

CHAPTER 12

Biosensor Technologies in the Context of Medical Physiology

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Introduction

Physiology is a scientific field that focuses on maintaining optimal functioning of an organism by regulating homeostasis. When there is an imbalance in homeostasis, it can lead to pathological conditions and potentially permanent diseases if left unaddressed. The body has a sensor network in place to detect even the slightest changes and intervene to maintain homeostasis. Modern technology allows for detection at the microsensor level, which further enhances our ability to monitor and regulate the body's functioning.

With advancements in technology, there is a growing trend to treat pathological conditions by mimicking the functioning of the human body, which is considered to be the most advanced organism. Nanotechnology has played a particularly significant role in the diagnosis and treatment of cancer, a widespread disease in our era.

In the 21st century, technological advancements are happening at such a rapid pace that it is difficult to keep up. While there are concerns that the constant influx of new technology may have harmful effects on human health, its undeniable benefits in the diagnosis and treatment of diseases have been proven, as seen during the recent Covid-19 pandemic that impacted the world. Vaccine technology is also evolving in parallel with current technological advancements.

Current technological research has made it possible to detect and treat potential diseases in fetuses. Studies are being conducted on cell and subcellular structures, thanks to microchip discoveries and developments at the nano and micro level. Promising research is being carried out against common conditions such as stem cell therapy, neurological diseases, Alzheimer's disease, and obesity.

Advancements in imaging system technologies have allowed us to better understand cellular interactions, and micro-surgery techniques are also a result of current technological development. Artificial intelligence and virtual reality research are gaining increasing significance in conjunction with neurophysiological studies.

1. Homeostasis

Homeostasis refers to the maintenance of a stable internal environment within the body. All tissues and organs are responsible for preserving this equilibrium. The human body monitors and processes a plethora of messages from both its own metabolism and the external environment through the nervous and endocrine systems. To generate appropriate responses, it receives and evaluates stimuli from control systems via a network of receptors and sensors. This intricate system allows the human body to function in harmony. The homeostatic mechanism, which involves positive and negative

feedback, regulates the functioning of approximately 100 trillion cells. If the functioning of one group of cells is disrupted, all cells will eventually be affected. Mild dysfunctions can lead to pathological conditions, while severe ones can result in death.

The nervous system plays a crucial role in maintaining homeostasis by responding to sensations perceived by sensory receptors, either through the nervous or hormonal system. These sensory receptors allow the body to monitor its environment and respond accordingly,

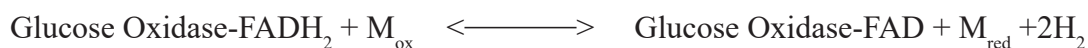
- By mechanoreceptors mechanical pressure, tension,
- Changes in cold, heat and temperature by thermoreceptors,
- Physical or chemical damage to tissues by nociceptors,
- Light detected by electromagnetic receptors located on the retina of the eye,
- Chemoreceptors detect taste, smell, O_2/CO_2 concentration in arterial blood, osmolality in body fluids and other factors in body chemistry.

Biosensor structures have been created by merging analysis systems for biological substances, allowing for the detection of stimuli within living organisms. Essentially, the biological systems that living organisms use to sense and respond to changes in their environment have served as the foundation for biosensor development. When ligands are biological materials, these systems are referred to as biosensors in vivo.

In the laboratory, this sensing mechanism has been utilized to develop biosensors. Research has led to advances in microelectronics and the discovery of the remarkably sensitive responsiveness of biological structures, leading to rapid progress in biosensor technology. Biosensor technology has enabled the integration of molecular identification and most biochemical reactions with the capabilities of electronic and optical technology to enhance signal processing and transmission (Turner, 1989).

The definition of biosensors involves the combination of the selectivity of biological molecules or systems with the processing capability of modern electronic techniques, which draws from various scientific fields including biology, chemistry, biochemistry, and engineering (Spichiger-Keller, 1998). The history of biosensors dates back to the mid-1950s when L. C. Clark first measured glucose levels in the blood using biosensors. The biosensors developed by Clark and Lyons used oxygen as the electron acceptor, while later studies utilized redox mediators as electron acceptors (Telefoncu, 1999).

Biosensors are devices that utilize the knowledge of various scientific fields such as biology, chemistry, biochemistry, and engineering. They combine the selectivity of biological molecules or systems with the processing power of modern electronic techniques. The history of biosensors dates back to the 1950s when L.C. Clark first measured glucose levels in the blood. While the biosensors developed by Clark and Lyons used oxygen as an electron acceptor, later studies utilized redox mediators as electron acceptors.



