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EDITORIAL

New perspectives in biosensor technology

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Biosensor is a device for the detection of molecules with high selectivity on the basis of molecular recognition (1). The main parts of a biosensor include; a) the sensitive biological element such as tissue, microorganisms, organelles, cell receptors, enzymes, etc; b) the transducer or the detector element that works in a physicochemical way (optical, piezoelectric, electrochemical, etc.) that transforms the signal resulting from the interaction of the analyte with the biological element into another signal; c) associated electronics or signal processors which are primarily responsible for displaying of the results. Sensitivity and selectivity are two important measures in the evaluation of DNA biosensor devices (2, 3).

Applications

There are many potential applications for biosensors of various types. The main requirements for a biosensor approach to be valuable in terms of research and commercial applications are the identification of a target molecule, availability of a suitable biological recognition element, and the potential for disposable portable detection systems to be preferred to sensitive laboratory-based techniques in some situations. Some examples are given below:

- Detection of pathogens or toxic metabolites
- Drug discovery and evaluation of biological activity of new compounds
- Detection of biomarkers such as glucose at femtomolar concentrations
- Sensing of airborne bacteria e.g. in counter-bioterrorist activities
- Determination of drug residues in food such as antibiotics and growth promoters
- Environmental applications e.g. detection of pesticides or water contaminants (4-7).

Principles of detection

Photometric

Many optical biosensors based on the phenomenon of surface plasmon resonance are evanescent wave techniques utilizing a property of gold and other materials. In general, a thin layer of gold on a high refractive index glass surface can absorb laser light, producing electron waves on the gold surface. This occurs only at a specific angle and wavelength of incident light and is highly dependent on the surface of the gold, such that binding of a target analyte to a receptor on the gold surface produces a measurable signal.

Electrochemical

Electrochemical biosensors are normally based on enzymatic catalysis of a reaction that produces or consumes electrons, such enzymes are rightly called redox enzymes. The sensor substrate usually contains three electrodes; a reference electrode, an active electrode and a sink electrode. The target analyte is involved in the reaction that takes place on the active electrode surface and the ions produced create a potential which is subtracted from that of the reference electrode to give a signal.

Others

Piezoelectric sensors utilize crystals which undergo an elastic deformation when an electrical potential

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is applied to them. An alternating potential produces a standing wave in the crystal at a characteristic frequency. This frequency is highly dependent on the elastic properties of the crystal such that if a crystal is coated with a biological recognition element, the binding of a target analyte to a receptor will produce a change in the resonance frequency which gives a binding signal (8-12).

Since introducing the electrochemical DNA (e-DNA) hybridization biosensors, this exciting research area has received intense attention from several groups around the world. DNA biosensors convert the Watson-Crick base pair recognition event into a readable analytical signal (13-15). A basic DNA biosensor is designed by the immobilization of a single-stranded (ss) oligonucleotide (probe) on a transducer surface to recognize its complementary (target) DNA sequence via hybridization. The DNA duplex formed on the electrode surface is known as a hybrid. This event is then converted into an analytical signal by a transducer. Electrochemistry has superior properties over the other existing measurement systems, because electrochemical biosensors enable fast, simple and low-cost detection. Electrochemical detection of hybridization is mainly based on the differences in the electrochemical behaviour of the labels with or without double-stranded DNA (dsDNA) or single-stranded DNA (ssDNA). The labels for hybridization detection can be anticancer agents, organic dyes, metal complexes, enzymes or metal nanoparticles. There are basically four different pathways for electrochemical detection of DNA hybridization:

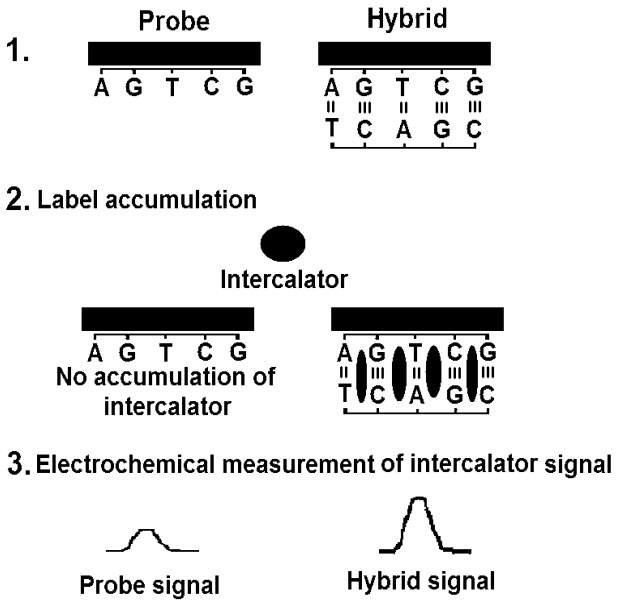
(1) A decrease/increase in the oxidation/reduction peak current of the label that selectively binds with dsDNA/ssDNA, is monitored.

(2) A decrease/increase in the oxidation/reduction peak current of electroactive DNA bases such as guanine or adenine is monitored.

(3) The electrochemical signal of the substrate after hybridization with an enzyme-tagged probe is monitored.

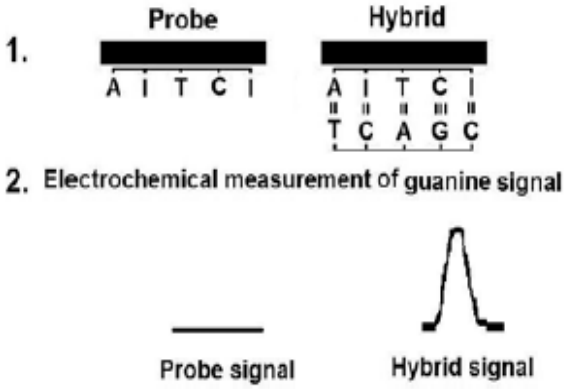
(4) The electrochemical signal of a metal nanoparticle probe attached after hybridization with the target is monitored (16-18).

Label-based electrochemical detection of DNA hybridization:



An intercalator, which can selectively bind to the hybrid on the electrode surface, causes an increase in the electrochemical signal.

Label-free electrochemical detection of DNA hybridization:



Since inosine (I) is electro-inactive, therefore, inosine-substituted probe shows no electrochemical signals. After hybridization with the target DNA, the appearance of the guanine (G) oxidation signal provides specific detection.

It should be mentioned that the main target in all the DNA chip technologies has been to eliminate

the role of the polymerase chain reaction (PCR) from their protocols.

PCR-free DNA biosensors based on the enzymatic amplification of electrochemical signals with their cost-effectiveness, rapid response and impressive miniaturization have become increasingly popular in recent years. In e-DNA sensor thechnology, sequence-specific detection of DNA is one of the major challenges in pathogen detection, single nucleotide polymorphism analysis, and tissue matching. Detection of biological markers at femtomolar concentrations, single-base mutations, cancer-associated genes, diagnosis and monitoring of blood-borne analytes that enable the evaluation of pathological conditions including liver diseases may be performed as point-of-care testing or home care system. With the rapid progress in the eDNA biosensing world, it may be envisaged that DNA biosensors without PCR amplification and suitability for microfabrication will become increasingly popular in the near future.

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