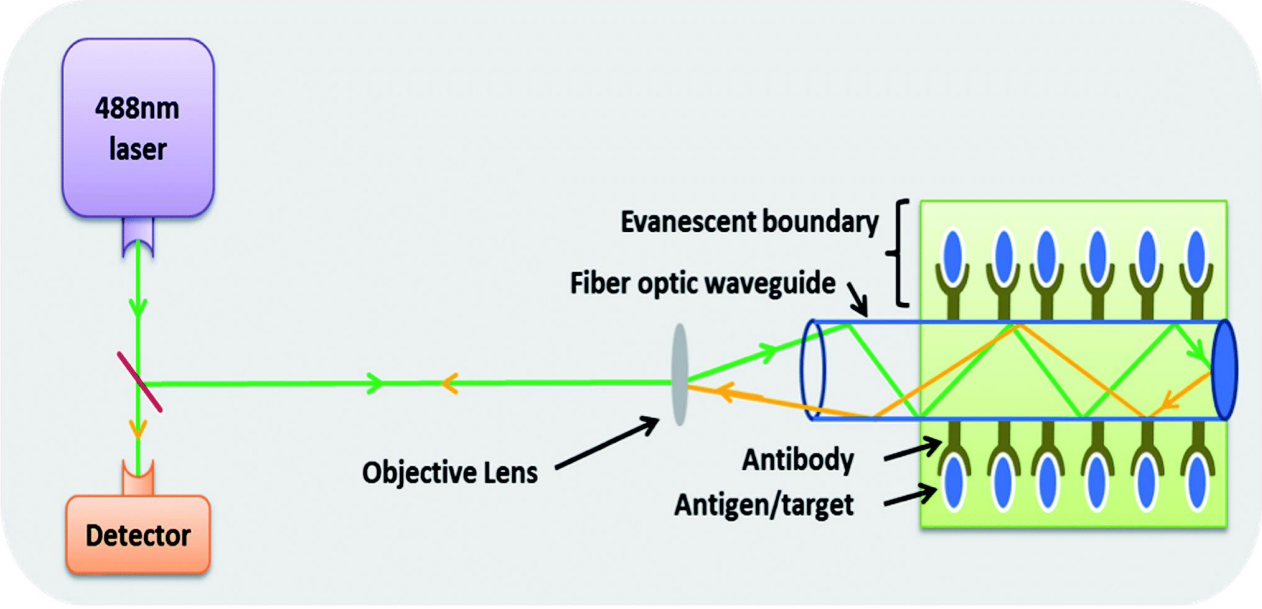


Microcantilever working in static mode. The formation of the antigen-antibody complexes provokes a surface stress and, consequently, a deflection of microcantilever, which is detected optically.

Optical - involve determining changes in light absorption between the reactants and products of a reaction, or measuring the light output by a luminescent process