The third generation of biosensors achieves direct electrical communication between the enzyme's redox center and the electrode surface, eliminating the need for redox mediators (Telefoncu,1999).

2. Structure and Function of Biosensors

Biosensors consist of biocomponents (receptor) and physical components (transducer). The working principle of the biosensor is schematized in Table 1.

Table 1
Structure and Working Principle of Biosensors

	Biocomponents	Converters		
Example	-Texture	- Physical sensing	Signal booster	Data acquisition, evaluation
	- Microorganism	-- Electrochemical methods		
	- Cell	Potentiometric		
	- Organel	Amperometric		
	- Immuno agent	Thermometric		
	- Hormone	Conductometric		
	- Enzyme	Impedimetric		
	- Nucleic acid	-- Piezoelectric		
	- Synthetic biore- ceptor	-- Optics		
		- Chemical detection		

a. Biocomponents

Enzymes and antibodies are frequently used as bioreceptors in the structure of biosensors. Biocomponents, also known as bioreceptors, in biosensors include enzymes, antibodies, nucleic acids, chemical receptors embedded in biological membranes, microorganisms, organelles, and tissue sections. These bioreceptors transform the substance being analyzed, and the changes that occur are detected by the transducer. Enzymes are commonly used due to their high specificity, while cell systems and microorganisms are used when suitable enzymes are not available or when multiple substances need to be determined. Microorganisms are useful in biological oxygen demand, toxicity, and mutagenicity tests because they exhibit different receptor behaviors. Biosensors are devices that convert biochemical responses into physical, chemical, or electrical signals, with bioreceptors recognizing the analyte and transducers converting the chemical or physical signal produced into electrical signals (Telefoncu,1999).

b. Transducers

Transducers convert the biological reaction of receptors into a measurable physical signal. The transducer is selected according to the biochemical reaction. Electrodes are used in amperometric and potentiometric measurements, where the target is the analyte. In optical sensors the target is light and in piezoelectric sensors the target is the change in the oscillation resonance of the crystal due to mass loading (Grattarola & Massobrio 1998).

The classifications of biosensors are based on various factors, such as the type of transducer or the reaction they undergo. One of the most common classifications is based on whether the biosensor undergoes a physical or chemical reaction.

A. Physical sensing

Physical sensing involves converting the signal generated by the reaction between the biosensor and the analyte into an electrical signal. This conversion occurs due to changes in physical quantities by the transducer.

A.1. Electrochemical Biosensors

The detection and quantification of foodborne pathogens can be achieved using electrochemical biosensors. Various types of electrochemical biosensors exist, which measure changes in current, impedance, voltage, and conductivity that result from the interactions between antigens and bioreceptors.

A.1.1. Amperometric Biosensors

In 1956, Clark began research on amperometric biosensors using oxygen electrodes, which paved the way for further developments in this field. Among the various electrochemical detection methods used for pathogen detection, amperometric biosensors are the most commonly used. The signal of these biosensors is produced by the exchange of electrons between the biological system in the bioreceptor layer and the electrode.

Clark initiated research in the field of amperometric biosensors in 1956 using oxygen electrodes. These biosensors are widely used for pathogen detection and employ electron exchange between the biological system and the electrode in the bioreceptor layer to generate a signal. Several researchers have reported the successful detection of foodborne pathogens, including *E. coli* O157:H7, using amperometric biosensors (Abdel-Hamid et al., 1999. Chemburu et al., 2005).

A.1.2. Potentiometric Biosensors

Potentiometric biosensors are a type of electrochemical biosensors that operate at a constant current. Potentiometry is the measurement of the potential difference between a working electrode and a reference electrode. The reference electrode has a constant voltage value and is not affected by its environment, while the measuring electrode represents the voltage value resulting from the reduction and oxidation reactions that occur on solid and liquid surfaces (Grattarola & Massobrio, 1998). Glass electrodes sensitive to pH or monovalent ions, ion-selective electrodes sensitive to anions or cations, and gas-sensitive electrodes such as CO₂ or NH₃ are commonly used in potentiometric biosensors. Among these, field effect-based potentiometric sensors are preferred due to their high pH sensitivity (Wagner et al., 2012). Photosensitive potentiometric sensors have also been utilized for detecting *E. coli* cells in vegetable foods (Ercole et al., 2003).

