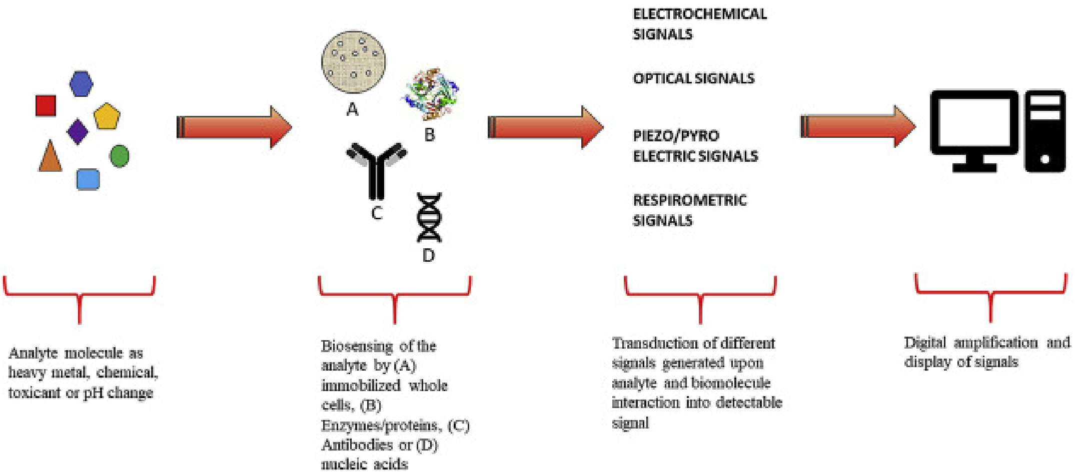
Biosensors and its Applications

Introduction:

What is a Biosensor? The most widely accepted definition of a biosensor is: “an analytical device which incorporates a biologically active element with an appropriate physical transducer to generate a measurable signal proportional to the concentration of chemical species in any type of sample”.

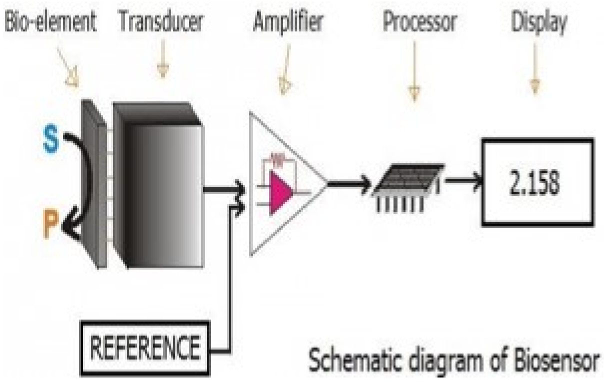
Type of Biosensors:

Biosensors can be categorized according to the basic principles of signal transduction and biorecognition elements. In the general scheme of a biosensor (figure1)



the bio recognition element responds to the target compound and the transducer converts the biological response to a detectable signal, which can be measured electrochemically, optically, acoustically, mechanically, calorimetrically, or electronically, and then correlated with the analyte concentration. Biological elements include enzymes, antibodies, micro-organisms, biological tissue, and organelles. When the binding of the sensing element and the analyte is the detected event, the instrument is described as an affinity sensor. When the interaction between the biological element and the analyte is accompanied or followed by a chemical change in which the concentration of one of the substrates or products is measured the instrument is described as a metabolism sensor.

Finally, when the signal is produced after binding the analyte without chemically changing it but by converting an auxiliary substrate, the biosensor is called a catalytic sensor. The method of transduction depends on the type of physicochemical change resulting from the sensing event. Often, an important ancillary part of a biosensor is a membrane that covers the biological sensing element and has the main functions of selective permeation and diffusion control of analyte, protection against mechanical stresses, and support for the biological element.



Schematic diagram of Biosensor

Types of biosensors

Biosensors started in the 1960s by the pioneers Clark and Lyons. Various types of biosensors being used are enzyme-based, tissue-based, immunosensors, DNA biosensors, and thermal and piezoelectric biosensors.

The first enzyme-based sensor was reported by Updike and Hicks in 1967. Enzyme biosensors have been devised on immobilization methods, i.e. adsorption of enzymes by van der Waals forces, ionic bonding or covalent bonding. The commonly used enzymes for this purpose are oxidoreductases, polyphenol oxidases, peroxidases, and aminooxidases.

