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An Approach to Biosensors Principle and its Applications

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Abstract: Biosensors are the device in which there is a coupling of biological sensing element with a detector system using a transducer. In comparison with any other currently available diagnostic device, biosensors are much higher in performance in terms of sensitivity and selectivity both. Biosensors have found potential applications in the industrial processing and monitoring, environmental pollution control, also in agricultural and food industries. Important features for commercialization of the biosensors are selectivity, sensitivity, stability, reproducibility and low cost. This article reviews the brief history, basic principles, and the various types' of biosensors available.
Keyword: Biosensors, Principle, Types and Application

I. INTRODUCTION

A biosensor is an analytical device which converts a biological response into an electrical signal (Fig. 1). The term 'biosensor' is often used to cover sensor devices used in order to determine the concentration of substances and other parameters of biological interest even where they do not utilize a biological system directly. Biosensors function by coupling a biological sensing element with a detector system using a transducer. The first scientifically proposed as well as successfully commercialized biosensors were electrochemical sensors for multiple analytes. The following statement is also defined for the biosensor, "A chemical sensing device in which a biologically derived recognition is coupled to a transducer, to allow the quantitative development of some complex biochemical parameter." The Schematic diagram shown below for the biosensor is mainly divided into three sections.

1) Sensor: a sensitive biological element (biological material (eg. tissue, microorganisms, organelles, cell receptors, enzymes, antibodies, nucleic acids, etc),
2) Transducer: it is the detector element (works in a physicochemical way; optical, piezoelectric, electrochemical, etc.) that transforms the signal resulting from the interaction of the analyte with the biological responsible for the display of the results in a user-friendly way,
3) third section is the associated electronics, which comprises of signal conditioning circuit (amplifier), processor and a display unit.

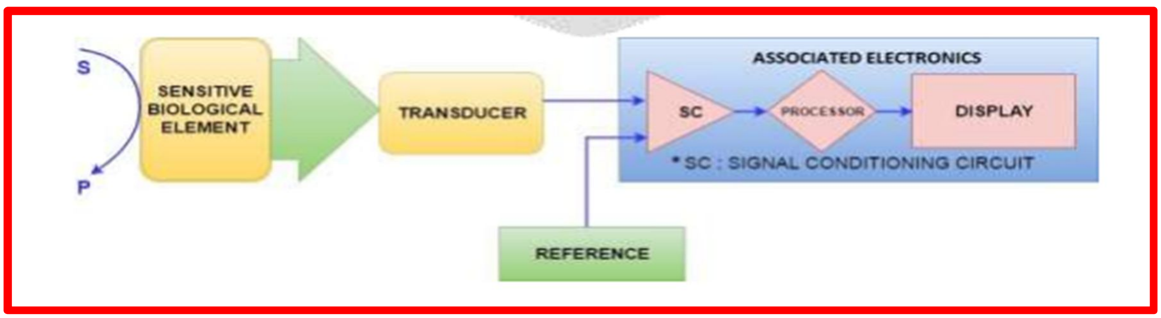

Fig -1: Schematic diagram showing main components of a biosensor

A. *Principle of a Biosensor*

The desired biological material (usually a specific enzyme) is immobilized by conventional methods (physical or membrane entrapment, non- covalent or covalent binding). This immobilized biological material is in intimate contact with the transducer. The analyte binds to the biological material to form a bound analyte which in turn produces the electronic response that can be measured. In some instances, the analyte is converted to a product which may be associated with the release of heat, gas (oxygen), electrons or hydrogen ions. The transducer can convert the product linked changes into electrical signals which can be amplified and measured

