Science Education Collection

Electrochemical Biosensing

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Abstract

Electrochemical biosensors detect the binding of a target molecule by sensing an oxidation-reduction event. These sensors paved the way for modern biosensing after the invention of the glucose biosensor. This video will introduce electrochemical biosensing, show the workings of the glucose biosensor, and discuss how electrochemical biosensors are used in cancer detection.

Transcript

Electrochemical biosensors exploit the natural redox properties of many biological processes, such as enzyme catalysis and other binding events. Electrochemical sensors utilize electrodes which are often functionalized with redox active enzymes. When the target molecule is involved in a reaction with the enzyme the gain or loss of electrons is measured and related to concentration. In this video, we will review the principles of electrochemical sensing. Then describe the basics of an example electrochemical sensor, the blood glucose biosensor.

First let's delve into the general concepts behind an electrochemical biosensor. Like classic electrochemical cells, these sensors are normally composed of three electrodes. The working electrode, counter electrode, and reference electrode. The reaction occurs at the working electrode. While the counter electrode completes the circuit. The reference electrode provides a stable reference point for the redox potential. The electrode materials are chosen based on the type of sensor, the analyte to be detected, and measurement technique used. In order to increase the specificity of the target molecule, the biorecognition element, such as complimentary enzymes, antibodies, or single-stranded DNA is immobilized onto the electrodes surface and used to capture the corresponding target molecule. Then an electrical signal is applied. Which results in the reduction or oxidation of the target. This creates either a surplus or deficit of electrons which is detected. Now, using the classic three electrode cell as an example, let's take a look at how electrochemical sensors measure this redox event. Electrochemical systems are divided into different categories- amperometric, potentiometric, and impedimetric based on the type of output signal measured. Amperometric devices measure the change in currents between the working and the counter electrodes when the voltage is known. The voltage input is either held at a constant value or as a linear ramp or is continuously cycled between two values. The measured oxidation or reduction current change is directly proportional to the analyte concentration. For more information on this technique please refer to our cyclic voltammetry video. Potentiometric devices measure the change in voltage between the working and reference electrode at a constant current. The concentration of the solution can then be calculated using the change in potential. Finally, impedimetric devices measure the change in electrical conductivity of the analyte solution. By measuring the change in current between the working and the counter electrodes over time. At a known input A/C voltage frequency. From this current in voltage the impedance of the analyte solution is calculated. This impedance decreases when the electrical conductivity of the analyte solution increases. And increases when the electrical conductivity of the analyte solution decreases.

Having overviewed the principles and the different types of electrochemical sensing, let us now look at the workings of an electrochemical biosensor, the handheld blood glucose sensor as an example. Current day home testing on blood sugar levels is performed using electrodes that are screen printed on disposable strips. These electrode strips, or circuitry, are then coated with the enzyme and mediator layer, a liquid wicking layer, and a circuit protective film. All held together by thin adhesive sheets and spacers. The liquid wicking layer of the strip helps blood cell separation. So that only the blood serum reaches the enzyme and mediator covered electrodes. Finally, a voltage is applied between the electrodes. Which triggers the glucose enzyme mediator redox reaction. On the immobilized mediator-enzyme layer, glucose in the blood serum is converted to gluconic acid. While reducing the enzyme glucose oxidase. The reduced enzyme reverts to its oxidized state by losing the electrons to the mediator molecule, thus reducing the mediator. Now this reduced mediator acts as a shuttle for the electrons between the mediator-enzyme layer and the electrode layer below it. It loses the electrons at the electrodes surface and gets oxidized. Generating current at the electrode. This current increase, measured at a given potential, is directly proportional to the glucose concentration in the sample.

Having reviewed the electrochemistry of glucose oxidase, let's take a quick look at the glucose sensor being used on a patient. The blood for this test is collected using a safety lancet. Then the collected blood is carefully spotted on the blood collection area of the disposable strip for accurate testing. The glucose meter counts the electrons deposited by the mediator at the electrodes as current. And then calculates how much glucose it took to generate that much electricity. The glucose meter then displays that number on its screen.

Now that we have covered the principles and procedure behind blood glucose sensors, let's see how researches are applying electrochemical biosensing in some other fields. Electrochemical sensing can also be used to detect cancer. In one sensor system, cancer protein specific antibodies are immobilized onto the surface of magnetic beads. Which are incubated in the sample solution. Followed by a second redox active detector antibody solution that is also complimentary to the target. The beads are then captured using magnetic fields onto an electrode surface and amperometric measurements are performed to detect the cancer protein concentration in the sample. Finally, electrochemistry is also used with microorganisms to generate power. Known as bioelectrochemical fuel cells. The microorganisms are cultured to form a film on the anode or cathode surface of the fuel cell. The redox active proteins in the microbes participate in the redox reactions of the electrodes. Which generate electrons and produce power that is harnessed for other applications.

You've just watched Jove's video on electrochemical biosensing. This video contained a basic overview of the key principles of electrochemical biosensors and explained the functioning of the blood glucose sensor in detail. Lastly, we illustrated a few real-world applications of electrochemical biosensing. Thanks for watching.