The first microbe-based or cell-based sensor was actualized by Diviès. The tissues for tissue-based sensors arise from plant and animal sources. The analyte of interest can be an inhibitor or a substrate of these processes. Rechnitz[9] developed the first tissue based sensor for the determination of amino acid arginine. Organelle-based sensors were made using membranes, chloroplasts, mitochondria, and microsomes.

However, for this type of biosensor, the stability was high, but the detection time was longer, and the specificity was reduced.

The DNA biosensors were devised on the property that single-strand nucleic acid molecule is able to recognize and bind to its complementary strand in a sample. The interaction is due to the formation of stable hydrogen bonds between the two nucleic acid strands.

Magnetic biosensors: miniaturized biosensors detecting magnetic micro- and nanoparticles in microfluidic channels using the magnetoresistance effect have great potential in terms of sensitivity and size.

Thermal biosensors or calorimetric biosensors are developed by assimilating biosensor materials as mentioned before into a physical transducer.

Piezoelectric biosensors are of two types: the quartz crystal microbalance and the surface acoustic wave device. They are based on the measurement of changes in resonance frequency of a piezoelectric crystal due to mass changes on the crystal structure.

Optical biosensors consist of a light source, as well as numerous optical components to generate a light beam with specific characteristics and to beeline this light to a modulating agent, a modified sensing head along with a photodetector.

Applications of biosensors

Some examples of the fields that use biosensor technology include:

- General healthcare monitoring
- Screening for disease
- Clinical analysis and diagnosis of disease
- Veterinary and agricultural applications
- Industrial processing and monitoring
- Environmental pollution control

Biosensors have been applied in many fields namely food industry, medical field, marine sector etc., and they provide better stability and sensitivity as compared with the traditional methods.

In food processing, monitoring, food authenticity, quality and safety)

Ghasemi-Varnamkhasti et al. worked on the monitoring of ageing of beer using enzymatic biosensors, based on cobalt phthalocyanine. These biosensors evinced a good capability to monitor the ageing of beer during storage.

Biosensors are used for the detection of pathogens in food. Presence of *Escherichia coli* in vegetables, is a bioindicator of faecal contamination in food. *E. coli* has been measured by detecting variation in pH caused by ammonia (produced by urease–*E. coli* antibody conjugate) using potentiometric alternating biosensing systems.

Washing the vegetables such as sliced carrots and lettuce with peptone water provides us with the liquid phase. It is then separated by amalgamating it in a sonicator, to disaffiliate bacterial cells from food items. Enzymatic biosensors are also employed in the dairy industry.

A biosensor, based on a screen-printed carbon electrode, was integrated into a flow cell. Enzymes were immobilized on electrodes by engulfment in a photocrosslinkable polymer. The automated flow-based biosensor could quantify the three organophosphate pesticides in milk.

One of the popular food additives extensively used today are sweeteners, which are adversely causing undesirable diseases including dental caries, cardiovascular diseases, obesity and type-2 diabetes

In fermentation processes

In fermentation industries, process safety and product quality are crucial. Thus effective monitoring of the fermentation process is imperative to develop, optimize and maintain biological reactors at maximum efficacy. Biosensors can be utilized to monitor the presence of products, biomass, enzyme, antibody or by-products of the process to indirectly measure the process conditions. Biosensors precisely control the fermentation industry and produce reproducible results due to their simple instrumentation, formidable selectivity, low prices and easy automation. Nowadays, several kinds of commercial biosensors are accessible; capable of detecting biochemical parameters (glucose, lactate, lysine, ethanol etc.) and are widely used in China, occupying about 90% of its market.

Biosensing technology for sustainable food safety

The term food quality refers to the appearance, taste, smell, nutritional value, freshness, flavour, texture and chemicals. Smart monitoring of nutrients and fast screening of biological and chemical contaminants are of paramount importance, when it comes to food quality and safety. Material science, nanotechnology, electromechanical and microfluidic systems are striding in to make sensing technology imminent for use in market. Efforts are being made for developing control systems ensuring food quality and safety and, as a consequence, human health.

Glucose monitoring becomes indispensable as during storage the food content and composition may get altered.