A.1.3. Thermometric Biosensors

Thermal biosensors, also called calorimetric biosensors, are developed by combining the biomaterial with a physical transducer such as a thermometer. Thermal-based calorimetric biosensors can be used in enzyme activity measurements, clinical monitoring, process control, water-free environment measurements and environmental monitoring by monitoring the temperature changes that occur (Yakovleva et al., 2013).

A.1.4. Conductometric (Conductivity) Biosensors

The ability of an analyte under investigation to conduct an electric current between electrodes is measured by conductometric devices. Due to the externally applied current, ion mobility occurs between the two electrodes. Conductometric biosensors measure this ion mobility. Devices based on conductometry can be employed to investigate enzymatic reactions that lead to alterations in the concentration of charged species present in a solution.

A.1.5. Impedimetric Biosensors

It is created by immobilization of biological recognition elements on an electrode surface. The electrical impedance signal generated by the analyte at the output is measured or monitored and the result report is generated (Dinçkaya, 1999).

A.2. Optical Biosensors

Due to their sensitivity and selectivity, optical biosensors have become increasingly popular for the detection of bacterial pathogens. These biosensors operate by measuring the light absorbed or emitted during a biochemical reaction. Biotransduction elements such as enzymes, antibodies, antigens, nucleic acids, whole cells, and tissues can be employed in optical biosensors.

A.2.1. Biosensors Based on Surface Plasmon Resonance (SPR)

SPR is a straightforward and direct method that detects the alteration in the refractive index adjacent to a metallic surface. In this type of biosensor, light from a light-emitting diode (LED) reflects off a gold surface, and the angle and intensity associated with the minimum SPR are evaluated.

A.2.2. Optical Fiber Biosensors

Fiber optic biosensors rely on tapered fibers to deliver laser light for exciting the sensing surface and detect the emitted light. Light traveling through a fiber or waveguide can be highly sensitive to changes in its surroundings, which makes optical fibers a great candidate for various food applications, including pathogen detection and identification. For instance, Simpson and colleagues employed optical fiber biosensors in conjunction with other optical techniques to detect foodborne pathogens like *Listeria*, *Salmonella*, *E. coli* and *Clostridium botulinum* (Simpson and LimRapid, 2005).

A.3. Piezoelectric Biosensors

Piezoelectricity refers to the phenomenon where certain materials produce electric charge when subjected to mechanical stress or deformation. The word "piezein" from ancient Greek, meaning pressure, inspired the term. The study of piezoelectricity originated from crystal physics and was pioneered by Jacques Curie and Pierre Curie. In 1880, Pierre and Jacques Curie discovered that several crystals, such as quartz, tourmaline, and sugar cane, exhibit piezoelectric properties (Curie and Curie, 1880).

Piezoelectric devices were first used as a major breakthrough during World War 1. The development of a tool for locating sunken transport ships required the use of these devices. Physicist Paul Langevin, who was involved in the work, invented an ultrasonic submarine detection technique in 1918 that utilized a quartz-based piezoelectric transducer. This technique, called sonar, later proved valuable in World War II. Langevin's discovery created opportunities for further research on piezoelectricity,

including ultrasonic transducers, microphones, and accelerometers. Materials with these properties are utilized in sensors, temperature regulators, nonlinear capacitors, electromagnetic radiation receivers, and devices that operate in a frequency range from radio waves to visible light.

A sensor is a device that transforms physical or chemical quantities, such as temperature, humidity, sound, pressure, force, distance, acceleration and pH, into electrical signals. Piezoelectric sensors are a type of device that utilizes the piezoelectric effect to detect variations in pressure and acceleration and convert them into electrical signals. By converting mechanical energy into electrical energy, these sensors are able to carry out their functions.

Piezoelectric transducers have led to the development of various devices such as ultrasonic delay lines, ultrasonic medical diagnostic and treatment devices, and industrial control sensors for physical and chemical substances. Furthermore, advancements in electroacoustic transducers have made piezoelectric transducers more efficient. These transducers are now used in different industries, such as ultrasonic tomography, pulse measurements, tone measurements, urology, ophthalmology, medicine and bioengineering. Piezoelectric transducers can be found in numerous applications, including airbag sensors in automobiles, disk drives in computers, and ultrasonic imaging systems in medical fields.

A.3.1. Quartz Crystal Microbalance

The Quartz Crystal Microbalance (QCM) is a detection platform based on piezoelectricity and is utilized for clinical applications. It operates by measuring the changes in resonance frequency (Δf) that occur due to analytes binding to the sensor surface. QCMs are commercially available devices.