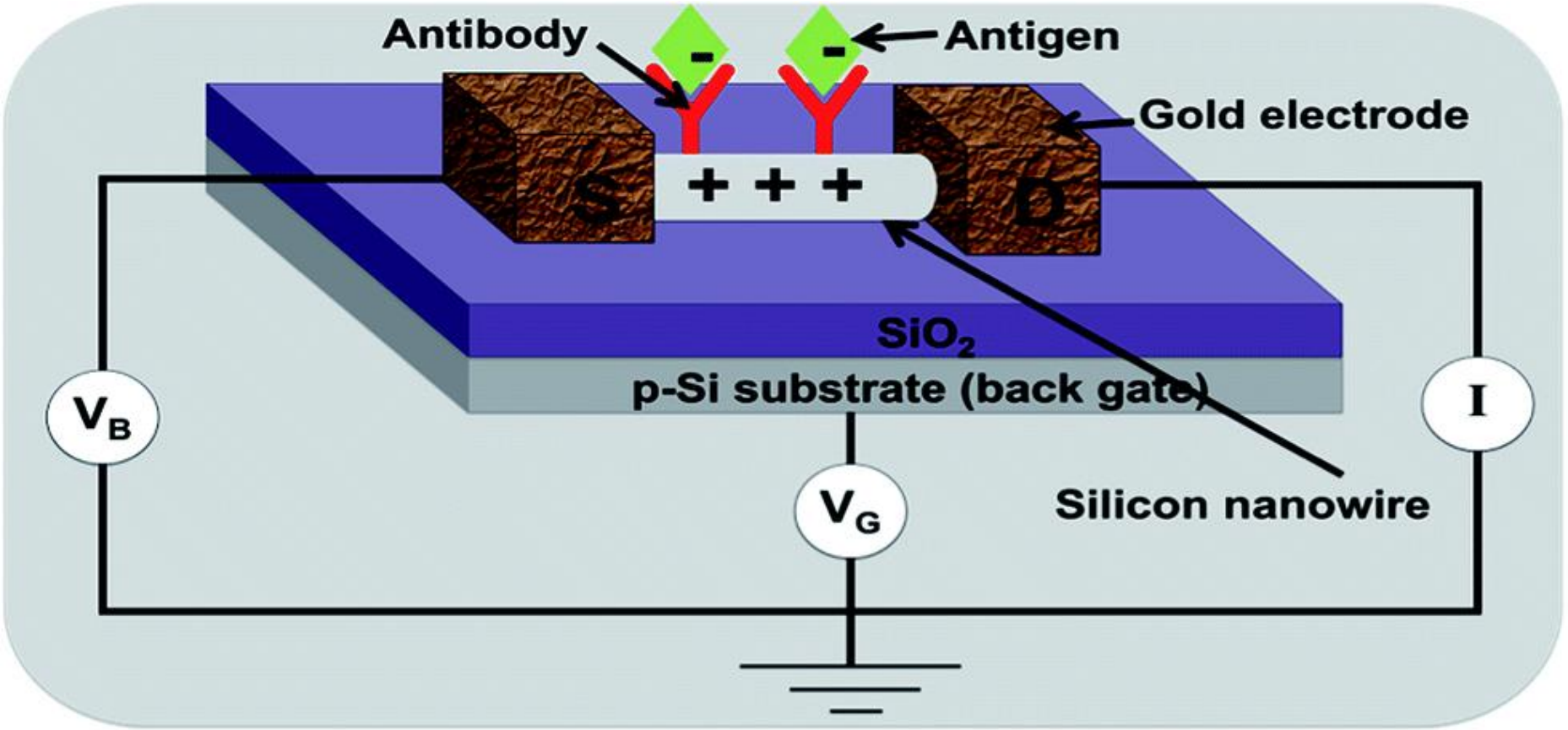


Surface plasmon resonance-based optical biosensor.



Fibre optic

Immunosensors - to detect and amplify an antigen-antibody reaction



Type	Principle	Advantage	Disadvantages
1. Optical			
a Fiber optics	Evanescent wave based, allows measurement of binding at the fiber surface	Remote in-situ measurement, inherent sensitivity of optical approaches	Costly equipment and not portable,
b. Laser interferometry	Planar waveguides have evanescent field responsible to change in index of refraction	Highly sensitive, detect up to 1 cell	Susceptibility to turbidity interference
2. Electrochemical			Highly buffered
a. Conductometric	Change in conductance	Fast, low cost	solution may
b. Potentiometric	Electric potential		interfere
c. Amperometric	Oxidation/reduction		
3.Piezoelectric	Quartz crystals oscillation at defined frequency, binding of an analyte to it changes the mass of crystal hence oscillation frequency	High sensitive, fast	Sensitivity level up to 1 cell have not demonstrated
4. Colorimetric/Strip	Color development	Not required any instruments	Not quantitative Quantitative
5. DNA biochip	Array based	Instrument required	