In medical field

In the discipline of medical science, the applications of biosensors are growing rapidly. Glucose biosensors are widely used in clinical applications for diagnosis of diabetes mellitus, which requires precise control over blood-glucose levels. Blood-glucose biosensors usage at home accounts for 85% of the gigantic world market.

Biosensors are being used pervasively in the medical field to diagnose infectious diseases. A promising biosensor technology for urinary tract infection (UTI) diagnosis along with pathogen identification and anti-microbial susceptibility is under study.

Fluorescent biosensors

Fluorescent biosensors are imaging agents, for use in cancer and drug discovery. They have enabled insights into the role and regulation of enzymes at cellular level. GFP-based and genetically encoded FRET biosensors play a vital role.

Fluorescent biosensors are used in drug discovery programmes for the identification of drugs by high throughput, high content screening approaches, for postscreening analysis of hits and optimization of leads.

Biodefense biosensing applications

Biosensors can be used for military purposes at times of biological attacks. The main motive of such biosensors is be to sensitively and selectively identify organisms posing threat in virtually real time called biowarfare agents (BWAs) namely, bacteria (vegetative and spores), toxins and viruses. Several attempts to device such biosensors has been done using molecular techniques which are able to recognize the chemical markers of BWAs.

Nucleic acid-based sensing systems are more sensitive than antibody-based detection methods as they provide gene-based specificity, without utilizing amplification steps to attain detection sensitivity to the required levels.

The human papilloma virus HPV (double stranded DNA virus) has been categorized into two types: HPV 16 and 18; and is related to invasive cervical cancer. HPVs can be rapidly detected using a novel leaky surface acoustic wave peptide nucleic acid biosensor with double two-port resonators. This probe directly detects HPV genomic DNA without polymerase chain reaction amplification, and can also bind to the target DNA sequences with a lot of efficacy and precision.

In metabolic engineering

Environmental concerns and lack of sustainability of petroleum-derived products are gradually exhorting need for development of microbial cell factories for synthesis of chemicals. Researchers view metabolic engineering as the enabling technology for a sustainable bioeconomy.

Biosensors in plant biology

Revolutionary new technologies in the areas of DNA sequencing and molecular imaging, have lead to advancements in plant science.

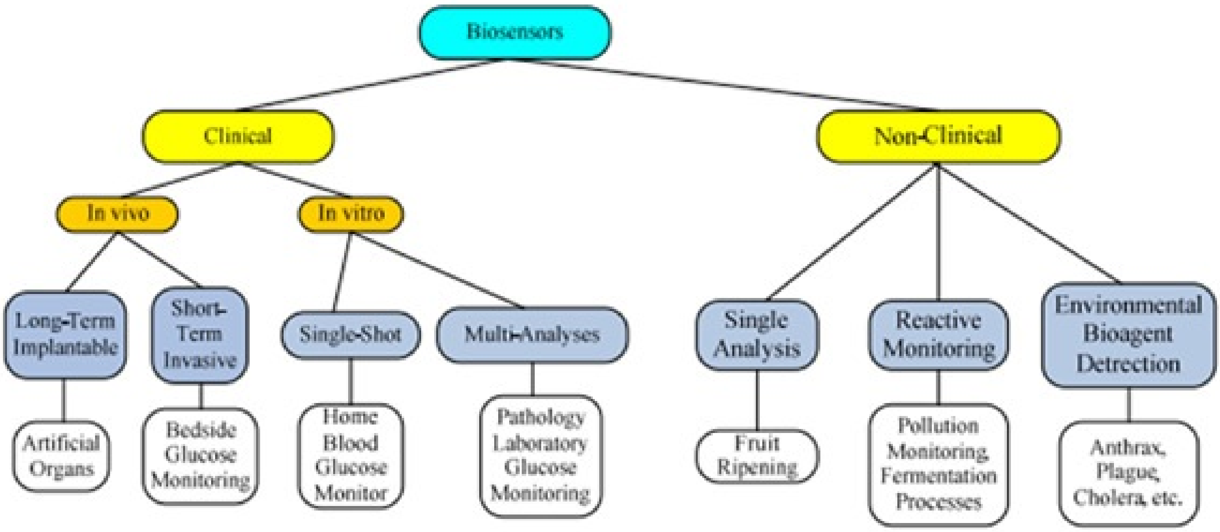


Fig. 2: Potential Applications of Biosensors.