Biosensors — classification, characterization

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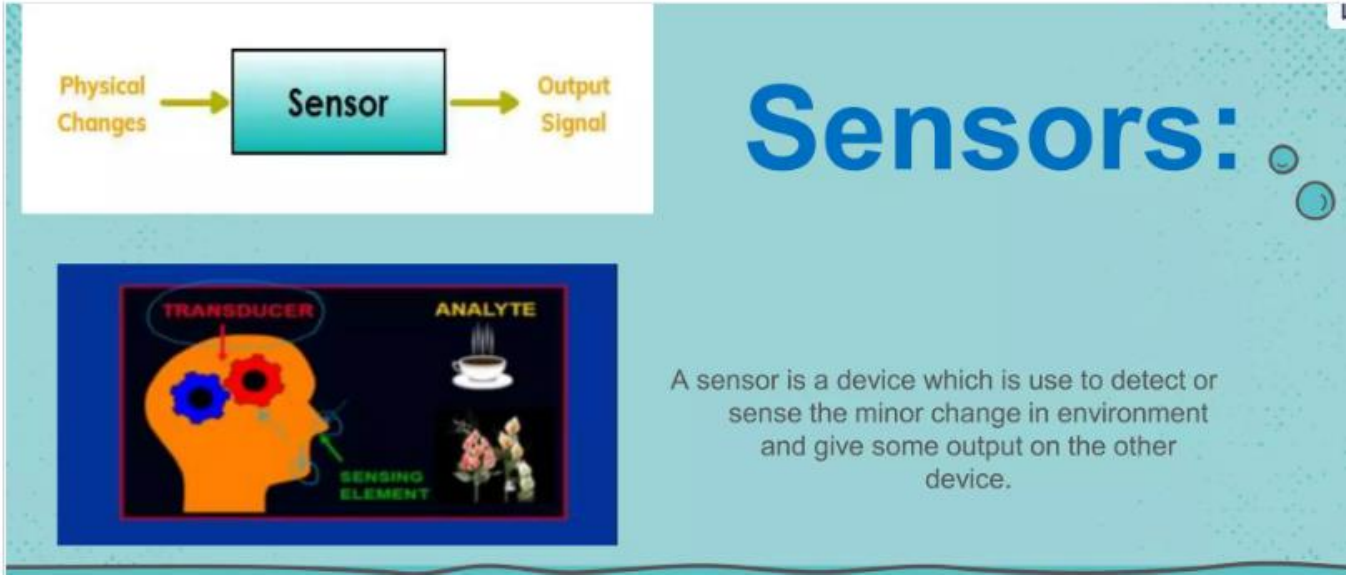


Biosensors are nowadays ubiquitous in biomedical diagnosis as well as a wide range of other areas such as point-of-care monitoring of treatment and disease progression, environmental monitoring, food control, drug discovery, forensics and biomedical research. A wide range of techniques can be used for the development of biosensors. Their coupling with high-affinity biomolecules allows the sensitive and selective detection of a range of analytes.

is a device that uses specific biochemical reactions mediated by isolated enzymes, immuno-systems, tissues, organelles or whole cells to detect chemical compounds usually by electrical, thermal or optical signals . Beginning of biosensors may be dated to 1962, when Clark, known as the father of the biosensor concept, published an experiment in which glucose oxidase (GOX) was entrapped at a Clark oxygen electrode using dialysis membran bio-components, an enzyme, antibody, nucleic acid, lectine, hormone, cell structure or tissue can be used. Its role is to interact specifically with the target analyte and the result of biochemical reaction is consequently transformed through transducer to measurable signal. The transducing systems can be electrochemical, optical, piezoelectric, thermometric, ion-sensitive, magnetic or acoustic one. Very important part of a biosensor fabrication is the immobilization of bio-component. Performance of biosensors with immobilized molecules depends also on factors such as the chemical and physical conditions (pH, temperature and contaminants), thickness and stability of the materials

Biosensors are analytical devices that employ sensitive biological materials to "recognize" certain molecules and provide information on their presence and amount as a signal convenient for recording and processing Any biosensor consists of the following three basic components:

1- recognition element, which is a bioselective membrane involving various biological structures. recognition element is the basic component of any sensor. It is due to its recognition element that a sensor can selectively respond to one or several analytes among a large number of other substances. All types of biological structures—enzymes, antibodies, receptors, nucleic acids, and even living cells—are used as a recognition element in biosensors.