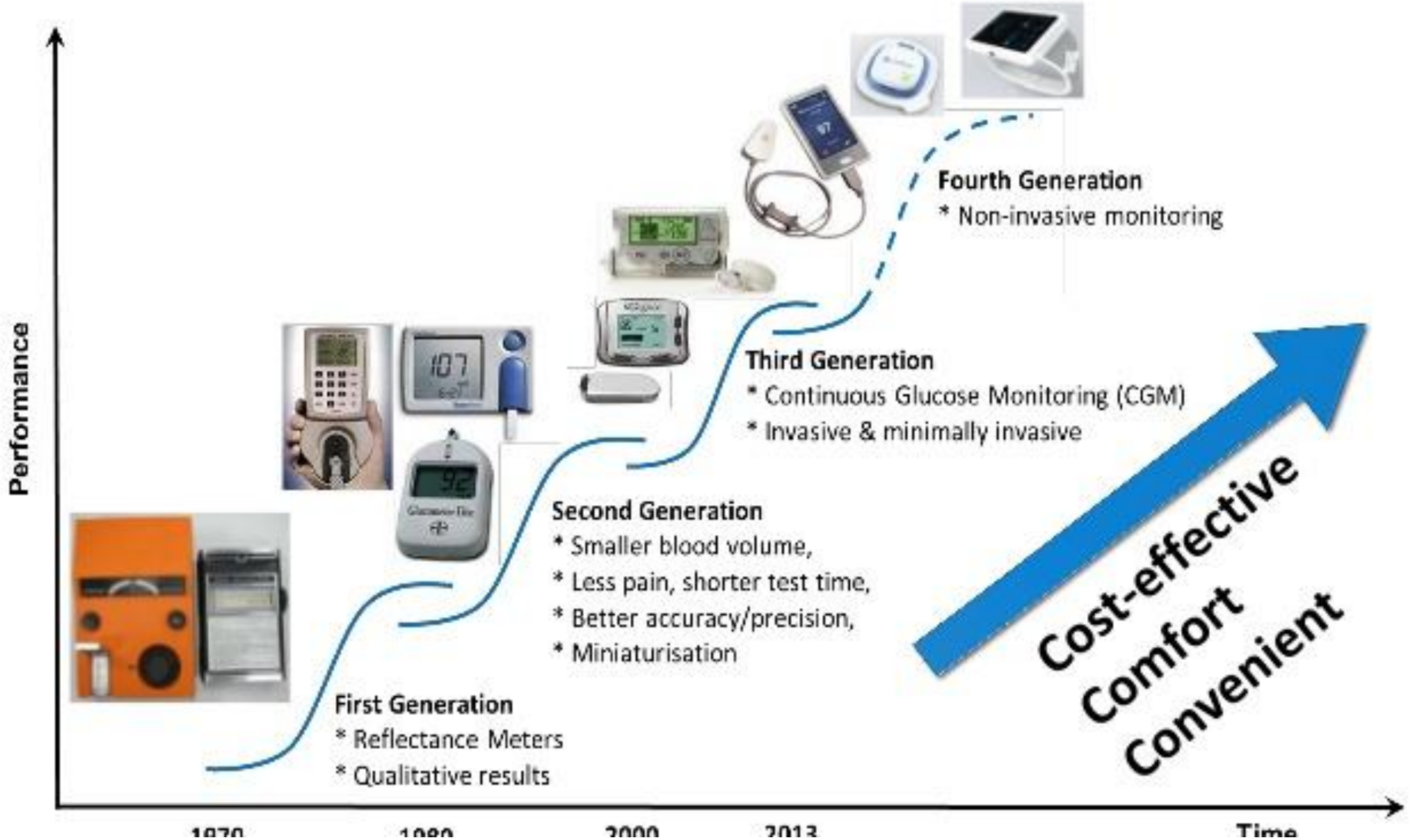
Advantages

- Highly specific
- Independent of factors like stirring, pH, etc.
- Linear response, Tiny and Biocompatible
- Easy to use, Durable
- Require only Small Sample Volume
- Rapid, Accurate, Stable and Sterilizable