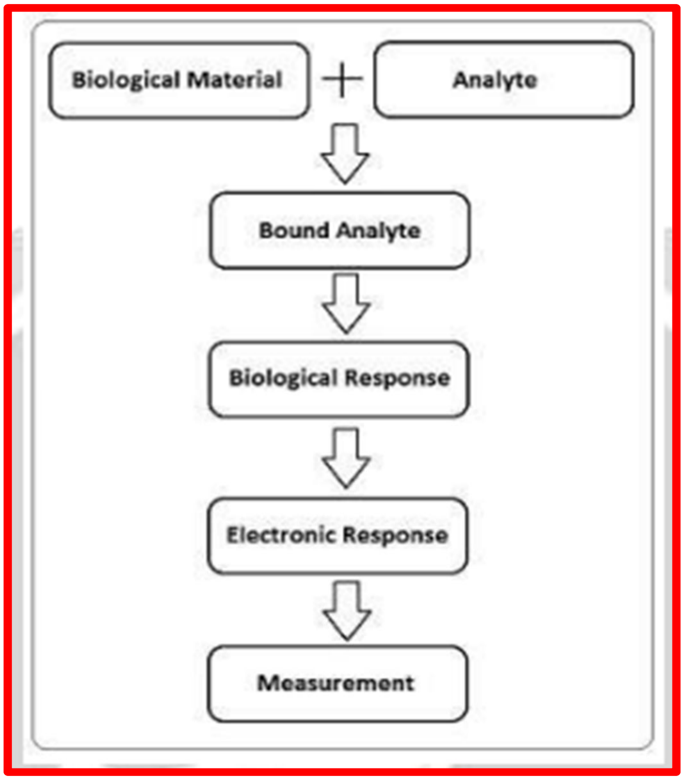

Fig -2: Measurement flow for a biosensor

B. *Working of a Biosensor*

The electrical signal from the transducer is often low and superimposed upon a relatively high and noisy (i.e. containing a high frequency signal component of an apparently random nature, due to electrical interference or generated within the electronic components of the transducer) baseline. The signal processing normally involves subtracting a 'reference' baseline signal, derived from a similar transducer without any biocatalyst membrane, from the sample signal, amplifying the resultant signal difference and electronically filtering (smoothing) out the unwanted signal noise. The relatively slow nature of the biosensor response considerably eases the problem of electrical noise filtration. The analogue signal produced at this stage may be output directly but is usually converted to a digital signal and passed to a microprocessor stage where the data is processed, manipulated to desired units and output to a display device or data store.

II. GROWTH OF THE BIOSENSORS TECHNOLOGY

There are mainly three so-called 'generations' of biosensors; First generation biosensors where the normal product of the reaction diffuses to the transducer and causes the electrical response, second generation biosensors which involve specific 'mediators' between the reaction and the transducer in order to generate improved response, and third generation biosensors where the reaction itself causes the response and no product or mediator diffusion is directly involved. The development of biosensors began in 1950, when L. L. Clark develops biosensors with an oxygen electrode (popularly known as Clark electrode) in Cincinnati, USA to measure the dissolved oxygen in blood. Later, glucose oxidase enzyme in a gel was coated and immobilized on the oxygen electrode to measure blood sugar. Similarly, enzyme urease was used in combination with an electrode was developed which was specific for NH4++ions for measuring urea in body fluids like blood and urine. [1].There are initially two following types of transducer technologies. In the first one, the estimates were made by measurement of electric current (amperometric) and in the second case for urea measurements, the estimates were based on the measurement of charge on the electrode (potentiometric). The biosensors based on the use of enzymes involving catalytic action are described as catalytic biosensors as against bioaffinity biosensors developed later, which do not make use of enzymes, but instead make use of antibodies, receptor molecules, etc., which have high affinity with the analyte. In 1980s, the first bioaffinity biosensors were developed, in which radiolabelled receptors were immobilized on to a transducer surface. Biosensors based on ELISA have also been developed using labelled antibody or labelled antigen coupled with a suitable transducer.

III. TECHNOLOGY USED FOR TRANSDUCER IN BIOSENSORS

The technology used for transducer can be any one of the four types listed below and depend upon the biological sensor used. [5] In biosensors, suitable transducers are designed, keeping in view the following:

1) Specific desired interaction between the analyte and the biological elements;
2) The intended use of the biosensors and the
3) Manufacturing cost of the device.

A. BioSensing Method

The critical aspect of the biosensor is matching the appropriate biological and electronic components to produce a relevant signal during analysis. Isolation of the biological component is very much essential to ensure that only the molecule of interest is bound or immobilized on the electronic component or the transducer. Attachment of the biological component to the electronic component is vital for the success of these devices. The stability of the biological component is also quite critical, since it is being used outside its normal biological environment..

IV. TYPES OF BIOSENSORS

Biosensors can be grouped according to their biological element or their transduction element. Biological elements include enzymes, antibodies, micro-organisms, biological tissue, and organelles. The method of transduction depends on the type of physicochemical change resulting from the sensing event. Primarily biosensors based on transducer element are mass based (piezoelectric, etc), electrochemical biosensors (potentiometric, amperometric, etc), and optical types of biosensors (fiber optics, etc).