2-physical transducer. A transducer converts the changes caused by the reaction between the selective biological layer and the analyte into an electric or optical signal. This signal is then measured using a light-sensitive and/or electronic device

3-electronic system for signal amplification and recording and for user-friendly data representation . Figure 1 presents a general scheme of a biosensor.

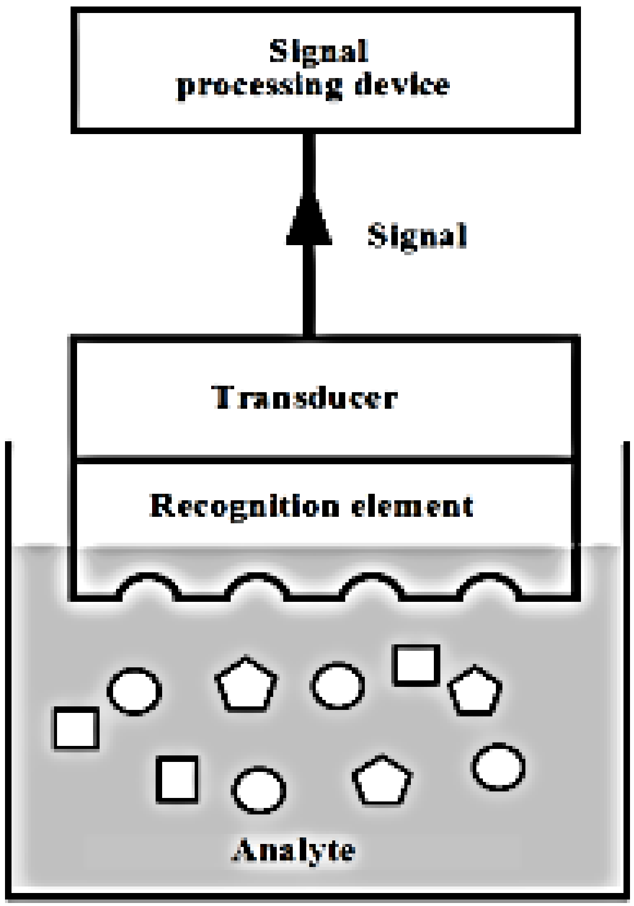


Fig. 1. General scheme of a biosensor.

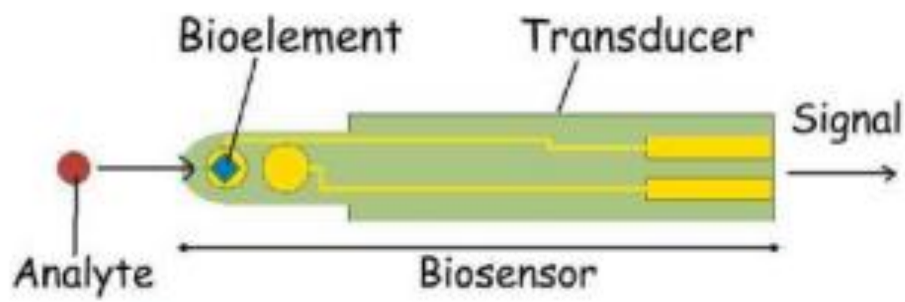


Fig. 1. Basic scheme of a biosensor.

