



# NEWSLETTER



## ENVIS NODE ON ENVIRONMENTAL BIOTECHNOLOGY

Department of Environmental Science  
University of Kalyani

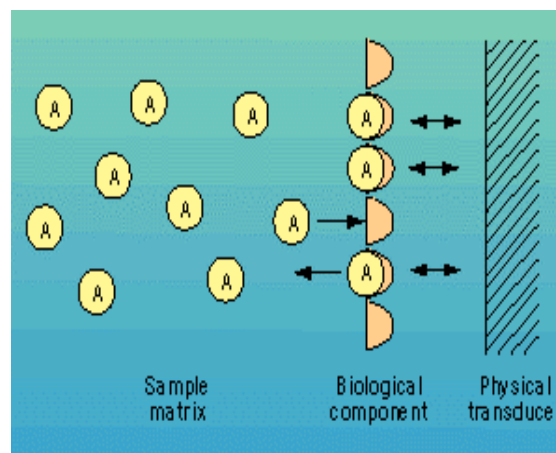
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### Special issue on Biosensor

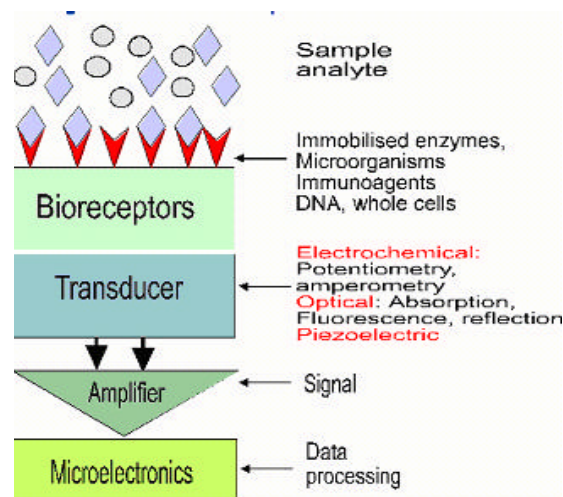
#### Editorial

Thousands of years ago man began to utilize biotechnological process, for example in brewing, baking and wine- making. Having its roots in this tradition, and aided by the great advances of modern molecular biology, biotechnology has experienced an enormous growth in recent decades. Together with genetic engineering, novel immuno-techniques, and protein engineering, biosensors nowadays appear at the leading edge of biotechnology in both research and practical applications. Biosensors are devices incorporating a biologically active element in intimate contact with a physico-chemical signal transducer and an electronic signal processor. The goal of this combination is to utilize the high sensitivity and selectivity of biological sensing for analytical purpose in various fields of research and technology. The following news is devoted in its entirety to a survey of present and some future aspects of biosensor development and application. After a short survey the fundamentals of signal transducers and the present state of thermometric, optoelectronic and piezoelectric biosensors are presented. Recent developments give information on the function of the biocomponents used in biosensors, primarily enzymes, and kinetics of enzyme activity. It also illustrates the potential application and potential impact on both man and animal species of different pesticides and their toxic effect on tissue materials.

Prof. S.C.Santra  
ENVIS In-Charge



Schematic of the generic biosensor strategy.



Various components of a biosensor

## **BIOSENSOR CHARACTERISTICS AND ITS APPLICATION**

*S. Kar\*, A. C. Samal\*, Tanmay Mukherjee\* & S. C. Santra\*\**

In analytical chemistry, there is a problem in selectivity, particularly at low analyte concentrations and in the presence of interfering substances. The sensitive and selective determination of a large number of compound is of great relevance for scientific research as well as for several branches of industry i.e., for process control in the chemical and food industries. In the field of health care it is also indispensable for the diagnosis of diseases. Biotechnology too requires the analysis of complex media, high selectivity, even in trace analysis that has been gained by the considerable process in analytical instrumentation like AAS, gas chromatography, mass spectrometry etc. However, owing to their high costs and not suitable for online operation, the development of different kind of sensors has been made which are highly selective and easy to handle. Among them, electrochemical sensors having ion selective electrode & are widely used volta metric sensors for determination of metal ions and various organic compounds. These sensors are found unsuitable for measurement of physiologically important substances like glucose, urea or cholesterol even more for biological macromolecules such as enzymes, antibodies and microorganisms. But living beings are capable of recognizing and adapting to chemical changes of their own metabolic state and their environment with high selectivity and sensitivity by using so called receptors.

The outstanding specificity and the sensitivity of these biological receptors make them highly attractive for the development of the biosensors. Therefore, Biosensor are characterized by the direct spatial combination of a matrix-bound biologically active substances – the so called receptor with an electronic device. For molecular recognition, biosensor may also be equipped with antibodies in place of enzymes. Besides nearly all kinds of electrodes various other signal transducers have been combined with the immobilized biomaterials. Biosensors because of their specificity, fast response times, low cost, portability and a continuous real time signal can present distinct advantages in certain cases particularly in environmental monitoring.