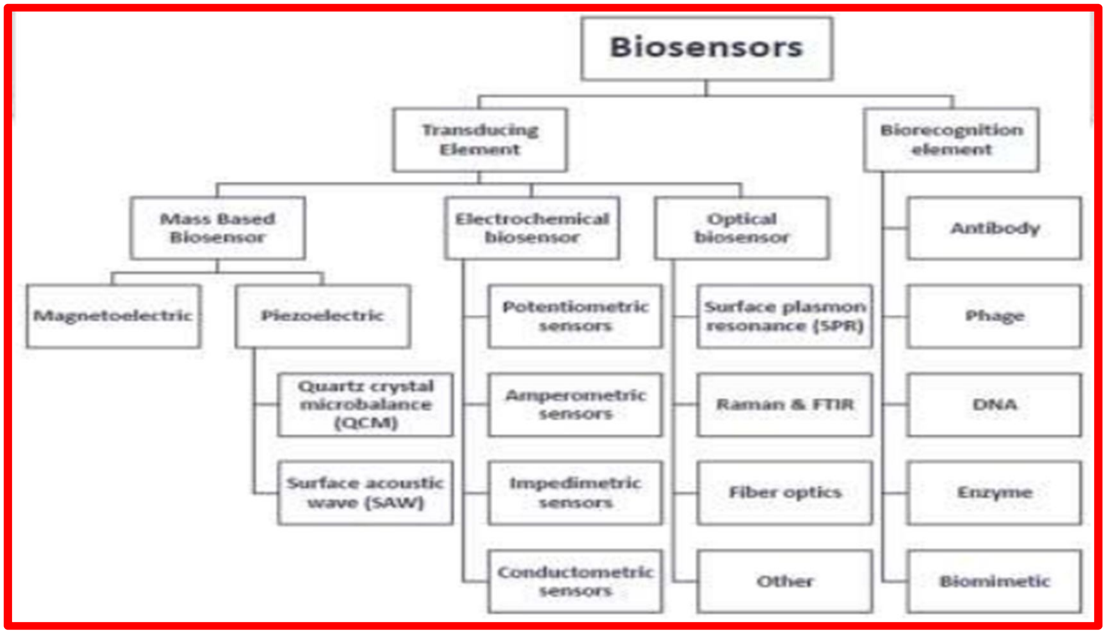

Fig -3: Classification of biosensors based on the transducer element & bio-recognition element

V. BIOSENSORS AND THEIR USES

Biosensors can be broadly classified as follows, based on the principle involved.

A. Piezoelectric Sensors

Piezoelectric biosensors are considered as mass-based biosensors. Piezoelectric biosensors are based on the principle of acoustics (sound vibrations), hence they are also called as acoustic biosensors. Piezoelectric biosensors produce an electrical signal when a mechanical force is applied. In this mode, sensing molecules are attached to a piezoelectric surface - a mass to frequency transducer - in which interactions between the analyte and the sensing molecules set up mechanical vibrations that can be translated into an electrical signal proportional to the amount of the analyte. Example of piezoelectric sensor is quartz crystal micro or nano balance.

B. Electrochemical Sensors

Electrochemical biosensors have been the subject of basic as well as applied research for nearly fifty years. Leland C. Clark introduced the principle of the first enzyme electrode with immobilized glucose oxidase at the New York Academy of Sciences Symposium in 1962. In this configuration, sensing molecules are either coated onto or covalently bonded to a probe surface. A membrane holds the sensing molecules in place, excluding interfering species from the analyte solution. The sensing molecules react specifically with compounds to be detected, sparking an electrical signal proportional to the concentration of the analyte. Based on their operating principle, the electrochemical biosensors can employ potentiometric, amperometric and impedimetric transducers converting the chemical information into a measurable amperometric signal.

C. Optical Sensors

In optical biosensors, the optical fibers allow detection of analytes on the basis of absorption, fluorescence or light scattering. Here both catalytic and affinity reactions can be measured. The reaction causes a change in fluorescence or absorbance resulting due to change in the refractive index of the surface between two media which differ in density. For instance, if antibodies bind on a metal layer, the refractive index of the medium in contact with this layer will change. Since they are non-electrical, optical biosensors have the advantages of lending themselves to in vivo applications and allowing multiple analytes to be detected by using different monitoring wavelengths. The versatility of fiber optics probes is due to their capacity to transmit signals that reports on changes in wavelength, wave propagation, time, intensity, distribution of the spectrum, or polarity of the light.