QCM applications and studies with piezoelectric sensors

Due to their various advantages, QCM systems can be applied in multiple sectors such as the cheap and small size of the recognizer section, ease of use, the ability to work with very small concentrations of samples, specificity, on-site measurement, repeatability and high sensitivity. Especially recently, the use of QCM systems has increased considerably. Some of the areas of use are listed below.

- Biotechnology
- Biocompatibility of surfaces
- The binding of complementary sequences of DNA and RNA
- Detection of bacteria, viruses, mammalian cells
- By immobilized receptors
- Recognition of protein ligands
- Pharmaceutical research
- In the distribution of the drug
- Melting polymer coatings
- Interaction of drugs at a molecular level

- Electrode surfaces
- Electrochemistry of interfacial processes
- Functionalized surfaces
- Lipid membranes
- Polymer coatings
- Thin film formation
- Reactive surfaces
- Gas sensors

B. Chemical sensing:

Some biosensors use transformation reactions or binding reactions to identify structures in the analyte. Conversion reactions involve using an enzyme as a bioreceptor to convert the component being analyzed into a detectable product through a transducer. An instance of this is the transformation of penicillin into penicillic acid via the penicillinase enzyme. In this structure, a pH electrode is then used for measurement. Binding reactions are a special detection method based on antibody-antigen association reactions. The change in electrical charge, mass or optical properties that occurs after the reaction is detected by the types of transducers described above.

Another way to classify biosensors is based on their transducer's working principle. In this case,

- In biocatalytic sensors, enzymes, microorganisms and tissue elements used as receptors interact catalytically with the molecule to be analyzed.
- In bioaffinity sensors, molecular sensing is performed by antibodies, receptors or immobilized proteins.
- Another way to classify biosensors is based on their application or use. These are,
 - Disposable: used to measure the amount of glucose in the blood
 - Intermediate-use: nM-sized measurements are performed under laboratory conditions.
 - Continuous use: in the form of biosensors.

3. Application Areas of Biosensors

Biosensors play a crucial role in medicine, agriculture, food, pharmacy, environmental pollution, defense and many industrial activities, especially in automation, quality control, energy extraction and condition detection. To date, sensors have been prepared for more than 180 different substances, of which only about 25 are commercially available. Possible application areas for biosensors:

- Clinical diagnostics, biomedical
- Process control
- Bioreactor control

- Food production and analysis
- Agriculture and veterinary medicine
- Diagnosis of bacteria and viruses
- Drug analysis
- Industrial wastewater control
- Environmental protection and pollution control
- Toxic gas analysis in mining enterprises
- Military applications.

The biomedical industry is recognized as the most promising market for biosensors. Enzyme sensors were among the first biosensors utilized in this field, and the glucose oxidase electrode was the first biosensor to be commercially produced. This biosensor facilitated the detection of glucose in blood and urine, which is crucial for the diagnosis of diabetes.

In biotechnology and food industry, enzyme sensors are employed for detecting or measuring glucose levels, many monosaccharides, amino acids, organic acids (lactic acid) urea and alcohol. In addition, biosensors can be prepared for complex parameters such as aroma and freshness as well as foreign substances in foods (pesticides, toxins and foreign hormones, etc.).

Biosensors are expected to play a role in combating drug abuse and addiction. Biosensors can replace drug-seeking dogs. This will save time especially at customs and police stations. Microbial sensors and enzyme sensors are used to control soil, air and water pollution.

Urea and creatinine electrodes, cholesterol electrodes, acetylcholine electrodes are also examples of medical biosensors. These sensors can be used to diagnose very important diseases. For example, urea levels are used to monitor kidney function, cholesterol levels are used to prevent arteriosclerosis, and acetylcholine electrodes are used to assess muscle fatigue (Rainina et al., 1996)

Due to the high specificity of immunological reactions, immunological biosensors are very suitable for use in medicine. These sensors are widely used in the measurement of drug active substances. For example, theophylline sensor, HCG hormone sensor for pregnancy testing, alpha-fetoprotein sensor for cancer diagnosis, surface antigen sensor for hepatitis B are immunological sensors used in medicine (McGlennen RC, 2001).

Biosensors implanted in prostheses detect the types of bacteria growing on the surface of the prosthesis, and antibacterial agents in the prosthesis are secreted to prevent infection (D'Souza, 2001).

