IJPSR (2025), Volume 16, Issue 5 (Review Article)

INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH

Received on 18 November 2024; received in revised form, 17 December 2024; accepted, 22 December 2024; published 01 May 2025

A REVIEW ON RECENT ADVANCEMENT IN PORTABLE BIOSENSOR FOR HEALTH MONITORING

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Keywords:

Portable biosensor, Health monitoring, Disease diagnostic, Real time monitoring, Point-of-care testing

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ABSTRACT: The use of biosensors and devices as instruments for health, education, and prevention has garnered a lot of attention in recent years. Personalized therapy depends on accurate and timely monitoring of biological markers and drug effectiveness, which is made feasible by biosensing devices in medications. The creation of the first real biosensor for oxygen sensing touches on the idea of biosensors. The "Web of Science" database had over 84,000 articles regarding "biosensors" between 2005 and 2015. Today, the field of research connects the foundations of electronics, micro/nanotechnology, applied medicine, and the basic sciences (physics, chemistry, and biology). The three primary components of a biosensor a bioreceptor, a transducer, and a signal processing system as well as the principles behind the various biosensor types are the main topics of the review. Additionally, the paper outlines several instances of biosensors being utilized to treat a range of illnesses, including infectious infections, diabetes mellitus, cardiovascular disease, and Alzheimer's disease. Biosensors have several uses, many of which are intended to improve people's quality of life. Applications in drug research, defence, food safety, illness detection, environmental monitoring, and many other fields are included in this spectrum. Additionally, biosensors can serve as platforms for tracking the nutritional content, safety, quality, and traceability of food.

INTRODUCTION: Effective patient treatment depends on the early identification and diagnosis of a variety of human diseases. Therefore, in order to accurately detect the illnesses, it is vital to create straightforward, sensitive, and affordable diagnostic instruments like biosensors. Real-time monitoring tools called biosensors can be used to identify and track any illness or condition (heartbeat, heart rate, breath).

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DOI: 10.13040/IJPSR.0975-8232.16(5).1169-81

This article can be accessed online on www.ijpsr.com

DOI link: https://doi.org/10.13040/IJPSR.0975-8232.16(5).1169-81

Because of its uses in the pharmaceutical, biological, clinical treatment, and healthcare sectors, biosensor research is receiving a lot of attention. Human health management, disease diagnosis, prevention, rehabilitation, and patient health monitoring have all benefited from the successful application of biosensors. Furthermore, biosensors may be used to detect viruses, bacteria, and illnesses [1].

In recent years, there has been a lot of interest in the use of biosensors and devices as tools for preventative, educational, and health medicine. As industrialized economies transition to an older population, medical technology that can be utilized in daily life particularly for testing, diagnosis and sensing is essential to reducing the growth in lifestyle-related disorders and their severity. Nanomaterials have demonstrated a wide range of applications in the creation of biosensors in recent years. The primary objective of clinical medicine is to classify patients using easily implementable biosensors [2].

The precise and prompt monitoring of biological markers and medication efficacy, made possible by biosensing devices in medicines, is essential to personalized treatment. They aid in medication research, illness diagnosis, and therapy monitoring by detecting proteins, DNA, or infections. These tools enhance real-time data collecting, which promotes safe, effective drug usage, advances research, and enhances patient care. Over the past 20 years, wearable sensor research has expanded quickly. As biosensors and MEMS technology have developed, they have grown in size and complexity. These non-invasive, wearable gadgets have been used to measure patients' exercise regimens and conduct ongoing patient monitoring. Numerous physical sensor systems for basic biometric measures and fitness have been created and put on the market. In 2017, the market for "mHealth," or mobile health, was valued at an estimated US$24.2 billion. It is anticipated to have increased by almost 4.5 times to reach US$110 billion by 2023. In the healthcare industry, this is one of the markets with the quickest growth rates. However, it is still challenging to deploy wearable physical sensors for illness screening and diagnosis. Additional development is necessary in order to continually evaluate an individual's health [3].

Key Milestone in Portable Biosensors: The earliest reports of biosensors came from M. Cremer's 1906 discovery that a liquid's electric potential is related to its acid content. Up till then, this industry has seen a number of advancements. Biosensors are a group of naturally occurring sensing components, such as a receptor and a transducer. Leland C. Clark, Jr. is considered the father of biosensors [4]. To determine the blood's oxygenation level, he planned to measure the oxygen decrease using a platinum electrode. Blood particles stuck to the electrode's surface and distorted the signal, causing his first sensor to fail. Clark then realized that he could use a cigarette packet's cellophane wrapper on his sensor [5].