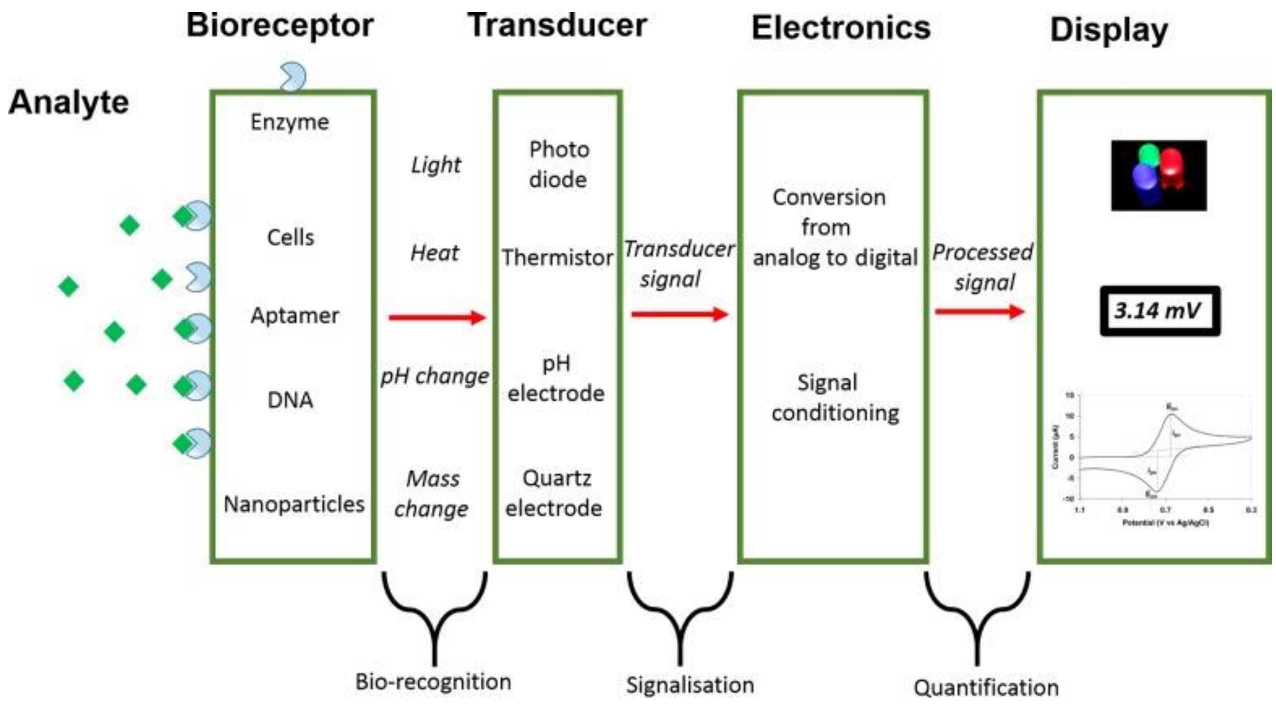
1- Analyte: A substance of interest that needs detection. For instance, glucose is an 'analyte' in a biosensor designed to detect glucose.

2- Bioreceptor: A molecule that specifically recognises the analyte is known as a bioreceptor. Enzymes, cells, aptamers, deoxyribonucleic acid (DNA) and antibodies are some examples of bioreceptors. The process of signal generation (in the form of light, heat, pH, charge or mass change, etc.) upon interaction of the bioreceptor with the analyte is termed bio-recognition.

3-Transducer: The transducer is an element that converts one form of energy into another. In a biosensor the role of the transducer is to convert the bio-recognition event into a measurable signal. This process of energy conversion is known as signalisation. Most transducers produce either optical or electrical signals that are usually proportional to the amount of analyte–bioreceptor interactions.

4-Electronics: This is the part of a biosensor that processes the transduced signal and prepares it for display. It consists of complex electronic circuitry that performs signal conditioning such as amplification and conversion of signals from analogue into the digital form. The processed signals are then quantified by the display unit of the biosensor.

5-Display: The display consists of a user interpretation system such as the liquid crystal display of a computer or a direct printer that generates numbers or curves understandable by the user. This part often consists of a combination of hardware and software that generates results of the biosensor in a user-friendly manner. The output signal on the display can be numeric, graphic, tabular or an image, depending on the requirements of the end user.



Characteristics of a biosensor

1-Selectivity : is perhaps the most important feature of a biosensor. Selectivity is the ability of a bioreceptor to detect a specific analyte in a sample containing other admixtures and contaminants. The best example of selectivity is depicted by the interaction of an antigen with the antibody. Classically, antibodies act as bioreceptors and are immobilised on the surface of the transducer. A solution (usually a buffer containing salts) containing the antigen is then exposed to the transducer where antibodies interact only with the antigens. To construct a biosensor, selectivity is the main consideration when choosing bioreceptors.

2-Reproducibility

Reproducibility is the ability of the biosensor to generate identical responses for a duplicated experimental set-up. The reproducibility is characterised by the precision and accuracy of the transducer and electronics in a biosensor. Precision is the ability of the sensor to provide alike results every time a sample is measured and accuracy indicates the sensor's capacity to provide a mean value close to the true value when a sample is measured more than once. Reproducible signals provide high reliability and robustness to the inference made on the response of a biosensor.