VI. APPLICATIONS OF BIOSENSORS IN VARIOUS FIELDS

The advantages of biosensors include low cost, small size, quick and easy use, as well as a sensitivity and selectivity greater than the current instruments. Biosensors have many uses in clinical analysis, general health care monitoring. The most popular example is glucose oxidase-based sensor used by individuals suffering from diabetes to monitor glucose levels in blood. Biosensors have found potential applications in the industrial processing and monitoring, environmental pollution control, also in agricultural and food industries. The introduction of suitable biosensors would have considerable impact in the following areas:

A. Clinical and Diagnostic Applications

Among wide range of applications of biosensors, the most important application is in the field of medical diagnostics. The electrochemical variety is used now in clinical biochemistry laboratories for measuring glucose and lactic acid. One of the key features of this is the ability for direct measurement on undiluted blood samples. Consumer self-testing, especially self-monitoring of blood components is another important area of clinical medicine and healthcare to be impacted by commercial biosensors. Nowadays reusable sensors also permit calibration and quality control unlike the present disposable sticks where only one measurement can be carried out. Such testing will improve the efficiency of patient care, replacing the often slow and labour intensive present tests. It will bring clinical medicine closer to bedside, facilitating rapid clinical decision-making.

B. Industrial Applications

Along with conventional industrial fermentation producing materials, many new products are being produced by large-scale bacterial and eukaryotes cell culture. The monitoring of these delicate and expensive processes is essential for minimizing the costs of production; specific biosensors can be designed to measure the generation of a fermentation product.

C. Environmental Monitoring

Environmental water monitoring is an area in which whole cell biosensors may have substantial advantages for combating the increasing number of pollutants finding their way into the groundwater systems and hence into drinking water. Important targets for pollution biosensors now include anionic pollutants such as nitrates and phosphates. The area of biosensor development is of great importance to military and defense applications such as detection of chemical and biological species used in weapons.

D. Agricultural Industry

Enzyme biosensors based on the inhibition of cholinesterases have been used to detect traces of organophosphates and carbamates from pesticides. Selective and sensitive microbial sensors for measurement of ammonia and methane have been studied. However, the only commercially available biosensors for wastewater quality control are biological oxygen demand (BOD) analyzers based on micro-organisms like the bacteria Rhodococcus erythropolis immobilized in collagen or polyacrylamide. [10]

E. Food Industry

Biosensors for the measurement of carbohydrates, alcohols, and acids are commercially available. These instruments are mostly used in quality assurance laboratories or at best, on-line coupled to the processing line through a flow injection analysis system. Their implementation in-line is limited by the need of sterility, frequent calibration, analyte dilution, etc. Potential applications of enzyme based biosensors to food quality control include measurement of amino acids, amines, amides, heterocyclic compounds, carbohydrates, carboxylic acids, gases, cofactors, inorganic ions, alcohols, and phenols. [11] Biosensors can be used in industries such as wine beer, yogurt, and soft drinks producers. Immunosensors have important potential in ensuring food safety by detecting pathogenic organisms in fresh meat, poultry, or fish. [12]

VII. CONCLUSIONS

In this paper we have discussed various biosensors in detail. The study initially explains the basic concepts of a biosensor. A brief overview for different types of biosensors, their working principles, advantages, and applications of various biosensors are described. Because of various transduction technologies, most of the research is focused on improving sensitivity, selectivity, and stability. Most commercial biosensors developed till date is needed to focus in clinical applications. However other applications areas like food, pharmaceutical, agriculture, and environment are still to be explored. This article will give a brief but clear picture about the biosensors especially for those who are new to this technology.

VIII. ACKNOWLEDGEMENT

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REFERENCES

[1] L.C. Clark, and C. Lyons, “Electrode systems for continuous monitoring in cardivascular surgery”, Ann N YAcad Sci, 1962, 102, 29-45
[2] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
[3] Schmid, R.D.; Scheller, F. Biosensors, Applications in Medicine, Environmental Protection and Process Control; GBF Monographs; VCH Publishers: New York, 1989.
[4] Kress-Rogers, E. Handbook of Biosensors and Electronic Noses; CRC Press Inc.: New York, 1997.
[5] F.W. Scheller, U. Wollenberger, A. Warsinke, and F. Lisdat, “Research and development in biosensors”, Curr Opin Biotechnol, 2001, 12, 35-40.
[6] A F Collings and F Caruso, Biosensors: recent advances, Rep. Prog. Phys. Vo1.60, pp.1397-1445, 1997.
[7] A P F Turner, I Karube and G S Wilson (Eds.), Biosensors: Fundamentals and Applications, Oxford University Press, New York.
[8] R S Sethi. Transducer aspects of biosensor, Biosens. Bioelectronics, VoI.9,pp.243- 264,1994.