3.1. Nanotechnology and biochips

Nowadays, a new generation of biosensors, called modern-day biosensors, are being developed using nanotechnology or chip technology. These biosensors make it possible to monitor and evaluate the results more easily. When a biochip is implanted into an object using advanced technologies, it is possible to follow the changes that occur during the detection phase without the need to go to the hospital. For example, thanks to advances

in nucleotide amplification and imaging techniques in nanotechnology, nucleotide-based biosensors are now widely used (Noh et al., 2011 and Arlett et al., 2011).

Biosensors have various applications in the biomedical field, and one of the most significant ones is the measurement of blood glucose levels in diabetic patients, gene analysis, regulating heart rhythms in chronic heart disease patients (pacemaker), analyzing antibodies produced as a result of allergic reactions, repairing damaged tissue or bone, monitoring metabolic products and monitoring patients undergoing dialysis treatment. In addition, so-called 'lab-on-a-chip' systems such as in vivo pressure sensors, implantable microelectrode arrays, drug delivery systems and biochemical sensors have been produced.

Glucose, cholesterol, lactate, urea, creatine biosensors in biomedical use are amperometric biosensors. They are used 'off line', 'in vivo' or 'on line'. Off line detectors determine the concentration of the analyte by injecting it into the environment to be measured (such as the human body). Glucose biosensors belong to this class. In in vivo applications, the biosensor is implanted into the body so that the relevant concentration of the analyte under investigation is continuously read. In on-line applications, the biosensor is connected to the flow line of the sample in the body.

DNA biosensors used in gene analysis provide important data in clinical and forensic investigations such as the determination of DNA-drug interactions, infectious and hereditary diseases.

Rapid progress is being made in the production of micro and nano-sized sensors. In particular, bio-micro and bio-nano electromechanical systems (BioMEMS/BioNEMS), which emerged with the application of micro and nano electromechanical system (MEMS/NEMS) technologies to biosensors, have enabled the creation of sensor systems where highly sensitive measurements can be made, especially in in vivo applications. The utilization of nanomaterials for biosensor production offers notable enhancements in properties like sensitivity, measurement range, and speed.

With biochips, chemical separations can be performed, as well as many processes such as clinical analysis, DNA analysis, protein analysis, synthesis and analysis of chemical substances, detection of toxic structures (Borsting et al., 2004).

Biochip technology enables the performance of thousands of gene assays, with the goal of monitoring the entire genome on a single chip and determining interactions. This technology is based on biosensor structures and utilizes the infrastructure of previous biosensor studies. The clinical use of DNA microchips in small-sized devices began with a licensed company in the United States, marking the first steps in the clinical application of biochip technology (Liu et al., 1996).

Some examples of BioMEMS applications include the use of excitatory neural implants, retinal implants for the treatment of blindness, and microneedles for painless vaccination (Grayson et al., 2004).

3.2. Biomarker in cancer

Biomarkers are quantifiable molecules, including DNA, RNA, proteins and metabolites, present in body fluids at an abnormal level that signal a pathological condition such as cancer. A biomarker is a substance that can be indicative of the presence of cancer, such as a molecule secreted by a malignant tumor or a distinctive response of the body to

cancer. All types of cancer and their progression through different stages of development have been linked to changes in gene sequence or expression, as well as protein structure and function. Changes in gene and protein expression or modification are employed to detect cancer, determine prognosis, monitor disease progression, and evaluate therapeutic response (Rasooly & James, 2006).

The human body operates various metabolic pathways to maintain homeostasis, a state of equilibrium. In cases of carcinogenesis, this balance is disturbed and some of the regulatory systems in our body stop working. In such cases, the following biological molecules in tissues may be candidate biomarkers;

- DNA
- RNA
- Proteins
- Enzymes
- Metabolites
- Hormones
- Receptors
- Carbohydrates.

These biological molecules are used as biomarkers depending on the changes in their structure, their increase, decrease and the responses they receive. The following Table 2 lists some of the molecules used as cancer biomarkers (Tothill, 2009).

Biomarker Name	Cancer Type
AFP	Liver cancer
BCR-ABL	Chronic marrow leukemia
BRCA1/BRCA2	Breast, Ovarian Cancer
BRAF V600E	Skin, Colon Cancer
CA-125	Ovarian Cancer
CA 19.9	Pancreatic Cancer
CEA	Colon Cancer
EGFR	Non-small cell lung cancer
HER-2	Breast cancer
KIT	Digestive tract stromal cancer
PSA	Prostate Cancer
S100	Skin cancer
VEGF	Breast Cancer

The analytical methods used for detecting these molecules rely on the recognition of specific antibodies and antigens, which trigger an immune response. Characteristics of a biomarker:

- Its accuracy must be constant during the disease.
- High sensitivity.