### **Mechanism**

A biosensor can be defined as a device incorporating a biological sensing element connected to a transducer. Biosensors are generally concerned with sensing and measuring particular chemicals, sometimes may be biological components. The receptor systems of a biosensor consists of complex protein structures and are in most cases bound to cell membranes. They possess a high affinity for specific ligands which may be hormones, enzymes or antibodies. Binding of these ligands causes activation of enzyme cascades via structural changes in the receptor protein. This results in a substantial amplification of the incoming signal which can be observed in a digital response display. The part of the device which does this conversion is called a transducer.

Biosensor has three main components:

#### **A) Transducers – The detectors device:**

A transducer converts an observed change (Physical or Chemical) into a measurable signal, usually an electronic signal whose magnitude is proportional to the concentration of a specific chemical or set of chemicals. It combines the specificity and sensitivity of biological systems with the computing power of the microprocessor.

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Most biosensors have been constructed around electrochemical transducers, but a number of other types have been used, and photometric transducers in particular are growing in importance. However, as long as our microprocessors are driven by electrons, the directness of an electrical response will tend to have maximum appeal. Transducers can be subdivided into various types as follows –

- i) Electrochemical transducers (Potentiometric/Voltametric/Conductimetric)
- ii) FET based transducers
- iii) Optical transducers
- iv) Piezoelectric

### **B) The Analyte or substrate:**

There are now so many of these, it is impossible to generalize about categories of substrate. Virtually any substrate that is consumed or produced in a biochemical process can be analysed by a biosensor. A few examples are:

Sugars	Ethanol	Phosphate
Urea	Glutamic Acid	Penicillins
Creatine	Lactic Acid	Cholesterol
Paracetamol	Aspirin	TNT, Many amino acids

### **C) The Biological Components:**

The importance of the biological component is that its interaction with the substrate is highly specific to that substrate alone thus avoiding interferences from other substances. It may catalyse a reaction involving the substrate (enzyme) or it may bind selectively to the substrate. The most common component is the enzyme, although other components containing enzymes are often very suitable. These include microorganisms such as yeasts and bacteria and tissue materials such as the banana and liver. Antibodies are also used in various modes to bind substrates selectively. Nucleic acids sometimes have applications.

## **Method of Immobilization**

The biological component has to be intimately connected to the transducer and a number of methods of doing this have evolved.

- i) The simplest is *absorption* on to a surface.
- ii) *Microencapsulation* is the word used for trapping between membranes - one of the earliest methods as illustrated with the glucose and other urea biosensors.
- iii) *Entrapment*- the biological component is trapped in a matrix of a gel or a paste or a polymer. This is a very popular method.
- iv) *Covalent attachment*- covalent chemical bonds are formed between the biological component and the transducer.
- v) *Cross Linking*- a bifunctional agent is used to bond chemically the transducer and the biological material. This is often used in conjunction with other methods such as (i) or (iii).

## Performance Factors

### Selectivity:-

This is the most importance characteristic of biosensors - the ability to discriminate between different substrates. This is a function of the biological component, principally, although sometimes the operation of the transducer contributes to selectivity.

### Sensitivity Range:-

This is usually needs to be sub-millimolar, but in special cases can go down to the femtomolar ( $10^{-15}$  M) range.

### Accuracy :-

This is usually around + 5% to -5%

### Nature of Solution:-

Conditions such as pH, temperature and ionic strength must be considered.

### Times :-

- i) The response time is usually much longer than with chemical sensors. It may be 30s or longer.
- ii) The recovery time is the time before a biosensor is ready to analyze the next sample. It must not be too long not more than a few minutes.
- iii) The working lifetime is usually determined by the instability of the biochemical material. It can vary from a few days to a few months. The exactch glucose biosensor is usually usable for over one year.

## Application

1. **Health care:** This is the main area of application and practical application. Measurements of blood, gases, ions and metabolites are then necessary to show the patient's metabolic state. Many of these substrates have been determined by samples of urine and blood being taken away to a medical analytical laboratory for classical analysis, which may not he complete for hours or even days. The use of on the spot biosensors could enable analytical results to be obtained within minutes at most. The exactech glucose biosensors a reading in 30s.
2. **Control of Industrial Processes:** Biosensors can be used in various aspects of fermentation processes in three ways: i) offline in a laboratory ii) off-line, but close to the operation; and (iii) on - line, in real time. Such different types of monitoring could result in improved product quality, product yields, checks on tolerance of the variation in quality of raw materials, optimized energy efficiency. There are wide ranges of applications, in the food and drinks industry.
3. **Environmental monitoring:** There is an enormous range of potential analysis in air, water, soils and other situation. Such things as BOD, pesticides, fertilizers, industrial wastes and domestics' wastes require extensive analysis. Also veterinary science and mining are potential areas where biosensors could be used for environmental monitoring.