3-Stability

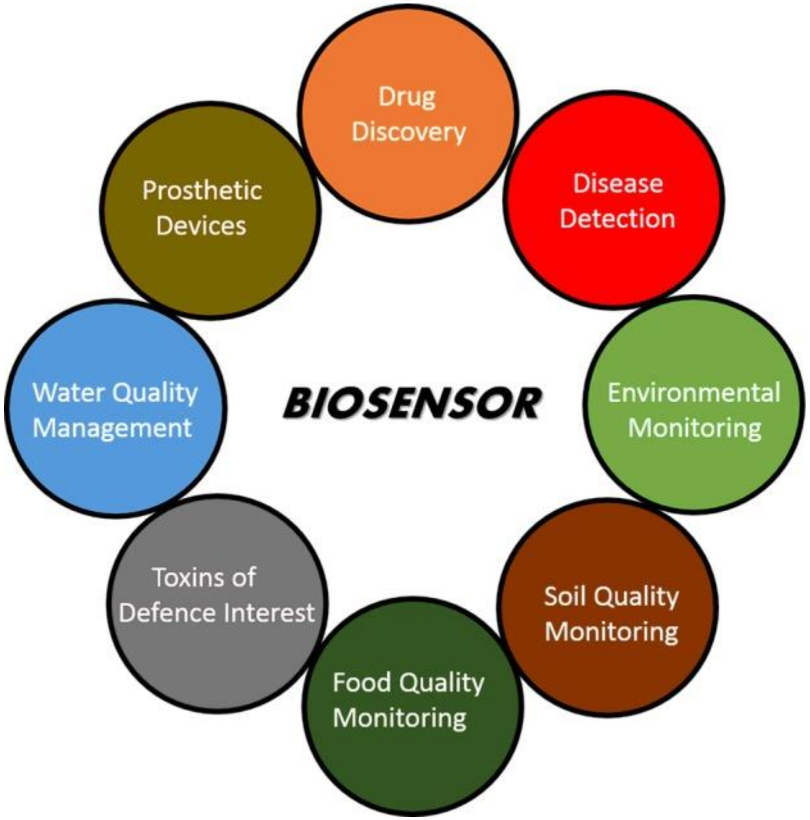
Stability is the degree of susceptibility to ambient disturbances in and around the biosensing system. These disturbances can cause a drift in the output signals of a biosensor under measurement. This can cause an error in the measured concentration and can affect the precision and accuracy of the biosensor. Stability is the most crucial feature in applications where a biosensor requires long incubation steps or continuous monitoring. The response of transducers and electronics can be temperature-sensitive, which may influence the stability of a biosensor. Therefore, appropriate tuning of electronics is required to ensure a stable response of the sensor.

4-Sensitivity

The minimum amount of analyte that can be detected by a biosensor defines its limit of detection (LOD) or sensitivity. In a number of medical and environmental monitoring applications, a biosensor is required to detect analyte concentration of as low as ng/ml or even fg/ml to confirm the presence of traces of analytes in a sample

Applications of biosensors

Biosensors have a very wide range of applications that aim to improve the quality of life. This range covers their use for environmental monitoring, disease detection, food safety, defence, drug discovery and many more. One of the main applications of biosensors is the detection of biomolecules that are either indicators of a disease or targets of a drug.



For example, electrochemical biosensing techniques can be used as clinical tools to detect protein cancer biomarkers . Biosensors can also be used as platforms for monitoring food traceability, quality, safety and nutritional value . These applications fall into the category of ‘single shot’ analysis tools, i.e. where cost-effective and disposable sensing platforms are required for the application. On the other hand, an application such as pollution monitoring requires a biosensor to function from a few hours to several days. Such biosensors can be termed ‘long-term monitoring’ analysis tools. Whether it is long-term monitoring or single shot analysis, biosensors find their use as technologically advanced devices both in resource-limited settings and sophisticated medical set-ups: e.g. with applications in drug discovery ; for the detection of a number of chemical and biological agents that are considered to be toxic materials of defence interest ; for use in artificial implantable devices such as pacemakers and other prosthetic devices ; and sewage epidemiology . A range of electrochemical, optical and acoustic sensing techniques have been utilised, along with their integration into analytical devices for various applications.