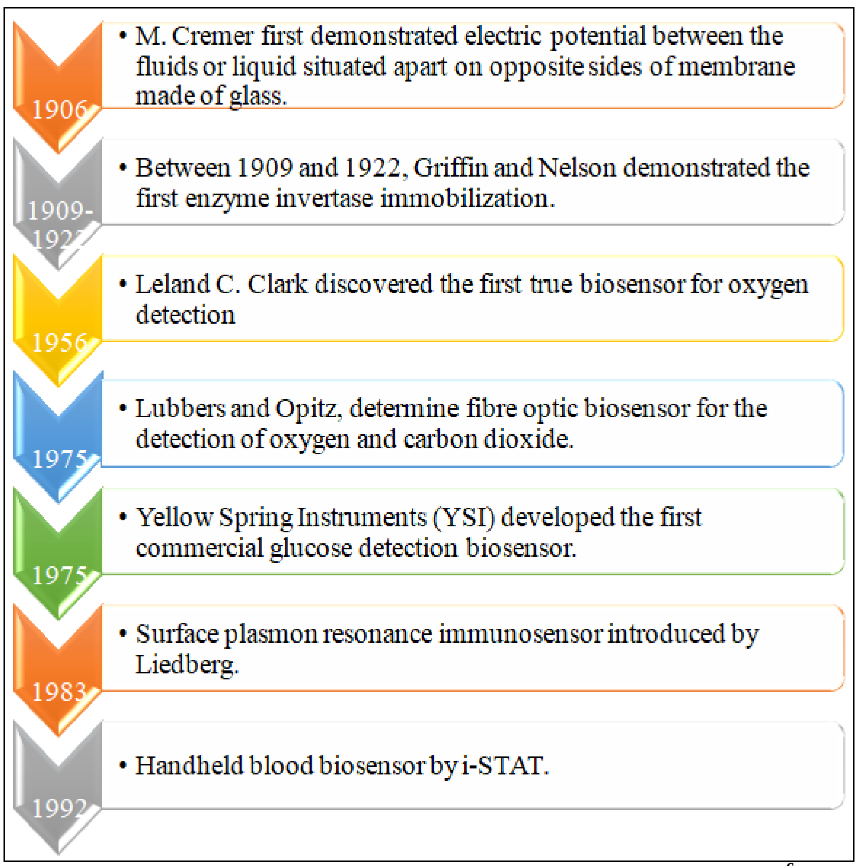

FIG. 1: DEVELOPMENT OF BIOSENSOR FROM 1906-1992 [6]

The first nano biosensor was demonstrated by Poncharal *et al.* in 1999. In 2018, S. Girbi *et al.* demonstrated a nerve-on-chip biosensor to measure nerve impulse conduction. Since the development of the i-STAT sensor, biosensor technology has made considerable strides. The discipline is now a multidisciplinary study area that links the fundamentals of the basic sciences (physics, chemistry, and biology), electronics, micro/ nanotechnology, and applied medicine. Between 2005 and 2015, there were around 84,000 articles about "biosensors" in the "Web of Science" database [7].

Advantages and Disadvantages:

High Sensitivity: Biosensors' high sensitivity, which allows for the detection of incredibly low concentrations of the target analytes, is one of its greatest advantages. This sensitivity is the result of special interactions between the target molecule and the recognition element (such as aptamers, enzymes, or antibodies), which ensure that even trace amounts are found and measured. Because the use of amplification techniques in signal transduction enhances the detection capabilities, biosensors are suitable for applications where detecting minute quantities is essential, such as environmental monitoring or early sickness diagnosis. This high sensitivity improves accuracy and reliability and guarantees the timely detection of significant changes [8].

Rapid Response: One significant advantage of biosensors is their speed; they provide detection in nearly real time, which significantly expedites analysis in contrast to conventional laboratory methods. This timely detection is made possible by efficient signal transduction algorithms that instantaneously convert the recognition event into a measurable signal [16]. In fields like food safety and environmental monitoring, where prompt action is necessary to prevent potential dangers, and in medical diagnostics, where prompt identification may impact treatment outcomes, rapid reaction is particularly helpful. By delivering results rapidly, biosensors increase efficiency, reduce wait times, and provide more dynamic monitoring and decision-making in a range of applications [9].

Portability: The mobility of biosensors is a major advantage, making them perfect for on-site and point-of-care testing. Because of their tiny size and light weight, they may be easily carried and utilized outside of traditional laboratory settings, such as in remote areas, clinics, or field settings. Due to its mobility, testing may be finished fast and easily, enabling timely decision-making without the need to send samples to centralized labs and wait for results. Portability is crucial for applications including emergency diagnostics, food safety inspections, and environmental monitoring. Researchers, field workers, and medical professionals may conduct accurate assessments anywhere because to the ease of use and mobility, which enhances accessibility overall [10].

Real-Time Monitoring: Real-time monitoring, which enables continuous observation of chemical or biological changes as they occur, is one of the primary advantages of biosensors. The ability to promptly identify variations in analyte concentrations is essential for applications such as environmental monitoring, industrial process control, and patient health monitoring. By providing instant feedback, real-time monitoring enables prompt and informed decision-making, whether it is avoiding water source contamination or altering a treatment strategy. This continuous data gathering guarantees greater accuracy and efficiency and enhances the ability to respond to dynamic changes. As such, biosensors offer a powerful tool for ongoing assessments [41].

Reusability: A key benefit of several biosensors is their reusability, which promotes sustainability and cost effectiveness. Certain biosensors can be used again without losing their effectiveness because of their long-lasting and regenerable recognition components. They are financially appealing for long-term uses in clinical diagnostics, environmental monitoring, and food safety testing because of their reusability, which lessens the need for frequent replacements and saves operating costs. Reusable biosensors also promote eco-friendly activities by reducing resource usage and material waste. They continue to be a useful and dependable option for repeated studies because of their capacity to carry out several detection cycles while retaining sensitivity and accuracy [10].