## Scope

The possible range of analytes is almost limitless. They range from simple inorganic ions such as nitrate, through simple molecules such as carbon monoxide, methane and methanol, to complex biomolecules such as NAD. There are limited only by the ingenuity of scientists to discover and match appropriate enzymes, bacteria, antibodies, etc. New ones are being discovered regularly. Mutation and genetic engineering open the possibilities of growing new or strains mutants which might have new applications. However, discovering and developing a biosensor in the laboratory is a long way from applying it in a practical situation, let alone developing it for mass manufacture and marketing. The most successful biosensor by far which is marketed by a number of different companies is the glucose biosensor. Other's which have been developed close to the marketing level are for cholesterol, aspirin and paracetamol.

**Table : Biosensor based microorganisms**

Sensor	Microorganisms	Device/probe	Response/mi	Range/mg dm <sup>-3</sup>
Glucose	<i>Pseudomonas fluorescens</i>	O <sub>2</sub>	10	2-20
Acetic Acid	<i>Trichosporon brassicae</i>	O <sub>2</sub>	10	3-60
Ethanol	<i>Trichosporon brassicae</i>	O <sub>2</sub>	10	2-25
Methane	<i>Methylomonas flagellato</i>	O <sub>2</sub>	2	0-7
BOD	<i>Trichosporon cutaneum</i>	O <sub>2</sub>	15	3-60
Ammonia	Nitrifying bacteria	O <sub>2</sub>	10	0.05-1
NO <sub>2</sub>	Nitrifying bacteria	O <sub>2</sub>	3	0.51-255
Vitamin B1	<i>Lactobacillus fermenti</i>	Fuel cell	360	10 <sup>-3</sup> -10 <sup>-2</sup>

## Reference

- A.P.F. Turner, I.Karube and G.S. Wilson (1987), "BIOSENSORS – Fundamentals and Applications", Oxford University Press, Oxford
- T.H. Scheper, & C. Muller, (1994). Optical Sensors for Biotechnological Applications. Biocensors & Bioelectronics, 9, 73-83.
- M.J. Dennison and A.P.F. Turner. Biosensors for Environmental Monitoring. Cranfield Biotechnology Centre, Cranfield, U.K.

## NEWS AND VIEWS

### ***First Deployment Marks Major Milestone in the Commercialization of the TIGER Biosensor System***

CARLSBAD, Calif., Aug. 5 /PRNewswire-First Call/ -- Isis Pharmaceuticals, Inc. (Nasdaq: ISIS) announced today that its Ibis division has shipped its first TIGER biosensor system to the United States Army Medical Research Institute for Infectious Disease (USAMRIID), which will use the system to identify infectious agents for biowarfare defense. Ibis is deploying the TIGER biosensor system with support from the Defense Advanced Research Projects Agency (DARPA) under a subcontract from San Diego-based Science Applications International Corporation (SAIC). The TIGER (Triangulation Identification for Genetic Evaluation of Risks) biosensor system is a revolutionary system that can simultaneously identify thousands of infectious organisms without needing to know what might be present in a sample.

#### **About TIGER and the ibis division:**

The Ibis division has developed the TIGER (Triangulation Identification for Genetic Evaluation of Risks) biosensor system, a revolutionary system to identify infectious organisms. Ibis plans to commercialize the TIGER biosensor system to government customers for use in biowarfare defense, epidemiological surveillance and forensics; and to non-government customers for use in pharmaceutical process control, hospital-associated infection control and infectious disease diagnostics. Additional information about Isis' Ibis division can be found at <http://www.ibistiger.com/> or accessed from Isis' homepage at <http://www.isispharm.com/>.

### **Biosensor Detects Alzheimer's Protein:**

Today, researchers presented work at the national meeting of the American Chemical Society on detecting a toxic protein suspected of triggering Alzheimer's disease. The group used a homemade biosensor to detect and estimate the size and structure of the small protein, which, they say, could lead to the development of new methods for diagnosis and treatment.

*(Reed Life Science News, by Elizabeth Tolchin, 8/31/05)*

### **Optical biosensors help spot bird-flu:**

A low-cost and portable optical wave-guide sensor could help control avian influenza during an outbreak. An optical wave guide sensor being developed by scientists at Georgia Tech Research Institute, US, could offer a fast, portable and reliable way to identify poultry infected with avian influenza (AI). With the only way to stop the infection spreading being a complete cull of birds that may have been exposed to the virus, the sensor could aid the control of an AI outbreak.