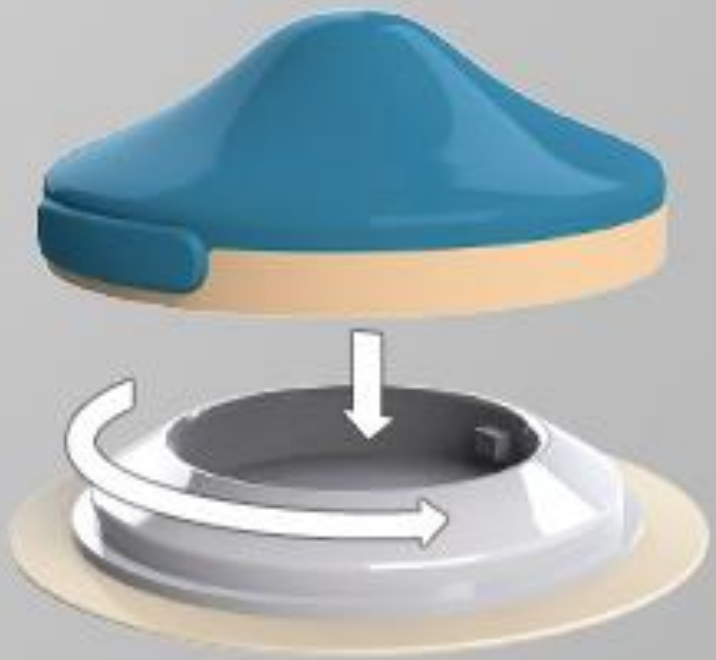
Applications

- In food industry: to monitor freshness
- Drug discovery: Evaluation of biological activity of new compounds.
- Potentiometric biosensor for monitoring the levels of carbon dioxide, ammonia and other gases in blood
- Environmental: Detection of pesticides, heavy metals etc.
- Analytical measurement of folic acid, biotin, vitamin B12 etc

Evolution of Blood Glucose Monitor



rechargeable pump



insulin patch (200 u)
suitable for 3 days

Googles Smart Lens

A smart contact lens measuring the glucose amount in tears was recently brought out by Google as wearable biosensors

Healthpatch Biosensor

Gather biometric data like Pulmonary, Neurologic, Cardiovascular (heart rate variability, heart rate, Single-lead ECG, contextual heart rate), and step count, posture, Temperature ,summarized activity, energy expenditure, stress).

Q™ Sensor

MIT – media labs Launches a Wearable Biosensor to Measure Human Emotions known as Affectiva Q™ Sensor.

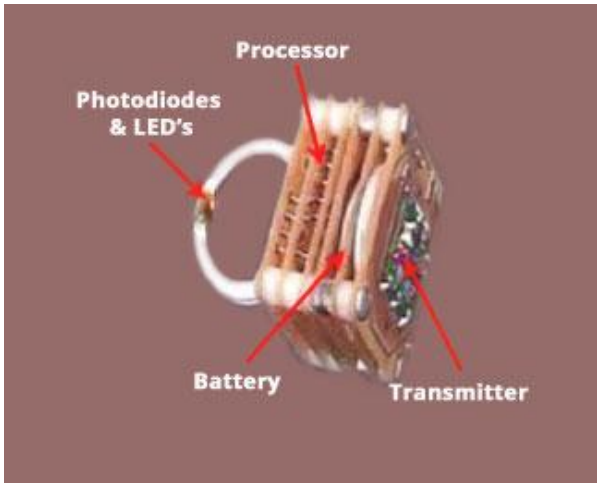
Simband Wearable Biosensors (Samsung)

The sensors in the band project beams of light into the skin at varying strengths in order to reach tissue near the surface or deeper in. The screen then displays metrics like heart rate and blood pressure in real time

Biosensor tattoos

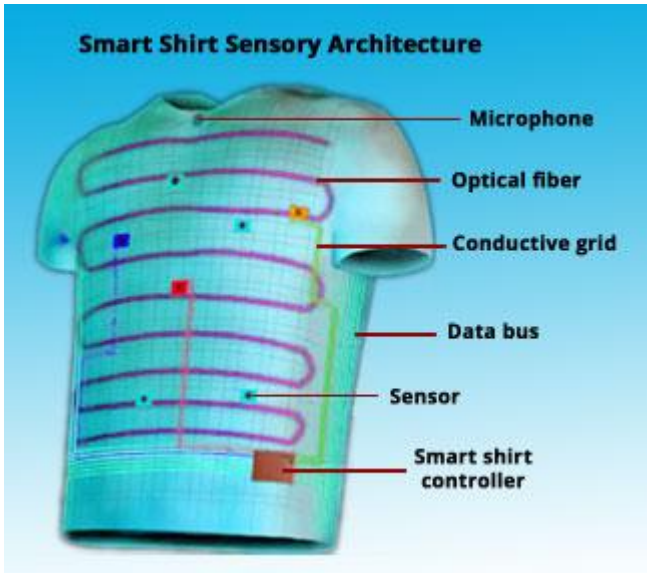
Wearable Biosensors tattoos monitor sweat to track weight by monitoring the amount of electrolytes, ammonia and sodium in sweat

Ring Sensor



Ring Sensor is a pulse oximetry sensor which allows monitoring heart rate and oxygen saturation.

Smart Shirt



Smart shirt developed at Georgia tech uses optical fibers to detect wounds and special sensors and interconnects to monitor the body vital signs.