Enhanced Safety: The enhanced safety of biosensors, which lowers exposure to potentially harmful or infectious elements, is one of its main advantages. By automating the detection process, biosensors remove the need for human handling of dangerous compounds, protecting laboratory and healthcare personnel from potential risks. In clinical diagnostics, this is especially crucial since infections may be promptly detected without involving a lot of bodily fluid manipulation. Further lowering the risk of exposure is the fact that biosensors often require smaller sample sizes. Their integration into closed systems or portable equipment enhances the safety of on-site testing. All things considered, biosensors improve compliance with health standards and establish safer working environments [9].

Integration with Electronics: The ability of modern biosensors to interact with electronics is a significant advantage, as it facilitates a seamless connection to data processing systems for increased use. This integration enables automatic signal processing, real-time data display, and remote monitoring, making biosensors very versatile for a variety of applications, such as wearable medical devices and intelligent environmental sensors. By integrating with microcontrollers and wireless communication modules, biosensors may send data to smartphones or cloud-based platforms for real-time analysis and decision-making. In addition to increasing user comfort, this electronic compatibility enables continuous tracking and logging of results. All things considered, the integration of biosensors with electronics expands their practical uses, utility, and adaptability [8].

Disadvantage:

Limited Stability: The limited endurance of biosensors is a significant disadvantage, particularly for those that rely on biological components like enzymes or antibodies. Over time, these biomolecules may degrade or cease to function due to environmental factors such as temperature, pH, and exposure to light or oxygen. This degradation reduces the biosensor's effectiveness, accuracy, and reliability. The instability of biological recognition components may lead to a reduction in sensor performance, necessitating frequent replacements or recalibrations. For long-term applications, such as environmental monitoring or medical diagnostics, where dependable performance is crucial, biosensors' low stability might be troublesome [11].

Sensitivity to Environmental Conditions: The effectiveness and accuracy of biosensors may be impacted by their extreme sensitivity to environmental factors. The stability of the biological recognition components can be affected by variables including temperature, humidity, pH, and light exposure, which might provide contradictory findings. Extreme temperatures, for example, can denature or stop the activity of enzymes or antibodies employed in biosensors, and variations in pH or humidity can modify the binding affinity between the sensor and the target analyte. Because of their sensitivity to environmental influences, biosensors are difficult to use in unpredictable or changing environments; for dependable performance, thorough calibration and environmental control are necessary [8].

Complexity of Fabrication: The complexity of producing biosensors is a major disadvantage, particularly when making very sensitive and tailored devices. Biological elements, such as enzymes or antibodies, must be combined with transducers and electrical devices to form a biosensor. This procedure requires a great degree of precision and technical skill. The process can be costly, time-consuming, and prone to mistakes, especially when trying to provide consistent and repeatable results. Furthermore, when production is ramped up to generate large quantities of high-performance biosensors, quality control may be challenging to maintain. Biosensors are more costly to produce overall due to their complexity, which limits their use in large-scale applications [10].

Interference from Non-Target Substances: Interference from non-target substances is a significant issue for biosensors since it can alter measurement accuracy or produce false positives. Despite the fact that biosensors are designed to detect specific analytes, contaminants, identical molecules, or environmental factors may adhere to the recognition element in the sample and provide false positive results. These non-specific interactions reduce the sensor's selectivity and might compromise the reliability of the results.

Achieving total specificity can be difficult, especially in complex samples like blood or environmental samples with different components, even though biosensor designs usually incorporate methods to lessen interference to address this issue [11].

Potential for Biofouling: Biosensors frequently experience biofouling, especially when employed in wet settings. It happens when undesirable biological substances, including proteins, cells, or microbes, build up on the surface of the sensor, reducing its sensitivity and functionality. This accumulation may hinder target analytes' ability to attach to the recognition element, decreasing the sensor's accuracy. Over time, biofouling can also result in signal drift or noise, which makes it challenging to get accurate data. Although researchers frequently look at methods like surface modifications or coatings that lessen nonspecific adsorption to combat biofouling, totally stopping it is still difficult for long-term biosensor functioning [9].

Limited Reusability: Limited reusability is a disadvantage of biosensors as many of them depend on biological components that degrade or cease to work with repeated use. Over time, structural changes or the loss of enzymes, antibodies, or other recognition components that take place throughout the detection process may impair the sensor's ability to generate reliable data. As a result, the biosensor needs to be changed or renewed often, increasing resource consumption and operational costs. Certain biosensors require cautious handling and regular calibration to ensure continual reliability since, even if they are designed to be reused, their efficacy may decline with each cycle. As a result, limited reusability might eventually reduce the economic viability of biosensor systems [11].

Mechanism and Working principle of Biosensors: In order to identify a certain bio-analyte, it is essentially an analytical instrument that combines a transducer to convert a physiological signal into an electrical signal with an identifying factor generated from biology or physiology. The three main parts of a biosensor are a bioreceptor, a transducer, and a signal processing system. In general, a bioreceptor or biological recognition element is an immobilized biocomponent that has the ability to identify the specific target analyte. Most of these biocomponents consist of cells, enzymes, antibodies, nucleic acids, and other materials. On the other hand, the transducer acts as a converter. The response between the analyte and bioreceptor results in chemical changes, such as the formation of a new chemical, heat release, electron movement, and changes to mass or pH. The transducer transforms the biological signal into an electrical signal. A data processor and microelectronics receive the enhanced electrical signal [12].

Interaction between Biological Sensing Element and Transducer: The collaboration of a biological sensing element and a transducer forms the basis of a biosensor. The biological sensing element, often an enzyme, interacts with many biological elements, including tissues, cells, bacteria, enzymes, and acids. By causing these materials to undergo minute modifications, this link initiates a procedure known as the electroenzymatic method. The transducer is a crucial component that transforms these biological occurrences into analogous electrical impulses [11].

