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Biosensors enable rapid and selective detection of biological and chemical analytes through biochemical recognition

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Abstract

Biosensors are analytical devices that combine a biological recognition element with a transducer to detect and quantify specific analytes with high sensitivity and selectivity. These devices convert biochemical interactions into measurable electrical, optical, or thermal signals. Biosensors are widely used in medical diagnostics, environmental monitoring, food safety, and biotechnology. This article discusses the principles, components, working mechanisms, and applications of biosensors in modern chemical science.

Keywords:* *Biosensors, Biorecognition, Electrochemical sensors, Enzyme sensors, Optical biosensors, Transducers, Medical diagnostics, Environmental monitoring, Analytical devices, Biomolecular detection.

Introduction

Biosensors represent a powerful integration of biology and chemistry where biological molecules are used to recognize specific analytes and convert that recognition into a measurable signal [1]. A typical biosensor consists of three main components: a biorecognition element such as an enzyme, antibody, or nucleic acid; a transducer that converts the biochemical interaction into a signal; and a signal processing system that displays the result. This combination allows highly selective and sensitive detection of substances even at very low concentrations. Enzyme-based biosensors are among the earliest and most widely used types, where enzymes catalyze reactions with specific substrates, producing measurable changes in current or potential. Glucose biosensors used by diabetic patients are a classic example of this technology [2]. Antibody-based biosensors rely on antigen–antibody interactions for detecting pathogens, toxins, or biomarkers. Electrochemical biosensors are particularly popular due to their simplicity, sensitivity, and low cost. These sensors measure changes in electrical properties such as current, voltage, or impedance resulting from biochemical reactions at the electrode surface. Optical biosensors, on the other hand, detect

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changes in light absorption, fluorescence, or refractive index caused by analyte binding [3]. Surface modification plays a critical role in biosensor performance. Immobilizing biological elements onto electrode surfaces using polymers, nanomaterials, or self-assembled monolayers enhances stability and sensitivity. Nanomaterials such as gold nanoparticles and carbon nanotubes significantly improve signal response due to their high surface area and conductivity [4]. Biosensors are extensively used in medical diagnostics for detecting glucose levels, cholesterol, infectious diseases, and cancer biomarkers. In environmental chemistry, they monitor pollutants, pesticides, and heavy metals in water sources. Food safety applications include detection of pathogens and contaminants in food products [5].

Conclusion

Biosensors provide efficient and selective detection of biological and chemical analytes through biochemical recognition and signal transduction. Their applications in healthcare, environmental monitoring, and food safety demonstrate their importance in modern chemical science. Continued advancements in nanomaterials and surface engineering will further enhance biosensor performance and versatility.

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