*(<http://optics.org>, Lasers, optics and photonics resources and news, September 2005)*

### **New Method for Cancer Risk Assessment:**

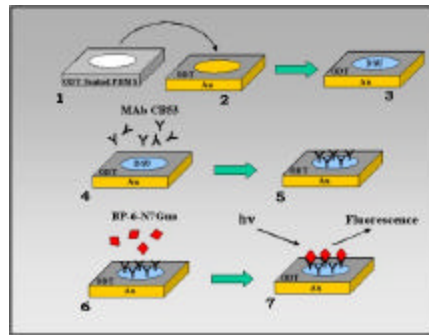
Scientists at the Department of Energy's Ames Laboratory have developed a chip-based, direct-readout methodology for detecting and quantifying DNA adducts, chemical compounds in which a carcinogen is attached to the DNA.

This newly developed biosensor chip tool, which scientists hope will aid pre-cancer diagnoses, consists of a gold biosensor chip with specific antibodies that can selectively bind carcinogen-derived (depurinating) DNA adducts excreted into urine. The DNA adducts are identified through high-resolution, "fingerprint" spectra that, in some cases, could be used in assessing and tracking a patient's risk of getting cancer.

*(April 23, 2005)*



Avian-flu detector



Gold biosensor chip for detection of cancer attached DNA

## MBT508 Topics in Molecular Biology (*Biosensors*):

A rapid, sensitive continuous and *in situ* application of food and environmental monitoring is in great demand now. Advances in biomaterials has expanded the capabilities of applying biosensor, incorporating specific elements of biology with signal transducers to measure the interaction of chemicals/pollutants in biological systems through biomolecular recognition capability.

Now a days researchers are utilizing the properties of DNA, proteins/enzymes, antibodies (as in immunosensors), natural or genetic engineered microorganisms with suitable transducer as biosensor for potential environmental and on-line process monitoring.

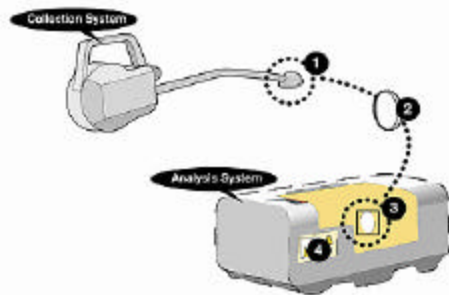
### Some Biosensor Instruments:



**The BIOSENS™** system for analysis of drugs and explosives with high sensitivity and low false alarms  
(<http://www.biosensor.se>)



**The BioCells™** allow the operator to combine analysis of drugs and/or explosives from one sample. (<http://www.biosensor.se>)



The Biosensor BIOSENS™ system provides Vapor and Trace Detection using the following two major system components:

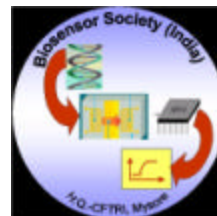
- Collection System
- Analysis System

The figure shows an outline of the BIOSENS™ system:

- 1) Sample collection system
- 2) Disposable filter
- 3) Analysis system
- 4) BioCell™

## BIOSENSOR SOCIETY (INDIA)- NEWS

Biosensors is a fast emerging field incorporating various sciences such as biotechnology, electronics, physics, chemistry etc. and is gaining popularity due to its wide applications in areas such as medical, environmental food, defense to name a few.



(<http://www.biosensor-india.org>)

Biosensor Society (India) (BSI) was launched during the International Workshop on Biosensors (August 11-13, 2003) at CFTRI, Mysore with an intention of providing a common platform for interaction between scientists and researchers to facilitate development of biosensors through exchange of views and collaboration and other allied activities. This Society has an exchange bureau for the dissemination of the technical information by organizing symposiums, seminars, workshops etc. BSI is a professional, educational and non-commercial organization registered under Karnataka Registered Society Act, Government of Karnataka, India

DST sponsored 7<sup>th</sup> National Workshop on Polymeric Sensors in collaboration with BS-I was held at Hindustan College of Science & Technology between 25th July 05 to 6th Aug 05. Totally 35 participants from academic, research institutions and industry participated from different parts of India. It was inaugurated by Prof. E.S.R. Gopal and Dr. B.D. Malhotra. The event was coordinated by Dr. M. S. Gaur, Department of Physics, HCS & T, Agra - Mathura

### FORTH-COMING EVENTS

Events	Date	Place
Workshop on "Wastewater treatment in wetlands - theoretical and practical aspects"	September 10-17, 2005	Starbienio, Poland
Biotech Patents	September 19, 2005	New York
CHI'S Second Annual Toxicity Biomarkers 2005	September 27, 2005	Philadelphia, USA
Cordia: Biotechnology Convention 2005	October 11, 2005	London E16 1XL, United Kingdom
Bangalore Bio 2006	June 7, 2006	Bangalore, India
International and European Symposium on Environmental Biotechnology 2006 (ISEB/ESEB 2006)	July 9-13, 2006	Leipzig, Germany

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