Signal Output and Conversion: The transducer generates electrical signals that can be either voltage or current, depending on the kind of enzyme being utilized. If the output is current, it must be converted into the proper voltage using an Op-Amp-based current-to-voltage converter for further processing [12].

Signal Refinement and Amplification: An Op-Amp-based amplifier is employed to refine the output signals, which are frequently characterized by low amplitude and susceptibility to high-frequency noise. The signals get stronger by this amplification process, which enhances their precision and durability [6].

Filtering and Signal Conditioning: A low pass RC filter is one of the signal conditioning devices that regulates the amplified signals. This method ensures the accuracy of the data and removes extraneous noise by altering the signals [7].

Data Analysis and Digital Conversion: A powerful processor or microcontroller carefully examines the produced data. This element is the foundation of analytical skills, allowing for the effective implementation of complex data analysis and deliberate decision-making procedures. The microcontroller then transforms the analogue impulses into digital form for processing, analysis, and storage [10].

Monitor & Visualization: An LCD monitor can rapidly display the digital signals that now reflect the biological quantity under observation. Rather, the data is routinely analysed and displayed to improve its usability and accessibility [13].

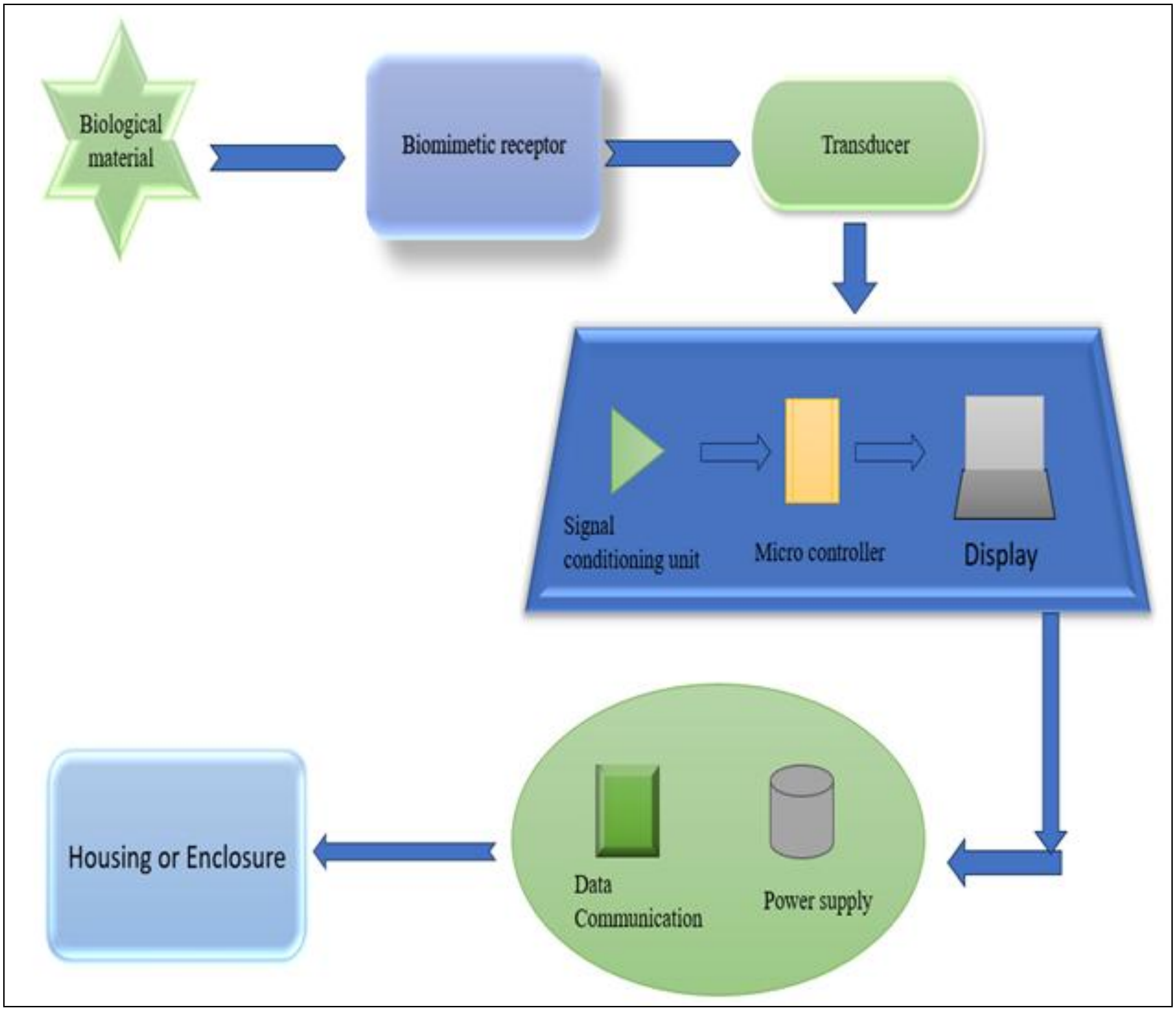

FIG. 2: MECHANISM OF BIOSENSOR

Types of Portable Biosensors: Biosensors are classified into numerous kinds based on the way signals are transduced. This review mainly focuses on the four different types of biosensors categorized as Electrochemical biosensors, Optical biosensors, Piezoelectric biosensors, Microfluidic biosensors [14].