- It should have high specificity, the margin of error should be minimized.
- It should give a definite response in early diagnosis.
- It should be decisive without the need for complicated medical procedures.
- An economical screening method is also desirable for selecting biomarkers. A biomarker that possesses these qualities can be utilized in medical settings and in vitro experiments (Bahadir & Sezginturk, 2015).

3.3. Importance of Early Diagnosis

Early diagnosis of diseases is crucial in determining the effectiveness of the treatment. The timely identification of diseases can delay the onset of severe symptoms, reduce their severity or prevent the disease from progressing to an incurable stage. However, certain diseases may exhibit symptoms only in their advanced stages, making it difficult to diagnose the disease at an early stage.

Biomarkers, which are biological indicators, play a crucial role in the early detection and diagnosis of diseases by helping to determine the presence and stage of the disease.

Antibodies or antigens in antibody-antigen interaction, nucleic acids (DNA, RNA) in nucleic acid-nucleic acid interaction or proteins in protein-protein interaction are called biomarkers. Biomarkers can be present in various body tissues like skin, hair, and nails, as well as in body fluids such as blood, urine, saliva, and cerebrospinal fluid. Although the importance of molecular diagnostics has increased in clinical practice in recent years, the lack of disease-specific biomarkers has limited molecular diagnostics (Wagner, 2004).

The serum components of saliva are derived from the local vascular network connected to the carotid artery. Hence, saliva is a rich source of fluids containing a multitude of molecules present in the systemic circulation, which can be utilized for the early detection of various diseases (Wong et al., 2003).

Saliva contains proteins and genetic molecules such as DNA and RNA. The fact that the analysis tests performed with saliva, which is similar to blood in terms of content, are cheap, easy and reliable reveals the importance of saliva biomarkers in the diagnosis of diseases. Saliva as diagnostic material:

- Hormonal diseases,
- Cardiovascular diseases,
- Infectious diseases (bacterial/viral),
- Oncologic diseases,
- Kidney diseases,
- Autoimmune diseases,
- It is used to detect drug addictions and drug use.

When saliva diagnostic methods become widespread in the future, effective screening programs can be carried out in regions with low socioeconomic status, and the health level of the society can be increased by identifying and treating patients in the risk

group (Kocík et al., 2007 and Pink et al., 2009).

In the near future, with the development of electrobiochemical analysis methods, expensive and space-consuming laboratory devices will be replaced by compact biosensor systems (Mugweru, 2007 and Kökbaş et al., 2013). In the R&D studies conducted after the COVID-19 pandemic, determination can be made with IgG biosensor. Covid-19 biosensors can measure in all body fluids. It is a method that has the reliability of Rt-PCR and the speed of rapid diagnostic tests (Harun-Ur-Rashid et L., 2022 and Parihar et al., 2020).

The prolongation of the life span in advanced industrial societies brings new problems. Neurodegenerative diseases such as Alzheimer's, Parkinson's, and Huntington's diseases, which have the highest mortality rate with advancing age, are caused by inflammation. Tumor necrosis factor is a glycoprotein cytokine secreted by many cells. It is known that TNF alpha levels increase in aging and neurodegenerative diseases due to decreased innate immune protection. Based on this point, biosensors are being developed for the early diagnosis of TNF alpha.

In summary, biosensors are cost-effective and easy-to-use devices that provide high sensitivity and rapid response time, making them valuable tools in various fields, including healthcare and environmental monitoring. As technology advances, wireless biosensors are increasingly being developed and employed for patient diagnosis and monitoring, particularly in the healthcare sector. Therefore, the design of different biosensors and the use of these biosensors are important. In the 50s, Clark and Lyons determined glucose in vitro. In recent years, wireless biosensors suitable for in vivo use have been designed. Nowadays, in vitro biosensors are being designed that get their energy from blood pumping, chemical changes in the body, breathing or body movements. Thanks to the microchips implanted in the body, the data transferred to the electronic environment (cell phone, computer, etc.) can be utilized to detect the component to be quantified in the body. Wireless biosensors are rapidly developing, continuous and wearable biosensors connected to network networks. For these reasons, wireless biosensors provide convenience in monitoring disease markers in the hospital environment or in daily life (Keskin & Arslan, 2020).

As long as homeostasis is maintained, the organism continues to exist in a healthy way. Biotechnological developments continue to develop and promise through biosensor mechanisms together with medical technology to ensure and maintain homeostasis.

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