Electrochemical Biosensors: Electrochemical biosensors have been the subject of basic and applied study for almost 50 years. At the Academy of Medicine in New York in 1962, Leland C. Clark originally put up the concept of the first electrode for an enzyme that has immobilized glucose oxidase [15]. Having an appropriate enzyme in the biorecognition layer that provides electroactive substances for detection by the physico-chemical transducer that transmits the measurable signal is the most common component of electrochemical biosensors. For example, developing virus-imprinted impedimetric biosensors using the molecular imprinting technique to detect whole viral particles with sensitivity or using dielectrophoresis force to boost the detection sensitivity of impedimetric immunosensors manufactured on Au micro-interdigitated electrodes [16].

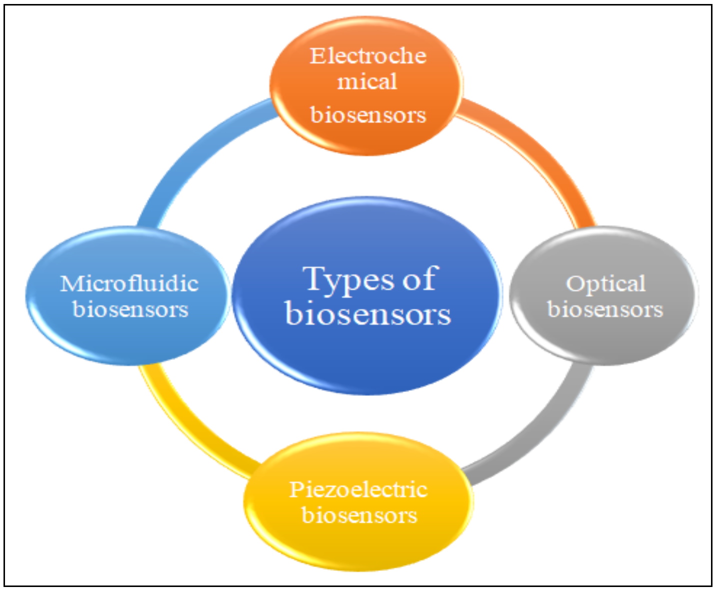

FIG. 3: TYPES OF BIOSENSORS

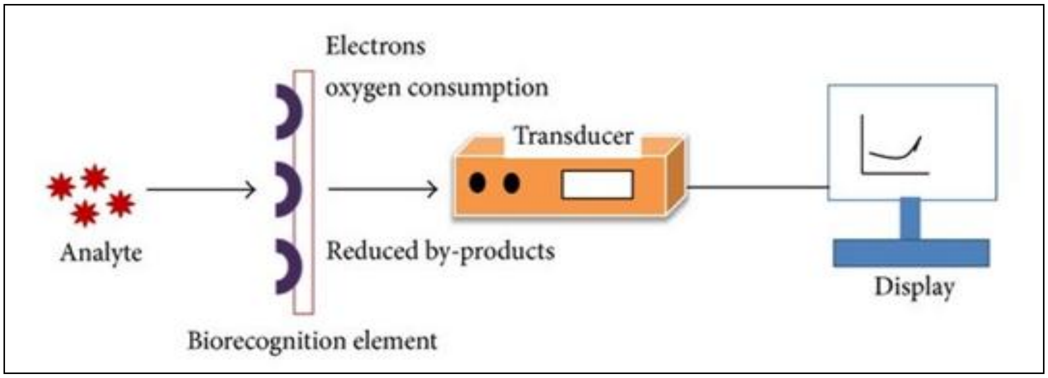

FIG. 4: ELECTROCHEMICAL BIOSENSORS (WORKING PRINCIPLE)

Optical Biosensors: Optical biosensor's mechanism can be tricked by understanding fluorescence technique. It measures the intensity, decay time, quenching efficiency, anisotropy, and quenching. Use plain sensor stripes, optical waveguide systems, arrays, and capillary-based technical sensors. Transducers that identify the presence of biological molecules are a type of optical biosensor. Because the biosensing element and the optical transducer are closely integrated in the optical biosensor, it is crucial to classify the optical biosensors according to their transducers because the key performance metrics and the principle of operation of these biosensors vary greatly depending on the type of optical transducer used. Various division of optical biosensor have been described in the figure number 2. Because of their quick, sensitive, and specific readings, optical biosensors have given biotechnology, environmental research, illness diagnosis, and pharmaceutical applications a competitive edge [17].

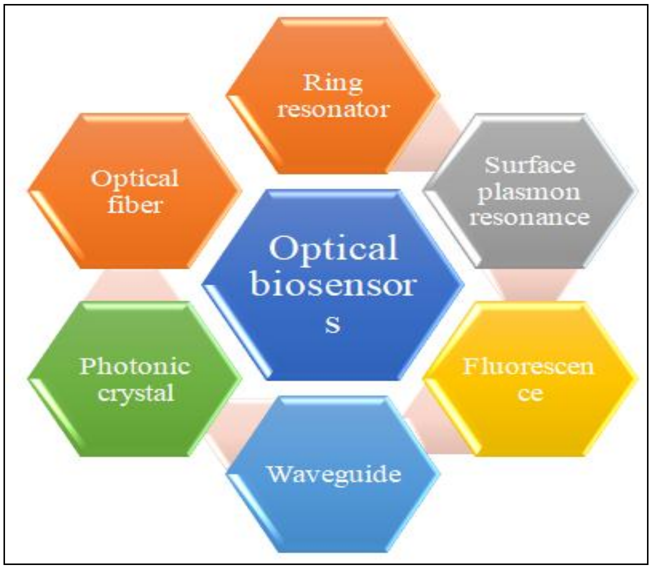

FIG. 5: TYPES OF OPTICAL BIOSENSORS

For example- In cancer detection, they have great potential for diagnosing many types of cancer. Optical biosensors can detect cancer in a few million malignant cells, as opposed to 1 billion cells in tumour tissue with a diameter of 7–10 nm, which is used in traditional diagnostic techniques. Current methods for detecting cancer procedures are also costly, time-consuming, difficult, laborious, and require technical specialists. Surface enhanced Raman spectroscopy technology, is capable of highly specific identification of a single molecule, and terahertz vibrations are a newly investigated technique for cancer diagnosis [17].

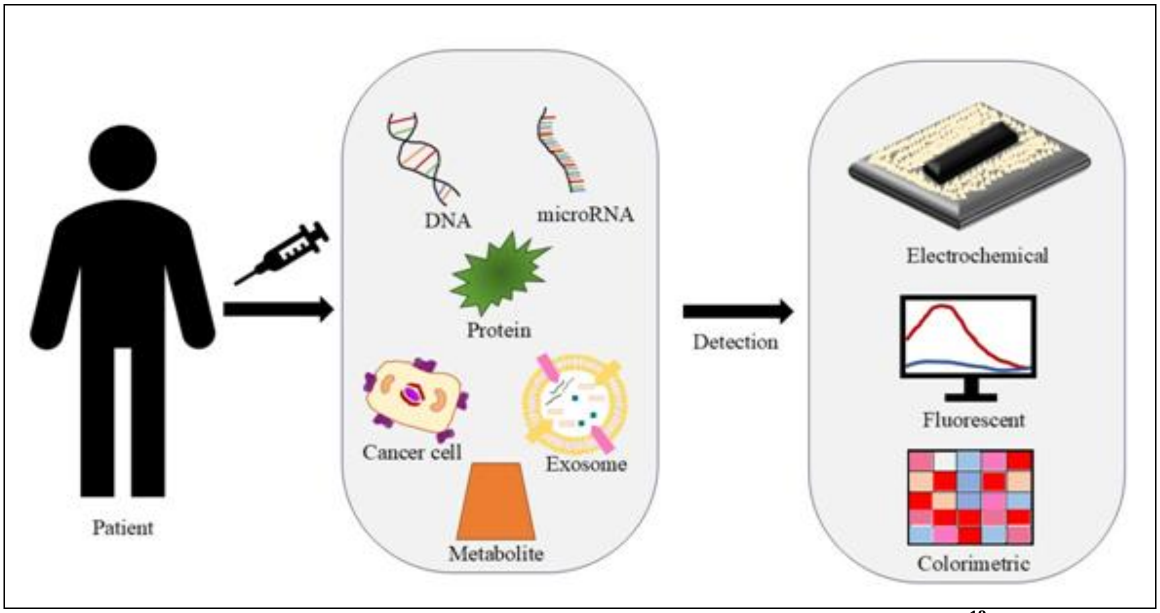

FIG. 6: OPTICAL BIOSENSORS USED IN CANCER DETECTION [18]

Piezoelectric Biosensors: The piezoelectric effect was discovered by physicists Pierre and Jacques Curie. They discovered that anisotropic crystals, or crystals without a centre of symmetry, can generate an electric dipole when mechanically squeezed. They described action may have the reverse effect when an anisotropic crystal is subjected to a voltage. Piezoelectricity is another term for the electric dipole. Piezoelectric biosensors are based on the ability of piezoelectric crystals to vibrate in response to an electric field and the ensuing mass-resonance frequency connection during biomolecular interaction [19].

Taken an example of creating wearable sensors that can continually check the surroundings for viruses might be a significant field of study. Along with examining magneto strictive sensors for the detection of bacterial spores, proteins, and classical swine fever and by the use of piezoelectric sensors for the detection of human papilloma, vaccinia, dengue, Ebola, influenza A, human immunodeficiency, and hepatitis B viruses. Furthermore, advancements in COVID-19 early detection [19].

Microfluidic Biosensors: By combining biological sensing components with microfluidic technology, a microfluidic biosensor is a kind of analytical instrument that can identify particular biological markers. Using channels that are usually tens to hundreds of micrometres in size, microfluidic technology manipulates and controls fluids on an extremely small scale [20]. Based on integrated microfluidic networks, wearable flexible sensors with multiplex analytic capabilities are emerging as a new paradigm for assessing human health and hold great potential for usage in clinical care and sports monitoring, among other application areas. Attaching well-designed microfluidic sensors to the skin's surface allows for accurate physiological data, which incorporates electrolyte balance, sweat loss, and metabolite information. 8 There may be different groups of microfluidics: (i) continuous-flow; (ii) droplet-based; and (iii) digital microfluidics [21].

Integration of smartphone, sensory elements and microfluidic components together can bring wide application of smartphone based microfluidic biomedical sensory system.

There are five types of smartphone-based biosensor systems based on the types of analytes: imaging biosensors that detect bacteria and cells, biochemical sensors that detect blood sugar and blood fat, immune biosensors that detect proteins that are specifically bound to antibodies, hybrid biosensors that detect more than one analyte, and molecular sensors that detect DNA and other biomolecules. The systems are separated based on the sensing modality and analytical technique, such as molecular diagnosis, biochemical parameter sensors, immunoassays, and on-chip imaging devices [22].

Biosensors used in various diseases:

Alzheimer's disease: A chronic illness that can impact those 65 and older is Alzheimer's disease (AD). Growing research indicates that effective treatment of AD depends on early diagnosis. Numerous methods of detection have been created. Finding AD biomarkers can be accomplished with the use of superior analytical instruments known as biosensors. The three most well-known and well-described biomarkers now considered for routine diagnosis of AD in human blood and cerebrospinal fluid (CSF) are tau protein, amyloid β peptides (Aβ), and apolipoprotein E4 (APOE4). Since biomarker research will help to better understand the early stages of the disease, early detection of AD is crucial for putting quick treatment measures into place to avoid the illness and aid in reducing patient deterioration [23].

Taken an example, there is a shape-code biosensor, which is a highly selective biosensor. It uses localized surface plasmon resonance (LSPR) based on the morphologies (shapes) of gold nanoparticles to detect the core biomarkers of Alzheimer's disease (AD) on a single platform. With just gold nanoparticles and an antibody, this plasmonic sensor can accurately differentiate between various materials and identify biomarkers without the need for additional techniques. This is the first time an extremely sensitive shape-code biosensor has been developed to identify AD biomarkers, which will make future AD diagnosis simpler [24].

Cardiovascular diseases: Cardiovascular disease (CVD) is the primary cause of high mortality and morbidity in both industrialized and developing nations. Biomarker detection plays a key role in the early diagnosis of several non-infectious and fatal diseases, including cardiovascular disease and certain types of cancer. This makes it possible for more effective therapy, which reduces the death rate. For diagnosis, prognosis, and therapy, biomarkers are helpful. The search for novel biomarkers with high sensitivity and specificity for CVD is now proceeding swiftly, employing proteomics, bio-sensing, micro-fluidics, and spectroscopic techniques in addition to the usage of gold standard biomarkers like troponin [25].

It is believed that cardiac troponin T and cardiac troponin I are more sensitive and specific for myocardial infarction compared to other cardiac biomarkers [26]. Cardiac troponin T is released from dead cells 2-4 hours after myocardial infraction symptoms appear, while cardiac troponin I is released 3-4 hours later. Being a biomarker that is specific to the heart, cardiac troponin has helped in distinguishing heart damage from damage to skeletal muscle or other organs. Troponin C is also an additional biomarker. It originates from the 3-unit troponin complex of the actin filament, which includes tropomyosin (troponins I, T, and C). It is essential for calcium-mediated control, which regulates the contraction of heart and skeletal muscles. However, it lacks cardiac specificity because slow-twitch skeletal muscles also share the cardiac isoform of troponin C, making it less suitable for use as a cardiac biomarker [27].

Infectious Diseases: Recently, infectious diseases (IDs) have demonstrated their destructive relevance in global health systems, especially due to the COVID-19 pandemic, which was the first pandemic of this century. Focusing on the impacts of COVID-19 clearly highlighted the detrimental effects on the global economy, health, education, tourism, food safety, and other sectors [28]. The COVID-19 pandemic also promoted further advancements in the fields of vaccine development and biosensor applications. Biosensing technologies for detecting infectious diseases (ID) have advanced significantly, and their detection methods (electrochemical, electrochemilumine-science, and capacitive) as well as the suggested biorecognition elements (antibodies, aptamers, and natural DNA fragments) have been thoroughly examined.

Lateral flow immunoassays are frequently employed in clinical settings for the (semi) quantitative or qualitative detection of a variety of analytes because of their affordability, ease of use, and quick turnaround times (5–30 min) [29]. In lateral flow immunoassays, as bioreceptors, antibodies are used to measure analytes such as proteins, antigens, and hormones. Lateral flow immunoassays consist of a conjugation pad with antibodies temporarily bonded to its surface. A mixed sample is then placed on a sample pad, which directs the material's flow to the conjugation pad, where the conjugated antibodies attach to the target analyte (or antigen). Following that, capillary flow via a membrane carries the analyte antibody interaction between test and control strips. A change in color between the test and control lines indicates a positive test [30].

Diabetes Mellitus: Diabetes Mellitus diabetes mellitus is a complex disease that impacts almost every tissue and organ system, with metabolic issues that extend far beyond impaired glucose metabolism. Although early identification and treatment are crucial to preventing diabetes and can postpone or even prevent its potentially lethal effects, there is currently no known cure for the illness. Biomarkers for type 2 diabetes can be utilized to detect and treat the disease early. Electrochemical, fluorescence-based, nano-monitor, SPR-based, and field-effect transistor biosensors are among the various biosensor types being used for diabetes early detection and management, with an emphasis on prediabetes [31]. Diabetes mellitus biosensors operate on the basis of determining analytes such as insulin and glucose, which are the primary markers in the disease's monitoring. The binding reaction determines the catalytic or affinity biosensor's specificity. A catalytic sensor can be used to measure a component's change in concentration, while an affinity biosensor tracks the binding event [32].

Application of Biosensor: Applications for biosensors are numerous and all aimed at enhancing people's quality of life [33]. This range includes their applications in drug development, defence, food safety, disease detection, environmental monitoring, and many more. Biosensors may also be used as platforms to monitor food's safety, quality, traceability, and nutritional value [34].

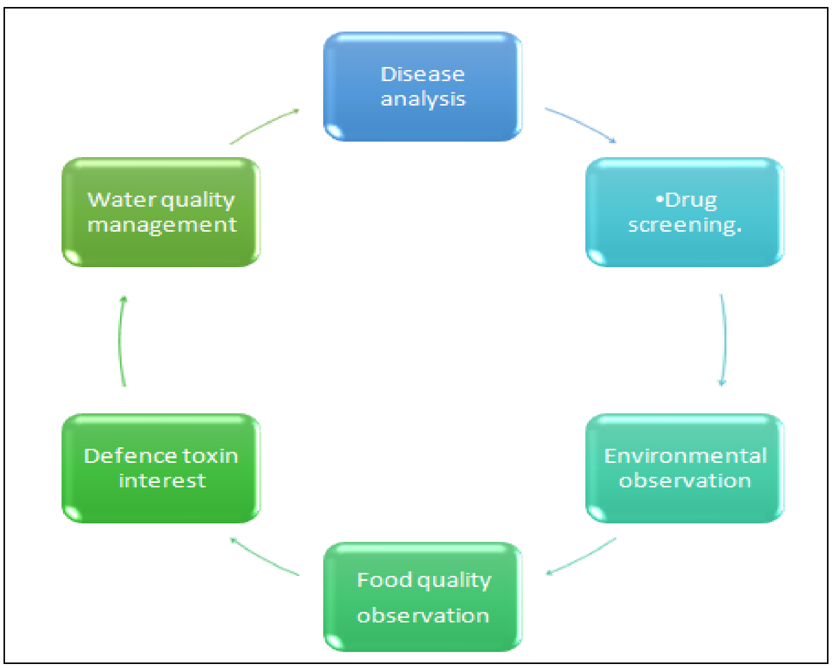

FIG. 7: APPLICATION OF BIOSENSOR

The extensive application of biosensors in clinical care, medicine, and food processing has led to a surge in interest in their development in the biomedical and healthcare domains [35].

Human health management, disease detection, diagnosis, and treatment have all benefited from the use of biosensors. Microorganisms such as viruses, fungi, and bacteria can also be identified using biosensors. Patients' performance can be remotely monitored with the use of intelligent wearable body sensors. By providing essential data on both acute and chronic illnesses, these wearable body sensors enable doctors to precisely treat patients with the aid of contemporary healthcare systems [36]. These wearable sensors can measure variables and send the data to a personal device or an online data storage application. Real-time, accurate mobile detection of illegal drug use can be achieved with wearable body sensors. These days, information gathered from testing biological specimens is used to detect drug use. The field of drug addiction can benefit greatly from the continuous information that portable wearable body sensors can provide to identify the location, context, and duration of drug use of those being observed [37].

Biosensors are frequently used in the medical profession to diagnose infectious diseases. A possible biosensor method for detecting urinary tract infections (UTIs) is being researched in addition to pathogen identification and antibiotic susceptibility [38]. As imaging tools, fluorescent biosensors can be used in drug discovery and cancer research. Understanding the function and control of enzymes at the cellular level has been made possible by them [39]. Genetically encoded and GFP-based FRET biosensors are essential. On cancer patient cells, a genetically-encoded FRET biosensor designed for Bcr-Abl kinase activity detection was used to measure Bcr-Abl kinase activity and establish a correlation with the disease status in chronic myeloid leukaemia. In order to predict the effect of alternative therapies, this probe was also used to control response to therapy and track the emergence of drug-resistant cells [40].

CONCLUSION: Even though portable biosensors have advanced recently, there are still a lot of obstacles to overcome before they can be used in real-world applications. To sum up, the large range of analytes and the corresponding portable biosensors offer a great chance for both distant health care monitoring and point-of-care diagnostics. Although biosensors may be made portable, the sample collection and preparation required to create fully portable devices that can genuinely increase the potential of diagnostics particularly in resource-constrained places and for instantaneous, on-demand measurement is essential. The field of research connects electronics, micro/nanotechnology, applied medicine, and basic sciences. There are several examples of biosensors being used to treat a variety of conditions, such as diabetes, heart disease, Alzheimer's disease, and viral diseases. The extensive usage of biosensors in clinical care, medicine, and food processing has raised interest in their development in the biomedical and healthcare domains. The use of biosensors has enhanced disease detection, diagnosis, and treatment as well as human health management. They also improve people's quality of life in drug research, defence, food safety, and environmental monitoring.

ACKNOWLEDGEMENTS: I would like to show my sincere gratitude and respect towards IPS Academy College of Pharmacy, Indore for providing me with the platform to showcase my knowledge and helping me throughout my work. Special thanks to the Centre for Drug Evaluation and Research (CDER) for providing the necessary resources, data, and support that were essential to this work. Without their contributions, this research would not have been possible. Lastly, I would like to acknowledge the role of emerging technologies, particularly artificial intelligence, in transforming the diagnosis and treatment of cardiovascular diseases. Your contributions have been essential in shaping this work.

CONFLICTS OF INTEREST: The authors have no conflicts of interest.

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How to cite this article:
Kag A, Hardenia S and Jain DK: A review on recent advancement in portable biosensor for health monitoring. Int J Pharm Sci & Res 2025; 16(5): 1169-81. doi: 10.13040/IJPSR.0975-8232.16(5).1169-81.